



# TIA STANDARD

## IP over Satellite (IPoS)

**TIA-1008-B**

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1 Revision History

<b>Date</b>	<b>Revision Number</b>	<b>Comments</b>
May 8, 2003	Version 0.1	Previous contributions have been consolidated for this first draft of the IPoS standard.
June 19, 2003	Version 0.2	This is an updated draft incorporating additions, clarifications, and corrections received during the May '03 and June '03 meetings of the Working Group.
August 7, 2003	Version 0.3	Incorporates updates, corrections, and editorial improvements received during the June '03 and August '03 meetings.
August 26, 2003	Ballot Version 0.4	This version includes improvements received during the August '03 meeting and the submission for ballot approval to TR34.1 on August 26, 2003.
September 8, 2003	Ballot Version 0.5	Includes updates received before the submission of the ballot version.
October 9, 2003	Publication Version 1.0	This version Includes Ballot comments received during the Ballot period from September 8, 2003 to October 8, 2003 and editorial corrections.
January 12, 2005	Update for high speed inroute	Includes updates for inroutes used for Class B remotes
March 1, 2005	Version 1.2	Updated for DVB-S2 and editorial improvement
May 12, 2005	Version A	Updated according to ballot comments resolution
May 12, 2006	Version A.1	Updated to address TIA legal requirements
August 2010	Draft version B	Full Update
June 2011	Draft B r2	Satyajit Roy, Tony Noerpel
June 2011	Draft Br3	Tony Noerpel
July 2011	Draft Br4	Clean version of r3, comments and change marks deleted
August	Draft Br5	Incorporated physical layer review and timing sync review comments

2

3

# 1 FOREWORD

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2 **(This foreword is not part of the standard)**

3 This standard specifies the satellite air interface standard to be used to support the delivery of IP  
4 satellite services between remote terminals and the satellite access networks' hub of satellite  
5 access networks using commercial geosynchronous satellites. Throughout the remainder of this  
6 document, the term IPoS is used to refer to the satellite air interface and the satellite access  
7 networks compliant with this standard.

8 This standard is oriented primarily toward requirements necessary for the design of remote  
9 terminals. The hub is described only to the extent necessary to understand the remote terminal  
10 specifications. Additional requirements not covered in this document are needed for the hub  
11 design.

12 This document was prepared by Working Group TR 34.1, of the Satellite Equipment and Systems  
13 Formulating Group of the Telecommunications Industry Association (TIA).





# 1 OVERVIEW

---

## 1.1 Scope

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3 This document contains the procedures used by remote terminals and the hub for  
4 delivery of traditional Internet Protocol (IP) services in a star and also in a mesh  
5 satellite access network.

6 Remote terminals built to the parameters and procedures specified in this  
7 document can be used to create satellite access networks using commercial Ku-  
8 band geostationary, nonprocessing transponders with footprints within the United  
9 States of America or any other part of the world.

## 10 1.2 Objectives

---

11 The purpose of this document is to assemble the parameters and procedures  
12 permitting remote terminals from a variety of manufacturers to be compatible  
13 and to obtain services from satellite access networks conforming to this standard.  
14 To ensure this compatibility, this standard defines the essential parameters,  
15 formats, and procedures to a level that creates the same response from the remote  
16 terminals without constraining the particular implementation.

17 Enhanced capabilities such as performance enhancing proxies (PEPs) are not  
18 defined in this version of the standard.

## 19 1.3 Document Organization

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20 This document is organized into four sections and two annexes:

21 Section 1, Overview: This is an introductory section that contains the  
22 document's organization, references, and definitions of terms.

23 Section 2, System Architecture: This section describes the major elements  
24 and interfaces in the IP over Satellite (IPoS) system and the organization of  
25 the satellite air interface between remote terminals and the hub.

26 Section 3, Physical Layer: This section describes the RF parameters,  
27 modulation, framing, and synchronization.

28 Section 4, MAC/SLC Layer: This section includes the procedures and  
29 formats used to encapsulate user and control information across the satellite  
30 air interface.

31 Annex A, State Machine: This annex shows the state machines for several of  
32 the processes executed by the remote terminals.

33 Annex B, IPoS Security: This annex describes the creation and distribution  
34 of various encryption keys used to provide the authentication of users and the  
35 confidentiality of the information exchanged across the satellite interface in  
36 the IPoS system.

## 1.4 References

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The following documents contain provisions that, through references in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or nonspecific.
- For a specific reference, subsequent revisions do not apply.
- For a nonspecific reference, the latest version applies.

References for sections 2, 3, 4, and Annex B are:

- [1] ISO/IEC 13818-1, "Information Technology - Generic Coding of Moving Pictures and Associated Audio Information Systems: Part 1: Systems."
- [2] ETSI TR 101 984 V1.1.1, "Satellite Earth Stations and Systems; Broadband Satellite Multimedia: Services and Architecture."
- [3] IETF RFC 791, "Internet Protocol," Sept. 1981.
- [4] IETF RFC 1883, "Internet Protocol, Version 6 (IPv6)," Dec. 1995.
- [5] Void
- [6] Void
- [7] Void
- [8] Void
- [9] Void
- [10] Void
- [11] ETSI EN 300 468, "DVB, Specification for System Information (SI) in DVB Systems."
- [12] ETSI EN 301 192, v1.2.1 (1999-06), "DVB, DVB Specification for Data Broadcasting."
- [13] ISO/IEC 13818-6, "Information Technology - Generic Coding of Moving Pictures and Associated Audio Information - Part 6: Extensions for DSM-CC."
- [14] IEEE Standard 802.3, "Carrier Sense Multiple Access with Collision Detection and Supplement (CSMA/CD)."
- [15] IETF RFC 1112, "Host Extensions for IP Multicast."
- [16] ETSI TR 101 202, "DVB, Implementation Guidelines for Data Broadcasting."

- 1 [17] ETSI ETS 300 802, "DVB, Network Independent Protocols for DVB  
2 Interactive Services."
- 3 [18] IETF RFC 3135, "Performance Enhancing Proxies Intended to Mitigate  
4 Link-Related Degradations," June 2001.
- 5 [19] ETSI EN 302 307: "Digital Video Broadcasting (DVB); Second generation  
6 framing structure, channel coding and modulation systems for  
7 Broadcasting, Interactive Services, News Gathering and other broadband  
8 satellite applications".
- 9 [20] CCITT (now known as ITU). V.35
- 10 [21] ETSI TS 102 606, "Digital Video Broadcasting (DVB); Generic Stream  
11 Encapsulation Protocol".

## 12 **1.5 Abbreviations, Definitions and Symbols**

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### 13 **1.5.1 Abbreviations**

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14 For the purposes of the present document, the following abbreviations apply:

ACM	adaptive coding and modulation
Adj	Adjacent
AGC	Automatic Gain Control
Agg	Aggregate
AIBO	aggregate input backoff
AIS	Adaptive Inroute Selection
Ant	Antenna
AOBO	aggregate output backoff
APSK	Amplitude and Phase Shift Key
ARQ	Automatic Repeat Request
Atmos	Atmospheric
Attn	Attenuation
AWGN	Additive White Gaussian Noise
BAP	Bandwidth Allocation Packet
BAR	Bandwidth Allocation Request
BCH	Bose-Chaudhuri-Hocquenghem code
BCR	
BER	bit error rate
BO	Backoff
Bps	bits per second
BurstNr	burst number
BW	Bandwidth
CBR	constant bit rate
CBC	cipher block chaining
CCITT	Consultative Committee for International Telegraphy and Telephony
CCM	constant coding and modulation

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CE	constant envelope
CE-OQPSK	constant envelope-offset quadrature phase-shift keying
C/N	carrier to noise
CLPC	Closed Loop Power Control
COI	Community Of Interest
CON	Confirm
CoS	Class of Service
C-Plane	control-plane
CRC	cyclic redundancy check
Crr	Carrier
CSMA/CD	carrier sense multiple access with collision detection
CW	continuous wave
D/A	digital to analog
DDC	
DES	Data Encryption Standard
DiffServ	differentiated services
DLC	data link control
DLL	data link layer
DNS	domain name server
DSM-CC	digital storage media command and control
DstIP	destination IP address
DVB <sup>1</sup>	Digital Video Broadcasting
DVB-S	digital video broadcasting via satellite
DVB-S2	digital video broadcasting via satellite, second generation
EBU	European Broadcasting Union
EEK	encrypted element key
EEMK	encrypted effective master key
EGK	encrypted group key
EIRP	effective isotropic radiated power
EK	element key
Elv	Elevation
EMK	effective master key
ESS	Enhanced Signaling Security
E/S	earth station
ETSI	European Telecommunication Standards Institute
ETSI DTS/SES	European Telecommunication Standards Institute Data Transport Service/Satellite Earth Stations
ETSI EN	European Telecommunication Standards Institute European Standard
ETSI ETS	European Telecommunication Standards Institute European Telecommunication Standard
ETSI TR	European Telecommunication Standards Institute Technical Report
FCC	Federal Communications Commission
FEC	forward error correction
FIFO	first in, first out
FIR	Finite Impulse Response
FLL	frequency lock loop

<sup>1</sup> DVB is a registered trademark of the DVB Project.

FSS	fixed satellite services
FTP	File Transport Protocol
GEO	Geostationary Earth Orbit
GK	group key
G/T	gain-to-noise temperature of the receiver
HDTV	High Definition Television
HPA	high power amplifier
HTTP	Hypertext Transport Protocol
I	Interference
IAP	inroute allocation packet
IB	interleaver B
IC	interleaver C
ICAP	inroute command/acknowledgment packet
ICAU	interactive conditional access update
ICAU-R	interactive conditional access update response
ICMP	Internet Control Message Protocol
ID	identification, identities, or identifier
IDU	indoor unit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IF	intermediate frequency
IGDP	inroute group definition packet
IGMP	Internet Group Management Protocol
Im	Intermodulation
IND	Indication
IntServ	integrated services
IP	Internet Protocol
IPoS	Internet Protocol over Satellite
IPsec	Internet Protocol Security
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IR	Interleaver R
IRD	integrated receiver decoder
IRU	indoor receive unit
IS	Interleaver S
ISO	International Organization for Standardization
ITU	indoor transmit unit
LAN	local area network
LDPC	Low Density Parity Check
LFSR	Linear Feedback Shift Register
LLC	logical link control
LNA	low noise amplifier
LSB	least significant bit

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MAC	media access control
Max	Maximum
MeGW	Mesh Gateway
MF-TDMA	multi-frequency time division multiple access
Min	Minimum
Mis	Miscellaneous
MK	master key
MODCOD	Modulation and Coding
MPEG	Motion Pictures Expert Group
MRC	Mesh Resource Controller
M-Plane	management plane
MSB	most significant bit
NACK	negative acknowledgment
NAT	Network Address Translation
NMC	Network Management Center
No.	Number
ODU	outdoor unit
OQPSK	offset quadrature phase-shift keying
OSI	open systems interface
PA	power amplifier
PACAU	periodic adapter conditional access update
PAT	Program Association Table
PC	personal computer
PDU	protocol data unit
PEB	periodic element broadcast
PEP	performance enhancing proxy
PHY	physical layer
PID	program identifier
PIM-SM	Protocol-Independent Multicast-Sparse Mode
PMP	point to multipoint
PMT	Program Map Table
PRBS	pseudorandom binary sequence
PSD	Power Flux Density
PSI	packet system information
PSK	Phase Shift Key
PSTN	Public Switched Telephone Network
PtP	point-to-point
PWM	pulse-width modulation
Pwr	Power
QEF	quasi-error free
QoS	Quality of Service
QPSK	quadrature phase-shift keying
RAM	random access memory
REQ	Request
RES	Response

RF	radio frequency
RMS	root-mean-square
RS	Reed-Solomon code
RX	Receive
SAP	service access point
SDNAL	satellite dependent network adaptation layer
SDU	service data unit
SDTV	Standard Definition Television
SeqNr	Sequence number
SerIP	Service Internet Protocol
SerNr	serial number
SF	Superframe
SFD	satellite flux density
SFNP	superframe numbering packet
SFNP <sub>N</sub>	superframe numbering packet that marks frame N (superframe number = N/8)
SI	service information
SI-SAP	satellite independent-service access point
SLC	satellite link control
SNAP	Subnet Access Protocol
SNR	Signal-to-Noise Ratio
SOHO	small office, home office
SQF	signal quality factor
SrcIP	source IP address
ST	satellite terminal
Sync	Synchronization
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	time division multiplexing
TDMA	time division multiple access
Temp	Temperature
TIA	Telecommunications Industry Association
TK	traffic key
TX	Transmit
UDP	User Datagram Protocol
U-Plane	user-plane
USB	universal serial bus
UW	unique word
VCM	variable coding and modulation
VOIP	Voice Over IP
VSAT	Very Small Aperture Terminal
VSWR	voltage standing wave ratio
Xmission	Transmission
XOR	exclusive Ors
Xpol	cross-polarization

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Xponder	Transponder
8PSK	8-ary Phase Shift Key
16APSK	16-ary Amplitude and Phase Shift Key
32APSK	32-ary Amplitude and Phase Shift Key

1

## 2 **1.5.2 Definitions**

---

3 For the purposes of the present document, the following terms and definitions  
4 apply:

5 Access network: A satellite, cable, wireline, or wireless network that provides  
6 data transport facilities (satellite, cable, wireline, or wireless) and resources (IP  
7 addresses, DNS service) needed to provide IP-based services to remote users.

8 Adaptive Inroute Selection: Adaptive Inroute Selection is a method by which a  
9 remote terminal can optimally select the symbol rate, FEC coding rate and  
10 transmission power for its inroute transmission.

11 Aloha: An access method to inroute channels where remote terminals transmit  
12 with no bandwidth assignments from the hub. Conflicting transmissions are  
13 rescheduled by the remote terminals at a later time using a random backoff  
14 mechanism.

15 Always on: Type of service that maintains the subscriber session active over the  
16 IPoS satellite access network after the subscriber is registered in the satellite  
17 access network.

18 Automatic Repeat Request (ARQ): Error detection and correction mechanism  
19 that provides error correction by retransmission.

20 Best effort: Type of service that delivers packets from source to destination  
21 without QoS guarantees.

22 Closed Loop Timing: Closed Loop Timing is a process by which a receiver at the  
23 hub determines timing error and feedbacks timing corrections to remote  
24 terminals.

25 Cyclic Redundancy Check (CRC): A class of linear error detection codes that  
26 generate check bits by finding the remainder of a polynomial division.

27 Differentiated Services (DiffServ): An approach to provide QoS guarantees in  
28 the Internet where packets are classified into a small number of service classes by  
29 encoding the field in the IP header designated Differential Services Code Point.

30 Digital Video Broadcasting (DVB): DVB is an ITU-specified transmission  
31 scheme that supports the transfer of MPEG-2 compressed video, audio, program  
32 guides, and packet data that is adopted in the outroute direction of IPoS.

33 Digital Video Broadcasting – Second Generation (DVB-S2): DVB-S2 is a  
34 second-generation specification for satellite broadcasting – developed by the

- 1                    DVB project. It makes use of the latest modulation and coding techniques to  
2                    deliver performance that approaches the theoretical limit for such systems.
- 3                    Domain Name Servers (DNS): DNS is a distributed database that maps Internet  
4                    names to IP addresses.
- 5                    Doppler Shift: The Doppler Shift, names after Austian physicist Christian  
6                    Doppler who proposed it in 1842 in Prague, is the change in frequency of a wave  
7                    for an observer moving relative to the source of the wave.
- 8                    Enhanced Signaling Security: The IPoS Enhanced Signaling Security (ESS)  
9                    feature provides protection of management and control plane signaling traffic.
- 10                   Ethernet: Ethernet is a Local Area Network (LAN) technology that uses 48-bit  
11                   addresses to identify the host computers connected to the LAN. Information over  
12                   Ethernet is encapsulated into units called frames. The Ethernet frame has a  
13                   14-byte header that includes two 48-bit addresses (source and destination) and  
14                   the length/type of the payload.
- 15                   Forward Error Correction (FEC): Method to enhance the robustness of  
16                   transmissions by using additional bits to protect the information units.
- 17                   Inroute group: A set of inroute carriers that use the same physical layer (PHY)  
18                   parameters, such as transmission rate and coding scheme, for the group of  
19                   logical control and traffic channels supported by the inroute group.
- 20                   Integrated Services (IntServ): An approach to provide sensitive applications with  
21                   QoS guarantees based on reserving specific resources at every router traversed by  
22                   the data flows of the application requesting preferential treatment.
- 23                   LDPC Codes: Low Parity Density Codes
- 24                   Logical channel: A communication path between the hub and the remote  
25                   terminals described in terms of direction, connectivity, and the intended use of  
26                   the information transferred.
- 27                   Mesh: Peer to peer one satellite hop communication
- 28                   Multicast: A service that delivers packets from a sender to a group of receivers.  
29                   IPoS provides multicast by the hub transmitting only one copy of each packet for  
30                   each multicast group over the outroute direction.
- 31                   Multiprotocol Encapsulation: DVB-compliant specification that supports the  
32                   transmission of IP datagrams over broadcast networks.
- 33                   Network Address Translation (NAT): NAT is an Internet procedure that  
34                   translates between two different sets of addresses, typically a set of globally  
35                   registered IP addresses for external traffic and a second set of private addresses  
36                   used for internal traffic in an access network or a LAN.
- 37                   Performance Enhancing Proxy (PEP): An approach for improving the  
38                   performance of TCP/IP over satellite links by providing TCP spoofing functions  
39                   at the hub and the desired remote terminals. PEPs operate above the DLC layer

- 1 attempting to hide the losses and delays of the underlying satellite link from the  
2 end-to-end TCP/IP protocol.
- 3 Private IP network: A network that reuses the IP address space by being isolated  
4 from the global Internet. Private IP networks might be connected to the global  
5 Internet through a service gateway that provides the translation between private  
6 IP and global IP addresses.
- 7 Protocol stack: A conceptual model of a communication protocol using  
8 sequential layers that are represented in a vertical group or stack with the lower  
9 layer at the bottom of the stack.
- 10 Protocol Data Unit (PDU): Format used to encapsulate the data transferred  
11 between peer layers at the hub and remote terminals.
- 12 Punctured code: An error-correcting code derived from another error correcting  
13 code by deleting or puncturing coded bits from the output of the encoder.
- 14 Reserved: When used in connection with IPoS message fields, the term reserved  
15 means that the bits in these reserved fields might be used in future extensions.  
16 Unless otherwise specified, all reserved bits shall be set as binary value '0' and  
17 shall be ignored upon reception.
- 18 Satellite link: A physical connection across satellite transponders that a transport  
19 protocol uses to communicate between remote users and the hub in a satellite  
20 access network.
- 21 Service Access Point (SAP): Conceptual point at the interface between adjacent  
22 protocol layers where data and protocol information are exchanged.
- 23 Spreading: Spreading techniques are methods by which a signal generated in a  
24 particular bandwidth is deliberately spread in the frequency domain, which  
25 results in a signal with a wider bandwidth. These techniques are used for a  
26 variety of reasons, including the establishment of secure communication,  
27 increasing resistance to natural interference and jamming, to prevent detection,  
28 and to limit power flux density.
- 29 Sublayer: The result of decomposing a protocol layer into smaller functional  
30 groupings.
- 31 Systematic encoder: An encoder, the output of which includes the input  
32 information bits followed by the parity bits created by the encoder to provide a  
33 more reliable information transfer.
- 34 Transmission Control Protocol/Internet Protocol (TCP/IP): TCP is the most  
35 common transport protocol, using the unreliable IP for moving packets and  
36 datagrams from a source to a destination in terrestrial IP networks. TCP is a  
37 window-based acknowledgment and flow control protocol that uses timeouts,  
38 sends and receives acknowledgments, and performs retransmissions to provide  
39 end-to-end reliable transmissions across multiple networks.

1                    Turbo codes. Turbo encoders are structured with parallel concatenations of  
2 systematic convolutional encoders, the constituent encoders, with interleavers at  
3 the input of the constituent encoders. Turbo decoding uses an iterative decoding  
4 to achieve very good error-correction performance.

5                    User Datagram Protocol (UDP): An unreliable protocol where one end sends  
6 datagrams without any preliminary connection establishment or subsequent  
7 acknowledgments.

8                    Upper layers: General reference to protocol layers above the highest layer in the  
9 satellite network access stack. Examples are terrestrial transport layers such as  
10 TCP and UDP and application protocols such as HTTP, FTP, and e-mail.

### 11    **1.5.3       Symbols**

---

12                    For the purposes of the present document, the following symbols apply:

13	/ or :	division
14	x or *	multiplication
15	.	indicates absolute value
16	‘.’	single quotation mark used to represent binary fields
17	$\alpha$	rolloff factor for a root raised cosine shaped filter
18	$\Delta T$	change in time
19	$\pi$	angular 180 degrees
20	$\theta$	angle in degrees from the axis of the mainlobe of the antenna
21	$\mu s$	microsecond
22	$^{\circ}$	angular degrees
23	$^{\circ}C$	temperature in degrees Centigrade
24	0x	prefix used to represent hexadecimal numbers
25	BT	bandwidth times symbol duration product
26	cm	centimeter
27	dB	decibel
28	dB $\mu V/m$	field strength measured as its ratio (in dB) to one microvolt/m
29	dB $i$	decibels over an isotropic radiator
30	dB/K	gain-to-noise temperature of receivers in dB

1	dBm	power expressed as its ratio (in dB) to 1 milliwatt
2	dBc/Hz	noise power spectral density where the noise power in one Hz is expressed in dB relative to the power of the unmodulated carrier
3		
4	dBm/Hz	power spectral density indicating the power expressed in dBm over one Hertz of bandwidth
5		
6	dBW/kHz	power spectral density indicating the power expressed in dBW over one kilohertz of bandwidth
7		
8	dBpW	power expressed as its ratio (in dB) to one picowatt ( $10^{-9}$ watts)
9	dBW	power expressed as its ratio (in dB) to one watt
10	dBW/m <sup>2</sup>	power density indicating the power in dBW in 1 square meter
11	E(.)	exponential
12	E <sub>bi</sub>	energy per information bit of the received signal at the output of the decoder
13		
14	E <sub>bi</sub> /N <sub>o</sub>	ratio of the energy per information bit and the noise density at the output of the decoder expressed in dB
15		
16	E <sub>bt</sub> /N <sub>o</sub>	ratio of energy per received bit and the noise density at the output of the demodulator (input to the decoder) expressed in dB
17		
18	EIRP <sub>max</sub>	maximum EIRP
19	f <sub>N</sub>	Nyquist frequency
20	GHz	Gigahertz ( $10^9$ Hertz)
21	hex	hexadecimal notation
22	H(f)	filter frequency response
23	h(t)	filter impulse response or shaping pulse waveform
24	Hz	Hertz
25	I	in-phase component of the modulated signal
26	j	imaginary unit
27	k	time index
28	K	Temperature in degrees Kelvin and convolutional code constraint length
29		
30	kHz	kilohertz ( $10^3$ Hertz)
31	ksps	kilosymbols per second

1	$\log_{10}$	decimal logarithm
2	m	meter
3	MHz	Megahertz ( $10^6$ Hertz)
4	msec	millisecond
5	Msps	Megasymbols per second
6	$N_o$	Noise density (unit of bandwidth)
7	Q	quadrature component of the modulated signal
8	$R_s$	symbol rate
9	s	second
10	sps	symbols per second
11	Theta	angle designation; symbol is $\theta$
12	$T_{HO}$	hub offset time
13	$T_{H-S}$	propagation time from hub to satellite
14	$T_{H-S-H}$	$T_{H-S-H} = T_{H-S} + T_{S-H}$
15	$T_{RO}$	remote terminal offset time
16	$T_{R-S}$	propagation time from remote terminal to satellite
17	$T_{S-H}$	propagation time from satellite to hub
18	$T_s$	symbol duration
19	W	watts



## 2 SYSTEM ARCHITECTURE

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### 2.1 Introduction

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This section is an introduction to the Internet Protocol over Satellite (IPoS) system. In particular it contains a high-level description of the different functional capabilities and services of the system and the remote terminals that give access to users of these services and capabilities in the IPoS system. This section also describes the protocol architecture adopted for the satellite interface between remote terminals and the hub through which user data and signaling information are transferred among the different functional layers of the remote terminal and the hub.

### 2.2 System Overview

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The IPoS system delivers “always on” IP services via geosynchronous satellites primarily targeted to the following markets:

- Residential/Consumer: The primary service offered to consumers by IPoS is broadband Internet access, including traditional IP services such as e-mail, file transfer, and Web browsing based on Transmission Control Protocol/Internet Protocol (TCP/IP) with additional value-added IP multicast services such as video/audio streaming, distance learning, etc.
- Small office/home-office (SOHO): The primary IPoS service offered to the SOHO market is premium-level broadband Internet access, including the aforementioned value-added services.
- Business: The services provided for the satellite service provider, enterprise and government markets include premium-level secure broadband Intranet access, VoIP, Satellite backhaul, mobile broadband access, peer-to-peer single satellite hop communication. These include both the stationary and mobile broadband access.

This IPoS standard has been developed to create a multivendor procurement environment of remote terminals that result in efficient solutions for providing the two-way satellite Internet access transport capability required by these residential and SOHO markets, and private Intranet access transport capability required by these enterprise and Government markets. Key characteristics of this standard include:

- Terrestrial IP networks interoperability
- Easy scalability
- Universal applicability
- Easily deployability

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1

- Comprehensive management capability

2

## 1    **2.2.1    Network Architecture**

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2                    IPoS is a two way IP-based broadband satellite network that encompasses the  
3                    following three major segments:

4                    1. Hub segment: The hub segment supports Internet access of a large  
5                    number of remote terminals via satellite. It is composed of large hub  
6                    earth stations and related equipment through which all traffic flows. The  
7                    hub segment can be further broken down as follows:

8                                       • An IPoS hub earth station is the large earth station through  
9                    which many thousands of terminals communicate. A hub earth  
10                    station exists at a single location, may access space segment  
11                    resources from multiple satellites, and configures and manages  
12                    from a single, centralized database.

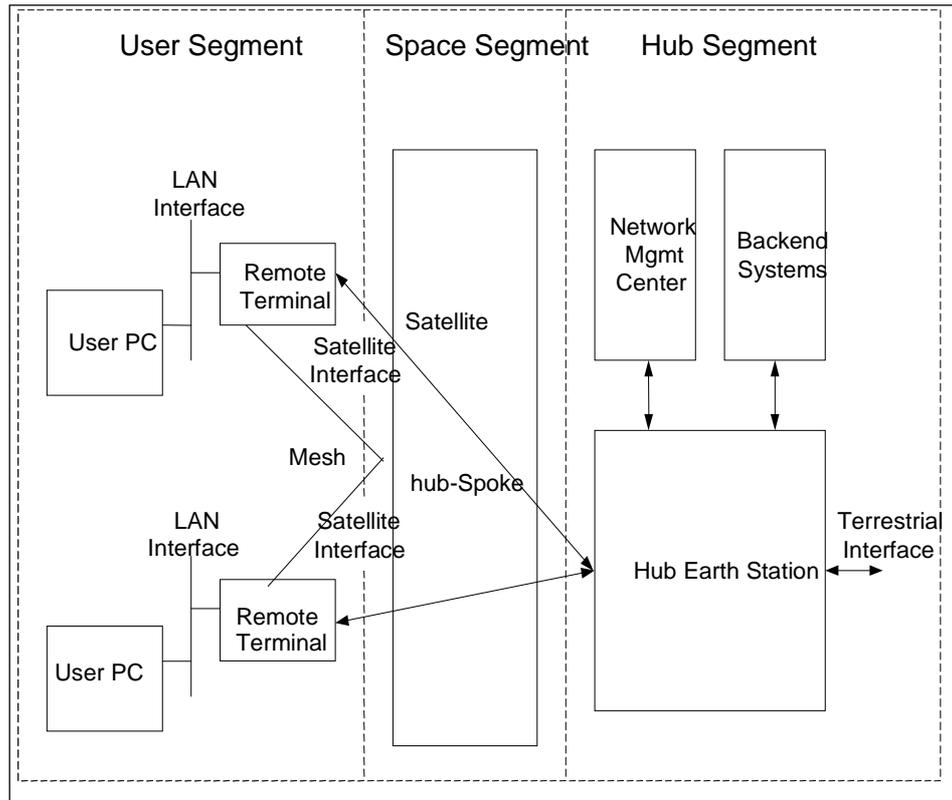
13                                       • An IPoS Network Management Center (NMC) is a single  
14                    management center, collocated with the IPoS hub earth station  
15                    that manages the entire IPoS system. The parts of the NMC that  
16                    directly manage hub earth stations and terminals are considered  
17                    to be components that are internal to the IPoS system.

18                                       • The IPoS backend systems include, but are not limited to,  
19                    routers, firewalls, Domain Name Servers (DNSs), etc. They  
20                    provide the interface between the IPoS and the external public  
21                    network, e.g., Internet.

22                    2. Space segment: The space segment consists of bent-pipe transponders  
23                    on geosynchronous satellites that allow transmission in both directions  
24                    between the hub and remote terminals, and also between two terminals  
25                    directly using a single satellite hop communication.

26                    3. User segment: In general, the IPoS user segment consists of thousands  
27                    of user terminals, each of them capable of providing broadband IP  
28                    communications to a remote site. User terminals are also referred to in  
29                    this standard as remote terminals or IPoS terminals or only terminals.  
30                    The remote terminal can be stationary or mobile or transportable. The  
31                    remote terminal is a self-hosted IP satellite modem that provides satellite  
32                    communication for the remote site which comprises of customer  
33                    premises LAN and IP user hosts. Customer LANs are considered  
34                    external to the IPoS system.

35                    Figure 2.2.1-1 illustrates the highest-level components in the IPoS architecture  
36                    and identifies the major internal and external interfaces in the IPoS system.



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**Figure 2.2.1-1. IPoS System Architecture**

IPoS supports both star and mesh network topologies and mobility. The remote terminal can be stationary or mobile or transportable.

A network can simultaneously support star and mesh connectivity. A mesh capable fixed or stationary IPoS terminal deployed on such a network will be able to perform both star and mesh communication.

A mobile IPoS terminal is restricted to only star connectivity. The following captures various possible IPoS network configuration and the type of terminals supported in a specific configuration.

- If the IPoS Hub is not mesh or mobile enabled, then the entire network can only support stationary or transportable terminals operating as a star.
- If the IPoS Hub supports mesh but not mobile, the entire network can support
  - Stationary or transportable terminals
  - Mesh operation
- If the IPoS Hub supports mobility, but not mesh, then the entire network can support
  - Stationary or transportable terminals

- 1 ○ Mobile terminals
- 2 ● If the IPoS Hub supports both mobility and mesh, then the entire network
- 3 can support
- 4 ○ Stationary or transportable terminals
- 5 ○ Mobile terminals

### 2.2.1.1 IPoS Star Network

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The IPoS star network is comprised of a Gateway located at a central site (aka Hub) and one or more Remote Terminals as illustrated by Figure 2.2.1.1-1.

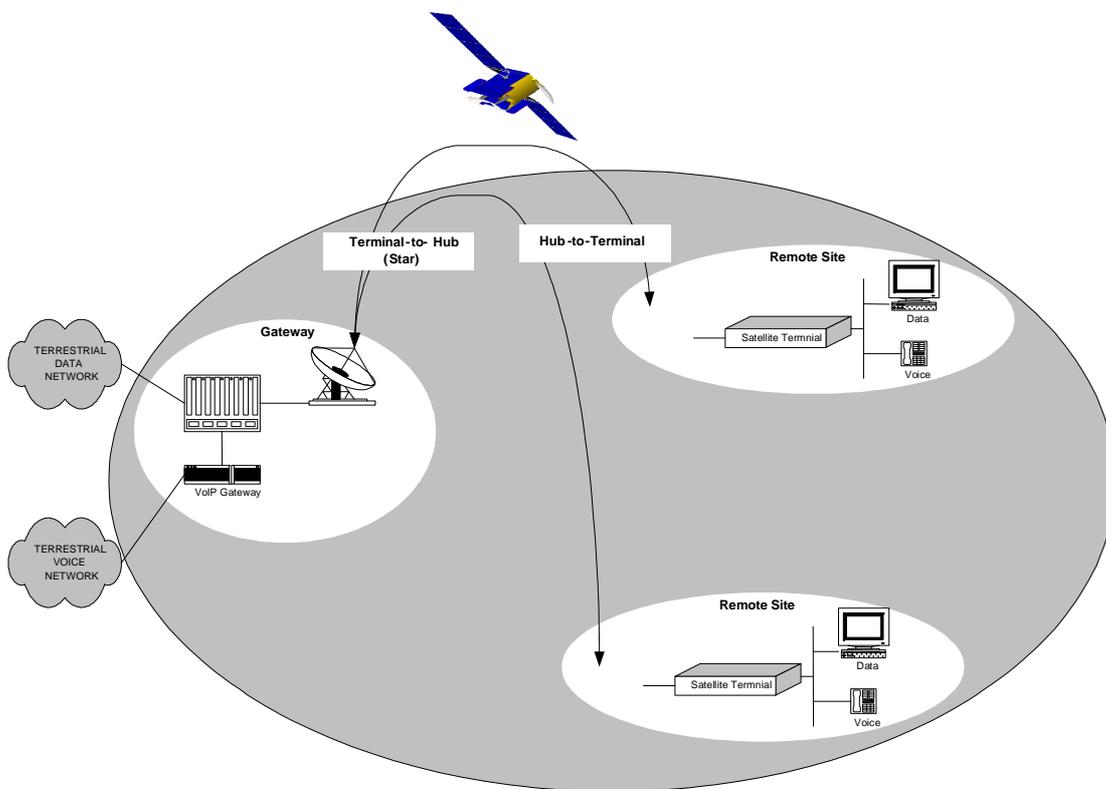


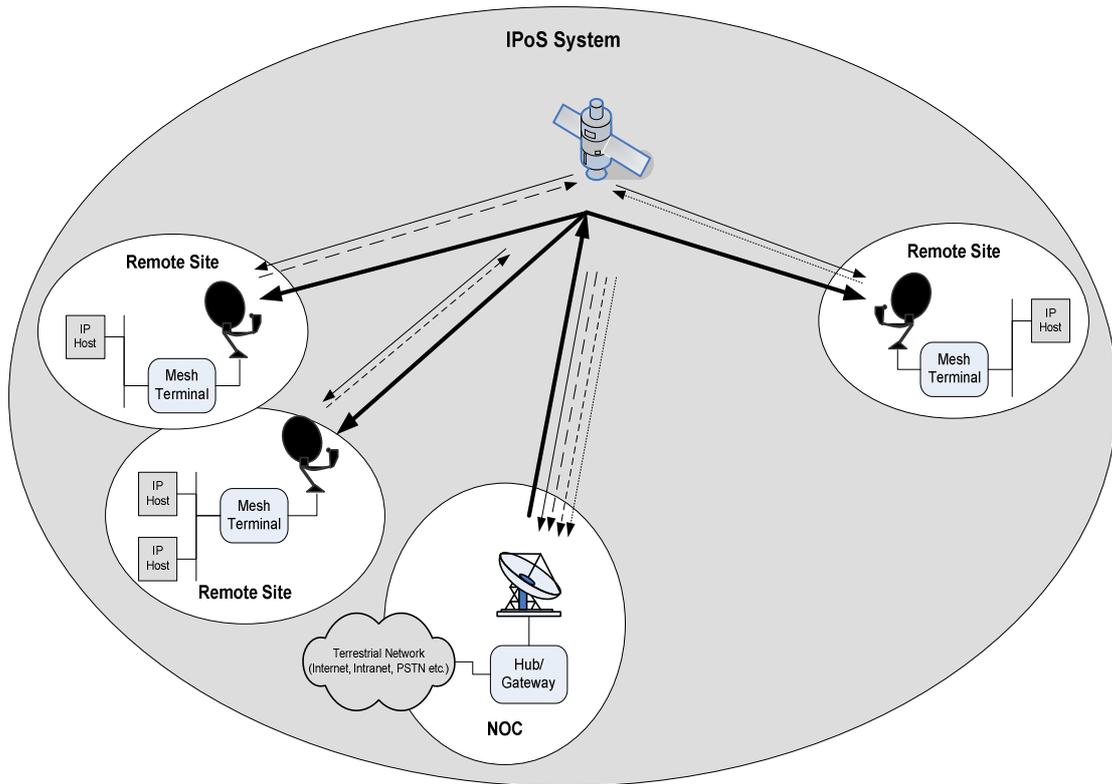
Figure 2.2.1.1-1. IPoS Star Network

The Gateway at the Hub provides network operation and control, and also provides connectivity to the Internet and/or Intranet for star based communications.

### 2.2.1.2 IPoS Mesh Network

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IPoS mesh extends the IPoS system capabilities to support dynamic, direct connectivity between Remote Terminals. A reference model for the mesh network is shown in figure 2.2.1.2-1.



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**Figure 2.2.1.2-1. IPoS Mesh Network**

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The Gateway at the Hub provides network operation and control functionality required to support the capability for Remote Terminals to dynamically setup mesh connections with each other. The Gateway also provides connectivity to the Internet and/or intranet for star based communication. Mesh Remote Terminal is a self-hosted IP satellite modem that provides both star and mesh communication for the remote site within the IPoS network.

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**2.2.1.3 IPoS Mobile Network**

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The IPoS satellite network for the mobile scenario comprises the same major segments (e.g. Hub Segment, Space Segment, User segment) and signaling mechanisms (outroute and inroute paths) as described for the fixed scenario.

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The mobile terminals and Hub/Gateway implement additional features, namely spreading, frequency and timing Doppler compensation to address two of the major mobile environment requirements which are use of small antennas and Doppler Effect compensation.

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Spread inroutes or channels are inroutes on which the transmission rate is higher than the information rate. Spread spectrum is often employed in communication systems because of its ability to address the following problems.

20

21

- Resistance to Interference,
- Resistance to Interception

- 1                                   • Resistance to Fading including Multi path Effects

2    **2.2.2       Network Interfaces**

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3                                   The main interfaces in the IPoS system are:

- 4                                   • Terminal LAN interface: This is the interface between the remote  
5                                   terminal and users' computing equipment, such as computers, switches,  
6                                   routers, and gateways.
- 7                                   • IPoS satellite interface: This is the interface where remote terminals and  
8                                   the hub exchange user, control, and management information. The IPoS  
9                                   satellite interface, or air interface, is the main focus of this standard.
- 10                                  • Hub terrestrial interface: This is the interface between the hub and the  
11                                  backbone connecting the hub to the external packet data networks, public  
12                                  Internet, or private data networks. The hub terrestrial interface uses IP  
13                                  protocols that are not part of this standard.

14                                  The IPoS satellite interface distinguishes between the two transmissions'  
15                                  directions:

- 16                                  • The outroute direction from the IPoS hub to the user terminals is  
17                                  broadcast over the entire bandwidth allocated to the outroute carrier.  
18                                  Because the IPoS outroute can multiplex a multiplicity of transmissions,  
19                                  it streams to many remote terminals.
- 20                                  • The inroute direction from the remote terminals to the IPoS hub is  
21                                  point-to-point (PtP), either using bandwidth assigned by the hub for  
22                                  individual remote terminals or using bandwidth shared by all terminals  
23                                  on a contention basis.

24    **2.2.2.1       Outroute Satellite Transmission**

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25                                  The IPoS outroute transmission format is DVB-S2 [19].

26                                  IPoS DVB-S2 outroute carriers use a statistical multiplexing scheme compliant  
27                                  with the DVB data format in reference [1] for sharing the outroute among the  
28                                  remote terminals. The distribution of IP traffic to the remote terminals is based  
29                                  on the DVB multiprotocol encapsulation in reference [12]. Symbol rates from 1  
30                                  Msps to 45 Msps are supported.

31                                  The DVB-S2 outroute [19] has three operation modes: VCM, CCM and ACM.

32                                  In the VCM (Variable Coding and Modulation) mode, the outroute bursts are  
33                                  coded with different modulations and coding rates depending on the service  
34                                  components (e.g. SDTV, HDTV, audio and multimedia).

35                                  In the CCM (Constant Coding and Modulation) mode, the single modulation and  
36                                  coding rate applies to all the service components.

1 In the ACM (Adaptive Coding and Modulation) mode, the outroute modulation  
2 and coding rate may differ per terminal. The modulation and coding may adapt  
3 in real-time or be chosen for each terminal at login. Real-time adaptation may be  
4 via a closed loop algorithm between the hub and the remote terminals, or through  
5 a hub-based algorithm alone.

### 6 **2.2.2.2 Inroute Satellite Transmission**

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7 A number of variations of inroute transmission are supported in IPoS system.  
8 Namely;

- 9 • Offset quadrature phase-shift keying (OQPSK) modulation at  
10 transmission rates of 256, 512, 1024, 2048, 4096 and 6144 Ksps with  
11 FEC Rates 1/3, 1/2, 2/3 and 4/5 using Turbo FEC and BCH encoding
- 12 • Offset quadrature phase-shift keying (OQPSK) modulation at  
13 transmission rates of 256, 512, 1024, and 2048 Ksps with FEC Rates 1/2,  
14 2/3 4/5 and 9/10 using LDPC encoding

15 IPoS uses demand-assigned MF-TDMA (multifrequency time division multiple  
16 access) on its inroutes to allow terminals to transmit to the hub. The IPoS inroute  
17 has a 45-millisecond TDMA frame length divided into a variable number of  
18 slots. Transmissions from a terminal to the hub are referred to as a “burst.” A  
19 burst requires an integral number of slots for overhead and then carries an  
20 integral number of slots of data. These overhead slots are used to provide the  
21 burst preamble and to allow adequate time between bursts to ensure that  
22 consecutive bursts do not overlap in time.

23 IPoS adopts the same demand-assigned MF-TDMA with a 45-millisecond  
24 TDMA frame length divided into a variable number of slots as used for the star  
25 communication on mesh links to allow terminal-to-terminal direct  
26 communications.

27 IPoS supports Closed Loop Power Control (CLPC) feature on inroute channel so  
28 that an IPoS terminal is able to transmit its bursts at the correct power and  
29 adaptively select the right inroute symbol rate and FEC Rate that matches its  
30 current link condition. This adaptive procedure is called Adaptive Inroute  
31 Selection (AIS). A specific case of AIS, called Adaptive Coding enables a  
32 terminal to dynamically switch between FEC rates while keeping its transmission  
33 on the same inroute channel. Closed Loop Power Control, Adaptive Inroute  
34 Selection and Adaptive Coding procedures are described in section 4.11.8 and  
35 4.11.9 .

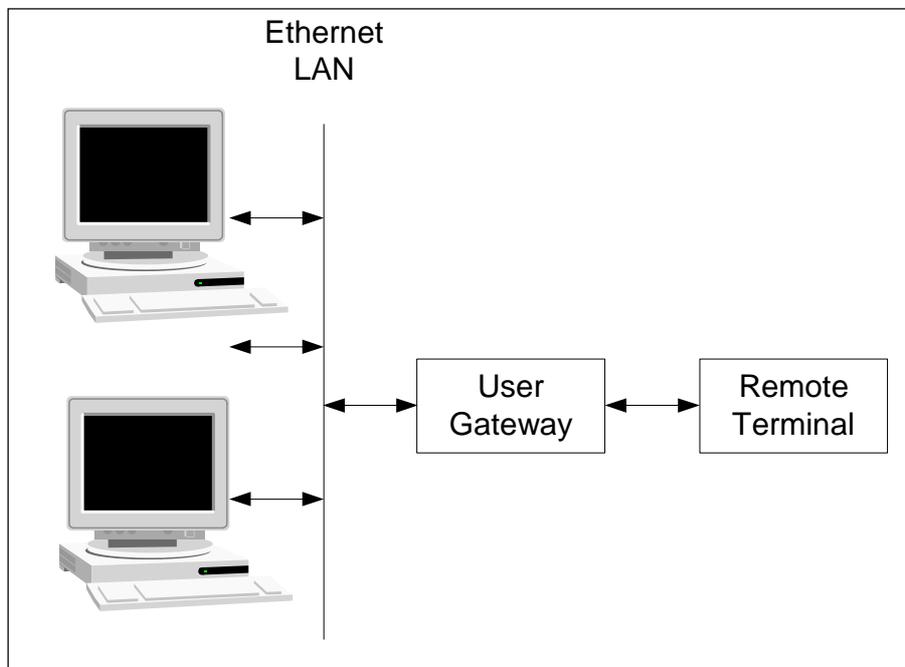
36 IPoS supports two variants of inroute TDMA timing synchronization procedure –  
37 open loop timing and closed loop timing. Timing synchronization procedure is  
38 described in section 4.11.1.

## 39 **2.3 Remote Terminal**

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40 The remote terminal is the access platform from which the user hosts access the  
41 services of the IPoS system.

- 1 An IPoS terminal also consists of an ODU and an IDU connected by two coaxial  
2 cables. The IDU contains a module that provides the user gateway functionality.  
3 See figure 2.3-1.



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5

Figure 2.3-1. IPoS Terminal

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The user gateway provides an Ethernet interface to LAN-based IP devices.

7

### 2.3.1 Remote Terminal Operational States

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The operational states determine the type functions performed by the remote terminals. Three main operational states are used in the operation of the remote terminals:

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1. **Commissioning state:** In this state the remote terminal gets the configuration parameters, addresses, and encryption keys needed to contact the hub. At the end of the commissioning state, the remote terminal is registered, authenticated, and ready to receive information from the hub.

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2. **Idle state:** In this state the remote terminals are an addressable entity that can receive system information and specific configuration parameters about the inroute direction. At the end of the Idle state, the remote terminals are ready for reaching the Active state.

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3. **Active state:** In this state the remote terminal can execute secure and reliable transfer of user, control, and management information with the hub.

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## 2.3.2 Remote Terminal Characteristics

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An IPoS terminal shall support the following transmission characteristics and features.

- DVB-S2 ACM outroute
- Offset quadrature phase-shift keying (OQPSK) modulation at transmission rates of 256, 512, 1024, 2048 Ksps with FEC Rates  $\frac{1}{2}$ ,  $\frac{2}{3}$  and  $\frac{4}{5}$  using Turbo FEC and BCH encoding
- Closed Loop Power Control, Adaptive Inroute Selection and Adaptive Coding
- Open Loop Timing, and Closed Loop Timing if the network configuration needs Closed Loop Timing as a conditional mandatory.

An advanced IPoS terminal may support the following additional transmission characteristics.

- Offset quadrature phase-shift keying (OQPSK) modulation at transmission rates of 4096 and 6144 Ksps with FEC Rates  $\frac{1}{3}$ ,  $\frac{1}{2}$ ,  $\frac{2}{3}$  and  $\frac{4}{5}$  using Turbo FEC and BCH encoding. The terminal needs to use a linear radio to support these rates.
- Offset quadrature phase-shift keying (OQPSK) modulation at transmission rates of 256, 512, 1024, and 2048 Ksps with Rates  $\frac{1}{2}$ ,  $\frac{2}{3}$ ,  $\frac{4}{5}$  and  $\frac{9}{10}$  using LDPC encoding

An IPoS mesh terminal shall support at least the basic characteristics and features and additionally peer-to-peer single hop connectivity in a mesh topology.

An IPoS mobile terminal shall support at least the basic characteristics and features, and additionally mobility related procedures.

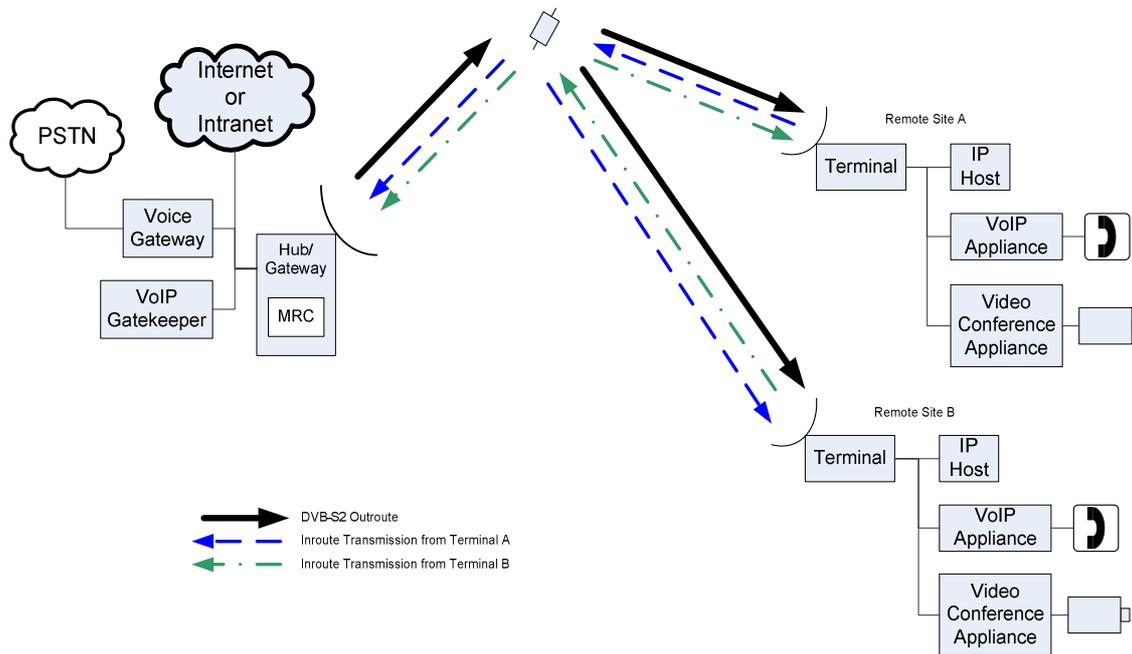
## 2.3.3 Mesh Transmission and Mesh Terminal

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The IPoS Mesh supports peer to peer single satellite hopconnectivity.

Figure 2.3.3-1 illustrates mesh connectivity.

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**Figure 2.3.3-1. Mesh Transmission**

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An IPoS Mesh Terminal includes two types of receivers. The first is the TDM receiver to receive traffic from the Gateway at the NOC via a DVB-S2 outroute. The second type of receiver provides the ability for the Mesh Terminal to receive one or more mesh channels (transmission), thus allowing the terminal to receive bursts transmitted by other Mesh Terminals on IPoS inroutes. A Mesh Resource Controller (MRC) in the Gateway at the NOC dynamically coordinates connectivity between Mesh Terminals.

## 2.4

### IPoS Protocol Reference Model

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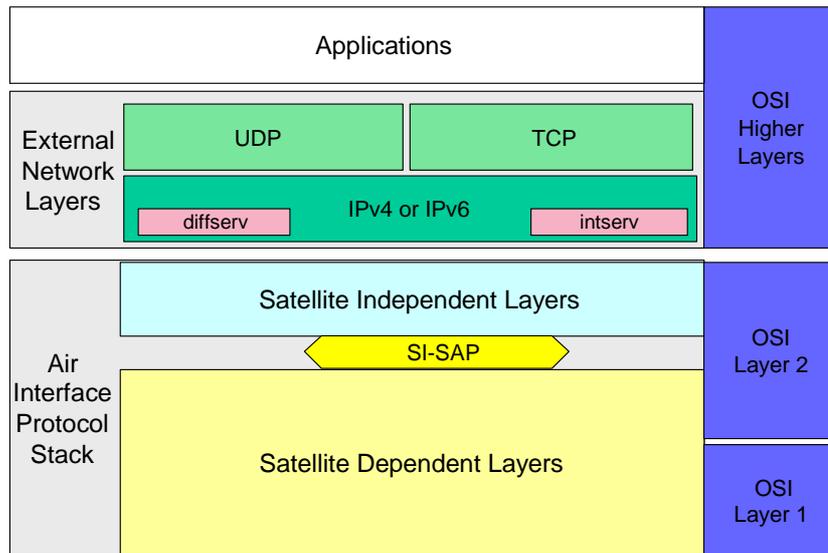
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The IPoS protocol is a multilayered peer-to-peer protocol providing the mechanisms to exchange IP traffic and signaling information between the entities in the hub and remote terminals.

The IPoS protocol is structured according to the architecture in Reference [2], which provides a split between satellite-dependent functions and satellite-independent functions, as illustrated in figure 2.4-1.



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**Figure 2.4-1. Protocol Reference Model**

The protocol architecture separates satellite-dependent functions and satellite-independent functions via an interface designated the SI-SAP. The purpose of this split is as follows:

- Separate the satellite-specific aspects from the satellite-independent higher layer. This separation is designed to permit future market developments, in particular IP enhancements.
- Provide flexibility for the addition of more complex market segment-based solutions (e.g., PEPs).
- Elements above the SI-SAP can be ported with greater ease to new satellite systems.
- Extensibility to support new higher-layer functionalities without major reengineering of existing designs.

As shown in figure 2.4-1, the SI-SAP is positioned between the data link (layer 2) and network layers in the International Organization for Standardization (ISO) layering model. Elements above the SI-SAP can be, and indeed should be, designed without specific knowledge of the supporting satellite link layer. The satellite-independent layers in figure 2.4-1 are generic, including services not currently specified by IPoS such as IntServ, DiffServ, and IPv6.

The IPoS interface is organized into planes, layers, and directions of transmission over the satellite. There are three protocol planes:

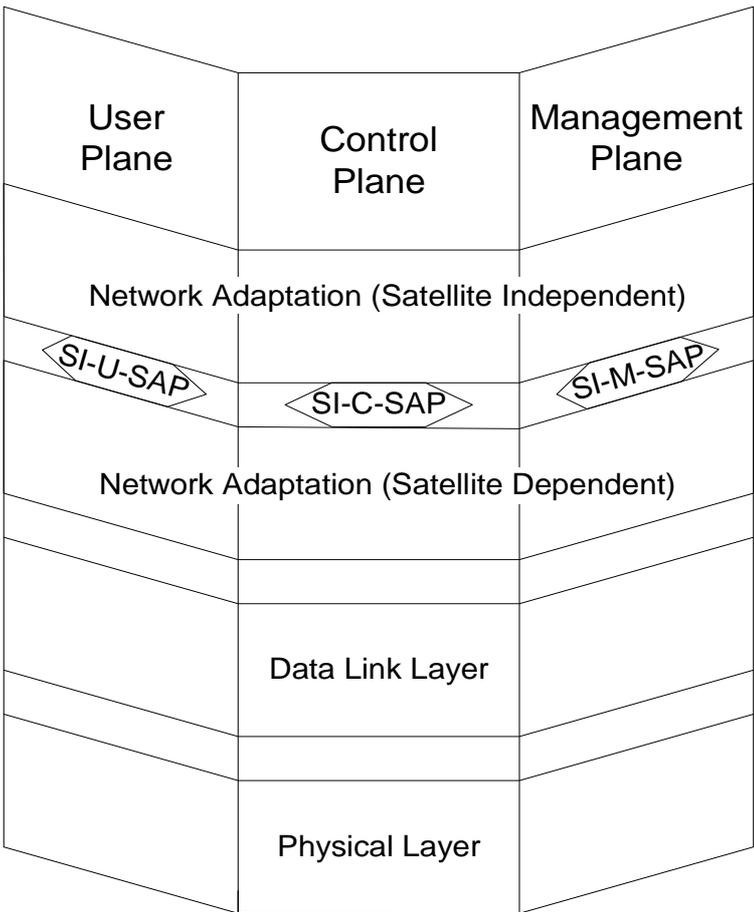
1. User plane (U-Plane): provides the protocols needed for reliable transport of IP traffic containing user information across the satellite interface.



- 1                    1. The outroute direction from the IPoS hub to user terminals is broadcast
- 2                    over the entire bandwidth allocated to the outroute carrier. Because the
- 3                    IPoS outroute can multiplex transmissions, it streams to many remote
- 4                    terminals.
  
- 5                    2. The inroute direction from the remote terminals to the IPoS hub is PtP,
- 6                    either using bandwidth assigned by the hub to individual remote
- 7                    terminals or using bandwidth shared by all terminals on a contention
  
- 8                    Mesh single-hop communications from one remote terminal to another are
- 9                    considered to be inroute transmission.

**2.4.1 Service Points and Primitives**

Adjacent sublayers in the IPoS protocol architecture connect to each other through interface points, designated Service Access Points (SAPs). Through the SAPs the sublayers access the services and capabilities provided by the adjacent sublayer. In general, there are three SAPs at each layer; the SAPs are associated with the U-Plane, C-Plane, and M-Plane, as illustrated in figure 2.4.1-1.

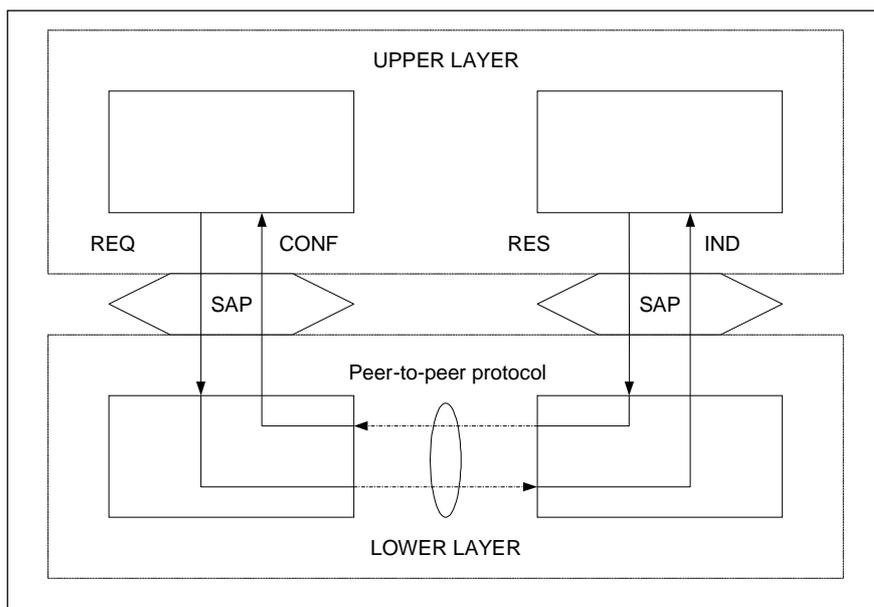


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**Figure 2.4.1-1. Service Access Points**

- 1 Interactions between adjacent layers across SAPs are in terms of primitives. A  
2 primitive is an abstract representation of the information and control exchanges  
3 through the SAP. Four types of primitives are used in the IPoS interface to  
4 represent the passing information across the layers of the U-Plane and C-Plane.  
5 The actions implied by these primitives are:
- 6 1. Request (REQ): occurs when a higher layer invokes services or  
7 functions from the adjacent lower layer
  - 8 2. Indication (IND): used by the lower layer to notify the higher layer of a  
9 REQ at the peer layer
  - 10 3. Response (RES): carries the acknowledgment from the higher layer to  
11 the lower layer for an indication primitive
  - 12 4. Confirm (CON): used by the lower layer to notify the higher layer that  
13 the requested service has been completed

14 The primitive type also indicates the direction of the flow of information. These  
15 flows are indicated in figure 2.4.1-2.



16  
17 **Figure 2.4.1-2. Primitive Flow**

18 The general syntax of primitives in the IPoS contains the following four  
19 elements:

- 20 1. Sublayer
- 21 2. Plane
- 22 3. Generic Name
- 23 4. Type

1 where:

- 2 • Sublayer designates the initials of the sublayer or SAP, providing the  
3 services (PHY for physical, media access control (MAC) for the medium  
4 access layer, DLC for data link control, or SI for primitives across the SI-  
5 SAP interface).
- 6 • Plane designates the initial of the plane where the interaction occurs  
7 (U for U-Plane, C for C-Plane, or M for M-Plane).
- 8 • The Generic Name designates the type of service or function invoked,  
9 e.g., data for data transfer.
- 10 • Type designates the initials of the type of primitive, e.g., REQ, IND,  
11 RES, or CON.

12 For example, the primitive used by the satellite-independent layers to request the  
13 transfer of IP data by the IPoS DLC over the IPoS air interface is SI-U-DATA-  
14 REQ, and the primitive that the DLC uses to deliver an IP packet received over  
15 the IPoS air interface to the satellite-independent layers is SI-U-DATA-IND.

## 16 **2.5 Layer-wise Functional Partitioning**

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17 This subsection gives the functional responsibilities for the layers in the satellite-  
18 dependent part of the IPoS interface.

### 19 **2.5.1 Network Adaptation Layer**

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20 The Network Adaptation Layer function provides the following major  
21 subfunctions:

- 22 • IP Packet Transport: This function determines the Class of Service of  
23 the IP packet based on packet type, application type, destination, and  
24 internal configuration.
- 25 • Traffic Management: This function performs the traffic shedding and  
26 policing functions on IP packets before they are offered to the IPoS  
27 transport services.
- 28 • PEPs: This function improves the performance of certain applications  
29 for improving service over a satellite link. PEPs are often used to reduce  
30 the degradations in throughput experienced by TCP applications because  
31 of the delays and losses in satellite links. Reference [18] (found in  
32 subsection 1.4 of this document) discusses various types of PEPs and the  
33 mechanisms they use to improve performance. Use of PEPs is optional  
34 in IPoS. Typically the PEP sits at the hub, splitting the end-to-end TCP  
35 transport link, acting as virtual TCP senders/receivers connecting the  
36 satellite access system from the terrestrial Internet to the satellite system.  
37 PEP is customized to match the characteristics of the IPoS satellite links.

- 1                                   • Multicast Proxy: This proxy adapts IP multicast protocols  
2                                   (e.g., PIM-SM) to the appropriate IPoS transport services to provide the  
3                                   multicast.

4                                   The Network Adaptation Layer is not part of the IPoS air interface specification.

## 5   **2.5.2           Data Link Layer (DLL)**

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6                                   The DLL provides the actual transport service over the IPoS network. It is  
7                                   divided into the following sublayers:

- 8                                   • Satellite Link Control (SLC)  
9                                   • Media Access Control (MAC)  
10                                  • Outroute multiplexing

### 11   **2.5.2.1           Satellite Link Control Sublayer**

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12                                  The SLC layer is the sublayer of the DLC that is responsible for transmission of  
13                                  packets between remote terminals and the hub, and between terminals for mesh.

14                                  IPoS supports different delivery methods over the outroute and inroute  
15                                  directions.

16                                  A reliable error-free delivery method is used in the inroute direction using  
17                                  selective retransmissions. In this reliable delivery method, the receiving SLC  
18                                  entities deliver only error-free data packets to the higher layers.

19                                  Over the outroute where the transmission errors are very low  
20                                  (typical BER =  $1 \cdot E(-10)$ ), the transmit SLC delivers each data packet only once  
21                                  without retransmission of errored or missing packets.

22                                  The functional responsibilities of the SLC are:

- 23                                  • Generation of session IDs and mapping incoming packets into the  
24                                  corresponding session
- 25                                  • Encryption of specific IP PDUs (protocol data units) for user-to-user data  
26                                  privacy
- 27                                  • Segmentation and reassembly, which performs segmentation/reassembly  
28                                  of variable-length higher layer data packets into smaller PDUs
- 29                                  • Delivery of data in sequence to the peer using the reliable/unreliable  
30                                  mode of delivery

### 2.5.2.2 Medium Access Control Sublayer

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The services or functions provided by the MAC layer can be grouped into the following categories:

- Data transfer: This service provides unacknowledged transfer of MAC interactions between peer MAC entities. This service does not provide any data segmentation; therefore, the upper layers provide the segmentation/reassembly function.
- Reallocation of radio resources and MAC parameters: This service performs control procedures for identifiers that are allocated to a particular DLC layer by the network layer for an interval of time or on a permanent basis. It also performs procedures for the establishment and termination of transfer modes over the DLC layer.
- Error detection: Procedures for the detection of procedural errors or errors occurring during the transmission of frames.
- MAC Addressing: This service filters packets based on MAC addresses.

### 2.5.2.3 Outroute Multiplexing

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In the outroute direction, the multiplexing permits the hub to transmit several traffic types, programs, or services within the same outroute carrier and controls the transmission of each individual program. The IPoS multiplexing sublayer is based on the Digital Video Broadcast /Motion Pictures Expert Group (DVB/MPEG) statistical multiplexing format in reference [1] (found in subsection 1.4 of this document). In this DVB/MPEG format, all the frames or packets associated with one of the traffic types have the same Program Identifier (PID). At the remote terminals, a demultiplexer breaks the outroute multiplex into specific transport streams with the remote terminal filtering only those that match the PID addresses configured in the terminal.

IPoS remote terminals are configured to filter two types of PIDs associated with the following types of transport streams, which are relevant to the IPoS system:

1. PSI tables, which provide both IPoS and non-IPoS terminals with configuration of services. The IPoS terminals receive the PSI tables to determine the specific configuration of the IPoS system.
2. IPoS user and control information, which is transported in the IPoS logical channels. The information contained in the IPoS logical channels can be targeted to all, a group, or individual IPoS terminals.

Outroute DVB/MPEG packets are broadcast over the entire outroute carrier bandwidth with IPoS terminals filtering those packets that do not match their own addresses. The addressing scheme is included as part of the transport packet header and MAC header.

### 1 **2.5.3 Physical Layer (PHY)**

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2 The Physical Layer function provides the transmission and reception of the  
3 modulated waveforms used to transport the data provided by the data link and  
4 higher layers over the satellite. At the PHY, there is no distinction among the  
5 transport methods provided for U-Plane, C-Plane, or M-plane information. This  
6 distinction is made at higher layers.

7 The services provided by the PHY layer are grouped into the following  
8 categories:

- 9 • The initial acquisition, synchronization, and ranging procedures with the  
10 hub, including the timing alignment of the transmissions with the frame  
11 structure of the inroute carriers and the adjustment of the power  
12 transmitted by the remote terminals
- 13 • The modulation, coding, error correction, scrambling, timing, and  
14 frequency synchronization of information flows, provided by the DLC's  
15 U-Plane and C-Plane to the outroute and inroute carriers
- 16 • The performance of local measurements such as received  $E_s/N_0$ ,  
17 recovered clock, and status and supervision of the physical parameters  
18 (such as timing) and their reporting to higher layers
- 19 • Spreading, Frequency, Doppler compensation and additional (to FSS  
20 system) time synchronization procedure to support mobility

### 21 **2.6 Terminal Procedures**

---

22 The IPoS system relies on a multiplicity of procedures and algorithms to perform  
23 its functionality. The subsections below identify the procedures used over the  
24 IPoS air interface. The procedures are divided into:

- 25 • Commissioning procedures: These are mainly M-Plane procedures  
26 concerned with the initial configuration of the remote terminals and  
27 database at the hub and the binding of addresses and encryption keys  
28 used to transfer data over the IPoS system to the individual remote  
29 terminals.
- 30 • Idle state procedures: These are mainly C-Plane procedures a terminal  
31 needs to perform before becoming active and in returning to the Idle state  
32 after exchanging traffic.
- 33 • Transport procedures: These are procedures that provide the reliable  
34 exchange of user, control, and management information in the Active  
35 state.
- 36 • Security procedures: These are procedures executed to protect the  
37 unauthorized use of services in the IPoS system and to provide  
38 encryption of the information transferred across the satellite.

## 1 **2.6.1 Commissioning Procedures**

---

2 The following describes the commissioning procedures needed to be performed  
3 before the terminal is ready to exchange traffic over the IPoS system. The  
4 parameters needed during the commissioning procedures (such as satellite  
5 location, transponder frequencies, addresses, and encryption keys) are  
6 determined by the IPoS network managers or at the factory.

### 7 **2.6.1.1 Installation**

---

8 The following parameters are configured during the installation:

- 9 • Satellite orbital location in degrees
- 10 • Characteristics of the outroute carrier to be used, i.e., such as frequency,  
11 symbol rate, modulation, and coding
- 12 • Transponder polarization
- 13 • The latitude and longitude of the IPoS remote being configured  
14 (alternatively a Post Code or ZIP code lookup table could be used)
- 15 • IP address of IP packet processor at the hub
- 16 • The remote terminal's own internal address within the system
- 17 • Terminal capability to support the TDMA bursts
- 18 • Spreading multiplication options
- 19 • Mesh communications related parameters

20 The installer points the antenna and adjusts the antenna polarization plane to  
21 minimize cross-polarization interference.

### 22 **2.6.1.2 System Timing**

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23 During the system timing procedure, the remote terminal uses parameters  
24 configured during installation to acquire and demodulate the outroute carrier and  
25 extract system timing and other relevant information conveyed by the outroute  
26 carrier.

27 The acquisition of the outroute carrier provides the remote terminal with:

- 28 • The symbol clock of the demodulated carrier to be used for the frequency  
29 stability of the local frequency reference used to derive the frequency of  
30 the inroute carriers
- 31 • Reception of the superframe numbering packets transmitted by the hub  
32 every 360 msec at the beginning of every superframe

- 1                   • The PIDs used by the remote to prefilter the control and traffic
- 2                   information contained in the outroute
  
- 3                   • The information in the channels with the PID addresses monitored for
- 4                   the terminal

### 5   **2.6.1.3   Synchronization**

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6                   Synchronization refers to the process of aligning the remote terminals'  
7                   transmissions over the inroute direction with the reference timing of the inroute  
8                   frames at the hub. During synchronization, the remote terminals calculate the  
9                   initial timing offset needed to introduce the marker received from the superframe  
10                  over the outroute carrier for the IPoS hub. This marker is needed so that the hub  
11                  can receive the remote transmission assigned from the frame structure of the  
12                  inroute carriers at the hub.

13                 The IPoS remote uses rough location information (such as ZIP code or lat/long)  
14                 from the remote site and the satellite ephemeris for an initial course estimation of  
15                 the timing offset needed for inroute transmissions.

### 16   **2.6.1.4   Ranging**

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17                 Ranging is the process for obtaining a fine timing offset estimate for inroute  
18                 transmissions. During the ranging procedure, the remote terminals transmit over  
19                 specific inroute channels designated for this purpose. The hub receives the  
20                 ranging bursts. The hub then estimates the timing adjustment needed to align the  
21                 remote terminal's inroute transmissions and sends the adjustment to the remote.

22                 Also, during ranging the hub estimates the power level of the remote and sets the  
23                 inroute power of the remote terminal. The remote terminal supplies the hub  
24                 within the Ranging Request with a measurement of the receive signal strength of  
25                 the outroute carrier. The hub records this information along with other  
26                 information about the remote terminal.

### 27   **2.6.1.5   Registration**

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28                 Registration is the process whereby authorized remote terminals are given the  
29                 internal addresses. In addition, the terminals are also given the encryption keys  
30                 needed at the hub to forward traffic to these terminals and for the remote  
31                 terminals to decrypt the information and exchange traffic with the hub.

32                 The registration information and the bindings to IPoS internal addresses and  
33                 encryption keys are stored in the IPoS management database containing  
34                 parameters relevant for the operation and billing of users. These parameters are:

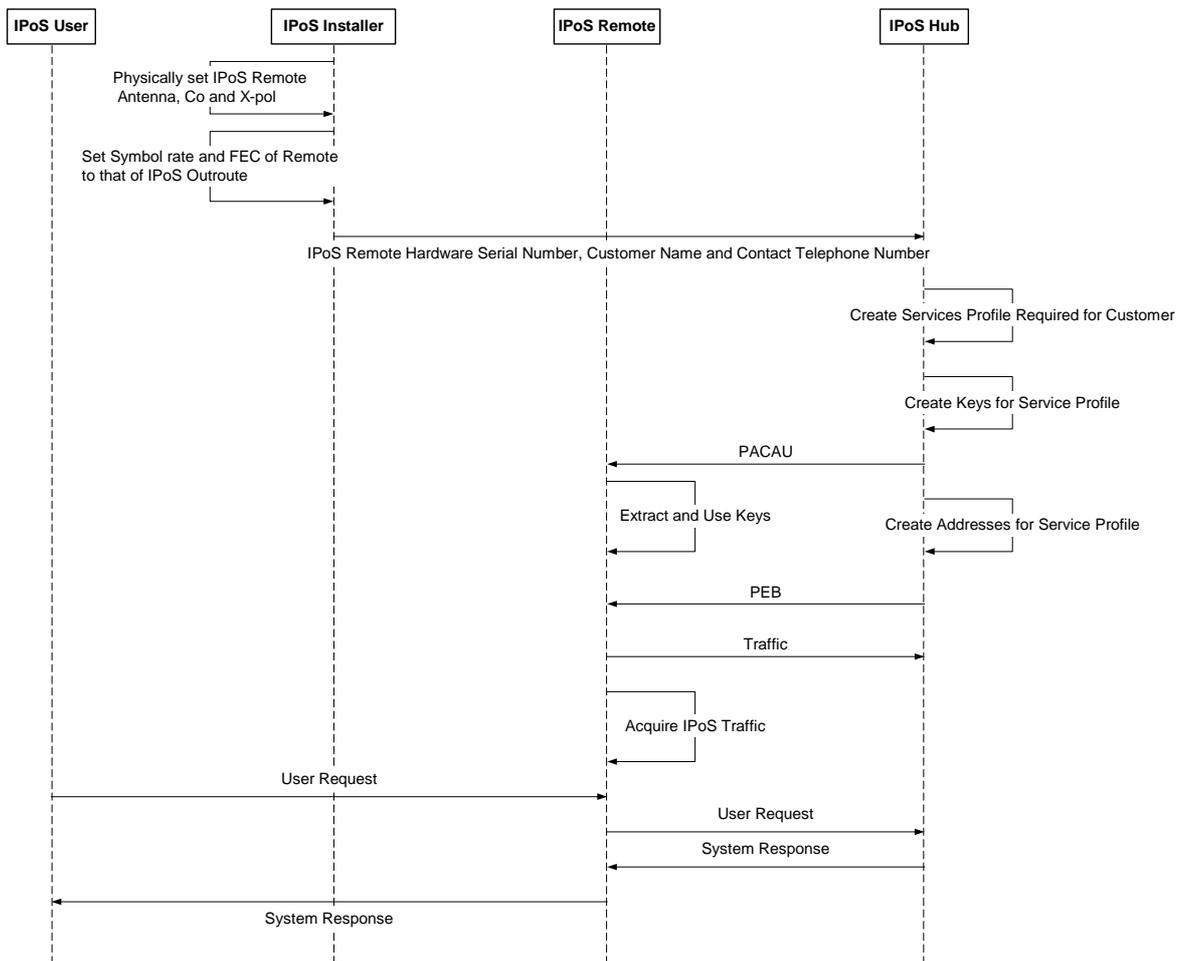
- 35                   • Remote terminal serial number
  
- 36                   • Customer name and contact information

37                 Based on the parameters stored in the database, the hub creates the addresses and  
38                 encryption keys for the different services to which the terminal is entitled. The

1 IPoS internal addresses are configured in the terminal at installation time. The  
 2 encryption keys are distributed to the remote terminals over the outroute carrier.

3 Several types of encryption keys are used in the IPoS system, as discussed in the  
 4 security sections of this document. Key encrypting keys are used to encrypt  
 5 other keys used to encrypt the actual user information. The remote terminal  
 6 receives these keys during registration and stores the keys in the decryption  
 7 hardware so that it is ready for decrypting the outroute information when entering  
 8 the Active state.

9 After completing registration, the remote terminal is ready to begin operation in  
 10 the IPoS system. This process is illustrated by figure 2.6.1.5-1.



11  
 12

13 **Figure 2.6.1.5-1. IPoS User Registration**

14 **2.6.1.6 Authentication**

15 No terminal authentication procedure is required of the IPoS. The identity of a  
 16 terminal is demonstrated by its ability to decrypt the messages received over the  
 17 outroute containing the keys that will be used later to decrypt user information.

1 For this action, the terminal Master Key (MK) installed at the terminals must  
2 coincide with an MK used at the hub to create the encryption keys. An  
3 unauthorized terminal will not have the same MK data as that on the authorized  
4 terminal, so it will not be able to decode outroute data.

## 5 **2.6.2 Idle Mode Procedures**

### 6 **2.6.2.1 System Information Reception**

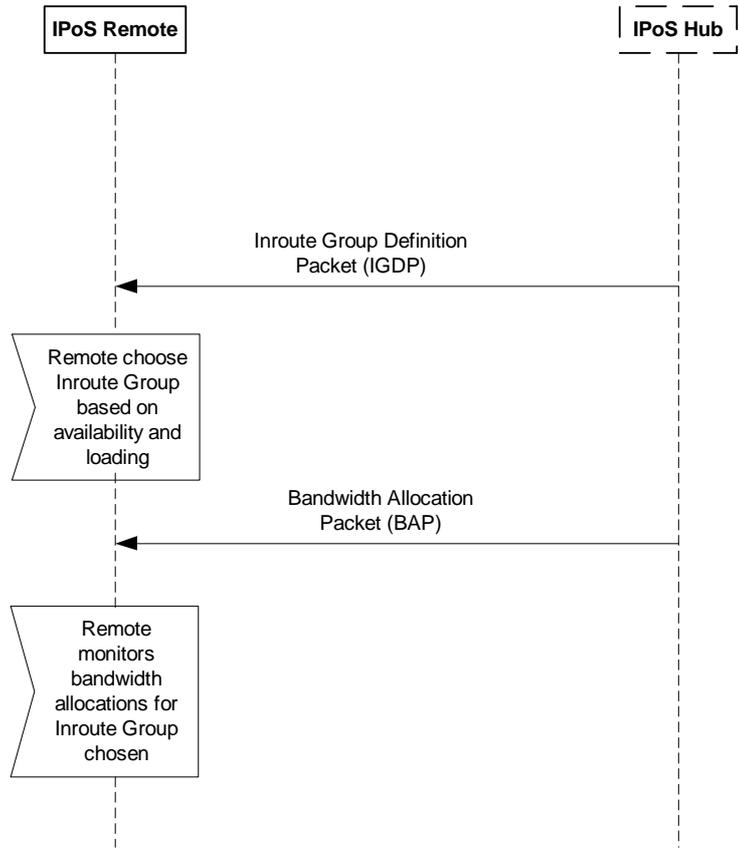
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7 Before remote terminals can send information to the hub, they must gain  
8 knowledge of the inroute carrier frequencies used for user and control channels  
9 and the associated data rates and encoding used in these channels.

10 IPoS provides automated inroute load balancing and high availability by  
11 subdividing the IPoS inroutes into several inroute groups. The hub periodically  
12 broadcasts this information about the inroute groups over the outroute. The  
13 reception of the outroute carrier provides the remote terminals with system  
14 information related to the organization of the inroute into inroute groups,  
15 including the burst-time plan of all inroute groups associated with the IPoS  
16 outroute. The burst time plan provides the remotes with a description that  
17 includes:

- 18 • The inroute frequencies and burst type where the remote is allowed to  
19 transmit
- 20 • The duration and location of the bursts

21 The hub also advertises its traffic-loading levels in all inroute groups. The  
22 remote terminals use traffic-loading information to choose the least-loaded  
23 inroute group. However, the IPoS remote can change these inroute groups  
24 depending on the loading information conveyed by the Return Broadcast  
25 Channel, which is always monitored by the remote terminals to obtain the  
26 available inroute groups and the resources available in each inroute group. See  
27 figure 2.6.2.1-1.



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**Figure 2.6.2.1-1. IPoS System Information Reception**

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In idle mode, an IPoS terminal shall monitor Inroute Group Definition Packet (IGDP) messages for learning information of all inroute groups. Information and characteristics of all inroute groups are broadcast via IGDP messages. To transition to active mode, the terminal shall select an inroute group from among all advertized groups based on availability and advertized load information of these inroute groups.

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After selecting an inroute group, the remote terminal shall send bandwidth request on unallocated channel and monitor for bandwidth allocation messages for the selected inroute group. The terminal transmits bursts on assigned bandwidth slots.

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**2.6.2.2 Addressing and Routing**

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IPoS connectivity to the external terrestrial networks is based on IP version 4 (IPv4) routable addresses according to reference [3] (found in subsection 1.4 of this document) and will evolve to support IPv6 in reference [4] (found in subsection 1.4 of this document). The IPoS system is home to a static set of IP addresses that support both globally unique Internet addresses, or internal subnet IPoS addresses that are associated to a global hub address for each of the remote terminals. Network Address Translation (NAT) between the global IP and the internal subnet addresses is provided by the hub.

1 A static IP address is assigned as part of the commissioning process. This  
2 allocated IP address remains unchanged as long as the user is part of the IPoS  
3 system. The remote terminal's allocated IP address is the IP destination address  
4 used by hosts in the public network to contact the remote terminal in the IPoS  
5 system; IP packets received at the hub include this destination IP address that  
6 identifies the remote terminal to the hub. When an IPoS remote terminal intends  
7 to contact a host external to the IPoS system, the remote terminal includes the IP  
8 address of the destination host in the IP packets sent to the hub. The hub  
9 includes the IP destination address of the external host in the IP header of the  
10 packets sent by the hub over the terrestrial network so that they could be routed  
11 to the destination host.

12 When the remote terminal is using NAT, remote-terminal initiated connections  
13 are not possible until one of the globally unique Internet addresses supported by  
14 the hub is associated with the remote terminal as part of an Internet connection  
15 initiated by the hub.

16 IP addressing is not used for routing within IPoS. Instead, a layer 2 routing  
17 based on IPoS internal MAC addresses is used to identify and route within IPoS.  
18 The terminals' internal MAC addresses are created during terminal registration  
19 and the binding between the external IP address and its internal remote terminal  
20 MAC address is stored at the hub.

21 For IP packets arriving at the hub for delivery over the outroute direction, the hub  
22 performs the mapping between the remote terminal's IP address and the internal  
23 IPoS MAC address. The IP packet received at the hub, including the IP address  
24 for that particular terminal, is then encapsulated by the hub into PDUs that  
25 contain the internal MAC address used for routing within the IPoS system.

26 The internal MAC addressing provides three types of connectivity within the  
27 IPoS system:

- 28 1. PtP (point-to-point): defined with unicast addresses to deliver  
29 information from the hub to a single IPoS terminal.
- 30 2. PMP (point-to-multipoint): defined with multicast addresses to deliver  
31 the same information from the hub to a group of IPoS terminals.
- 32 3. Broadcast connectivity: defined with broadcast addresses to deliver the  
33 same information from the hub to all IPoS terminals in the system.

34 In the inroute direction, the remote terminals use the hub destination to send  
35 information over the inroute carriers. The remote terminals encapsulate the IP  
36 packets, including the IP address identifying the final destination to the Internet  
37 routers over the inroute direction. The hub removes the IPoS internal inroute  
38 encapsulation before sending the IP packet over the terrestrial Internet.

### 39 **2.6.2.3 Access Session**

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40 IPoS provides satellite users with a virtual "always on" type of access that does  
41 not require the remote terminals to dial-up or establish an access session once the  
42 terminal has completed its registration. In this "always on" service, all registered

1 IPoS remote terminals maintain permanent IP connectivity to the external  
2 Internet, via the allocated IP address and internal IPoS connectivity and via the  
3 assigned MAC address, without the need for access session initiation or  
4 termination. The hub provides the attachment point where the IPoS network is  
5 connected to the Internet.

6 In Idle mode, the hub is always ready to accept IP packets for delivery to remote  
7 terminals over the IPoS system. For the remote terminals to be able to send IP  
8 packets, they first need to exchange control packets with the hub in order to  
9 obtain the inroute bandwidth needed to support the transmissions from the  
10 remote terminal to the hub.

11 The IPoS system is transparent to the service level sessions between user hosts  
12 and Internet servers that might take place based on the user IP address.

#### 13 **2.6.2.4 Bandwidth Request and Allocation**

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14 Before the remote terminal can transfer data over the inroute, it needs to request  
15 bandwidth on one of the inroute groups defined in the IPoS system. The  
16 Bandwidth Allocation Request (BAR) packet is sent by the remote over the  
17 Aloha channels defined for the particular inroute group.

18 The hub processes the bandwidth request and acknowledges the bandwidth  
19 request with an explicit acknowledgment sent over the multicast logical channel  
20 associated to the particular inroute group.

21 Once the hub determines the bandwidth to be assigned over the particular inroute  
22 group, it sends the Bandwidth Allocation Packet (BAP) indicating which active  
23 terminals on that inroute group are assigned to which timeslots in the inroute  
24 group. After the remote terminal transmits the assigned timeslots, the hub  
25 indicates which bursts were received correctly. Bandwidth allocation is  
26 illustrated in figure 2.6.2.4-1.

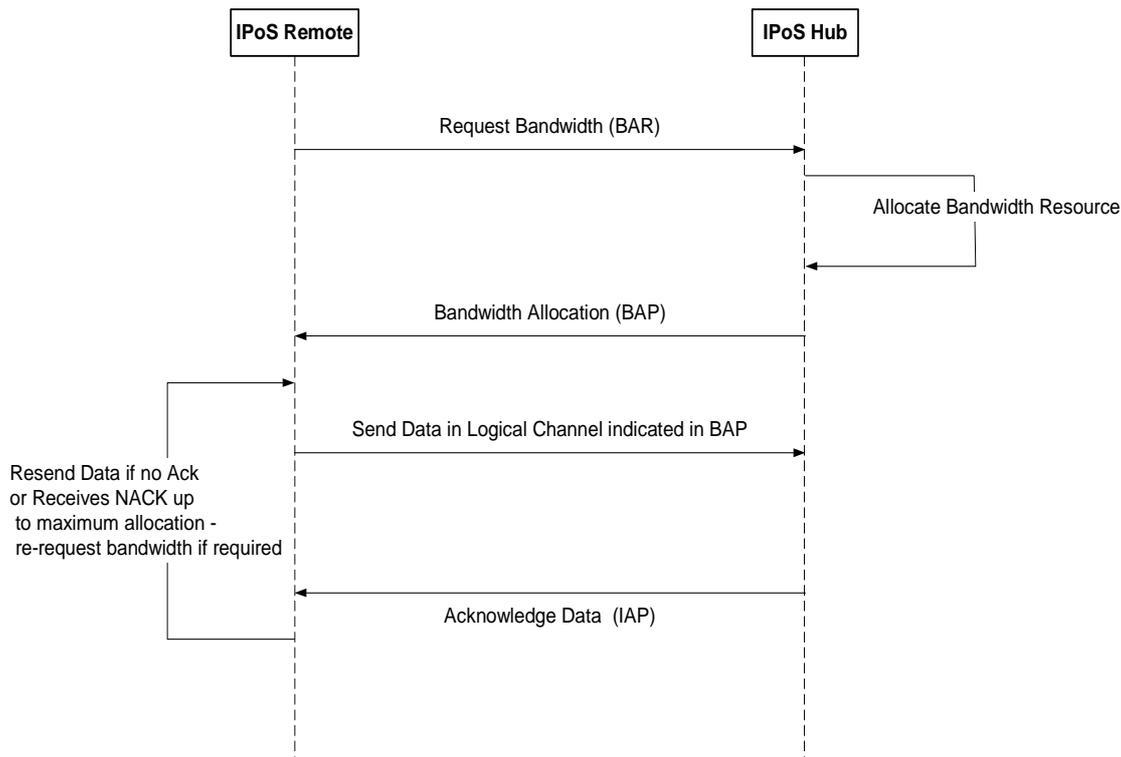


Figure 2.6.2.4-1. Bandwidth Request Allocation

### 2.6.2.5 Transition to the Idle State

The remote terminal transitions to the Idle state when it completes its transmission and does not receive a bandwidth assignment after a bandwidth request. (The transition of remote terminals to the Idle state is controlled by the hub; a mobile terminal needs to transmit when it receives a bandwidth assignment even if it has no data to transmit.) From the Idle state, the remote terminal will send a new bandwidth request to resume sending data on the inroute.

## 2.6.3 Transport Procedures

The following subsections describe the procedures for the reliable transfer of user, control, and management information between remote terminals and the hub. This reliable transfer of information in the IPoS system is based on:

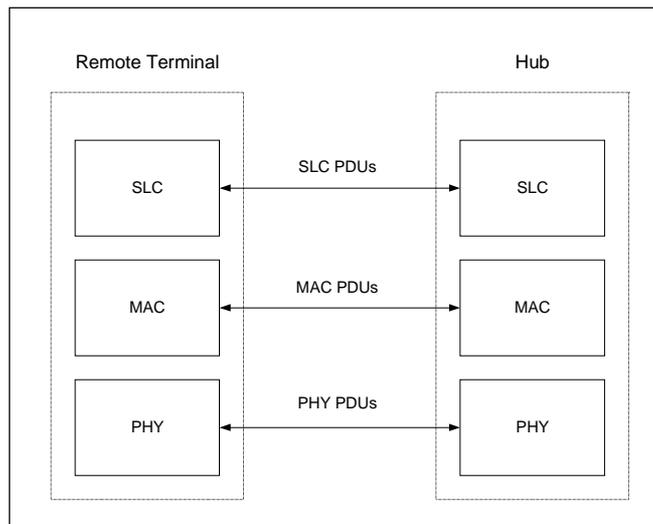
- Encapsulation formats specific for each information type
- The segmentation used to break the information into fragments that can be accommodated within the length limits of the different encapsulation formats
- The definition of logical channels that convey preestablished message types

- 1                   • The error protection, error detection, and error control procedures used
- 2                   over the different types of logical channels.
- 3                   Internet user traffic (e.g., TCP applications) originating at the remote terminal
- 4                   passes through the IPoS system in the following steps:
- 5                   • The PC sends IP packets to the IRU in the remote terminal.
- 6                   • The IRU segments, encapsulates, and transmits each IP packet (possibly
- 7                   in multiple bursts) over the inroute carriers.
- 8                   • The hub reassembles each IP packet from burst received from the remote
- 9                   terminal.
- 10                  • The hub communicates with the destination host over the Internet using
- 11                  the destination address in the received packet.
- 12                  • Packets received from the destination host are buffered at the hub then
- 13                  sent to the remote terminal over the outroute carrier.

**2.6.3.1 Encapsulation Formats**

The processes in the peer layers at the remote terminal and the hub interact with each other through the set formats designated as PDUs. These PDUs contain the set of user, control, and management information exchanged across the air interface in the form described in this standard, where PDUs are defined for the physical layer, PHY PDU; at the MAC sublayer, MAC PDU; and at the SLC sublayer, SLC PDU.

These exchanges of PDUs among the different peer layers are illustrated in figure 2.6.3.1-1.



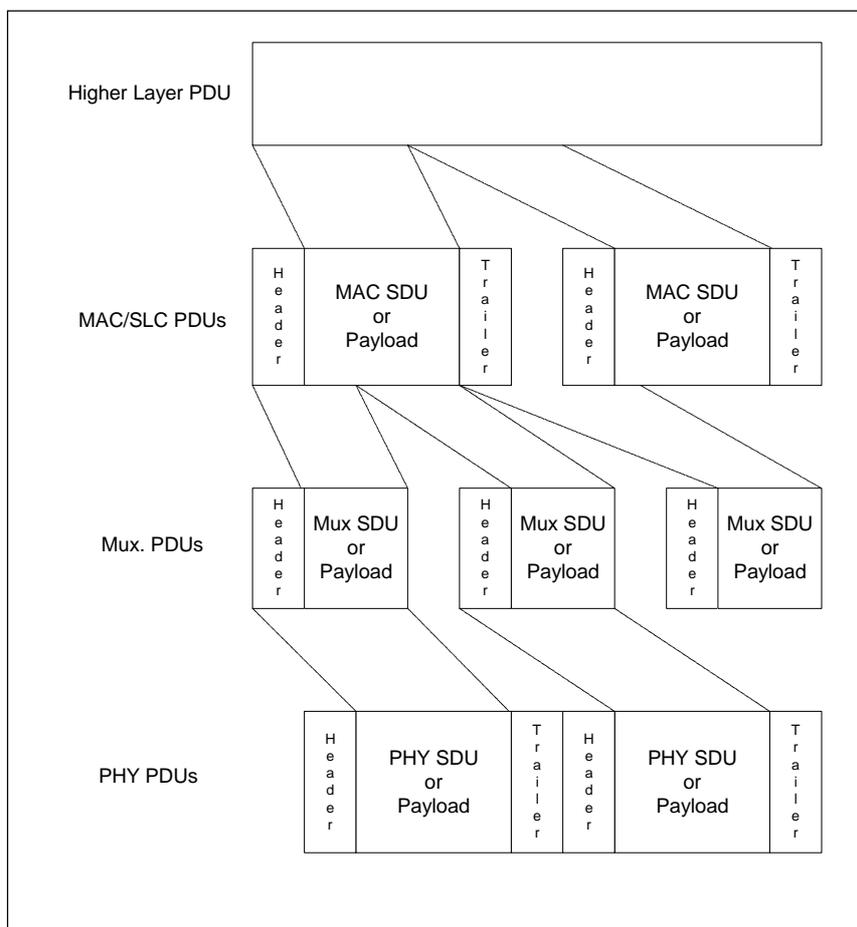
**Figure 2.6.3.1-1. Peer Layer PDU Exchanges**

### 1    **2.6.3.2    Segmentation and Packetization**

2                    The encapsulation formats transferred across the IPoS system are referred to as  
3                    PDUs.

4                    In general, the format of the PDUs used across IPoS peer layers consists of a  
5                    header, the payload or Service Data Unit (SDU), and a trailer. Headers, SDUs,  
6                    and trailers are defined specifically for each layer.

7                    Primitives across the sublayer, SAPs, provide the information and the instruction  
8                    for different sublayers in IPoS protocol. The information from the higher layer  
9                    PDUs is encapsulated into the SDU of the lower sublayers, including a  
10                    DVB-MPEG compatible protocol encapsulation used in the multiplexer sublayer  
11                    that allows multiple types of services to share the same outroute PHY.  
12                    Figure 2.6.3.2-1 illustrates the different encapsulation formats used in the IPoS  
13                    outroute direction.



14

15

**Figure 2.6.3.2-1. IPoS Outroute Data Flows**

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17

Figure 2.6.3.2-2 illustrates the encapsulation formats across the inroute, formats that are similar to the formats in the outroute without the multiplexing layer.

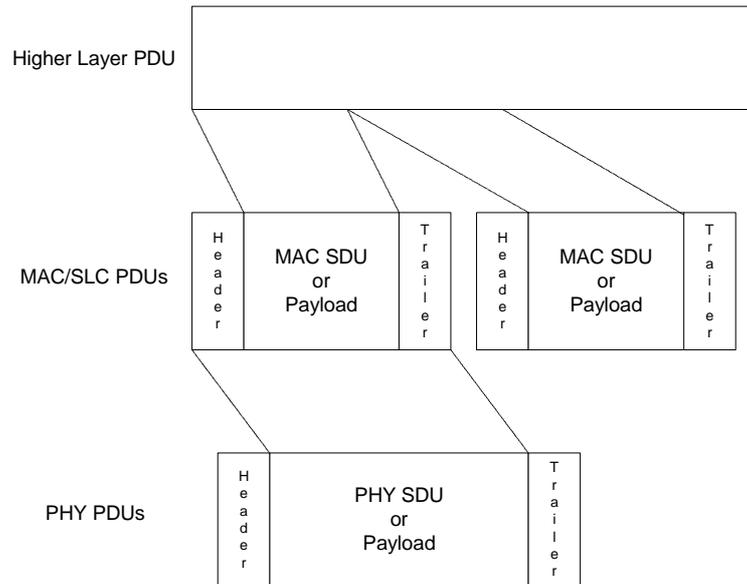


Figure 2.6.3.2-2. IPoS Inroute Data Flows

### 2.6.3.3 Logical Channels

Transfers of user, control, and management information in IPoS take place over logical channels. Logical channels are unidirectional and defined in both the outroute and inroute directions.

Outroute logical channels are classified according to the characteristics of the information transferred into

- Traffic channels: used for transferring user plane and management plane information
- Control channels: used for transferring control plane information

Also, outroute logical channels are classified by the type of connectivity provided from the IPoS hub to the IPoS remotes. Three types of connectivity are supported by the outroute logical channels:

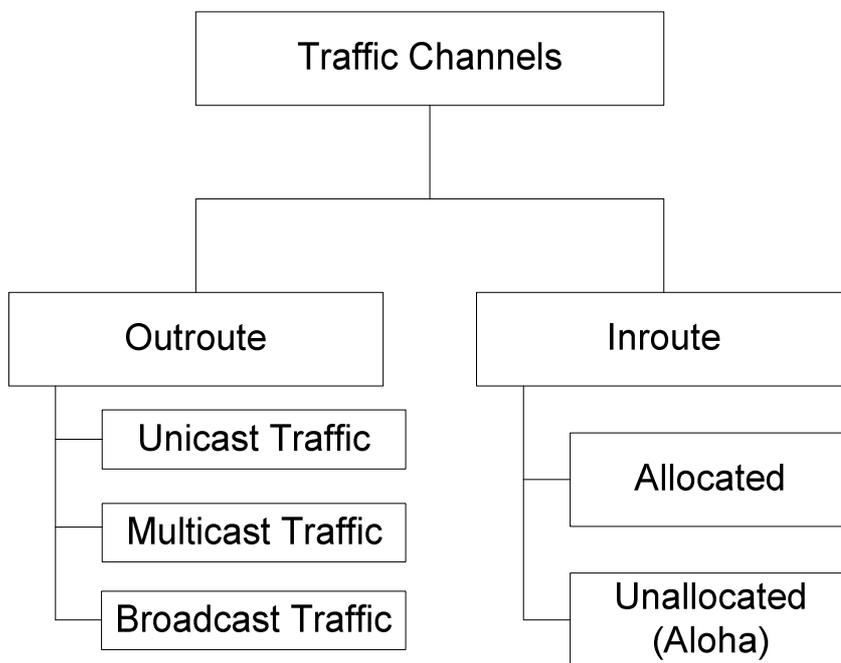
1. PtP connections: defined with a unicast address to deliver information to a single IPoS terminal
2. PMP connections: defined with a multicast address to deliver the same information to a group of IPoS terminals
3. Broadcast connectivity: delivers the same information to all IPoS terminals in the system

In the inroute direction, IPoS provides PtP connectivity from the particular remote terminal to the hub (star topology) or from a remote terminal to another remote terminal (mesh topology), both for traffic and control channels. The classification of logical channels for the inroute direction is made according to

1 whether the channel bandwidth could be shared by multiple remote terminals or  
2 is dedicated to a particular terminal. Two types of inroute logical channels are  
3 defined in the IPoS:

- 4 1. Unallocated channels: These are channels shared by multiple IPoS  
5 terminals using contention access procedure. These channels are also  
6 known as Aloha channels. Mostly control information is sent on these  
7 channels.
- 8 2. Allocated channels: These are channels dedicated to one specific IPoS  
9 terminal for the transmission of user information during an allocated time  
10 interval. Control information is also sent on these channels.

11 The designation of traffic channels and their connectivity is shown in  
12 figure 2.6.3.3-1. Also, unallocated channels could be used to carry user traffic.



13

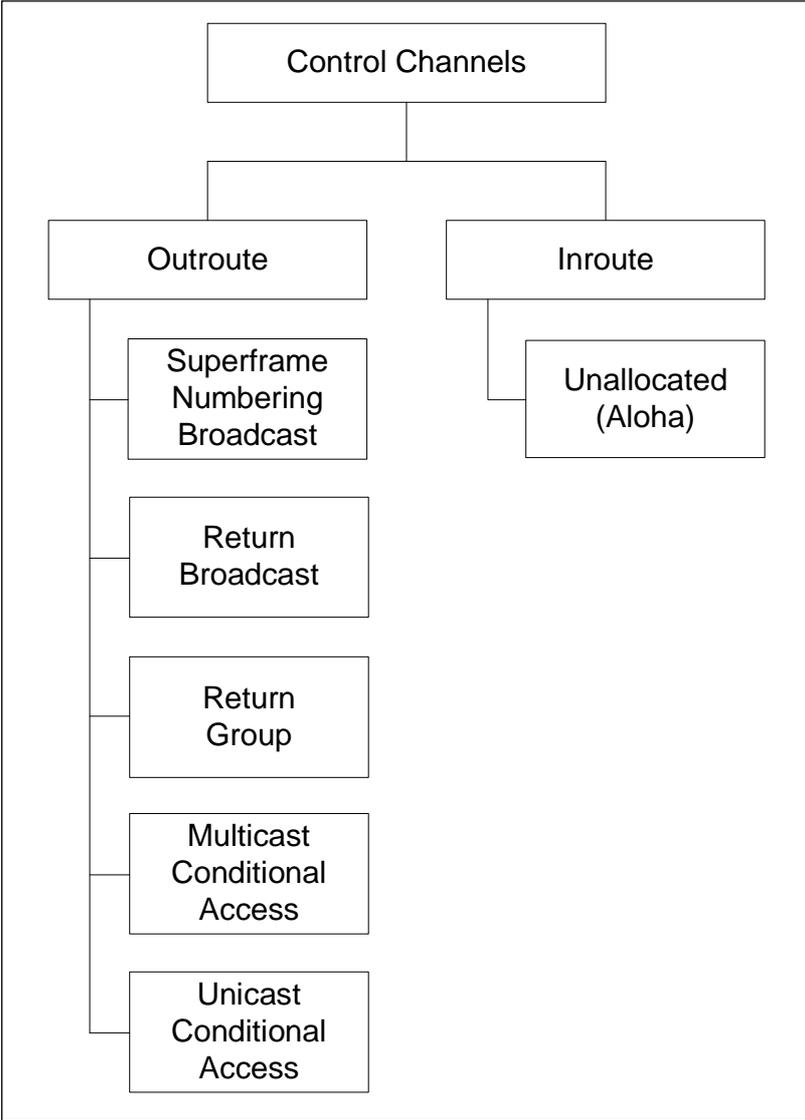
14

**Figure 2.6.3.3-1. Traffic Channel Types**

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Figure 2.6.3.3-2 shows the different types of logical control channels defined both for both outroute and inroute directions.



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**Figure 2.6.3.3-2. Control Channel Types**

**2.6.3.4 Error Control**

In IPoS, error control is achieved by a combination of error control strategies across the different layers of the protocol stack. These strategies include:

- FEC in the physical sublayer
- Cyclic Redundancy Checking (CRC) in the MAC sublayer for inroute is used for LDPC coded inroute. The BCH code is used to correct and also detect the burst error for turbo coded inroute.
- Procedures to control the repetition of SLC/MAC segments

- 1 The FEC design in IPoS is different for outroute and inroute directions:
- 2 • The outroute direction uses the concatenation of a Reed-Solomon code
- 3 with a LDPC with BCH coding.
- 4 • The inroute direction includes the option to use the following coding
- 5 ○ Turbo coding or
- 6 ○ LDPC coding.

7 The IPoS procedures that control repetitions over the different logical channels

8 include three modes of operation:

- 9 1. Unacknowledged operation
- 10 2. Acknowledged operation
- 11 3. Contention access

#### 12 **2.6.3.4.1 Unacknowledged Operations**

---

13 Unacknowledged operation is applicable to all logical channels in the outroute

14 direction and for all addressing modes: broadcast, multicast, and unicast. In this

15 unacknowledged operation, the MAC PDUs are neither acknowledged nor

16 retransmitted, even if transmission errors or format errors are detected.

#### 17 **2.6.3.4.2 Acknowledged Operation**

---

18 IPoS provides acknowledged operation over the inroute traffic, allocated, and

19 logical channels. Acknowledged operation uses an Automatic Request (ARQ)

20 procedure providing error correction by retransmission for the recovery of remote

21 terminal transmissions that have been corrupted.

22 The ARQ procedure allows selective repeat retransmission where only those

23 inroute bursts that are not acknowledged by the hub in the outroute direction (the

24 acknowledgment could also be lost) will be retransmitted by the remote terminal.

25 ARQ go-back-N-based procedure is also supported by this standard.

26 Error detection at the hub and the remote terminals are based on CRC fields

27 included at the MAC sublayer.

#### 28 **2.6.3.4.3 Contention Access**

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29 Contention access based on a backoff-and-retry procedure is used on the

30 unallocated inroute channels to arbitrate the access of multiple remote terminals

31 to these inroute logical channels. These inroute unallocated logical channels are

32 also designated as Aloha channels. The contention procedure provides the ability

33 to transmit the same information on two unallocated channels in a scheme

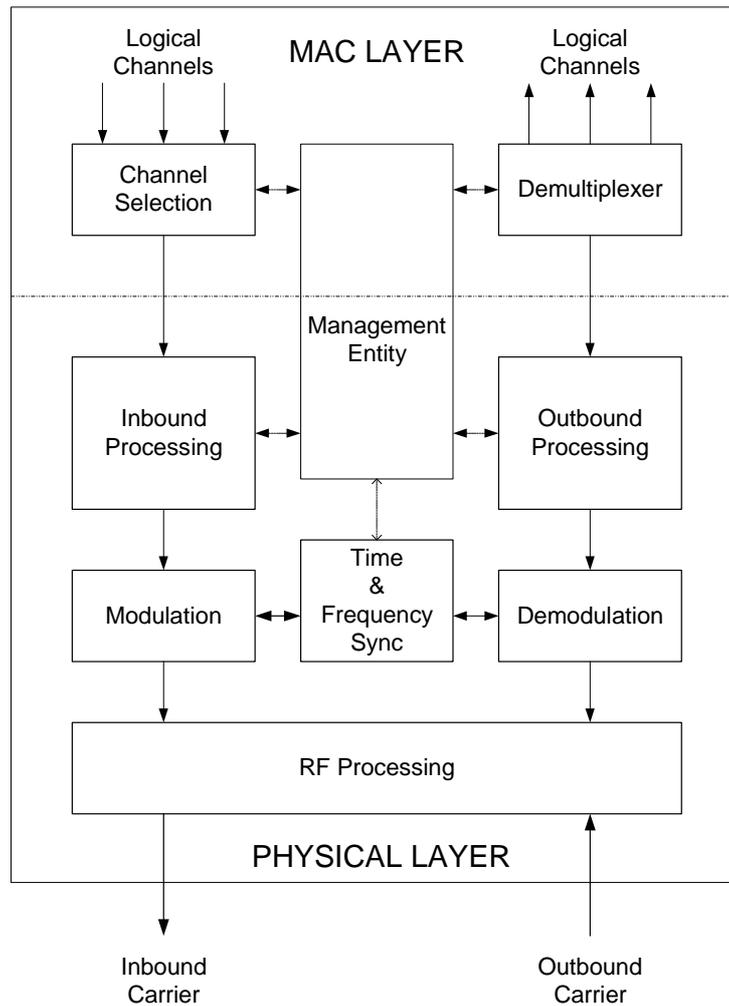
34 designated as diversity Aloha, which reduces the overall probability of collision.

**TIA-1008-B**

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1 The Aloha channels are primarily used for control messages, mainly bandwidth  
2 requests from the remote terminals, in the inroute direction. Piggybacking of  
3 user data with control messages is also supported in the Aloha channels.





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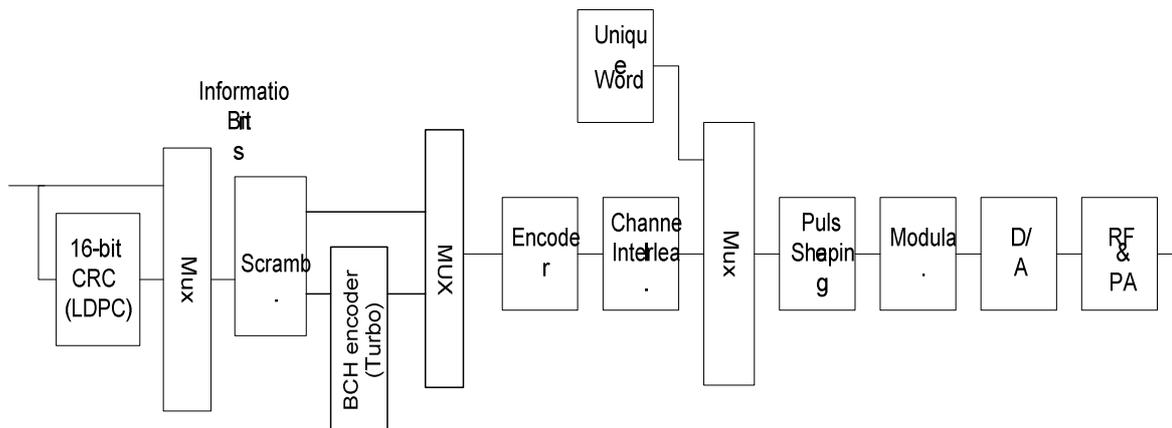
**Figure 3.2-1. The Physical Layer and Its Relationship to the MAC Layer**

### 3.3 Outroute Physical Layer

IPoS outroute utilizes DVB-S2 [19] compliant modulation and coding.

### 3.4 Inroute Physical Layer

The high-level structure of the inroute transmit chain is shown in figure 3.5-1.



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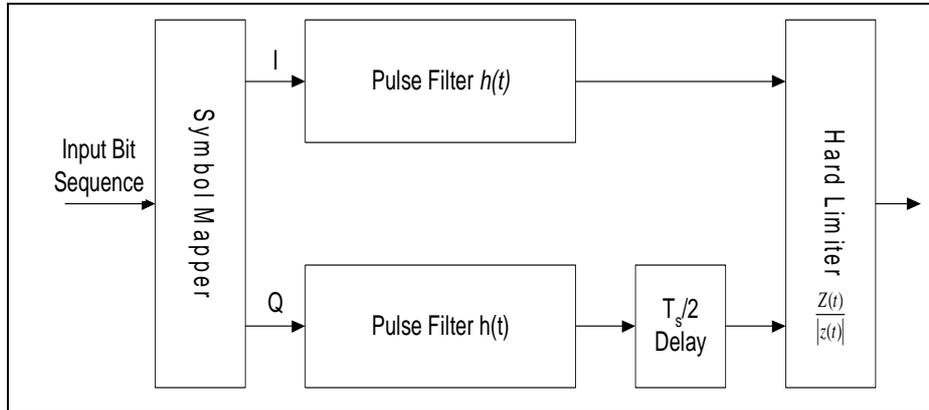
**Figure 3.5-1. High-Level IPoS Inroute Diagram**

The following paragraphs describe the blocks illustrated in figure 3.5-1.

- **16-bit CRC:** Used for LDPC inroutes. This unit adds bits to the information stream to allow the verification of its integrity across the inroute direction.
- **Scrambler:** This unit randomizes the inroute stream to avoid the concentration of transmitted energy in particular parts of the spectrum.
- **BCH:** Used for turbo-coded inroutes. This unit adds bits to the information stream to allow error detection and error correction across the Inroute direction.
- **Encoder:** This unit introduces an error protection bit using Turbo-coding or LDPC techniques
- **Channel Interleaver:** This unit modifies the order of the transmitted bits in an attempt to randomize the errors introduced in the inroute channel.
- **Unique Word (UW):** This unit introduces fixed patterns of bits to assist with the timing synchronization of the received signal.
- **Pulse shaping:** This unit conforms to the spectrum of the transmitted signal.
- **Modulator:** This unit maps the baseband bits into the constellation of allowed carrier phases.
- **D/A (digital-to-analog) converter:** This unit transforms the digital samples of the inroute waveform into an analog signal.
- **RF and PA (power amplifier):** This unit performs the frequency translation and amplification of the inroute signal

1 **3.4.1 Modulation**

2 The IPoS remote shall use Constant Envelope Offset-QPSK (CE-OQPSK)  
 3 modulation for the IPoS inroute. The baseband equivalent diagram of the  
 4 modulator is shown in figure 3.4.1-1.



5  
 6 **Figure 3.4.1-1. Block Diagram of the Modulator**

7 The OQPSK baseband signal before the hard limiter is given by:

8 
$$z(t) = \sum_k \{I(k) \cdot h(t - kT_s) + j \cdot Q(k) \cdot h(t - kT_s - T_s / 2)\}$$

9 where:

10  $I(k) + j \cdot Q(k)$  denotes QPSK symbol.

11  $T_s$  is the symbol duration.

12  $h(t)$  is the shaping pulse created by the shaping filter.

13  $k$  is the time index.

14 The mapping between the input bit sequence to the modulator and the OQPSK  
 15 symbol is given in table 3.4.1-1.

**Table 3.5.1-1. OQPSK Signal Mapping**

Bit Pair (b(2k-1),b(2k))	Modulated Symbol (I(k) + jQ(k))
(1, 1)	$(1 + j) / \sqrt{2}$
(0, 1)	$(-1 + j) / \sqrt{2}$
(0, 0)	$(-1 - j) / \sqrt{2}$
(1, 0)	$(1 - j) / \sqrt{2}$



1

2

FEC 2/3 Unique Word

3

In Phase : 0111 0110 1011 1000 1110 0110 110

4

Quadrature : 0100 0100 0010 1111 0100 0011 010

5

6

FEC 4/5 Unique Word

7

In Phase : 0011 1011 1011 1001 0110 0101 101

8

Quadrature : 0101 0100 1110 0101 1111 1000 011

9

FEC 9/10 Unique Word

10

In Phase : 0100 0100 0010 1111 0100 0011 010

11

Quadrature : 1110 0110 1011 1000 0111 0110 110

12

The left-most bit of the UW is transmitted first.

13

### 3.4.3 Coding

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14

IPoS Remote Terminals may use two types of encoding schemes in the inroute direction:

15

16

1. Turbo encoding, where data is passed through the scrambler, followed by the BCH encoder, Turbo encoder and channel interleaver

17

18

2. LDPC coding, where data is passed through the V.35 scrambler [20], followed by the CRC calculator, LDPC encoder and Burst formatter.

19

20

#### 3.4.3.1 Turbo Coding with BCH

---

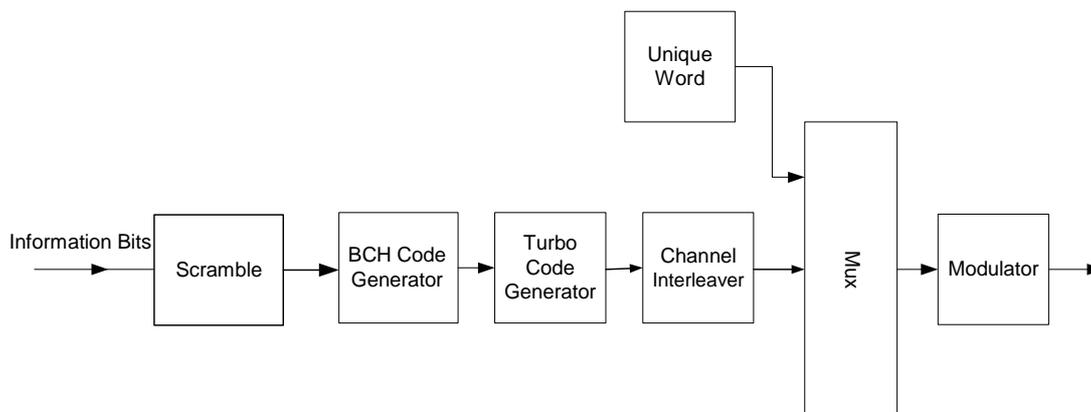
21

When Turbo coding is used, the IPoS terminals shall use BCH code as shown in this section for link layer check. Where Turbo coding is used, a channel interleaver shall also be used. A block diagram of this encoder is illustrated by figure 3.4.3.1-1.

22

23

24



**Figure 3.4.3.1-1. IPoS Turbo Coder with BCH Block Diagram**

The BCH coding has the ability to correct two bit errors and to detect if a burst has more than two bit errors.

### 3.4.3.1.1 BCH Coding

The BCH encoding uses a single BCH "mother" code. All the BCH codes for different block sizes will be obtained by shortening the mother BCH code. The output of the BCH encoder is stuffed with 1 bit of 0 to make 40 bits and sent to the Turbo encoder.

If the maximum size before turbo encoding is 8191 bits or 1023 bytes, the mother BCH code is  $(n_{bch}, k_{bch}) = (8191, 8152)$  (bits), i.e. 39 bits of redundancy, with generator polynomial,

$$g(x) = (1+x+x^3+x^4+x^{13}) \times (1+x^4+x^5+x^7+x^9+x^{10}+x^{13}) \times (1+x+x^4+x^7+x^8+x^{11}+x^{13})$$

or

$$g(x) = 1+x^2+x^3+x^5+x^6+x^7+x^8+x^{10}+x^{11}+x^{12}+x^{13}+x^{15}+x^{17}+x^{20}+x^{21}+x^{23}+x^{24}+x^{26}+x^{28}+x^{29}+x^{30}+x^{31}+x^{33}+x^{35}+x^{36}+x^{37}+x^{39}$$

With systematic encoding, shortening is achieved by assigning a group of  $s$  information bits to 0. After encoding, those  $s$  information bits are deleted from the code word leading to an  $(n_{bch} - s, k_{bch} - s)$  code.

Systematic BCH encoding of information bits  $\mathbf{m} = (m_{k_{bch}-1}, m_{k_{bch}-2}, \dots, m_1, m_0)$  onto a codeword

$\mathbf{c} = (m_{k_{bch}-1}, m_{k_{bch}-2}, \dots, m_1, m_0, d_{n_{bch}-k_{bch}-1}, d_{n_{bch}-k_{bch}-2}, \dots, d_1, d_0)$  is achieved as follows:

Multiply the message polynomial  $m(x) =$

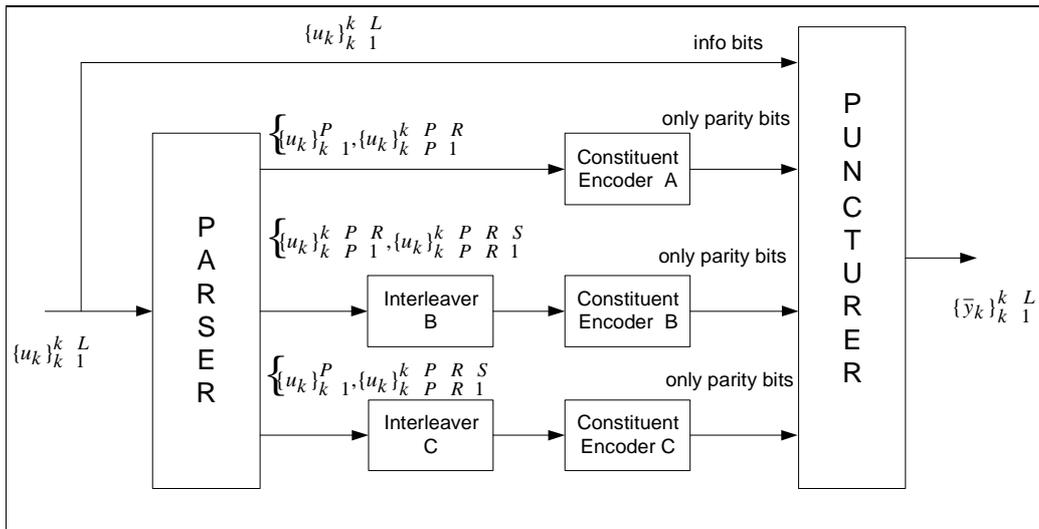
$$m_{k_{bch}-1}x^{k_{bch}-1} + m_{k_{bch}-2}x^{k_{bch}-2} + \dots + m_1x + m_0 \text{ by } x^{n_{bch}-k_{bch}}$$

1 Divide  $x^{n_{bch}-k_{bch}} m(x)$  by  $g(x)$ . Let  $d(x) = d_{n_{bch}-k_{bch}-1}x^{n_{bch}-k_{bch}-1} + \dots + d_1x + d_0$  be  
 2 the remainder.

3 Set the codeword polynomial  $c(x) = x^{n_{bch}-k_{bch}} m(x) + d(x)$

4 **3.4.3.1.2 Turbo Generator**

5 The unit shall implement a Turbo encoder that uses a parsed  
 6 parallel-concatenated convolutional code (P2C3). See figure 3.4.3.1.3-1.



7  
 8 **Figure 3.4.3.1.3-1. Encoder Block Diagram for Parsed Parallel Concatenated**  
 9 **Convolutional Codes**

10 This is a Rate 1/2 systematic, recursive, convolutional code where the parity bit  
 11 and next state equations are given in the following subsections.

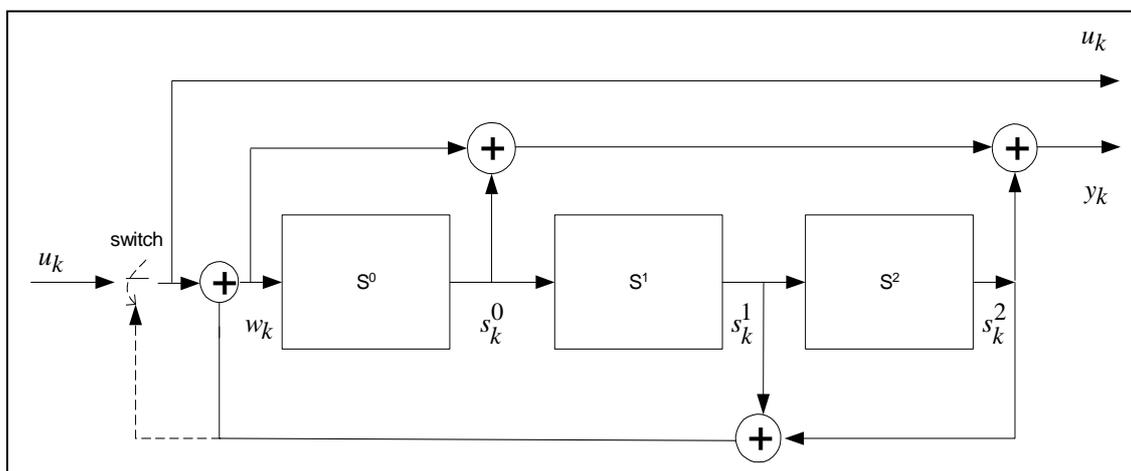
12 **3.4.3.1.2.1 Parser**

13 Each constituent encoder processes approximately two-thirds of an L information  
 14 bit. Information bits in a burst,  $\{u_k\}_{k=1}^L$ , are divided into three subgroups: the  
 15 first P bits  $\{u_k\}_{k=1}^P$ , the following R bits  $\{u_k\}_{k=P+1}^{k=P+R}$ , and the last S bits  
 16  $\{u_k\}_{k=P+R+1}^{k=P+R+S}$ . The values P, R, and S are determined as follows:

17 
$$\begin{cases} \text{if } (L \bmod 3) = 0, \text{ then, } P = R = S = L/3 \\ \text{if } (L \bmod 3) = 1, \text{ then, } P = (L-1)/3+1, R = S = (L-1)/3 \\ \text{if } (L \bmod 3) = 2, \text{ then, } P = R = (L-2)/3+1, S = (L-2)/3 \end{cases}$$

18 Note that currently the burst payload size shall be restricted to an integer number  
 19 of bytes, hence, P, R, and S all have the same value.

1 The bits in  $\{u_k\}_{k=1}^P$  and  $\{u_k\}_{k=P+1}^{k=P+R}$  are encoded by constituent encoder A, while  
 2 the bits in the  $\{u_k\}_{k=P+1}^{k=P+R}$  and  $\{u_k\}_{k=P+R+1}^{k=P+R+S}$  are encoded by constituent encoder B,  
 3 and the bits in  $\{u_k\}_{k=1}^P$  and  $\{u_k\}_{k=P+R+1}^{k=P+R+S}$  are encoded by constituent encoder C.  
 4 Moreover the information bits to constituent encoders B and C are interleaved  
 5 before encoding. The constituent encoder is shown in figure 3.4.3.1.3.1-1.



6  
 7 **Figure 3.4.3.1.3.1-1. Constituent Encoder (Dotted Lines Effective for Trellis**  
 8 **Termination Only)**

9 This is a Rate  $\frac{1}{2}$ , systematic, recursive, convolutional code where the parity bit  
 10 and next state equations are given by:

$$11 \begin{cases} y_k = w_k + s_k^0 + s_k^2 \\ s_{k+1}^2 = s_k^1, s_{k+1}^1 = s_k^0, \text{ and } s_{k+1}^0 = w_k \\ w_k = u_k + s_k^1 + s_k^2 \end{cases}$$

12 **3.4.3.1.2.2 Trellis Termination**

13 Tail bits shall come from the current contents of the shift registers as shown in  
 14 figure 3.4.3.1.3.1-1. Moreover, because of the Turbo interleaver, the contents of  
 15 the shift that register at the beginning of trellis termination (after the encoding of  
 16 information bits) are different for each constituent encoder. Therefore for the  
 17 eight-state Turbo code (with three memory elements), a total of  $3 \times 3 = 9$  tail  
 18 input bits are required to terminate all three constituent encoders. Together with  
 19 parity bits, a total of  $9 \times 2 = 18$  bits are transmitted for trellis termination.

20 To represent the output of the Rate  $\frac{1}{2}$  turbo code the following notation is used:

- 21 Systematic bits before interleaving:  $u(1), u(2), u(3), \dots, u(L)$
- 22 Transmitted parity bits of encoder A:  $y_A(1), y_A(3), y_A(5), \dots, y_A(2L/3-1)$
- 23 Transmitted parity bits of encoder B:  $y_B(1), y_B(3), y_B(5), \dots, y_B(2L/3-1)$
- 24 Transmitted parity bits of encoder C:  $y_C(2), y_C(4), y_C(6), \dots, y_C(2L/3)$

1 Systematic and parity tail bits of encoder A:  $u_{T_A}(0), y_{T_A}(0), u_{T_A}(1), y_{T_A}(1),$   
 2  $u_{T_A}(2), y_{T_A}(2)$   
 3 Systematic and parity tail bits of encoder B:  $u_{T_B}(0), y_{T_B}(0), u_{T_B}(1), y_{T_B}(1),$   
 4  $u_{T_B}(2), y_{T_B}(2)$   
 5 Systematic and parity tail bits of encoder C:  $u_{T_C}(0), y_{T_C}(0), u_{T_C}(1), y_{T_C}(1),$   
 6  $u_{T_C}(2), y_{T_C}(2)$

7  
 8 The output bit representation for the Rate  $\frac{1}{2}$  turbo code is then:  
 9

10  $u(1), y_A(1), u(2), y_A(3), \dots, u(L/3), y_A(2L/3-1),$   
 11  $u(L/3+1), y_B(1), u(L/3+2), y_C(2), u(L/3+3), y_B(3), \dots, u(2L/3), y_C(L/3),$   
 12  $u_{T_A}(0), y_{T_A}(0), u_{T_A}(1), y_{T_A}(1), u_{T_A}(2), y_{T_A}(2),$   
 13  $u(2L/3+1), y_B(L/3+1), u(2L/3+2), y_C(L/3+2), u(2L/3+3), y_B(L/3+3), \dots, u(L),$   
 14  $y_C(2L/3),$   
 15  $u_{T_B}(0), y_{T_B}(0), u_{T_B}(1), y_{T_B}(1), u_{T_B}(2), y_{T_B}(2)$   
 16  $u_{T_C}(0), y_{T_C}(0), u_{T_C}(1), y_{T_C}(1), u_{T_C}(2), y_{T_C}(2)$   
 17

### 18 **3.4.3.1.2.3 Interleavers for Parser Output**

---

19 The parser output sequence shall be interleaved before the encoder. The  
 20 following steps describe the interleaver design where the input sequence in a  
 21 burst can have an arbitrary length.

22 **Step 1:** Given a desired burst size of  $L$ , find the three integers  $P$ ,  $R$ , and  $S$ , as  
 23 follows:

$$24 \begin{cases} \text{if } (L \bmod 3) = 0, \text{ then, } P = R = S = L/3 \\ \text{if } (L \bmod 3) = 1, \text{ then, } P = (L-1)/3+1, R = S = (L-1)/3 \\ \text{if } (L \bmod 3) = 2, \text{ then, } P = R = (L-2)/3+1, S = (L-2)/3 \end{cases}$$

25 **Step 2:** Construct three interleavers -  $IP$ ,  $IR$ , and  $IS$  - with sizes  $P$ ,  $R$ , and  $S$ ,  
 26 respectively, and explained in the Note below.

27 **Step 3:** Interleaver B (denoted by  $IB$ ) has size  $R+S$  and shall be formed by  
 28 interlacing  $IR$  and an identity interleaver of size  $S$ . Interleaver C  
 29 (denoted by  $IC$ ) has size  $P+S$  and shall be formed by interlacing  $IP$  and  
 30  $IS$ .

31 The following shows an example where the interleaver is of size  $L=11$ .

32 **Step 1:**  $P = 4, R = 4, S = 3$

33 **Step 2:** Suppose the interleaver tables  $IP$ ,  $IR$ , and  $IS$  are constructed as follows:

34  $IP = (1,3,0,2), IR = (2,0,3,1), IS = (2,0,1)$

35 **Step 3:**  $IB = (2,4,0,5,3,6,1)$  and  $IC = (1,6,3,4,0,5,2)$

36 **Note:** Procedure to obtain the interleaver tables  $IP$ ,  $IR$ , and  $IS$

37 First, determine two parameters,  $r$  and  $c$ , from table 3.5.3.2.3.3-1, which are a  
 38 function of interleaver size  $P$  ( $R$  or  $S$  for  $IR$  and  $IS$  generation).

1 From  $r$  and  $c$ , create an integer  $i$ , which has  $r+c$  bits that shall be:

2 
$$i = \underbrace{b_0 b_1 b_2 \dots b_{c-1}}_{r+c} \underbrace{b_c \dots b_{r+c-1}}_{bits}$$

3 Table 3.4.3.1.3.3-1 shows various interleaver sizes.

**Table 3.4.3.1.3.3-1. Parameters R and C for Various Interleaver Size**

Interleaver Size Interval	R	C
[64, 128]	4	3
[129, 208]	4	4
[209, 256]	5	3
[257, 416]	4	5
[417, 512]	5	4
[513, 1024]	5	5
[1025,2048]	5	6

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Initially all bits are zero.

Take the first  $c$  bits in  $i$  and multiply by a constant  $v$  in table 3.5.3.2.3.3-2 determined by the bit-reversed last  $r$  bits of  $i$ . Then keep the last  $c$  (LSB) bits of the multiplication to get the last  $c$  bits of another  $r+c$  bit integer variable  $j$ . The bit-reversed last  $r$  bits in  $i$  become the first  $r$  bits in  $j$ :

$$j = b_{r+c-1}b_{r+c-2}...b_c\tilde{b}_0\tilde{b}_1... \tilde{b}_{c-1} \text{ where } \tilde{b}_0\tilde{b}_1... \tilde{b}_{c-1} = LSB[k * (b_0b_1...b_{c-1})]$$

If  $j$  is less than  $P$ , accept it to the interleaver table as  $(i, j)$ ; otherwise, discard it.

Increment the  $i$  by 1 ( $i = i + 1$ ) and repeat steps 3 and 4 until all  $P$  values of the interleaver table are obtained.

Table 3.4.3.1.3.3-2 shows values for various interleaver sizes.

**Table 3.4.3.1.3.3-2. Values for Various Interleaver Sizes**

[64-128]			[129-208]			[209-256]			[257-416]			[417-512]			[513-1024]			[1025-2048]		
P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	P	R	S
1	5	7	5	9	13	1	5	7	11	25	13	9	5	11	29	1	27	55	57	9
3	3	5	13	1	3	3	3	5	21	17	1	3	11	7	1	13	15	13	1	43
5	7	1	7	5	15	5	7	1	7	9	3	13	1	1	27	17	19	7	15	35
7	1	3	1	11	7	7	1	3	29	3	19	7	7	9	5	9	3	59	23	23
5	7	1	11	13	5	5	7	1	1	15	29	11	3	3	11	19	5	15	49	7
7	1	3	15	3	1	7	1	3	15	11	17	1	5	7	17	27	9	11	33	21
1	5	7	3	7	11	1	5	7	17	23	7	3	9	5	3	5	13	61	61	53
3	3	5	9	15	9	3	3	5	13	31	21	15	13	13	7	29	17	27	3	19
3	1	5	11	7	11	3	1	5	27	19	31	9	15	11	21	21	5	35	11	61
5	5	1	3	11	5	5	5	1	5	1	5	1	7	3	19	31	31	31	19	25
7	3	3	7	1	9	7	3	3	3	27	25	7	1	1	13	5	25	51	29	1
1	7	7	13	9	13	1	7	7	23	13	23	13	9	5	1	13	15	3	41	11
7	3	3	5	15	7	7	3	3	9	5	9	7	13	7	7	11	13	17	63	29
1	7	7	9	13	1	1	7	7	19	21	15	5	15	13	23	25	11	39	7	39
3	1	5	15	3	15	3	1	5	25	7	27	11	3	9	15	7	9	49	31	41
5	5	1	1	5	3	5	5	1	31	29	11	9	1	3	9	23	1	41	35	59
						3	1	7				15	7	15	29	3	27	21	55	63
						1	1	5				3	3	11	31	15	19	63	25	17
						3	7	3				3	9	1	3	19	29	9	45	27
						5	3	1				7	5	13	13	25	23	1	21	45
						7	5	1				11	13	5	19	31	11	19	17	51

[64-128]			[129-208]			[209-256]			[257-416]			[417-512]			[513-1024]			[1025-2048]		
P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	P	R	S
						1	1	3				1	11	11	27	29	7	33	39	13
						1	7	7				5	15	13	17	1	25	47	51	57
						5	3	7				15	3	9	5	23	21	23	5	3
						5	7	5				15	1	15	11	3	17	29	27	49
						1	5	1				11	15	7	23	9	23	5	37	31
						7	5	5				1	9	3	31	11	1	57	13	15
						7	1	3				5	5	9	25	15	31	43	9	5
						3	3	7				9	7	1	9	17	3	25	59	33
						5	3	3				13	11	5	25	21	7	53	53	55
						7	5	5				5	13	15	15	27	29	37	47	47
						3	7	1				13	11	15	21	7	21	45	43	37

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### 3.4.3.1.3 Puncturing

The output bits of each constituent encoder are punctured to achieve the desired code rate. For IPoS, code Rate 1/2 shall be achieved by transmitting all information bits  $\{u_k\}_{k=1}^{k=L}$ , while every other bit of encoder output shall be punctured. (A puncturing pattern of 10 is applied to the first two encoder outputs, whereas a pattern of 01 shall be applied to the last encoder outputs.) The puncturing patterns for all the code rates are defined in Table 3.4.3.1.4-1.

**Table 3.4.3.1.4-1. Puncturing Pattern for TurboCoding with BCH**

Code Rate	Constituent Encoder A and B	Constituent Encoder C
1/3	1	1
1/2	10	01
2/3	1000	0100
4/5	10000000	01000000

### 3.4.3.1.4 Channel Interleaver

The channel interleaver is a block interleaver and shall have a size as large as 2048 bits. The channel interleaver shall interleave on the bit, not the symbol, boundary. Where the burst (or subburst) size of the encoded bits is greater than 2048 bits, the burst size shall be partitioned into two equal segments. If the segments are still greater than 2048 bits in size, then each segment is further divided into two equal parts. For various encoded burst sizes of E bits, the encoded bit sequence shall be segmented into the following lengths to remain within the maximum interleaver size limit:

$E$	for $0 \text{ bit} < E \leq 2048 \text{ bits}$
$E/2, E/2$	for $2048 \text{ bits} < E \leq 4096 \text{ bits}$
$E/4+1, E/4+1, E/4, E/4$	for $4096 \text{ bits} < E \leq 8192 \text{ bits}$
$E/8+1, E/8+1, E/8, E/8, E/8, E/8, E/8, E/8$	for $8192 \text{ bits} < E \leq 12306 \text{ bits}$

For each data segment, the actual interleaver size shall be the smallest power of 2 greater than the segment size. When possible, the number of columns shall be the same as the number of rows. When it is not possible, the number of columns

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1 shall be twice as many as the number of rows. Table 3.4.3.1.5-1 illustrates the  
 2 size of the interleaver.

**Table 3.4.3.1.5-1. Channel Interleaver Sizes (Example)**

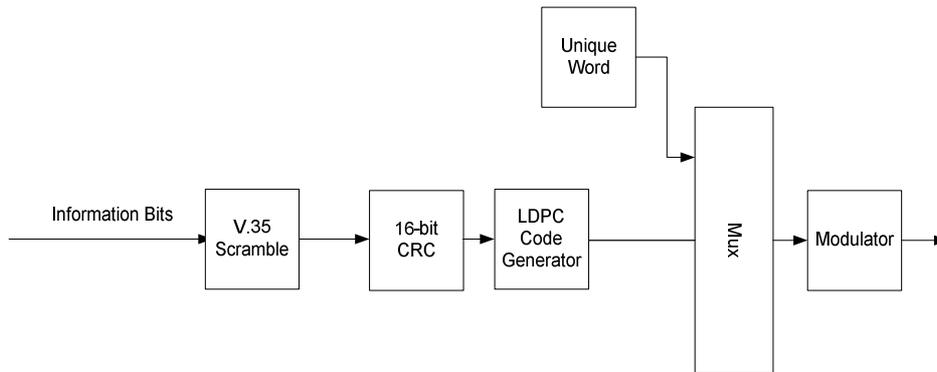
Size (Number of Encoded Bits)	Number Rows	Number Columns
Less than 257	16	16
257 to 512	16	32
513 to 1024	32	32
1025 to 2048	32	64

3  
 4 The data shall be written into the interleaver from the lowest numbered column  
 5 to the highest numbered column of the lowest numbered row before proceeding  
 6 to filling the next higher numbered row. The interleaved data are read from the  
 7 interleaver from the lowest numbered row to the highest numbered row of the  
 8 lowest numbered column before proceeding to output the next higher numbered  
 9 column. If a location of the interleaver has not been written to, that location shall  
 10 be skipped during the interleaved output sequence.

11 **3.4.3.2 LDPC coding**

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12 When LDPC coding is used, the IPoS terminals shall use CRC-16. A block  
 13 diagram of this encoder is illustrated by figure 3.4.3.2-1.



14  
 15 **Figure 3.4.3.2-1. IPoS LDPC encoder with CRC-Check Block Diagram**

16 **3.4.3.2.1 Data Scrambler**

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17 The LDPC coder shall use the CCITT v.35 data scrambler [20] without the  
 18 modifications defined in subsection 3.4.3.1.2.

19 **3.4.3.2.2 Cyclical Redundancy Check**

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20 Each packet is protected by a 16-bit CRC. The highest bit of the MSB shall be  
 21 sent out first when the scrambler requires the CRC value. Other aspects of the  
 22 hardware CRC generator are:



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For puncturing, the following  $XP$  parity bits are not transmitted:

$P_{X_{offset}}, P_{X_{offset} + XP_{period}}, P_{X_{offset} + 2XP_{period}}, \dots, P_{X_{offset} + (XP-1)XP_{period}}$  where  $XP_{period}$  and  $X_{offset}$  are code dependent parameters. (Note that the first parity bit is denoted as  $p_0$ )

For each block size which is not a mother code size, the parameters related to shortening and puncturing as well as the mother code is given in Table 3.4.3.2.3.1-1.

If  $K_{mother}$  and  $N_{mother}$  denote the number of uncoded and coded bits of the mother code respectively, then the derived code will have

$$K = K_{mother} - XS$$

$$N = N_{mother} - XS - XP$$

**Table 3.4.3.2.3.1-2. Shortening and Puncturing Parameters**

Rate/Block size	XS	XS <sub>start</sub>	XP	XP <sub>period</sub>	X <sub>offset</sub>	mother code
1/2 1200	120	0	120	6	0	1/2 1440
1/2 1680	240	0	240	4	0	1/2 2160
1/2 1920	120	0	120	9	0	1/2 2160
1/2 2400	240	0	240	4	0	1/2 2880
1/2 2640	120	0	120	12	0	1/2 2880
1/2 3120	240	0	240	7	6	1/2 3600
1/2 3360	120	0	120	15	0	1/2 3600
1/2 3840	240	0	240	9	0	1/2 4320
1/2 4080	120	0	120	18	0	1/2 4320
1/2 4560	600	0	600	3	0	1/2 5760
1/2 4800	480	0	480	3	0	1/2 5760
1/2 5040	360	0	360	8	0	1/2 5760
1/2 5280	240	0	240	12	0	1/2 5760
1/2 5520	120	0	120	24	0	1/2 5760
2/3 1200	160	480	80	6	0	2/3 1440
2/3 1680	320	720	160	3	0	2/3 2160
2/3 1920	160	720	80	9	0	2/3 2160
2/3 2400	320	960	160	6	0	2/3 2880
2/3 2640	160	960	80	12	0	2/3 2880
2/3 3120	320	1200	160	7	1	2/3 3600
2/3 3360	160	1200	80	15	0	2/3 3600
2/3 3840	320	1440	160	9	0	2/3 4320
2/3 4080	160	1440	80	18	0	2/3 4320
2/3 4560	800	1920	400	3	0	2/3 5760
2/3 4800	640	1920	320	3	0	2/3 5760
2/3 5040	480	1920	240	8	0	2/3 5760
2/3 5280	320	1920	160	7	3	2/3 5760
2/3 5520	160	1920	80	24	0	2/3 5760
4/5 1200	192	288	48	6	0	4/5 1440

4/5 1680	384	1104	96	4	0	4/5 2160
4/5 1920	192	432	48	9	0	4/5 2160
4/5 2400	384	576	96	6	0	4/5 2880
4/5 2640	192	576	48	12	0	4/5 2880
4/5 3120	384	720	96	7	4	4/5 3600
4/5 3360	192	720	48	15	0	4/5 3600
4/5 3840	384	864	96	9	0	4/5 4320
4/5 4080	192	864	48	18	0	4/5 4320
4/5 4560	960	1152	240	4	0	4/5 5760
4/5 4800	768	1152	192	6	0	4/5 5760
4/5 5040	576	1152	144	8	0	4/5 5760
4/5 5280	384	1152	96	12	0	4/5 5760
4/5 5520	192	1152	48	24	0	4/5 5760
9/10 1200	216	0	24	N/A	9	9/10 1440
9/10 1680	432	0	48	N/A	3	9/10 2160
9/10 1920	216	0	24	N/A	0	9/10 2160
9/10 2400	432	0	48	N/A	2	9/10 2880
9/10 2640	216	0	24	N/A	0	9/10 2880
9/10 3120	432	0	48	N/A	5	9/10 3600
9/10 3360	216	0	24	N/A	1	9/10 3600
9/10 3840	432	0	48	N/A	2	9/10 4320
9/10 4080	216	0	24	N/A	4	9/10 4320
9/10 4560	1080	0	120	N/A	0	9/10 5760
9/10 4800	864	0	96	N/A	0	9/10 5760
9/10 5040	648	0	72	N/A	4	9/10 5760
9/10 5280	432	0	48	N/A	2	9/10 5760
9/10 5520	216	0	24	N/A	4	9/10 5760

1

### 2 3.4.3.2.3.2 Degree Distribution

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For each mother LDPC code, the degree distribution of bit nodes is given in Table 3.4.3.2.3.2-1 where N denotes the total number of bit nodes, i.e. coded block size. For each code, all of the check nodes except one have the same degree, namely  $d_c=7$  for rate 1/2,  $d_c=11$  for rate 2/3,  $d_c=10$  for rate 4/5 and  $d_c=34$  for rate 9/10. The remaining check node has degree one less.

**Table 3.4.3.2.3.2-3. Degree Distribution of Bit Nodes**

10

Rate	8	7	6	5	4	3	2	1
1/2			N/4		N/4		N/2-1	1
2/3	N/6				N/6	N/3	N/3-1	1
4/5			2N/5			2N/5	N/5-1	1
9/10					N/2	2N/5	N/10-1	1

11

### 1 3.4.3.2.4 LDPC Encoding

2 The task of the encoder is to determine  $n_{ldpc} - k_{ldpc}$  parity bits  
 3  $(p_0, p_1, \dots, p_{n_{ldpc} - k_{ldpc} - 1})$  for every block of  $k_{ldpc}$  input bits,  $(i_0, i_1, \dots, i_{k_{ldpc} - 1})$ . The  
 4 procedure is as follows:

5 • Initialize  $p_0 = p_1 = p_2 = \dots = p_{n_{ldpc} - k_{ldpc} - 1} = 0$

6

7 • Accumulate the first input bit,  $i_0$ . For example, for 2/3 720 code,

8

$$p_{83} = p_{83} \oplus i_0$$

9

$$p_{117} = p_{117} \oplus i_0$$

10

$$p_{156} = p_{156} \oplus i_0$$

11

$$p_{169} = p_{169} \oplus i_0$$

12

$$p_{231} = p_{231} \oplus i_0$$

13

$$p_{126} = p_{126} \oplus i_0$$

14

$$p_{112} = p_{112} \oplus i_0$$

15

$$p_{106} = p_{106} \oplus i_0$$

16

(All additions are modulo 2)

17

18 • For the next  $M-1$  input bits,  $i_m, m = 1, 2, \dots, M-1$  accumulate  $i_m$  at  
 19 parity bit addresses  $\{x + m \bmod M \times q\} \bmod(n_{ldpc} - k_{ldpc})$  where  $x$   
 20 denotes the address of the parity bit accumulator corresponding to the

21 first bit  $i_0$  and  $q = \frac{n_{ldpc} - k_{ldpc}}{M}$ . Continuing with the example,

22

$M = 30, q = 8$  for 2/3 720 code. So for example for input bit  $i_1$ , the  
 23 following operations are performed,

24

$$p_{91} = p_{91} \oplus i_1$$

25

$$p_{125} = p_{125} \oplus i_1$$

26

$$p_{164} = p_{164} \oplus i_1$$

27

$$p_{177} = p_{177} \oplus i_1$$

28

$$p_{239} = p_{239} \oplus i_1$$

29

$$p_{134} = p_{134} \oplus i_1$$

30

$$p_{120} = p_{120} \oplus i_1$$

31

$$p_{114} = p_{114} \oplus i_1$$

32

33 • In a similar manner the addresses of the parity bit accumulators for the  
 34 following  $M-1$  input bits  $i_m, m = M+1, M+2, \dots, 2M-1$  are  
 35 obtained using the formula  $\{x + m \bmod M \times q\} \bmod(n_{ldpc} - k_{ldpc})$

1 where  $x$  denotes the address of the parity bit accumulator corresponding  
 2 to the input bit  $i_M$ .

- 3 • In a similar manner, for every group of  $M$  new input bits, a new row is  
 4 used to find the addresses of the parity bit accumulators.

5 After all of the input bits are exhausted, the final parity bits are obtained as  
 6 follows,

- 7 • Sequentially perform the following operations starting with  $i = 1$

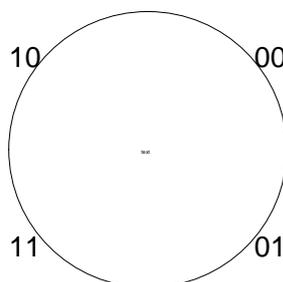
$$8 \quad p_i = p_i \oplus p_{i-1}, \quad i = 1, 2, \dots, n_{ldpc} - k_{ldpc} - 1$$

- 9 • Final content of  $p_i$ ,  $i = 0, 1, \dots, n_{ldpc} - k_{ldpc} - 1$  is equal to the parity bit  
 10  $p_i$ .

### 14 3.4.3.2.5 System Constellation and Interface between the Demodulator 15 and Decoder

---

16 QPSK constellation is given in Figure 3.4.3.2.5-1. The I/Q demod output is first  
 17 multiplied by a constant and quantized to the nearest integer between -15 and  
 18 +15. The multiplying constant is given in Table 3.4.5.2.5-1, assuming that the  
 19 noise-free QPSK symbol is on the unit circle.



21 **Figure 3.4.3.2.5-1. QPSK Symbol Constellation**

22 **Table 3.4.3.2.5-4. Multiplying Constant for QPSK LDPC Codes**

23 Code Rate	24 Constant
$\frac{1}{2}$	5.1
$\frac{2}{3}$	7.8
$\frac{4}{5}$	11.3
$\frac{9}{10}$	17.0

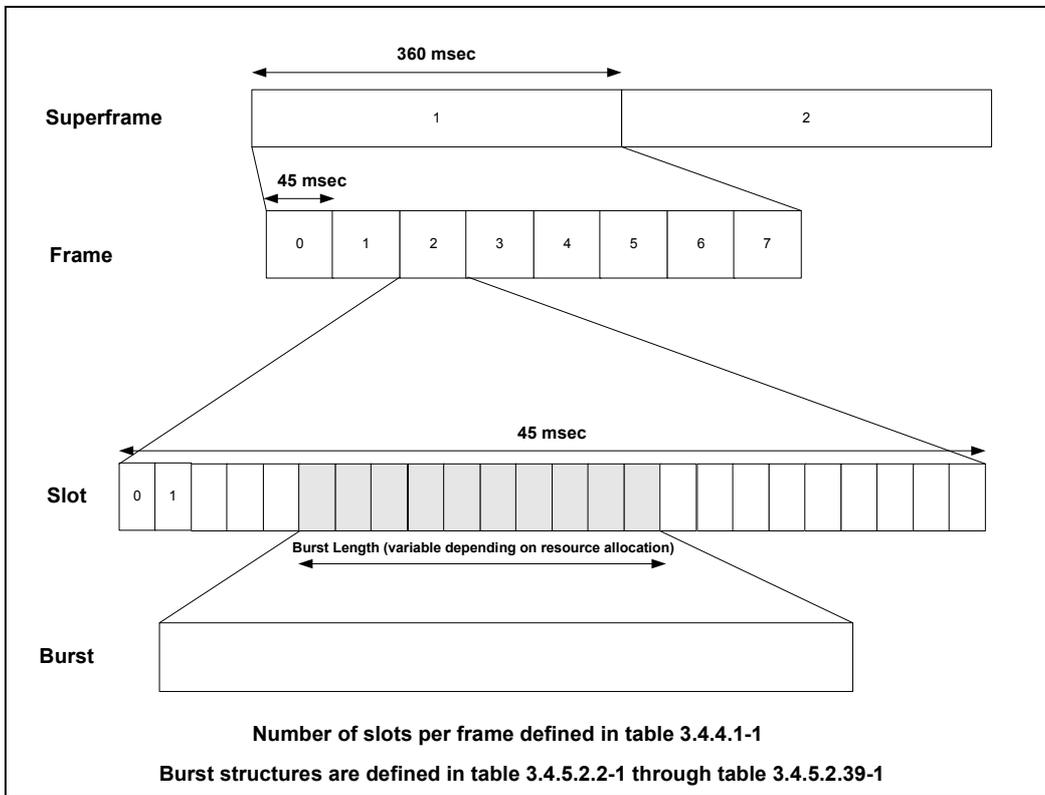
1

2 **3.4.4 Inroute Framing Structure**

3 In the inroute link, IPoS uses a periodic TDMA structure that permits several  
 4 remotes to share the same inroute carrier or group of inroute carriers. This  
 5 TDMA structure includes:

- 6 • A frame duration of 45 msec
- 7 • A superframe consisting of eight frames with a duration of
- 8  $8 * 45 = 360$  msec

9 Each frame is divided into slots. The number of slots per frame, N, depends  
 10 upon the transmission rate and the type of encoding used in the payload of the  
 11 burst. Figure 3.4.4-1 illustrates inroute framing.



12

13 **Figure 3.4.4-1. Inroute Framing Structure**

14 On turbo coded inroute, the number of unencoded bytes per burst must be a multiple of three.  
 15 The remote shall add or subtract one byte if the allocated bytes in the burst is not a multiple of  
 16 three.

17

1 **3.4.4.1 TDMA Slots**

2 Table 3.4.4.1-1 shows the number of slots per frame, the duration of the slots,  
 3 and the number of modulated symbols for the different transmission rate and  
 4 coding schemes.

5 **Table 3.4.4.1-1 IPoS Inroute TDMA Characteristics**

Burst Type	FEC Encoding	CRC or BCH	Symbol Rate (ksps)	Slots /Frame	Unco ded Bytes /Slot	Coded Bits /Slot	Slot Time (µs )
BTCH256_1/3TB	1/3 Turbo	BCH	256	96	10	240	468.75
BTCH256_1/2TB	1/2 Turbo	BCH	256	96	15	240	468.75
BTCH256_2/3TB	2/3 Turbo	BCH	256	96	20	240	468.75
BTCH256_4/5TB	4/5 Turbo	BCH	256	96	24	240	468.75
BTCH512_1/3TB	1/3 Turbo	BCH	512	192	10	240	234.375
BTCH512_1/2TB	1/2 Turbo	BCH	512	192	15	240	234.375
BTCH512_2/3TB	2/3 Turbo	BCH	512	192	20	240	234.375
BTCH512_4/5TB	4/5 Turbo	BCH	512	192	24	240	234.375
BTCH1024_1/3TB	1/3 Turbo	BCH	1024	384	10	240	117.1875
BTCH1024_1/2TB	1/2 Turbo	BCH	1024	384	15	240	117.1875
BTCH1024_2/3TB	2/3 Turbo	BCH	1024	384	20	240	117.1875
BTCH1024_4/5TB	4/5 Turbo	BCH	1024	384	24	240	117.1875
BTCH2048_1/3TB	1/3 Turbo	BCH	2048	768	10	240	58.59375
BTCH2048_1/2TB	1/2 Turbo	BCH	2048	768	15	240	58.59375
BTCH2048_2/3TB	2/3 Turbo	BCH	2048	768	20	240	58.59375
BTCH2048_4/5TB	4/5 Turbo	BCH	2048	768	24	240	58.59375
BTCH4096_1/2TB	1/2 Turbo	BCH	4096	1536	15	240	29.29687
BTCH4096_2/3TB	2/3 Turbo	BCH	4096	1536	20	240	29.29687
BTCH4096_4/5TB	4/5 Turbo	BCH	4096	1536	24	240	29.29687
BTCH6144_1/2TB	1/2 Turbo	BCH	6144	3072	15	240	14.64837
BTCH6144_2/3TB	2/3 Turbo	BCH	6144	3072	20	240	14.64837
BTCH6144_4/5TB	4/5 Turbo	BCH	6144	3072	24	240	14.64837
ATCH256_1/2LDPC	1/2 LDPC	CRC	256	96	10	240	468.75
ATCH256_2/3LDPC	2/3 LDPC	CRC	256	96	15	240	468.75
ATCH256_4/5LDPC	4/5 LDPC	CRC	256	96	24	240	468.75
ATCH256_9/10LDPC	9/10 LDPC	CRC	256	96	27	240	468.75
ATCH512_1/2LDPC	1/2 LDPC	CRC	512	192	15	240	234.375
ATCH512_2/3LDPC	2/3 LDPC	CRC	512	192	20	240	234.375
ATCH512_4/5LDPC	4/5 LDPC	CRC	512	192	24	240	234.375
ATCH512_9/10LDPC	9/10 LDPC	CRC	512	192	27	240	234.375
ATCH1024_1/2LDPC	1/2 LDPC	CRC	1024	384	10	240	117.1875
ATCH1024_2/3LDPC	2/3 LDPC	CRC	1024	384	15	240	117.1875
ATCH1024_4/5LDPC	4/5 LDPC	CRC	1024	384	24	240	117.1875
ATCH1024_9/10LDPC	9/10 LDPC	CRC	1024	384	27	240	117.1875
ATCH2048_1/2LDPC	1/2 LDPC	CRC	2048	768	10	240	58.59375
ATCH2048_2/3LDPC	2/3 LDPC	CRC	2048	768	15	240	58.59375
ATCH2048_4/5LDPC	4/5 LDPC	CRC	2048	768	24	240	58.59375
ATCH2048_9/10LDPC	9/10 LDPC	CRC	2048	768	27	240	58.59375

6  
 7 The slot designator number starts at 0 and ends at N-1.

## 1 **3.4.5 Burst Formats**

---

2 Two types of burst are used in the inroute direction:

- 3 1. The user burst is used for data traffic over the inroute channels.
- 4 2. Ranging burst used by remotes to obtain delay and power information
- 5 and to carry resource requests to the IPoS hub.

6 Each of these types of burst is associated with a different time uncertainty in its  
7 arrival at the hub or aperture, but each one uses the same burst format with  
8 different data in the payload. This time uncertainty associated with the  
9 misalignment of the timing between the hub and remotes and the uncertainties in  
10 the satellite position are designated as aperture. The distinction between Ranging  
11 and User bursts is defined by the Burst Allocation Packet (BAP) defined in  
12 Section 4.

### 13 **3.4.5.1 Apertures**

---

14 The imprecision in the arrival of the inroute bursts at the hub defined at the slot  
15 boundaries is designated as the aperture. Three aperture types are defined:

- 16 1. For user data bursts, there is open loop timing aperture.
- 17 2. For user data bursts, there is closed loop timing aperture.
- 18 3. The ranging burst aperture: 1 ms aperture independent of open and
- 19 closed loop timing.

20 With open-loop timing, the streaming user burst aperture of 125 microseconds is  
21 used irrespective of symbol rates. The aloha user burst aperture is always 125  
22 microseconds irrespective of open and closed loop timing. However, with  
23 closed-loop timing, the aperture size for 4096 and 6144 Ksps is given by table  
24 3.4.5.1-1.

25 **Table 3.4.5.1-1. Closed-Loop Timing Mode Stream Data Aperture**

Symbol Rate	Aperture size (μs)
4096 Ksps	42
6144 Ksps	28.5

26

### 27 **3.4.5.2 User Data Burst Structure**

---

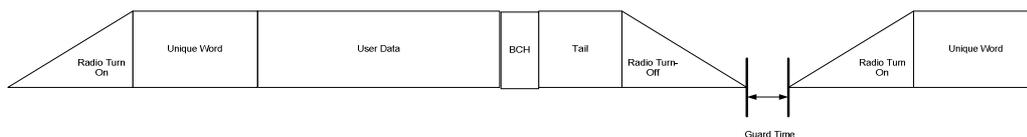
28 Inroute transmissions are made with variable-length bursts occupying one or  
29 more consecutive slots in the frame using either the following coding types;

- 30 • Turbo coding coding or

- 1 • LDPC coding.

2

3 Figure 3.4.5.2-1 illustrates the burst format for the inroute turbo-coded burst.



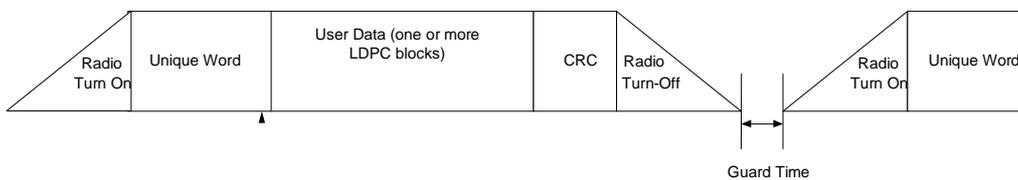
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**Figure 3.4.5.2-1. Burst Elements Turbo Coded Inroute**

6

Figure 3.4.5.2-2 illustrates the burst format for the inroute LDPC-coded burst.



7

8

**Figure 3.4.5.2-2. Burst Elements LDPC**

9

10 The burst formats for Turbo-coded and LDPC-coded IPoS inroutes include the  
11 following elements:

- 12 • Guard time or minimum separation between consecutive bursts.
- 13 • Radio turn-on or ramp-up time to control the emission of the burst.
- 14 • Radio turn-off or ramp-down period to control the emissions of the burst.

- 1                   • The UW is the preamble used to perform PHY processes related to
- 2                   frequency estimation, time estimation, and the estimation of the
- 3                   beginning of the burst.
  
- 4                   • Payload is used to convey encoded information for the higher layers.
  
- 5                   • Tail bits used to flush the encoders.

6                   One LDPC-coded burst may contain one or more than one LDPC blocks as

7                   specified in Table 3.4.5.2-1 .The duration of a burst payload is an integer number

8                   of slots from 1-to-N-1 slots in the frame.

9                   **Table 3.4.5.2-1. Burst Slot and LDPC blocks**

10

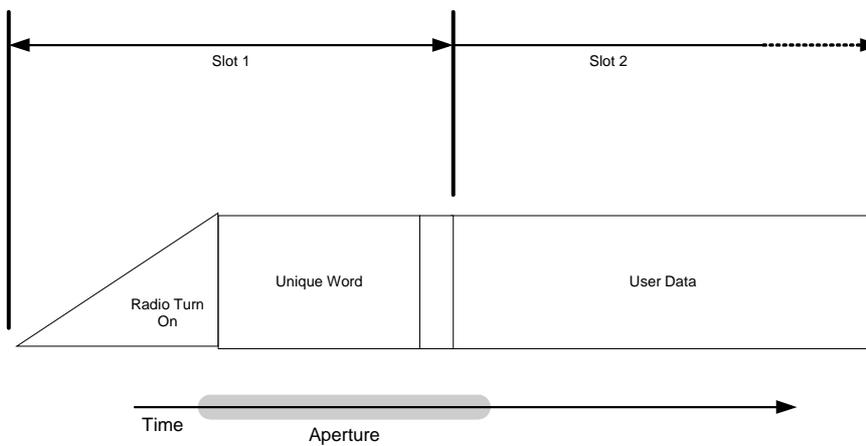
Burst Payload Slots	LDPC Blocks
3	LDPC720
4	LDPC960
5	LDPC1200
6	LDPC1440
7	LDPC1680
8	LDPC1920
9	LDPC2160
10	LDPC2400
11	LDPC2640
12	LDPC2880
13	LDPC3120
14	LDPC3360
15	LDPC3600
16	LDPC3840
17	LDPC4080
18	LDPC4320
19	LDPC4560
20	LDPC4800
21	LDPC5040
22	LDPC5280
23	LDPC5520
24	LDPC5760
25	LDPC2880 + LDPC3120
26	LDPC3120 + LDPC3120
27	LDPC3120 + LDPC3360
28	LDPC3360 + LDPC3360
29	LDPC3360 + LDPC3600
30	LDPC3600 + LDPC3600

Burst Payload Slots	LDPC Blocks
31	LDPC3600 + LDPC3840
32	LDPC3840 + LDPC3840
33	LDPC3840 + LDPC4080
34	LDPC4080 + LDPC4080
35	LDPC4080 + LDPC4320
36	LDPC4320 + LDPC4320
37	LDPC4320 + LDPC4560
38	LDPC4560 + LDPC4560
39	LDPC4560 + LDPC4800
40	LDPC4800 + LDPC4800
41	LDPC4800 + LDPC5040
42	LDPC5040 + LDPC5040
43	LDPC5040 + LDPC5280
44	LDPC5280 + LDPC5280
45	LDPC5280 + LDPC5520
46	LDPC5520 + LDPC5520
47	LDPC5520 + LDPC5760
48	LDPC5760 + LDPC5760
49	LDPC3840 + LDPC3840 + LDPC4080
50	LDPC3840 + LDPC4080 + LDPC4080
51	LDPC4080 + LDPC4080 + LDPC4080

1

2 **3.4.5.2.1 Burst Time Alignment**

3 The inroute bursts are transmitted by the IPoS remote with their payloads aligned  
4 to the boundaries of the slots of the frame as shown in figure 3.4.5.2.1-1.



5

6

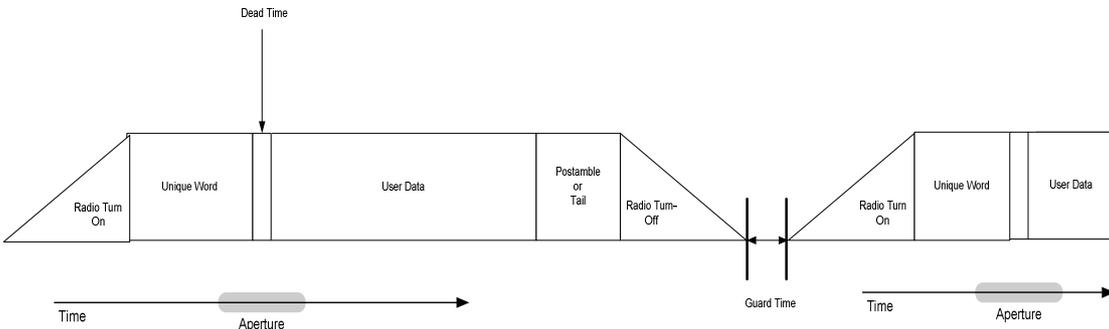
**Figure 3.4.5.2.1-1. IPoS Slot Frame Boundaries**

TIA-1008-B

1 The burst transmitted by a remote terminal begins at the end of the first slot  
 2 allocated to the terminal for inroute transmission; the payload begins at the  
 3 beginning of the second allocated slot and extends to the last allocated slot. The  
 4 tail and the turnoff time of the burst are sent in a slot that is not allocated to the  
 5 terminal but that is unused by the beginning of the burst from the next-allocated  
 6 terminal.

7 At the IPoS hub, the maximum misalignment between the received burst and the  
 8 frame boundaries is the aperture of the corresponding burst. Figure 3.4.5.2.1-2  
 9 illustrates this misalignment between bursts.

10



11

12 **Figure 3.4.5.2.1-2. Multiple Bursts Received Time Misalignment at IPoS Hub**

13 **3.4.5.2.2 BTCH256\_1/3TB: 256 kps Service Burst Structure – Turbo**  
 14 **R1/3 with BCH**

15 The burst overhead is one slot, with 96 slots per 45-millisecond frame. However,  
 16 a maximum burst length is 76 slots. The Tail and radio Turn-off are sent in a slot  
 17 not allocated to the terminal, but this is allowed since the first portion of the next  
 18 allocated slot is unused since it is the beginning of a burst. See table 3.4.5.2.2-1.

**Table 3.4.5.2.2-1 Burst Structure for 256 kps Turbo with BCH (BTCH256\_1/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		$\leq 29$	
Unique Word	48	187.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	$120 * N$	$468.75 * N$	Each slot is 10 bytes of user traffic
Postamble (or Tail)	9	35.2	
Radio Turn-off		$\leq 19$	

19

**3.4.5.2.3 BTCH256\_1/2TB: 256 kbps Service Burst Structure – Turbo R1/2 with BCH**

The burst overhead is one slot, with 96 slots per 45-millisecond frame. However, a maximum burst length is 51 slots (765 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused since it is the beginning of a burst. See table 3.4.5.2.3-1.

	<b>Symbols</b>	<b>Microseconds</b>	<b>Comments</b>
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 15 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	35.2	
Radio Turn-off		<=19	

**3.4.5.2.4 BTCH256\_2/3TB: 256 kbps Service Burst Structure – Turbo R2/3 with BCH**

The burst overhead is one slot, with 96 slots per 45-millisecond frame. However, a maximum burst length is 38 slots (760 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused since it is the beginning of a burst. See table 3.4.5.2.4-1.

**Table 3.4.5.2.4-1 Burst Structure for 256 kbps Turbo with BCH (BTCH256\_2/3TB)**

<b>Field</b>	<b>Symbols</b>	<b>Microseconds</b>	<b>Comments</b>
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 20 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	35.2	
Radio Turn-off		<=19	

**3.4.5.2.5 BTCH256\_4/5TB: 256 kbps Service Burst Structure – Turbo R4/5 with BCH**

The burst overhead is one slot, with 96 slots per 45-millisecond frame. However, a maximum burst length is 31 slots (744 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused since it is the beginning of a burst. See table 3.4.5.2.5.1.

**Table 3.4.5.2.5-1. Burst Structure for 256 kps Turbo with BCH (BTCH256\_4/5TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 24 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	35.2	
Radio Turn-off		<=19	

1

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### 3.4.5.2.6 BTCH512\_1/3TB: 512 kps Service Burst Structure – Turbo R1/3 with BCH

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The burst overhead is one slot, with 192 slots per 45-millisecond frame. However, a maximum burst length is 76 slots. The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused since it is the beginning of a burst. See table 3.4.5.2.6-1.

**Table 3.4.5.2.6-1. Burst Structure for 512 kps Turbo with BCH (BTCH512\_1/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	48	93.74	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 10 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	17.58	
Radio Turn-off		<=19	

10

11

12

### 3.4.5.2.7 BTCH512\_1/2TB: 512 kps Service Burst Structure – Turbo R1/2 with BCH

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The burst overhead is one slot, with 192 slots per 45-millisecond frame. However, a maximum burst length is 51 slots (765 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused since it is the beginning of a burst. See table 3.4.5.2.7-1.

**Table 3.4.5.2.7.1. Burst Structure for 512 kps Turbo with BCH (BTCH512\_1/2TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 15 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	17.58	
Radio Turn-off		<=19	

1

2 **3.4.5.2.8 BTCH512\_2/3TB: 512 kbps Service Burst Structure – Turbo**  
 3 **R2/3 with BCH**

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4 The burst overhead is one slot, with 192 slots per 45-millisecond frame.  
 5 However, a maximum burst length is 38 slots (760 user bytes). The Tail and  
 6 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 7 since the first portion of the next allocated slot is unused since it is the beginning  
 8 of a burst. See table 3.4.5.2.8-1.

**Table 3.4.5.2.8-1. Burst Structure for 512 kbps Turbo with BCH (BTCH512\_2/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 20 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	17.58	
Radio Turn-off		<=19	

9

10 **3.4.5.2.9 BTCH512\_4/5TB: 512 kbps Service Burst Structure – Turbo**  
 11 **R4/5 with BCH**

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12 The burst overhead is one slot, with 192 slots per 45-millisecond frame.  
 13 However, a maximum burst length is 31 slots (744 user bytes). The Tail and  
 14 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 15 since the first portion of the next allocated slot is unused since it is the beginning  
 16 of a burst. See table 3.4.5.2.9-1.

**Table 3.4.5.2.9-1. Burst Structure for 512 kbps Turbo with BCH (BTCH512\_4/5TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 24 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	17.58	
Radio Turn-off		<=19	

17

18 **3.4.5.2.10 BTCH1024\_1/3TB: 1024 kbps Service Burst Structure – Turbo**  
 19 **R1/3 with BCH**

---

20 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
 21 However, a maximum burst length is 76 slots. The Tail and radio Turn-off are  
 22 sent in a slot not allocated to the terminal, but this is allowed since the first  
 23 portion of the next allocated slot is unused and the last portion is used to open the  
 24 aperture. See table 3.4.5.2.10-1.

**Table 3.4.5.2.10-1. Burst Structure for 1024 ksps Turbo with BCH (BTCH1024\_1/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	48	46.88	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 10 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	8.79	
Radio Turn-off		<=19	

1

2 **3.4.5.2.11 BTCH1024\_1/2TB: 1024 ksps Service Burst Structure – Turbo**  
3 **R1/2 with BCH**

---

4 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
5 However, a maximum burst length is 51 slots (765 user bytes). The Tail and  
6 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
7 since the first portion of the next allocated slot is unused and the last portion is  
8 used to open the aperture. See table 3.4.5.2.111.

**Table 3.4.5.2.11-1. Burst Structure for 1024 ksps Turbo with BCH (BTCH1024\_1/2TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 15 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	8.79	
Radio Turn-off		<=19	

9

10 **3.4.5.2.12 BTCH1024\_2/3TB: 1024 ksps Service Burst Structure – Turbo**  
11 **R2/3 with BCH**

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12 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
13 However, a maximum burst length is 38 slots (760 user bytes). The Tail and  
14 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
15 since the first portion of the next allocated slot is unused and the last portion is  
16 used to open the aperture. See table 3.4.5.2.12-1.

**Table 3.4.5.2.12-1 Burst Structure for 1024 ksps Turbo with BCH (BTCH1024\_2/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 20 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	8.79	
Radio Turn-off		<=19	

1 **3.4.5.2.13 BTCH1024\_4/5TB: 1024 kbps Service Burst Structure – Turbo**  
 2 **R4/5 with BCH**

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3 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
 4 However, a maximum burst length is 31 slots (744 user bytes). The Tail and  
 5 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 6 since the first portion of the next allocated slot is unused and the last portion is  
 7 used to open the aperture. See table 3.4.5.2.13-1.

**Table 3.4.5.2.13-1. Burst Structure for 1024 kbps Turbo with BCH (BTCH1024\_4/5TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 24 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	8.79	
Radio Turn-off		<=19	

8

9 **3.4.5.2.14 BTCH2048\_1/3TB: 2048 kbps Service Burst Structure – Turbo**  
 10 **R1/3 with BCH**

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11 The burst overhead is three slots, with 768 slots per 45-millisecond frame.  
 12 However, a maximum burst length is 76 slots. The Tail and radio Turn-off are  
 13 sent in a slot not allocated to the terminal, but this is allowed since the first  
 14 portion of the next allocated slot is unused and the last portion is used to open the  
 15 aperture. See table 3.4.5.2.14-1.

**Table 3.4.5.2.14-1. Burst Structure for 2048 kbps Turbo with BCH (BTCH2048\_1/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	48	23.43	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.6*N	Each slot is 10 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	4.39	
Radio Turn-off		<=19	

16

17 **3.4.5.2.15 BTCH2048\_1/2TB: 2048 kbps Service Burst Structure – Turbo**  
 18 **R1/2 with BCH**

---

19 The burst overhead is three slots, with 768 slots per 45-millisecond frame.  
 20 However, a maximum burst length is 51 slots (765 user bytes). The Tail and  
 21 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 22 since the first portion of the next allocated slot is unused and the last portion is  
 23 used to open the aperture. See table 3.4.5.2.15-1.

**Table 3.4.5.2.15-1. Burst Structure for 2048 kbps Turbo with BCH (BTCH2048\_1/2TB)**

---

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.60*N	Each slot is 15 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	4.39	
Radio Turn-off		<=19	

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### 3.4.5.2.16 BTCH2048\_2/3TB: 2048 ksps Service Burst Structure – Turbo R2/3 with BCH

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The burst overhead is three slots, with 768 slots per 45-millisecond frame. However, a maximum burst length is 38 slots (760 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused and the last portion is used to open the aperture. See table 3.4.5.2.16-1.

**Table 3.4.5.2.16-1. Burst Structure for 2048 ksps Turbo with BCH (BTCH2048\_2/3TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.6*N	Each slot is 20 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	4.39	
Radio Turn-off		<=19	

9

### 3.4.5.2.17 BTCH2048\_4/5TB: 2048 ksps Service Burst Structure – Turbo R4/5 with BCH

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The burst overhead is three slots, with 768 slots per 45-millisecond frame. However, a maximum burst length is 31 slots (744 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed since the first portion of the next allocated slot is unused and the last portion is used to open the aperture. See table 3.4.5.2.17-1.

**Table 3.4.5.2.17-1. Burst Structure for 2048 ksps Turbo with BCH (BTCH2048\_4/5TB)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.6*N	Each slot is 24 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	4.39	
Radio Turn-off		<=19	

1 **3.4.5.2.18 BTCH4096\_1/2TB: 4096 kbps Service Burst Structure – Turbo**  
 2 **R1/2 with BCH**

3 The burst overhead depends on the unique word aperture size. It is 5 slots for 125  
 4 microseconds and 2 slots for 42 microseconds aperture size respectively with  
 5 1536 slots per 45-millisecond frame. However, a maximum burst length is 51  
 6 slots (765 user bytes). The Tail and radio Turn-off are sent in a slot not allocated  
 7 to the site, but this is allowed since the first portion of the next allocated slot is  
 8 unused and the last portion is used to open the aperture. See table 3.4.5.2.18-1.

**Table 3.4.5.2.18-1. Burst Structure for 4096 kbps Turbo with BCH (BTCH4096\_1/2TB)**

Field	Symbols	Microseconds	Comments
Radio Turn on		0	With linear radio, so there is no radio turn on time
Preamble		<=2	
Unique Word	27	6.59	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	29.30*N	Each slot is 15 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	2.19	
Radio Turn-off		0	

9

10 **3.4.5.2.19 BTCH4096\_2/3TB: 4096 kbps Service Burst Structure – Turbo**  
 11 **R2/3 with BCH**

12 The burst overhead depends on the unique word aperture size. It is 5 slots for 125  
 13 microseconds and 2 slots for 42 microseconds aperture size respectively with  
 14 1536 slots per 45-millisecond frame. However, a maximum burst length is 38  
 15 slots (760 user bytes). The Tail and radio Turn-off are sent in a slot not allocated  
 16 to the site, but this is allowed since the first portion of the next allocated slot is  
 17 unused and the last portion is used to open the aperture. See table 3.4.5.2.19-1.

**Table 3.4.5.2.19-1. Burst Structure for 4096 kbps Turbo with BCH (BTCH4096\_2/3TB)**

Field	Symbols	Microseconds	Comments
Radio Turn on		0	With linear radio, so there is no radio turn on time
Preamble		2	
Unique Word	27	6.59	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	29.30*N	Each slot is 20 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	2.19	
Radio Turn-off		0	

18

19

### 3.4.5.2.20 BTCH4096\_4/5TB: 4096 ksp Service Burst Structure – Turbo R4/5 with BCH

The burst overhead depends on the unique word aperture size. It is 5 slots for 125 microseconds and 2 slots for 42 microseconds aperture size respectively with 1536 slots per 45-millisecond frame. However, a maximum burst length is 31 slots (744 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the site, but this is allowed since the first portion of the next allocated slot is unused and the last portion is used to open the aperture. See table 3.4.5.2.20-1.

**Table 3.4.5.2.20-1. Burst Structure for 4096 ksp Turbo with BCH (BTCH4096\_4/5TB)**

Field	Symbols	Microseconds	Comments
Radio Turn on		0	With linear radio, so there is no radio turn on time
Preamble		$\leq 2$	
Unique Word	27	4.39	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	$120*N$	$29.30*N$	Each slot is 24 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	2.19	
Radio Turn-off		0	

### 3.4.5.2.21 BTCH6144\_1/2TB: 6144 ksp Service Burst Structure – Turbo R1/2 with BCH

The burst overhead depends on the unique word aperture size. It is 7 slots for 125 microseconds and 2 slots for 28.5 microseconds aperture size respectively with 2304 slots per 45-millisecond frame. However, a maximum burst length is 51 slots (765 user bytes). The Tail and radio Turn-off are sent in a slot not allocated to the site, but this is allowed since the first portion of the next allocated slot is unused and the last portion is used to open the aperture. See table 3.4.5.2.21-1.

**Table 3.4.5.2.21-1. Burst Structure for 6144 ksp Turbo with BCH (BTCH6144\_1/2TB)**

Field	Symbols	Microseconds	Comments
Radio Turn on		0	With linear radio, so there is no radio turn on time
Preamble		$\leq 2$	
Unique Word	27	4.39	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	$120*N$	$16.20*N$	Each slot is 15 bytes of user traffic
Postamble (or Tail)	9	1.46	
Radio Turn-off		0	

### 3.4.5.2.22 BTCH6144\_2/3TB: 6144 ksp Service Burst Structure – Turbo R2/3 with BCH

The burst overhead depends on the unique word aperture size. It is 7 slots for 125 microseconds and 2 slots for 28.5 microseconds aperture size respectively with

1 2304 slots per 45-millisecond frame. However, a maximum burst length is 38  
 2 slots (760 user bytes). The Tail and radio Turn-off are sent in a slot not allocated  
 3 to the site, but this is allowed since the first portion of the next allocated slot is  
 4 unused and the last portion is used to open the aperture. See table 3.4.5.2.22-1.

**Table 3.4.5.2.22-1. Burst Structure for 6144 kbps Turbo with BCH (BTCH6144\_2/3TB)**

Field	Symbols	Microseconds	Comments
Radio Turn on		0	With linear radio, so there is no radio turn on time
Preamble		<=2	
Unique Word	27	4.39	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	16.20*N	Each slot is 20 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	1.46	
Radio Turn-off		0	

5

6 **3.4.5.2.23 BTCH6144\_4/5TB: 6144 kbps Service Burst Structure – Turbo**  
 7 **R4/5 with BCH**

8 The burst overhead depends on the unique word aperture size. It is 7 slots for 125  
 9 microseconds and 2 slots for 28.5 microseconds aperture size respectively with  
 10 2304 slots per 45-millisecond frame. However, a maximum burst length is 31  
 11 slots (744 user bytes). The Tail and radio Turn-off are sent in a slot not allocated  
 12 to the site, but this is allowed since the first portion of the next allocated slot is  
 13 unused and the last portion is used to open the aperture. See table 3.4.5.2.23-1.

**Table 3.4.5.2.23-1. Burst Structure for 6144 kbps Turbo with BCH (BTCH6144\_4/5TB)**

Field	Symbols	Microseconds	Comments
Radio Turn on		0	With linear radio, so there is no radio turn on time
Preamble		<=2	
Unique Word	27	4.39	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	16.20*N	Each slot is 24 bytes of user traffic. N is number of slots.
Postamble (or Tail)	9	1.46	
Radio Turn-off		<=19	

14

15 **3.4.5.2.24 ATCH256\_1/2LDPC: 256 kbps Service Burst Structure – LDPC**  
 16 **R1/2 with CRC**

17 The burst overhead is one slot, with 96 slots per 45-millisecond frame. However,  
 18 a maximum burst length is 51 slots (765 user bytes). The Tail and radio Turn-off  
 19 are sent in a slot not allocated to the terminal, but this is allowed since the first  
 20 portion of the next allocated slot is unused since it is the beginning of a burst.  
 21 See table 3.4.5.2.24-1.  
 22

**Table 3.4.5.2.24-1. Burst Structure for 256 kbps LDPC with CRC (ATCH256\_1/2LDPC)**

	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 15 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

1

2 **3.4.5.2.25 ATCH256\_2/3LDPC 256 kbps Service Burst Structure – LDPC**  
3 **R2/3 with CRC**

4 The burst overhead is one slot, with 96 slots per 45-millisecond frame. However,  
5 a maximum burst length is 51 slots (1020 user bytes). The Tail and radio Turn-  
6 off are sent in a slot not allocated to the terminal, but this is allowed since the  
7 first portion of the next allocated slot is unused since it is the beginning of a  
8 burst. See table 3.4.5.2.25-1.

**Table 3.4.5.2.25-1 Burst Structure for 256 kbps LDPC with CRC (ATCH256\_2/3LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 20 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

9

10 **3.4.5.2.26 ATCH256\_4/5LDPC: 256 kbps Service Burst Structure – LDPC**  
11 **R4/5 with CRC**

12 The burst overhead is one slot, with 96 slots per 45-millisecond frame. However,  
13 a maximum burst length is 51 slots (1224 user bytes). The Tail and radio Turn-  
14 off are sent in a slot not allocated to the terminal, but this is allowed since the  
15 first portion of the next allocated slot is unused since it is the beginning of a  
16 burst. See table 3.4.5.2.26-1.

**Table 3.4.5.2.26-1. Burst Structure for 256 kbps LDPC with CRC (ATCH256\_4/5LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 24 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

17

1 **3.4.5.2.27 ATCH256\_9/10LDPC: 256 kbps Service Burst Structure – LDPC**  
 2 **R49/10 with CRC**

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3 The burst overhead is one slot, with 96 slots per 45-millisecond frame. However,  
 4 a maximum burst length is 51 slots (1377 user bytes). The Tail and radio Turn-  
 5 off are sent in a slot not allocated to the terminal, but this is allowed since the  
 6 first portion of the next allocated slot is unused since it is the beginning of a  
 7 burst. See table 3.4.5.2.27-1.

**Table 3.4.5.2.27-1. Burst Structure for 256 kbps LDPC with CRC (ATCH256\_4/5LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	105.5	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	468.75*N	Each slot is 27 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

8

9 **3.4.5.2.28 ATCH512\_1/2LDPC: 512 kbps Service Burst Structure – LDPC**  
 10 **R1/2 with CRC**

---

11 The burst overhead is one slot, with 192 slots per 45-millisecond frame.  
 12 However, a maximum burst length is 51 slots (765 user bytes). The Tail and  
 13 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 14 since the first portion of the next allocated slot is unused since it is the beginning  
 15 of a burst. See table 3.4.5.2.28-1.

**Table 3.4.5.2.28-1. Burst Structure for 512 kbps LDPC with CRC (ATCH512\_1/2LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 15 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

16 **3.4.5.2.29 ATCH512\_2/3LDPC: 512 kbps Service Burst Structure – LDPC**  
 17 **R2/3 with CRC**

---

18 The burst overhead is one slot, with 192 slots per 45-millisecond frame.  
 19 However, a maximum burst length is 51 slots (1020 user bytes). The Tail and  
 20 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 21 since the first portion of the next allocated slot is unused since it is the beginning  
 22 of a burst. See table 3.4.5.2.29-1.

**Table 3.4.5.2.29-1. Burst Structure for 512 kbps Turbo with BCH (BTCH512\_2/3TB)**

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Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 20 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

1

### 2 3.4.5.2.30 ATCH512\_4/5LDPC: 512 kbps Service Burst Structure – LDPC 3 R4/5 with CRC

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4 The burst overhead is one slot, with 192 slots per 45-millisecond frame.  
5 However, a maximum burst length is 51 slots (1224 user bytes). The Tail and  
6 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
7 since the first portion of the next allocated slot is unused since it is the beginning  
8 of a burst. See table 3.4.5.2.30-1.

**Table 3.4.5.2.30-1. Burst Structure for 512 kbps LDPC with CRC (ATCH512\_4/5LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 24 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

### 9 3.4.5.2.31 ATCH512\_9/10LDPC: 512 kbps Service Burst Structure – LDPC 10 R9/10 with CRC

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11 The burst overhead is one slot, with 192 slots per 45-millisecond frame.  
12 However, a maximum burst length is 51 slots (1377 user bytes). The Tail and  
13 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
14 since the first portion of the next allocated slot is unused since it is the beginning  
15 of a burst. See table 3.4.5.2.31-1.

**Table 3.4.5.2.31-1. Burst Structure for 512 kbps LDPC with CRC (ATCH512\_9/10LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	52.73	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	234.375*N	Each slot is 27 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

16

### 17 3.4.5.2.32 ATCH1024\_1/2LDPC: 1024 kbps Service Burst Structure – 18 LDPC R1/2 with CRC

---

19 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
20 However, a maximum burst length is 51 slots (765 user bytes). The Tail and

1 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 2 since the first portion of the next allocated slot is unused and the last portion is  
 3 used to open the aperture. See table 3.4.5.2.32-1.

**Table 3.4.5.2.32-1. Burst Structure for 1024 ksps LDPC with CRC (ATCH1024\_1/2LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 15 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

4

5 **3.4.5.2.33 ATCH1024\_2/3LDPC: 1024 ksps Service Burst Structure –**  
 6 **LDPC R2/3 with CRC**

7 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
 8 However, a maximum burst length is 51 slots (1020 user bytes). The Tail and  
 9 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 10 since the first portion of the next allocated slot is unused and the last portion is  
 11 used to open the aperture. See table 3.4.5.2.33-1.

**Table 3.4.5.2.33-1 Burst Structure for 1024 ksps LDPC with CRC (ATCH1024\_2/3LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 20 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

12 **3.4.5.2.34 ATCH1024\_4/5LDPC: 1024 ksps Service Burst Structure –**  
 13 **LDPC R4/5 with CRC**

14 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
 15 However, a maximum burst length is 51 slots (1124 user bytes). The Tail and  
 16 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
 17 since the first portion of the next allocated slot is unused and the last portion is  
 18 used to open the aperture. See table 3.4.5.2.34-1.

**Table 3.4.5.2.34-1. Burst Structure for 1024 ksps LDPC with CRC (ATCH1024\_4/5LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 24 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

1

### 2 3.4.5.2.35 ATCH1024\_9/10LDPC: 1024 ksps Service Burst Structure – 3 LDPC R9/10 with CRC

---

4 The burst overhead is two slots, with 384 slots per 45-millisecond frame.  
5 However, a maximum burst length is 51 slots (1377 user bytes). The Tail and  
6 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
7 since the first portion of the next allocated slot is unused and the last portion is  
8 used to open the aperture. See table 3.4.5.2.35-1.

**Table 3.4.5.2.35-1. Burst Structure for 1024 ksps LDPC with CRC  
(ATCH1024\_9/10LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	26.37	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	117.19*N	Each slot is 27 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

### 9 3.4.5.2.36 ATCH2048\_1/2LDPC: 2048 ksps Service Burst Structure – 10 LDPC R1/2 with CRC

---

11 The burst overhead is three slots, with 768 slots per 45-millisecond frame.  
12 However, a maximum burst length is 51 slots (765 user bytes). The Tail and  
13 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
14 since the first portion of the next allocated slot is unused and the last portion is  
15 used to open the aperture. See table 3.4.5.2.36-1.

**Table 3.4.5.2.36-1. Burst Structure for 2048 ksps LDPC with CRC  
(ATCH2048\_1/2LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.60*N	Each slot is 15 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

17

### 18 3.4.5.2.37 ATCH2048\_2/3LDPC: 2048 ksps Service Burst Structure – 19 LDPC R2/3 with CRC

---

20 The burst overhead is three slots, with 768 slots per 45-millisecond frame.  
21 However, a maximum burst length is 51 slots (1020 user bytes). The Tail and  
22 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
23 since the first portion of the next allocated slot is unused and the last portion is  
24 used to open the aperture. See table 3.4.5.2.37-1.

**Table 3.4.5.2.37-1. Burst Structure for 2048 ksps LDPC with CRC (ATCH2048\_2/3LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.6*N	Each slot is 20 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

1

2 **3.4.5.2.38 ATCH2048\_4/5TB: 2048 ksps Service Burst Structure – LDPC**  
3 **R4/5 with CRC**

---

4 The burst overhead is three slots, with 768 slots per 45-millisecond frame.  
5 However, a maximum burst length is 51 slots (1224 user bytes). The Tail and  
6 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
7 since the first portion of the next allocated slot is unused and the last portion is  
8 used to open the aperture. See table 3.4.5.2.38-1.

**Table 3.4.5.2.38-1. Burst Structure for 2048 ksps LDPC with CRC (ATCH2048\_4/5LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.6*N	Each slot is 24 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

9 **3.4.5.2.39 ATCH2048\_9/10TB: 2048 ksps Service Burst Structure – LDPC**  
10 **R9/10 with CRC**

---

11 The burst overhead is three slots, with 768 slots per 45-millisecond frame.  
12 However, a maximum burst length is 51 slots (1377 user bytes). The Tail and  
13 radio Turn-off are sent in a slot not allocated to the terminal, but this is allowed  
14 since the first portion of the next allocated slot is unused and the last portion is  
15 used to open the aperture. See table 3.4.5.2.39-1.

**Table 3.4.5.2.39-1. Burst Structure for 2048 ksps LDPC with CRC (ATCH2048\_9/10LDPC)**

Field	Symbols	Microseconds	Comments
Radio on		<=29	
Unique Word	27	13.18	Unique word needed for burst acquisition
Dead Time	0		
Turbo-Coded Payload	120*N	58.6*N	Each slot is 27 bytes of user traffic. N is number of slots.
Radio Turn-off		<=19	

1

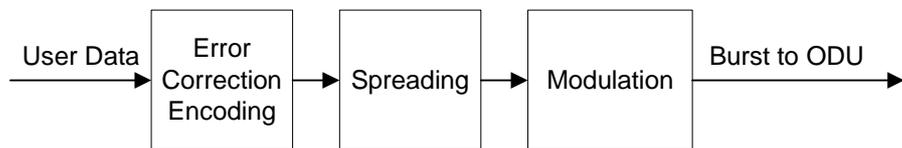
2 **3.4.6 Spreading**

---

3 IPoS optionally employs Direct Sequence spreading. The baseband signal is  
 4 intentionally spread over a larger frequency range by injecting a higher frequency  
 5 signal. However, the total transmit energy remains the same.

6 The interference problem is due to the transmit gain pattern of the small antenna  
 7 used in mobile applications. The gain pattern may contain off axis side lobes of  
 8 significant magnitude. Off-axis means in a direction different from the main lobe  
 9 pointed at the desired satellite. Their magnitude is significant in the sense that  
 10 when using a low symbol rate (e.g. 256 Ksps) transmitter in a non-spread  
 11 configuration, the power spectral density (PSD) in the direction of an adjacent  
 12 satellite may be high enough to cause interference. Spreading reduces the PSD to  
 13 an allowable level (as set by government regulations) by distributing the transmit  
 14 power over a larger frequency range. The ratio (in dB) between the spread signal  
 15 and the original signal is called processing gain. The difference in occupied  
 16 bandwidth is called the bandwidth expansion factor.

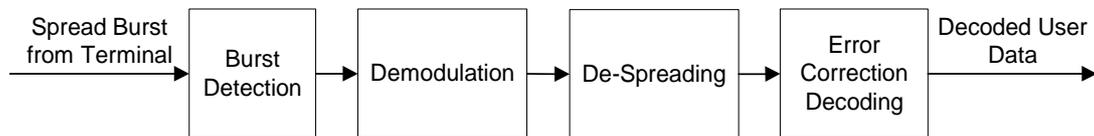
17 Spreading is independent of coding used. IPoS spreading applies to FEC turbo-  
 18 code rates 1/2, 2/3 and 4/5 that use BCH outercoding. On the transmitter side  
 19 (Figure 3.4.6-1) spreading occurs after a burst has been encoded and the UW  
 20 added. The unique words by-pass the encoder and are spread with the rest of the  
 21 burst without special consideration.



22

23 **Figure 3.4.6-1. Spreading at the Transmitter**

24 On the receiving side (Figure 3.4.6-2), de-spreading (opposite to spreading)  
 25 occurs after demodulation, but before the decoding process. The burst  
 26 demodulator detects the defined unique word in spread format.



27

28

29 **Figure 3.4.6-2. De-spreading at the Receiver**

30 The burst time plans (slot sizes) are identical for spread and non-spread inroutes.  
 31 Spreading shall be supported by mobile and mesh terminals that use very small  
 32 antennas. IPoS inroutes support the following rates and spreading factors  
 33 (Bandwidth Expansion Factor).

34 **Table 3.4.6-1. Spreading Rates and Factors**

SpreadSpectrum OQPSK Symbol Rate	Pre-spread, Post Encoding Symbol Rate	Spread Factor
512 Ksps	256 Ksps	2
1024 Ksps	256 Ksps	4
2048 Ksps	256 Ksps	8
1024 Ksps	512 Ksps	2
2048 Ksps	512 Ksps	4
2048 Ksps	1024 Ksps	2
4096 Ksps	2048 Ksps	2

1

### 2 3.4.6.1 Spreading Technique Overview

---

3 The IPoS terminal (transmitter) spreads transmission using a “Gold” code  
 4 sequence to achieve a lower power per Hertz requirement. The entire burst  
 5 transmission including unique word is spread before being transmitted over the  
 6 air.

7 The “Gold” code is generated by modulo-2 adding, or XORing, the output of two  
 8 linear feedback shift registers (LFSR). The “Gold” code consists of 2 sequences,  
 9  $PN_I$  and  $PN_Q$ .

10 The first LFSR is generated using the following polynomial:

$$11 \quad x^{16} + x^{12} + x^3 + x + 1$$

12 The second LFSR is generated using the following polynomial:

$$13 \quad y^{16} + y^{13} + y^{12} + y^{11} + y^7 + y^3 + y + 1$$

14 The combinations to generate the two PN sequences are as following:

$$15 \quad \begin{aligned} PN_I &= LFSR1_{(0001)_{16}} \wedge LFSR2_{(0001)_{16}} \\ PN_Q &= LFSR1_{(5213)_{16}} \wedge LFSR2_{(2B28)_{16}} \end{aligned}$$

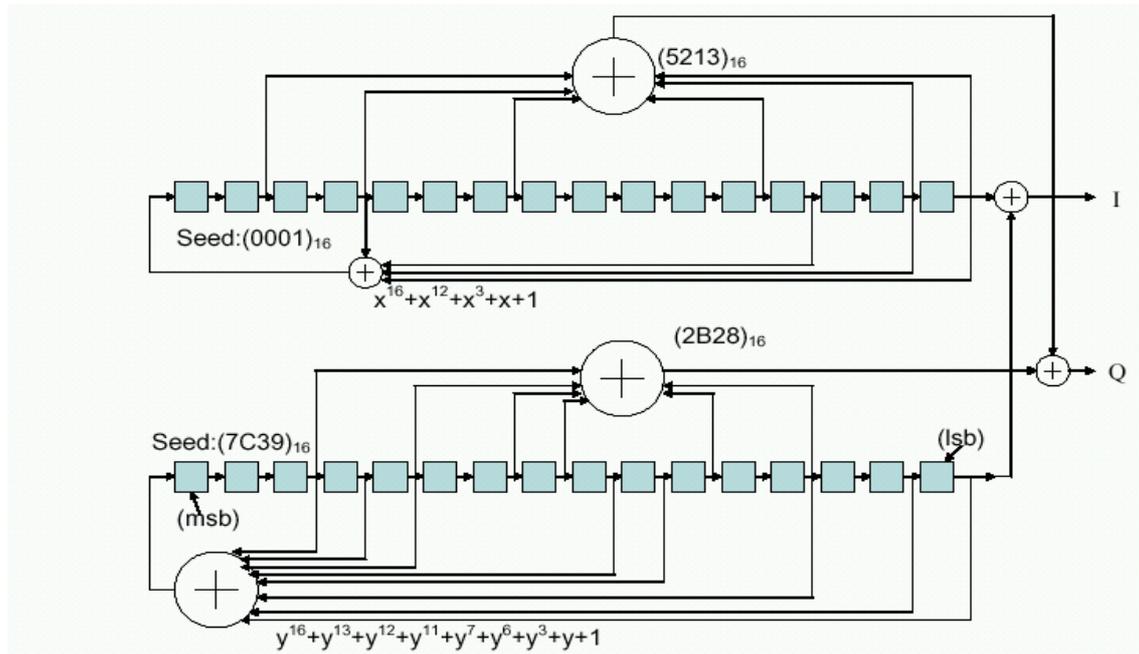


Figure 3.4.6.1-1. Spreading Technique

At the transmitter, the PN generator is stepped either 2 or 4 or 8 times, depending on the spreading factor, for each symbol; and each output from the PN generator is XORed with the symbol before being sent to the modulator. LFSR1 is initialized with seed value of  $(0001)_{16}$  and LFSR2 is initialized with a seed value of  $(7C39)_{16}$  at the start of every burst.

### 3.4.7 Adaptive Coding

IPoS Inroute physical layer is capable of detecting bursts where burst to burst FEC rate changes occur on the same channel. This feature is known as adaptive coding and supported on Turbo coded BCH inroutes for FEC rates  $\frac{1}{2}$ ,  $\frac{2}{3}$  and  $\frac{4}{5}$ , and LDPC coded inroutes for FEC rates  $\frac{1}{2}$ ,  $\frac{2}{3}$ ,  $\frac{4}{5}$  and  $\frac{9}{10}$ . This is performed at the demodulator of the IPoS hub and is provided here as an informative text.

There are three (3) parallel and identical Unique Word (UW) correlators present in the Demodulator with UW sequences can be programmed for Rates  $\frac{1}{2}$ ,  $\frac{2}{3}$  and  $\frac{4}{5}$  Unique Words. Each Unique Word correlator searches over the aperture at the same time with the highest Unique Word score and the position is recorded for each, and then three (3) scores from each correlator are compared. The one with the highest score is determined to be the FEC rate of a particular burst.

## 3.5 Mesh Physical Layer

IPoS mesh terminal is designed to enable both Mesh network topology (direct Terminal-to-Terminal communications) and/or Star network topology (communications via IPoS Hub).

1 For transmission and reception of Mesh network topology traffic, IPoS terminals  
 2 shall use the IPoS Inroute physical layer definition as defined within section 3.4  
 3 of this specification.

4 For transmsision of star network topology traffic, IPoS terminals shall use the  
 5 IPoS physical layer definition as defined within section 3.4 of this specification.

6 For reception of star network topology, IPoS terminals shall use the IPoS  
 7 physical layer definition as defined within section 3.3 of this specification.

## 8 **3.6 Physical Layer Measurements**

---

9 The PHY parameter included in this subsection shall be monitored in the PHY  
 10 and reported to a higher layer for support in the higher-layer procedures.

### 11 **3.6.1 Outroute Bit Error Rate**

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12 The remote shall measure the received  $\frac{E_{bt}}{N_0}$  of the outroute carrier to an accuracy  
 13 of  $\pm 0.2$  dB given that an equalizer has been implemented in the receiver. This  
 14 measurement is used by the higher layer for outroute and inroute rate adaptations  
 15 purposes.

### 16 **3.6.2 Signal Quality Factor**

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17 The Signal Quality Factor (SQF) provides the IPoS terminal's installer and user  
 18 with an easy-to-understand estimation of the quality of the received outroute  
 19 signal. To maintain consistency among the various IPoS remote brands and their  
 20 signal strength readings, the IPoS remote shall display the relationship of  $E_{bt}/N_0$   
 21 to SQF as defined by table 3.6.2-1 and figure 3.6.2-1.

**Table 3.6.2-1. Required Relationship Between  $E_{bt}/N_0$  (dB) and SQF**

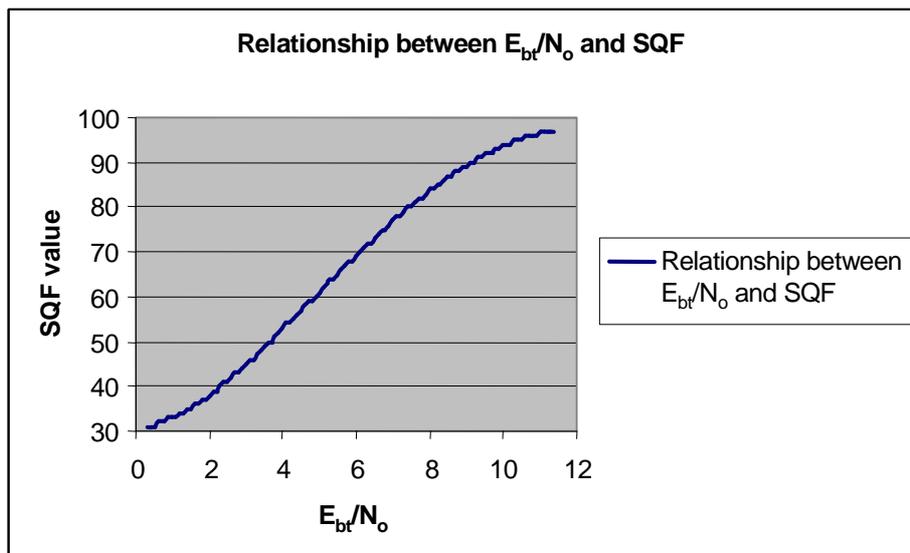
$E_{bt}/N_0$	SQF
0.5	31
1	33
1.5	35
2	38
2.5	41
3	45
3.5	49
4	53
4.5	57
5	61
5.5	65
6	69
6.5	73
7	77
7.5	80

**Table 3.6.2-1. Required Relationship Between  $E_{bt}/N_o$  (dB) and SQF**

$E_{bt}/N_o$	SQF
8	84
8.5	87
9	89
9.5	92
10	94
10.5	95
11	97
11.5	98
12	98
12.5	99
13	99
13.5	99
14	99

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Figure 3.6.2-1 illustrates the relationship between  $E_{bt}/N_o$  and SQF.



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**Figure 3.6.2-1. Required Relationship Between  $E_{bt}/N_o$  and SQF**

### 3.6.3 Frequency Offset

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The frequency offset is a measure of the difference between the frequencies at which bursts are being received at versus the inroute IF Frequency. The IPoS mesh terminal shall measure the frequency offset.

The AGC offset is the measure of the difference in the power level between the received bursts and the current DDC gain which may be nominal or not. AGC offset in linear DDC units are converted into 0.1 dB units using the following formula:

1 AGC\_Offset (0.1dB) =  $200 * \log_{10}(\text{agc\_offset\_ddc} * 2^6/4096)$

## 2 **3.6.4 Unique Word (UW) Timing Offset**

---

3 The Unique Word Timing Offset is the measured timing offset in units of  
4 microseconds relative to the beginning of the aperture if the burst is a ranging  
5 aperture burst or relative to the middle of the aperture for all other bursts types.  
6 The IPoS mesh terminal shall measure the frequency offset.

7  
8 This value is derived by multiplying sample offset (in number of samples) and  
9 sample duration and as such is symbol rate dependent as the sample time varies  
10 with symbol rates.

11 The formula used for calculating Unique Word Timing Offset is as follows:

- 12 • For Ranging Aperture:  $\text{UW\_Timing\_Offset} = (\text{Number\_Of\_Sample} * \text{Sample\_Duration})$
- 13  
14 • For Normal Aperture:  $\text{UW\_Timing\_Offset} = (\text{Number\_of\_Sample} * \text{Sample\_Duration}) - (\text{Time\_of\_Normal\_Aperture}/2)$
- 15

## 16 **3.6.5 SNR Estimation**

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17 The demodulator of IPoS mesh terminals measure the received  $\frac{E_s}{N_0}$  or SNR of  
18 inroute bursts to an accuracy of a 3-sigma standard deviation of 0.5 dB after  
19 averaging over 10 bursts. This measurement is used by the higher layer for closed  
20 loop power control purposes.

21

## 22 **3.7 Interface to Higher Layers**

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23 The following subsections describe the specific primitives used by the PHY to  
24 exchange information with the higher layers of the IPoS protocol stack.

### 25 **3.7.1 User Plane Primitives**

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26 The PHY uses the following primitives across the interface with the MAC  
27 sublayer over the user plane:

#### 28 **PHY-U-DATA-REQ**

29 Used to pass information flows between physical and MAC layers.

#### 30 **PHY-U-DATA-IND**

31 Indicates that the data transfer has been completed.

## 3.7.2 Control Plane Primitives

---

The PHY uses the following primitives across the interface with the MAC sublayer over the control plane:

### **PHY-C-Inroute Radio Power Control-REQ**

The IPoS remote shall have output power control. This power control shall allow control via messaging sent on the outroute.

### **PHY-C-Inroute Radio Power Control-RES**

Upon command, the IPoS remote shall be able to measure its output power to within 0.2 dB of the commanded value.

### **PHY-C-Inroute Radio Power Control-IND**

The IPoS remote shall indicate that it has implemented the power control command.

### **PHY-C-Outroute FEC Control-RES**

The IPoS remote shall set itself automatically to the correct FEC rate for the outroute.

### **PHY-C-Outroute FEC Control-IND**

The IPoS remote shall provide current outroute FEC rate information to higher levels of the IPoS protocol stack.

### **PHY-C-Outroute FEC Change-RES**

Upon sensing a change in the FEC rate, the IPoS remote shall change automatically to that rate and demodulate data.

### **PHY-C-Outroute Symbol Rate-RES**

The transmit symbol rate of the outroute shall be able to be set by DLL protocols.

### **PHY-C-Outroute Symbol Clock-IND**

The IPoS remote shall indicate that it has recovered the symbol clock to act as a source of clocking information and the symbol rate being demodulated.

### **PHY-C-Outroute Frequency Lock Loop-IND**

The IPoS remote indicates the status of the demodulator's FLL. The status types shall be locked and unlocked.

### **PHY-C-Outroute Demodulator Unlock-IND**

1 The IPoS remote indicates the status of the demodulator. The status types  
2 shall be locked and unlocked.

### 3 **PHY-C-Inroute Burst Time Management-REQ**

4 The IPoS remote shall be able to control the timing of each data burst under  
5 control from the data sent on the outroute. This data and the required timing  
6 for this data are specified in the inroute data link layer definition.

### 7 **PHY-C-Inroute Burst Time Management-IND**

8 The IPoS remote PHY shall indicate that it has used the data burst timing  
9 required by higher levels of the IPoS protocol stack.

### 10 **PHY-C-Inroute Burst Frequency Management-RES**

11 The IPoS remote shall be able to control the frequency of each data burst  
12 under control from the outroute data. This data and the required frequency  
13 for this data are specified in the inroute data link layer definition.

### 14 **PHY-C-Inroute Burst Frequency Management-IND**

15 The IPoS remote shall indicate the burst frequency used for each burst.

## 16 **3.7.3 Management Plane Primitives**

---

17 The physical layer uses the following primitives across the interface with the  
18 management entity:

### 19 **PHY-M-Activate Outroute-REQ**

20 For the activation of the activation of the outroute acquisition.

### 21 **PHY-M-Activate Outroute-IND**

22 Indication that the outroute is activated.

### 23 **PHY-M-Activate Inroute-REQ**

24 For the activation of the inroute transmissions.

### 25 **PHY-M-Activate Inroute-IND**

26 Indication that inroute transmissions are activated.

### 27 **PHY-M-Deactivate Outroute-REQ**

28 Deactivate the outroute reception.

### 29 **PHY-M-Deactivate Outroute-IND**

30 Indication that the outroute reception is deactivated.

- 1                   **PHY-M-Deactivate Inroute-REQ**
- 2                   Deactivate the inroute transmissions.
- 3                   **PHY-M-Deactivate Inroute-IND**
- 4                   Indication that the inroute transmitter is deactivated.
- 5                   **PHY-M-Inroute Transmitter Frame Count-REQ**
- 6                   The IPoS remote shall record the transmitted frame count.
- 7                   **PHY-M-Inroute Transmitter Frame Count-IND**
- 8                   The IPoS remote shall indicate the frame count that was transmitted.
- 9                   **PHY-M-Inroute Transmitter Reset-REQ**
- 10                  The IPoS remote shall reset its transmitter.
- 11                  **PHY-M-Inroute Transmitter Reset-IND**
- 12                  The IPoS remote shall indicate that its transmitter has been reset.
- 13                  **PHY-M-Inroute Transmitter Reset Count-IND**
- 14                  The IPoS remote shall record the number of times the transmitter was reset.

## 15   **3.8           Physical Layer Procedures**

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### 16   **3.8.1        Timing Synchronization**

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18                  Timing synchronization is used to align the remote terminal transmissions with  
19                  the inroute superframe, frame, and slot reference at the IPoS hub. This alignment  
20                  is composed of the following procedures:

- 21                   • Outroute carrier acquisition
- 22                   • Inroute frame alignment
- 23                   • Ranging

#### 24   **3.8.1.1     Outroute Carrier Acquisition**

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25                  During the commissioning procedure, the remote terminal is provided with  
26                  parameters that allow the acquisition and demodulation of the information  
27                  conveyed by outroute carrier. These parameters include:

- 28                   • Frequency, polarization, and symbol rate of the outroute carrier: Used  
29                   for the tuning and acquisition of the outroute carrier.





## 1    **4                    DATA LINK LAYER**

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### 2    **4.1                Scope**

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3                    The present document is the detailed specification of the MAC/SLC layer  
4                    protocol for the IPoS air interface. In particular, it contains MAC and SLC  
5                    procedures, messages, and message formats.

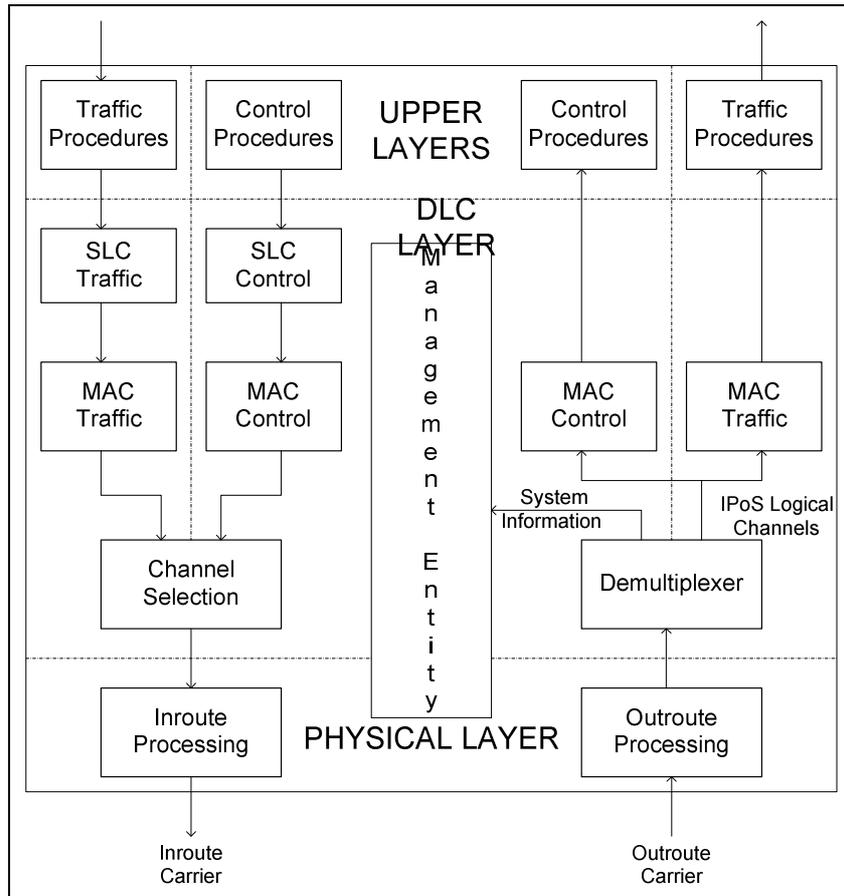
### 6    **4.2                Data Link Control Overview**

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7                    The DLC provides the higher protocol layers with IP transfer capabilities for  
8                    signaling and user data over the logical channels defined in the IPoS air interface.  
9                    The DLC layer is further subdivided into the following sublayers:

- 10                    • MAC sublayer that provides the format and data structure used to  
11                    encapsulate the user and control the information over the packets and  
12                    bursts defined over the PHY. This layer includes a multiplexing sublayer  
13                    that is defined only in the outroute direction
- 14                    • SLC sublayer that provides the communication protocols used to provide  
15                    reliable transfers and the shared access of channels among multiple IPoS  
16                    terminals.

17                    The general architecture of the DLC and its relationship with other layers is  
18                    shown from the IPoS terminal perspective in figure 4.2-1.



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**Figure 4.2-1. DLC Model**

The DLC is modeled from an IPoS terminal view in three planes (user, control, and management) for both transmission directions:

- Outroute: The hub transmissions are received by all IPoS terminals.
- Inroute – Star Topology: The hub receives transmissions from IPoS terminals.
- Inroute – Mesh Topology: The Mesh terminal receives transmissions from IPoS remote terminal.

## 4.3 Satellite Link Control Sublayer

### 4.3.1 Overview

The SLC layer is the sublayer of the DLC layer that is responsible for end-to-end transmission and reception of IP packets between IPoS remote terminals and the hub. It supports reliable delivery in the remote-to-hub direction and unacknowledged delivery in the hub-to-remote direction and Remote Terminal-to-Remote Terminal direction.

## 4.4 Modes of Operation

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### 4.4.1 Registration and Commissioning

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Registration and commissioning for IPoS remote terminals are accomplished by following these steps:

1. Configuring the unique data for this terminal at the hub and at the terminal, as subsection 4.14 describes. This includes the remote terminal's encrypted key at the hub.
2. The hub transmits the encrypted keys periodically for all remote terminals on the outroute. The keys are encrypted with the remote terminal's hard-coded secret data so that only the specified terminal can decrypt the key.
3. The remote terminal is installed at the remote location.
4. The remote terminal receives the encrypted keys (unicast and multicast) that are specified on the outroute for its serial number. IPoS serial numbers are unique across an IPoS system.
5. The remote terminal stores the encrypted keys in nonvolatile memory.
6. The remote terminal installs its encrypted keys in its decryption hardware. The decryption hardware decrypts the key and installs it in the decryption hardware so that it can begin decrypting the outroute data.

At this point, the IPoS terminal is ready to begin operation in the IPoS system. Note that there is no terminal authentication procedure required. An unauthorized terminal will not have the secret key data that the authorized terminal has, so it will not be able to decode outroute data.

### 4.4.2 IPoS Terminal Startup

---

To begin operation in an IPoS system, an IPoS terminal follows these steps:

1. Acquires timing and frequency with the outroute configured for it.
2. Installs the encrypted keys from nonvolatile memory so that it will be able to decrypt outroute data.
3. Receives system information including frame timing, inroute frequency, timing, and modulation timing.
4. Installs the proper DVB MAC filter addresses in its receiver so that it will receive only information that may be relevant to this particular terminal.

- 1                                   5. Performs a ranging procedure with the hub to determine its transmit  
2                                   timing parameters so that it can transmit inroute bursts that will be  
3                                   synchronized with the hub's frame timing.

#### 4   **4.4.3    IP Packet Delivery**

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5                                   Once a remote terminal has followed the startup procedure, its SLC layer is ready  
6                                   to accept IP packets for delivery to the hub at its upper-layer SAP. Similarly, the  
7                                   hub's SLC layer is ready to accept IP packets for delivery to remote terminal at  
8                                   its upper layer SAP. The hub and remote terminals are also ready to receive IP  
9                                   packets from the SLC's upper layer SAP. Note that there is no concept of access  
10                                  session over the air interface, meaning that IP connectivity between the remote  
11                                  terminals to the IP backbone is always on after the startup procedures are  
12                                  completed. Remote terminals exchange control packets with the hub to establish  
13                                  a communication session when they need bandwidth assigned to send IP data  
14                                  packets. That is, there is no sign-on or authentication each time the hub and  
15                                  remote terminal need to exchange IP packets.

### 16   **4.5       Interface with Higher Layers: SI-SAP**

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#### 18   **4.5.1    Overview**

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19                                  The higher layers use this SAP to communicate with the lower layers. This SAP  
20                                  and the associated Network Adaptation Layers provide the interface between the  
21                                  higher layer IP services and the lower layer DLC services.

22                                  This SAP is a subset of the SI-SAP that reference [2] describes. The IPoS system  
23                                  uses this standard SAP so that software or devices that use this SAP can be  
24                                  modified more easily to use another satellite system that implements the same  
25                                  standard SAP.

26                                  The SI-SAP contains a number of features that do not apply to the IPoS system  
27                                  architecture or are not implemented in the IPoS system. The following  
28                                  subsections describe the specific SI-SAP services that the IPoS system uses.

29

## 1    **4.5.2    User Plane**

---

2                    The IPoS system uses the following U-Plane services:

- 3                    • **Data transfer:** The upper layers at both the hub and remote terminals  
4                    use this service to send an IP packet to the lower layers and to receive an  
5                    IP packet from the lower layers.

## 6    **4.5.3    Control Plane**

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7                    The IPoS system uses the following C-Plane services:

- 8                    • **Resource reservation:** The upper layer at the remote terminal can use  
9                    these services to control the lower layer resources that are needed for  
10                    transporting IP packets to the hub.
- 11                   • **Flow control:** The upper layer at the remote terminals can use these  
12                   services to operate the flow control to regulate the flow of IP packets to  
13                   the lower layers.
- 14                   • **Group receive:** The upper layer at the remote terminal can use these  
15                   services to control the reception of multicast packets by the lower layers.

16                    The functions associated with these C-plane services are contained in the  
17                    Network Adaptation Layer.

## 19   **4.6       Media Access Control Sublayer**

---

### 21   **4.6.1    Overview**

---

22                    MAC is a sublayer of the DLC layer. This layer shall control the way an IPoS  
23                    terminal uses its inroute resources, i.e., Aloha contention channel, and processes  
24                    the DVB outroute. This layer handles the following functions:

- 25                    • Outroute
  - 26                    – IPoS DVB PID information
  - 27                    – IP packet segmentation and reassembly
  - 28                    – IP packet segmentation and reassembly
  - 29                    – Data encryption and decryption
  - 30                    – Data encryption and decryption
  - 31                    – Discriminate and filter traffic received by the IPoS terminal
  - 32                    – Discriminate and filter traffic received by the IPoS terminal
  - 33                    – Multiplex and demultiplex logical control channels
  - 34                    – Multiplex and demultiplex logical control channels
- 35                    • Inroute
  - 36                    – Request and allocate bandwidth

- 1  
2                   – Transmit and receive data bursts  
3  
4                   – IP packet segmentation and reassembly

## 5 **4.7 Interfaces, SAPs, Service Definitions, and** 6 **Service Primitives**

---

7                   This subsection gives details of different interfaces that the MAC sublayer has  
8                   with other layers and entities.

### 9 **4.7.1 MAC Interface with Physical Layer**

---

#### 10 **4.7.1.1 Service Access Point**

---

11                   The IPoS reference model defines a SAP between the MAC and the PHY. This  
12                   SAP shall provide the means for transfer of IP packets, control, and management  
13                   information between the MAC and the PHY for transmission over the air link.  
14

#### 15 **4.7.1.2 Services**

---

16                   The MAC sublayer expects the following services from the PHY:

- 17                   • Transmission/reception of MAC PDUs on the assigned logical channel  
18                   • Current status of radio link

#### 19 **4.7.1.3 Primitives**

---

20                   The primitives between the MAC and the PHY are given in subsection 3.7.

## 21 **4.7.2 Interfaces with Layer Management Entities**

---

22                   The MAC sublayer uses the following primitives across the interface with the  
23                   management entity:

#### 24                   **MAC-M-DATA-REQ**

25                   Used to transfer system information between the MAC and the management  
26                   plane.

#### 27                   **MAC-M-DATA-IND**

28                   Indicates that the transfer has been completed.

#### 29                   **MAC-M-ERROR-IND**

30                   This primitive provides error reports on events such as retransmissions,  
31                   discarded PDUs, etc.

1                   **MAC-M-ESTABLISH-REQ**  
2                   Used by the management entity to request the establishment of individual  
3                   logical channels.

4                   **MAC-M-ESTABLISH-IND**  
5                   Indicates that the individual logical channels have been established.

6                   **MAC-M-RELEASE-REQ**  
7                   Used by the management entity to request the release of individual logical  
8                   channels.

9                   **MAC-M-RELEASE-IND**  
10                  Indicates the release of logical channels.

11                  **MAC-M- ADJUST-REQ**  
12                  Used by the management entity to set the operational parameters of the  
13                  logical channels.

### 14    **4.7.3        Logical Interfaces with Peer Layer**

---

15                  The peer-to-MAC sublayer of an ST resides in the network. The ST interacts  
16                  with the bandwidth control component on the satellite over the U-Interface for  
17                  negotiating the required channel and bandwidth for both the rate and volume  
18                  traffic.

19                  This logical interface shall be supported with the set of messages listed in  
20                  subsections 4.11 and 4.13.

## 21    **4.8         Outroute Multiplexing**

---

22                  Multiple programs, services, or types of information are multiplexed within the  
23                  same outroute carrier. The outroute multiplexer sublayer statistically multiplexes  
24                  information streams specific to the IPoS system with other MPEG-encoded video  
25                  or data streams.

26                  The higher layer information in these programs is mapped by the multiplexing  
27                  sublayer into a continuous transport stream of packets that interfaces with the  
28                  PHY. This transport stream consists of DVB/MPEG compliant packets (see  
29                  reference [1]) with the following characteristics:

- 30                   • Fixed-length packets of 188 bytes containing a 4-byte DVB/MPEG  
31                   header and 184 bytes available for payload.
- 32                   • Fixed symbol transmission rate as determined by the PHY.
- 33                   • Individual program information mapped to an integer number of packets;  
34                   no packet contains information from two different programs.

- 1                   • Packets from different programs and services are statistically multiplexed
- 2                   in the outroute transmission stream; there is no fixed allocation or
- 3                   relationship between a program and the position of its packets in the
- 4                   transport stream.
- 5                   • Always-on outroute, null-packets are inserted in the transport stream
- 6                   when there is no information from the programs.

7                   Outroute DVB/MPEG packets are broadcast over the entire outroute carrier

8                   bandwidth with IPoS terminals filtering those packets that do not match their

9                   own addresses. The addressing scheme is included as part of the transport packet

10                  header and MAC header.

## 11    **4.8.1    Transport Packet Header**

---

12                  The 4-byte header of the DVB/MPEG transport packet is transmitted at the

13                  beginning of the 188-byte packet. The fields and values used in IPoS for the

14                  DVB/MPEG transport packet header are compliant with reference [1] (found in

15                  subsection 1.4 of this document), and defined in table 4.9.1-1. This transport

16                  header is applicable for DVB-S2 outroutes.

**Table 4.9.1-1. DVB/MPEG Transport Packet Header**

Field Name	Field Length (bits)
synch_byte	8
transport_error_indicator	1
payload_unit_start_indicator	1
transport_priority	1
PID	13
transport_scrambling_control	2
adaptation_field_control	2
continuity_counter	4

17

18

The description of the fields in the transport packet header is as follows:

19

- synch\_byte: Set to 0x47. This fixed 8-bit field is defined by the PHY.

20

21

- transport\_error\_indicator: Set to '0'. When set to '1' this 1-bit flag indicates that the packet contains an uncorrectable error.

22

23

- payload\_unit\_start\_indicator (PUSI): Set to '1' or '0'. If the payload includes IPoS-specific information, the following logic is used:

24

25

26

- First Packet - Contains the beginning of a MAC PDU and may or may not contain the start of another MAC PDU. The PUSI bit is set to '1'.

27

28

- Start Packet - Contains the start of at least one MAC PDU at the middle of the payload. The PUSI bit is set to '1'.



adaptation_field_length	8
adaptation_flags	8
adaptation_stuff_bytes	8
Pointer	8

1  
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3  
4  
5  
6  
7  
8  
9

The description of the extra fields in the transport packet header is as follows:

- adaptation\_field\_length: Shall be always set to 0x02.
- adaptation\_flags: Shall be always set to 0x00.
- adaptation\_stuff\_bytes: Shall be always set to 0xff.
- pointer: Set to 0x00 to indicate the beginning of datagram section immediately follows the pointer field. Set to 'x' where x is a non-zero value to indicate the offset in bytes from the pointer field where a datagram section starts.

## 10 4.8.2 Program Identifiers

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The DVB/MPEG header includes a 13-bit PID field intended to support the multiplexing of diverse programs or services such as video or data programs over the same outroute carrier. The PID field in the packet header identifies the program, which permits the terminals associated with a particular outroute carrier to receive one or more programs by filtering packets based on the PID field.

IPoS outroute carriers multiplex two types of relevant information to the IPoS terminals:

- PSI tables, which provide both IPoS and non-IPoS terminals with configuration of services. The IPoS terminals receive the PSI tables to determine the specific configuration of the IPoS system.
- IPoS user and control information, which is transported in the IPoS logical channels. The information contained in the IPoS logical channels can be targeted to all, a group, or individual IPoS terminals.

IPoS terminals determine the PIDs used for the IPoS logical channels by reading the two PSI tables, table 4.9.2-1 and table 4.9.2.-2:

- The Program Association Table (PAT) gives the PID of the Program Map Table (PMT).
- The PMT determines the PIDs of the various logical channels used in IPoS.

IPoS terminals shall be capable of receiving the PIDs in table 4.9.2-1

**Table 4.9.2-1. PID Range**

Description	PID (hex)
Program Association Table	0x0000
Program Map Table	From 0x0010 to 0x1FFE as defined in the PAT
IPoS Outroute Logical Channels	From 0x0010 to 0x1FFE as defined in the PMT

1

2

3

4

IPoS terminals are configured through the PAT with PID value 0x0000, which determines the PMT table's PID. Then, through the PMT table, the PIDs to use for IPoS-specific logical channels are determined.

5

6

When PAT and PMT tables are not present in the outroute carrier, the default values in table 4.9.2-2 are used for the IPoS specific logical control channels.

**Table 4.9.2-2. IPoS Default PIDs**

Description	PID (hex)
IPoS Logical Control Channels	0x0190
IPoS Logical Traffic Channels	0x012C

7

8

## **4.9 Outroute MAC Sublayer**

---

9

10

11

The purpose of the MAC sublayer is to provide higher layer information with access to the transmission services from the multiplexing sublayer and the physical layers. The outroute MAC sublayer performs the following functions:

12

13

- Mapping of higher layer information into MPEG packets defined at the multiplexer sublayer

14

15

- Addressing individual, group, or all IPoS terminals receiving the outroute carrier

16

17

- Logical channel definition and control of information flows over the various channels

18

- Detection of transmission errors introduced over the air interface

19

### **4.9.1 Outroute MAC Formats**

---

20

21

22

23

The MAC sublayer maps higher layer information over the 184-byte or 180 byte payload of the DVB/MPEG packets using MAC layer delimiters designated as MAC headers and trailers. Two types of MAC formats are defined in the outroute direction:

24

25

26

- The format associated with the PIDs containing PSI tables that enable the configuration of the DVB/MPEG multiplex with several programs.

- 1                                   ○ The MAC format for IPoS information forwarded through IPoS-  
2                                   defined logical channels.

### 3 **4.9.1.1           PSI Table Format**

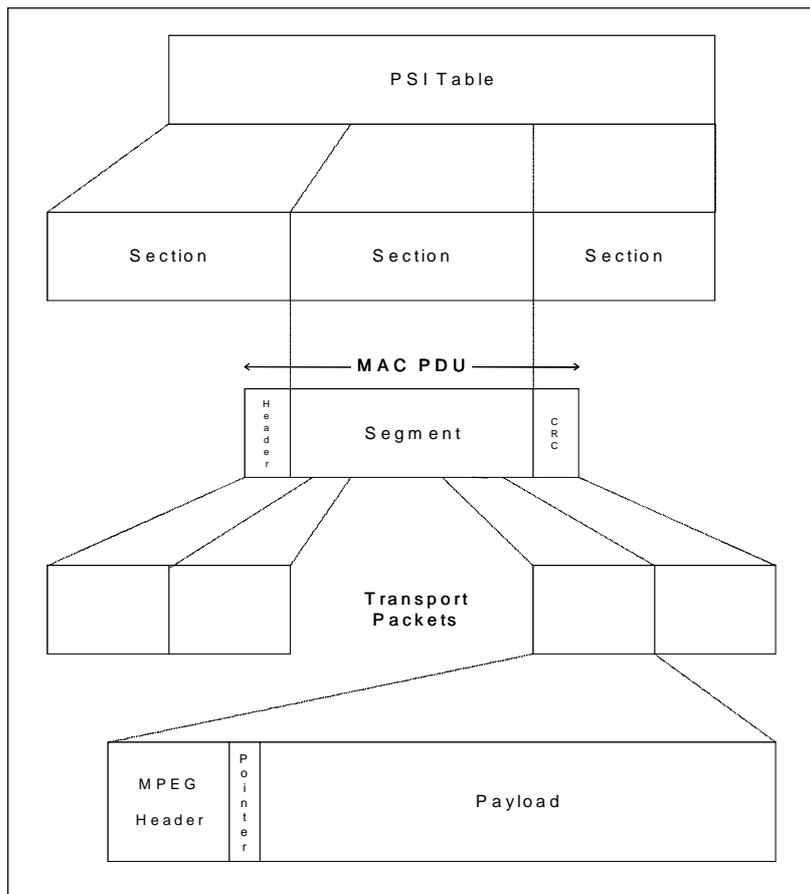
---

4                                   PSI tables are broadcast over the outroute carrier to enable the configuration of  
5                                   IPoS and non-IPoS terminals to the various programs that might exist in the  
6                                   outroute multiplex.

7                                   The encapsulation of PSI tables used to configure the IPoS terminals over the  
8                                   outroute transport stream complies with the definition for SI tables in reference  
9                                   [1]. This encapsulation is made according to the following rules:

- 10                                   • PSI tables may be segmented into one or more sections before being  
11                                   inserted into the transport packets.
- 12                                   • Sections are of variable length. The maximum length of the section is  
13                                   1024 bytes (including the section header and CRC).
- 14                                   • Each section may start at the beginning of the payload of an MPEG  
15                                   packet and span for one or more packets.
- 16                                   • The transport packet payload for PSI segments or tables contains an 8-bit  
17                                   pointer field following the 4-byte DVB/MPEG header as defined in  
18                                   subsection 4.9. The pointer field indicates the number of bytes following  
19                                   the pointer-field until the beginning of the MAC PDU in the first  
20                                   DVB/MPEG packet, e.g., a value of 0x00 in the pointer\_field, indicates  
21                                   that the section starts immediately after the pointer\_field.

22                                   Figure 4.9.1.1-1 shows the segmentation of tables into multiple sections, the  
23                                   formatting of each section into one MAC PDU, and the encapsulation of the  
24                                   MAC PDUs into the payload of one or more transport packets.



1

2

**Figure 4.9.1.1-1. MAC Encapsulation of PSI Tables**

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The payload of the transport packets for PSI segments or tables contains the 8-bit pointer\_field following the 4-byte DVB/MPEG transport header as defined in subsection 4.9.1. The pointer\_field value indicates the number of bytes following the pointer\_field until the beginning of the MAC PDU in the first packet, e.g., a value of 0x00 in the pointer\_field indicates that the section starts immediately after the pointer\_field.

9

The MAC PDU for PSI sections or tables includes the following elements:

10

- A 64-bit section header
- The PSI table/section content
- A 32-bit section trailer or CRC-32

11

12

13

#### **4.9.1.1.1 SI Section Header**

14

15

16

The 64-bit long section header for PSI sections is formatted according to the structure defined for SI in reference [1]. The fields in the section header are defined in table 4.9.1.1.1-1.

**Table 4.9.1.1.1-1. SI Section Header**

Field Name	Field Length (bits)
table_id	8
section_syntax_indicator	1
reserved_for_future_use	1
Reserved	2
section_length	12
network_id	16
Reserved	2
version_number	5
current_next_indicator	1
section_number	8
last_section_number	8

1

2

3

The description of the fields and of their values in the section header is as follows:

4

- table\_id: This field identifies the type of table as follows:

5

- PAT      0x00

6

- PMT      0x02

7

8

- section\_syntax\_indicator: Set to '1'. This indicates that the entire structure of the table header shall be used.

9

- reserved\_for\_future\_use: Set to '0'.

10

- reserved: Set to '11'.

11

12

13

- section\_length: The first two bits in this 12-bit field are set to '00'. The remaining 10-bit subfield specifies the number of bytes in the section, including the section header and the CRC.

14

15

- network\_id: This is a 16-bit field serving as a label to identify the particular IPoS network to which the table shall apply.

16

- Reserved: Set to '11'.

17

18

19

20

21

22

- version\_number: This 5-bit field is the version number of the table. The version\_number shall be incremented by 1, module 32, whenever the information carried within the table changes. When the current\_next\_indicator is set to '1', then the version\_number shall be that of the currently applicable table. When the current\_next\_indicator is set to '0', then the version\_number shall be that of the next applicable table.

23

24

25

26

- current\_next\_indicator: A 1-bit indicator, when set to '1' indicates that the table is currently applicable. When the bit is set to '0', it indicates that the table sent is not yet applicable and shall be the next table to be valid.

- 1 • section\_number: This 8-bit field gives the number of the section. The
- 2 section\_number of the first section in the table shall be '0x00'. The
- 3 section\_number shall be incremented by 1 with each additional section
- 4 with the same table\_id and network\_id.
- 5 • last\_section\_number: This 8-bit field specifies the number of the last
- 6 section (that is, the section with the highest section\_number) of the table
- 7 of which this section is a part.

#### 8 **4.9.1.1.2 PSI Table/Sections**

---

9 PSI tables and sections provide the information that permits configuration of the  
10 IPoS terminals to the logical channels included in the outroute carrier. The IPoS  
11 PSI data is included in two tables designated as:

- 12 • Program Association Table: The PAT\_PID is 0x0000. The PAT
- 13 indicates the correspondence between program numbers and the PID
- 14 values of the transport stream that carries this information.
- 15 • Program Map Table: The PMT\_PID is listed in the PAT. The PMT
- 16 contains a list of all the IPoS-specific logical channels.

17 The content of the PSI tables is structured with DVB-standard data broadcast  
18 descriptors defined in references [11] and [12] (found in subsection 1.4 of this  
19 document).

#### 20 **4.9.1.1.3 IPoS Data Broadcast Service Descriptor**

---

21 The IPoS service shall be indicated with a data broadcast descriptor with the  
22 fields in table 4.9.1.1.3-1.

**Table 4.9.1.1.3-1. Outroute IPoS Data Broadcast Descriptor**

Field Name	Field Length (bits)
data_broadcast_id	16
component_tag	8
selector_length	8
MAC_address_range	3
MAC_IP_mapping_flag	1
alignment_indicator	1
Reserved	3
max_sections_per_datagram	8

23

24 The description of the IPoS data broadcast descriptor's fields and values is as  
25 follows:

- 26 • data\_broadcast\_id: Set to 0x0005 to indicate the use of multiprotocol
- 27 encapsulation.

- 1                   • component\_tag: This field has the same value as a component\_tag field  
 2                   of a stream\_identifier\_descriptor that may be present in the PSI program  
 3                   map section for the stream on which the data is broadcast. If this field is  
 4                   not used, it shall be set to value 0x00.
- 5                   • selector\_length: Set to 0x02. Indicates the length of the following fields  
 6                   in the descriptor.
- 7                   • MAC\_address\_range: Set to 0x06. Indicates the number of MAC  
 8                   address bytes used in the service.
- 9                   • MAC\_IP\_mapping\_flag: Set to '1'. Indicates the type of mapping  
 10                  between IP to MAC addresses.
- 11                  • alignment\_indicator: Set to '1'. Indicates that the alignment between the  
 12                  datagram\_section and the transport stream is 32 bits.
- 13                  • reserved: Set to '111'.
- 14                  • max\_sections\_per\_datagram: Set to 0x01. Indicates the maximum  
 15                  number of sections that can be used to carry a single datagram unit.

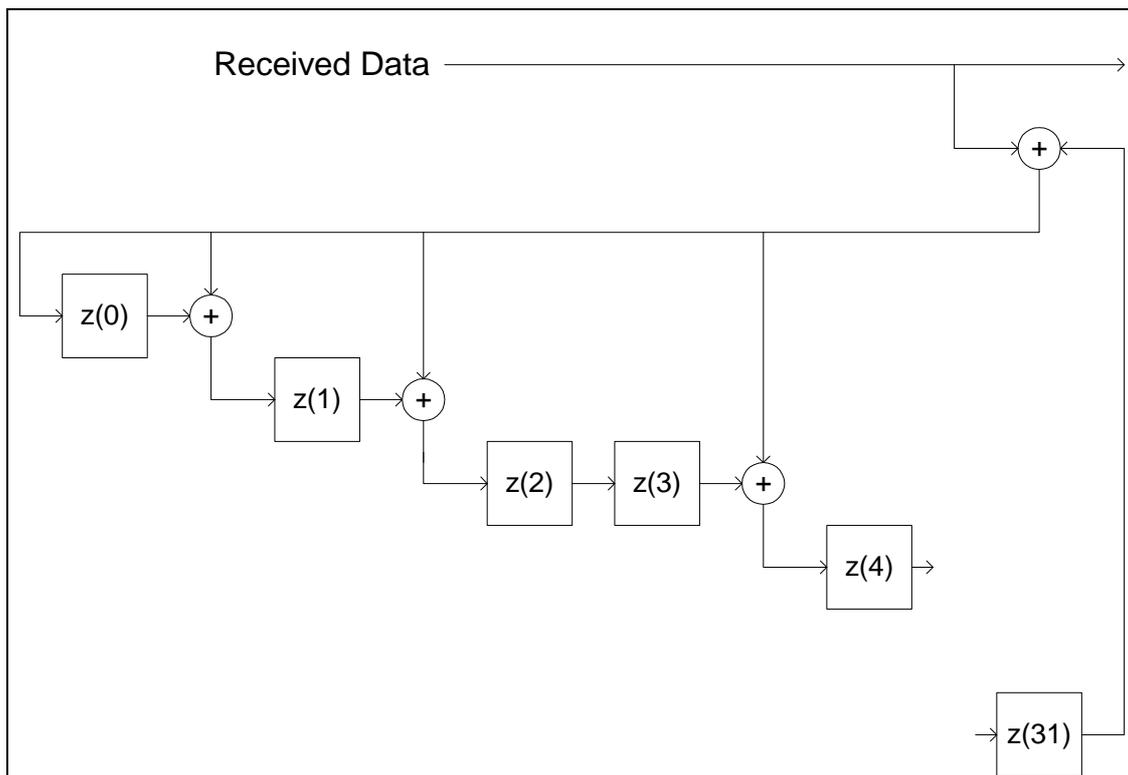
#### 16   **4.9.1.1.4   Section Trailer**

---

17                  This field contains a 32-bit CRC (CRC-32) as described in reference [1] (found  
 18                  in subsection 1.4 of this document). The CRC is calculated with the following  
 19                  polynomial:

$$20 \quad x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x^1 + 1$$

21                  The 32-bit CRC decoder operates at the bit level, a typical implementation of the  
 22                  decoder is shown in figure 4.9.1.1.4-1.



1  
2

3 **Figure 4.9.1.1.4-1. DVB/MPEG-2 Transport Packet CRC-32 Decoder**

4 The following steps describe the operation of the DVB/MPEG-2 transport packet  
5 CRC-32 decoder:

6  
7

- Before CRC processing, each delay element  $z(i)$  is set to its initial value '1'.

8  
9

- The MAC PDU, including header, section, and 32-bit CRC, is received with the first transmitted byte and its MSB first.

10  
11  
12

- After shifting the last bit of the CRC-32 into the decoder, e.g., into  $z(0)$  after the addition of the output of  $z(31)$ , the output of all delay elements is read.

13  
14

- In the case where there are no errors in the MAC PDU, each of the outputs of  $z(i)$  shall be zero.

#### 15 **4.9.1.2 IPoS MAC Formats**

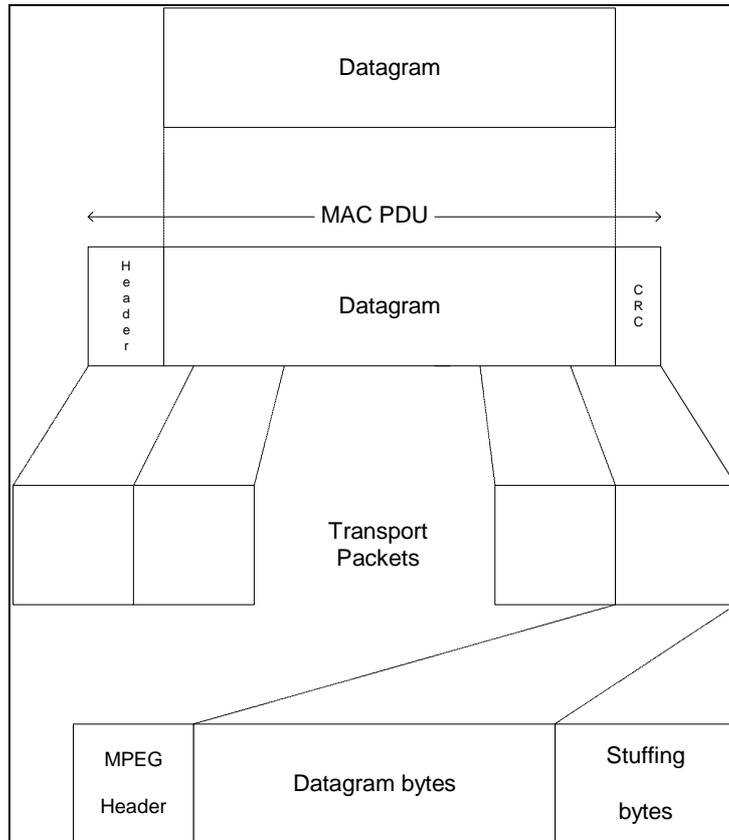
16  
17  
18  
19  
20

The MAC formats in this subsection define the mapping of IPoS specific control and user information over the DVB/MPEG-2 transport streams provided by the multiplexing sublayer. Within the IPoS specific outroute logical channels, the same MAC format is used for user traffic and control messages, independent of whether they are delivered in unicast, multicast, or broadcast connectivity.

1 IPoS control and user information are mapped into the DVB/MPEG transport  
 2 streams using a MAC format based on the DVB data broadcasting multiprotocol  
 3 encapsulation profile for the encapsulation of IP datagrams described in reference  
 4 [12] (found in subsection 1.4 of this document). The IP datagrams might, in turn,  
 5 encapsulate a network layer transport protocol such as TCP or UDP, as well as  
 6 IPoS control messages. This encapsulation is made according to the following  
 7 rules:

- 8 • The outroute MAC sublayer can fragment the datagrams.
- 9 • The MAC PDU containing the datagram starts at the beginning of the  
 10 payload of an MPEG packet or anywhere in the MPEG payload and may  
 11 span for one or more packets.
- 12 • Datagrams are variable length. Stuffing bytes, 0xFF, are used when  
 13 necessary to complete the payload of the last packet in the transport  
 14 stream.

15 Figure 4.9.1.2-1 shows the encapsulation of datagrams containing IPoS user or  
 16 control information into a single MAC PDU without segmentation, and the  
 17 encapsulation of the MAC PDUs into the payload of one or more transport  
 18 packets. The boundaries of the higher layer datagrams are preserved by  
 19 delimiters and the stuffing bytes defined at the MAC sublayer.



20

21

**Figure 4.9.1.2-1. MAC Encapsulation of Datagrams**

- 1 IPoS outroute MAC format includes the following elements:
- 2
- 3 • A 96-bit MAC header
  - 4 • The MAC payload with a datagram containing the IP packet or control message
  - 5 • The 32-bit trailer field

6 The routing of information to IPoS terminals is based on the address field  
 7 included in the 96-bit MAC header. This MAC addressing is different from the  
 8 program addressing provided by the PID field in the DVB/MPEG packet.

9 **4.9.1.2.1 IPoS MAC Header**

---

10 The 96-bit IPoS MAC header is formatted according to the multiprotocol  
 11 encapsulation profile in references [12] and [13] The fields in the outroute IPoS  
 12 MAC header are defined in table 4.9.1.2.1-1.

**Table 4.9.1.2.1-1. Outroute MAC Header**

Field Name	Field Length (bits)
table_id	8
section_syntax_indicator	1
private_indicator	1
Reserved	2
section_length	12
MAC_address_6	8
MAC_address_5	8
Reserved	2
payload_scrambling_control	2
address_scrambling_control	2
LLC_SNAP_flag	1
current_next_indicator	1
section_number	8
last_section_number	8
MAC_address_4	8
MAC_address_3	8
MAC_address_2	8
MAC_address_1	8

- 13
- 14 The outroute MAC header contains the following values:
- 15 • table\_id: Set to 0x3E. Indicates DSM-CC sections with private data.
  - 16 • section\_syntax\_indicator: Set to '1'. Indicates the use of CRC-32 as the  
 17 trailer to the MAC PDU.
  - 18 • private\_indicator: Set to '0'. Indicates that IPoS uses CRC-32.
  - 19 • reserved: Set to '11'.

- 1                   • section\_length: Set to the number in bytes in the section starting  
2 immediately following the section\_length field through the CRC-32  
3 inclusive.
- 4                   • MAC\_address: This 48-bit field contains the MAC address of the  
5 destination; see subsection 4.10.1.3.
- 6                   • Reserved: Set to '00'.
- 7                   • payload\_scrambling\_control: This 2-bit field defines the encryption  
8 mode of the payload section. This includes the payload starting after the  
9 MAC\_address\_1 but excludes the CRC-32 field. The IPoS outroute  
10 utilizes the payload\_scrambling\_control field to indicate whether the  
11 payload is encrypted or not. IPoS utilizes the following  
12 payload\_scrambling\_control field values:
- 13                             0x00 - unencrypted  
14                             0x01 - not used  
15                             0x02 - encrypted with even-numbered traffic-key version  
16                             0x03 - encrypted with odd-numbered traffic-key version
- 17                   • address\_scrambling\_control: Set to '00'. This 2-bit field defines the  
18 scrambling mode of the MAC address section as unencrypted.
- 19                   • LLC\_SNAP\_flag: Set to '0'. Indicates that the payload does not use  
20 LLC/SNAP encapsulation.
- 21                   • current\_next\_indicator: This 1-bit field shall be set to '1'.
- 22                   • section\_number: When the IP datagram is carried in multiple MAC  
23 PDUs, this field indicates the position of the section within the  
24 fragmentation process. The first section is numbered as 0x00, the second  
25 one is 0x01, and the (n + 1)th one is n and so on
- 26                   • last\_section\_number: In DVB-S2 CCM mode this field is set to 0x00.  
27 Indicates that Remote Terminal in CCM mode do not use fragmentation  
28 of IP packets in the Outroute direction across DVB-S2 code blocks. For  
29 DVB-S2 outroute supporting ACM,
- 30                             ○ Bits 7 to 3 - The most 5 significant bits of this field store the  
31 terminal's requested MODCOD.
- 32                             ○ Bit 2- From 'Fast block' high priority queue.
- 33                             ○ Bit 1 – Reserved and will set to 0.
- 34                             ○ Bit 0 – 1 – More fragments, 0 – No more fragments. The system  
35 supports multiple fragmentations

1     **4.9.1.2.2     MAC Payload**

---

2             The MAC payload contains a datagram with the IP packet or control message.  
 3             The encapsulation of the payload between the MAC header and the trailer is  
 4             described in table 4.9.1.2.2-1.

5             For outroutes employing DVB-S2 with ACM, a data packet can potentially be  
 6             fragmented across code blocks using different MODCODs. Also, the Remote  
 7             Terminal may receive Unicast traffic on a MODCOD different from that which  
 8             the Remote Terminal requested. To enable re-assembly of packets the MAC  
 9             payload requires an identifier to be included inside such that the receive Remote  
 10            Terminal is able to reassemble the fragmented data packets.

11            If an IP packet is fragmented across code blocks, each fragment is carried within  
 12            a complete MPE section or MAC PDU so that an MPE section or MAC PDU is  
 13            not fragmented across code blocks. The transportation of a unique ID, called  
 14            fragmentation ID inside the MAC PDU is required for the reassembly process at  
 15            the Remote Terminal side.

16            The Fragmentation ID is a 2 byte field that represents a unique number. Each  
 17            fragment of a particular IP packet carries the same value for this 2 byte field.

18            If an IP packet is not fragmented across code blocks, the MAC payload is as  
 19            defined in Table 4.9.1.2.2-1.

**Table 4.9.1.2.2-1. Outroute IPOS MAC PDU Format – No Fragmentation**

Field Name	Field Length (bytes)	Comments
Header	12	
Sequence Number	1	This field only exists when encryption is enabled.
Initialization Vector	7	This field only exists when encryption is enabled.
Datagram Bytes	N1	N1 is a variable length datagram bytes
Padding Bytes	1-to-7	Pad the datagram to an 8-byte encryption boundary.
CRC-32	4	

20  
 21

The description of the fields in the outroute payload is the following:

- 22            • Sequence Number: The first two bits of this 8-bit field contain the  
 23            packet priority (the value '00' representing the lowest priority, and the  
 24            value '11' the highest). The remaining 6 bits provide a sequence number  
 25            that is incremented by a value of one from the previous sequence number  
 26            for the same MAC address transmitted in all outroute logical channels  
 27            with the exception of the conditional unicast and multicast access  
 28            channels. On the outroute conditional channels, the sequence number is  
 29            set to '000000'. The remote terminals use the sequence number to detect  
 30            packet losses.

- 1                   • Initialization vector: A 7-byte field that providing the initialization input  
 2                   to the DES encryption module used to ensure that outroute information is  
 3                   only accessible to authorized users.
- 4                   • Datagram bytes: This field includes the bytes of the outroute datagram  
 5                   without segmentation.
- 6                   • Padding bytes, 0xFF bytes, are added to make the packet a multiple of 8-  
 7                   byte encryption words. The padding to the encryption boundary takes  
 8                   place regardless of the content of the payload\_scrambling\_control field.  
 9                   The padding bytes are encrypted if indicated by the  
 10                  payload\_scrambling\_control field.

11                  If an IP packet is fragmented across code blocks, the MAC payload carries the  
 12                  Fragmentation ID in a 16-bit field as defined in Table 4.10.1.2.2-2 and Table  
 13                  4.9.1.2.2-3. Whether the ID field is present or not in the MAC payload is derived  
 14                  from the section\_number and last\_section\_number as defined in Table 4.9.1.2.1-  
 15                  1. If both the section\_number and the least significant bit of the  
 16                  last\_section\_number fields hold value 0x00, it indicates to the Remote Terminal  
 17                  that the ID is not present inside the MAC payload and thus there is no  
 18                  fragmentation.

**Table 4.9.1.2.2-2. Outroute IPoS MAC PDU Format – Encrypted Payload**

Field Name	Field Length (bytes)	Comments
Header	12	
Sequence Number	1	
Initialization Vector	5	
Fragmentation ID	2	
Datagram Bytes	N1	
Padding Bytes	1-to-7	Pad the datagram to an encryption boundary.
CRC-32	4	

19  
 20                  The description of the fields in the Outroute payload is the following:

- 21                  • Sequence Number: The first two bits of this 8-bit field contain the  
 22                  packet priority (the value '00' representing the lowest priority, and the  
 23                  value '11' the highest). The remaining 6 bits provide a sequence number  
 24                  that is incremented by a value of one from the previous sequence number  
 25                  for the same MAC address transmitted in all outroute logical channels  
 26                  with the exception of the conditional unicast and multicast access  
 27                  channels. On the outroute conditional channels, the sequence number is  
 28                  set to '000000'. The remote terminals use the sequence number to detect  
 29                  packet losses.
- 30                  • Initialization vector: A 5-byte field that providing the initialization input  
 31                  to the DES encryption module used to ensure that Outroute information  
 32                  is only accessible to authorized users.

- 1                   • Fragmentation ID: 16-bit number that increases proportionally in value.
- 2                   This field is not encrypted
  
- 3                   • Datagram bytes: This field includes the bytes of the Outroute datagram
- 4                   without segmentation.
  
- 5                   • Padding Bytes: 0xFF bytes, are added to make the packet a multiple of 8-
- 6                   byte encryption words. The padding to the encryption boundary takes
- 7                   place regardless of the content of the payload\_scrambling\_control field.

**Table 4.9.1.2.2-3. Outroute IPoS MAC PDU Format – UnEncrypted Payload**

Field Name	Field Length (bytes)	Comments
Header	12	
Reserved	6	
Fragmentation ID	2	
Datagram Bytes	N1	
Padding Bytes	1-to-7	Pad the datagram to an encryption boundary.
CRC-32	4	

8

9

The description of the fields in the Outroute payload is the following:

- 10                   • Fragmentation ID: 16-bits number that increases proportionally in value.
- 11                   This field is not encrypted
  
- 12                   • Datagram bytes: This field includes the bytes of the Outroute datagram
- 13                   without segmentation.
  
- 14                   • Padding Bytes: 0xFF bytes, are added to make the packet a multiple of
- 15                   encryption words. The padding to the encryption boundary takes place
- 16                   regardless of the content of the payload\_scrambling\_control field.
- 17

18

**4.9.1.2.3      MAC Trailer**

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19

This field contains the CRC-32 described in subsection 4.9.1.1.4 to verify the integrity of the outroute transmission.

20

21

**4.9.1.3      MAC Addressing**

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22

The 96-bit MAC header in the multiprotocol encapsulation profile defines a 48-bit MAC\_address field that is used to convey the IPoS MAC address used to deliver user traffic and control messages to the appropriate IPoS terminal. The MAC\_address field in the header is fragmented in six fields of 8 bits labeled MAC\_address\_1 to MAC\_address\_6.

23

24

25

26

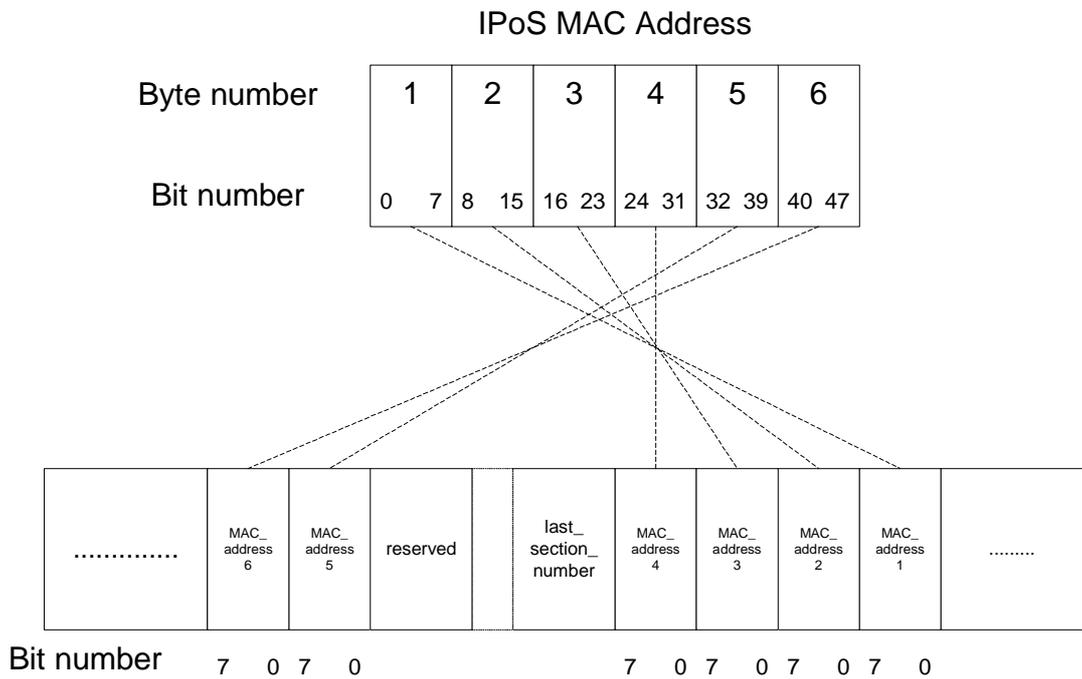
27

The IPoS MAC addresses are also 48 bits long, and they are represented by a string of 6 bytes, six pairs of hexadecimal digits, with each byte separated by a

28

1 space (for example 00 02 AE 6C 77 9B). IPoS MAC addresses comply with  
 2 reference [14] (found in subsection 1.4 of this document). In the IPoS MAC  
 3 addresses, the bytes are displayed left to right in the order in which they are  
 4 transmitted. Bit 0 of the address is bit 0 of the first byte. Bit 47 of the address is  
 5 bit 7 of the 6th byte.

6 The DVB Specification for data broadcasting's multiprotocol encapsulation  
 7 profile calls for the bytes within a MAC address to appear in the opposite order  
 8 that they appear within the Ethernet frame in reference [14]. The order in which  
 9 the IPoS MAC address appears in the MAC header is shown in figure 4.9.1.3-1;  
 10 the order of the bits within the byte does not change.



**IPoS MAC Header**

**Figure 4.9.1.3-1. IPoS MAC Address to MAC Header Mapping**

11 The MAC\_address\_1 field contains the MSB of the IPoS MAC address, while  
 12 MAC\_address\_6 contains the LSB of the IPoS MAC address.

13 IPoS MAC addresses take different forms depending on the type of traffic and  
 14 the number of IPoS terminals associated to the MAC addresses. IPoS supports  
 15 the following MAC addressing modes:

- 16 • Unicast
- 17 • Multicast
- 18 • Superframe Numbering

- 1                                   • Return Broadcast
- 2                                   • Return Group
- 3                                   • Unicast Conditional Access
- 4                                   • Multicast Conditional Access

5   **4.9.1.3.1    Unicast Addressing**

---

6                                   Unicast MAC addresses are used in all user traffic to and from each individual  
7                                   IPoS terminal or PC. Unicast MAC addresses are similar to a private Ethernet  
8                                   address on a LAN port.

9                                   Each IPoS terminal or PC is configured with one unicast MAC address. This  
10                                   IPoS unicast MAC address is related to the serial number of the IPoS terminal.  
11                                   The serial number of the IPoS terminal is loaded into the terminal at the factory.  
12                                   Serial numbers are unique within the particular IPoS system.

13                                   The unicast IPoS MAC address is determined by the IPoS terminal serial  
14                                   number. The low-order 24 bits of the serial number are placed into the three  
15                                   high-order bytes of the MAC address. The mapping of the serial number to  
16                                   fields of the unicast address is shown in table 4.9.1.3.1-1.

**Table 4.9.1.3.1-1. Unicast MAC Address**

MAC Address Bits	MAC Header field	Description
40-47	MAC_address_6	Holds bits 0...7 of the serial number unique to each IPoS terminal
32-39	MAC_address_5	Holds bits 8...15 of the serial number
24-31	MAC_address_4	Holds bits 16...23 of the serial number
16-23	MAC_address_3	Set to 0x0A
8-15	MAC_address_2	Set to 0x00
0-7	MAC_address_1	Set to 0x02, defining that the address is a unicast address

17                                   Examples of IPoS unicast addresses are given in table 4.9.1.3.1-2.

**Table 4.9.1.3.1-2. IPoS Unicast MAC Address Examples**

Address Type	IPoS Terminal Serial Number	MAC Address (Hex)
IPoS Unicast Address	Serial Number 1	02 00 0A 00 00 01
	Serial Number 256	02 00 0A 00 01 00

### 4.9.1.3.2 Multicast Addressing

IPoS multicast addresses are used to transport user information to groups of IPoS terminals or PCs receiving the same outroute carrier. The IPoS multicast addresses are determined from multicast addresses compliant with reference [15].

A MAC multicast address is obtained by mapping the low-order 23 bits of the IPoS multicast address into the three high-order bytes of the multicast MAC address. Since the IPoS multicast address has 28 significant bits and only 23 bits are mapped to the MAC address, more than one IPoS multicast address may map to the same MAC multicast address. Care should be taken to ensure that multiple IPoS addresses that map to the same MAC address are not used within the IPoS system.

The fields of the multicast address are shown in table 4.9.1.3.2-1.

**Table 4.9.1.3.2-1. Multicast MAC Address**

MAC Address Bits	MAC Header Field	Description
40-47	MAC_address_6	Holds bits 0...7 of the IP address.
32-39	MAC_address_5	Holds bits 8...15 of the IP address.
24-31	MAC_address_4	Holds bits 16...22 of the IP address. Bit 7 of this byte is zero.
16-23	MAC_address_3	Set to 0x5E
8-15	MAC_address_2	Set to 0x00
0-7	MAC_address_1	Set to 0x01, indicating that the address is a multicast address.

Examples of multicast addresses are given in table 4.9.1.3.2-2.

**Table 4.9.1.3.2-2. IPoS Multicast MAC Address Examples**

Address Type	Multicast Address	MAC Address (Hex)
IPoS Multicast Address	225.2.3.4	01 00 5E 02 03 04
	239.221.204.1	01 00 5E 6D CC 01

The value 0x01 in the first byte of the MAC address indicates the multicast nature of the address.

### 4.9.1.3.3 Superframe Numbering Address

The superframe numbering address is a dedicated broadcast address used by a special IPoS channel that allows IPoS terminals to distinguish the network to which they are connected and to obtain timing information needed for inroute transmissions.

The Superframe Numbering address is given in table 4.9.1.3.3-1

**Table 4.9.1.3.3-1. IPoS Superframe Numbering Address**

Address Type	MAC Address (Hex)
Superframe Numbering	03 00 01 02 00 00

1  
2 The value 0x03 in the first byte of the MAC address indicates the broadcast  
3 nature of the address.

4 **4.9.1.3.4 Return Broadcast Address**

---

5 The return broadcast address is used for control messages that must be received  
6 by all IPoS terminals on specific transponders. The IPoS return broadcast  
7 address is given in table 4.9.1.3.4-1.

**Table 4.9.1.3.4-1. IPoS Return Broadcast MAC Address Examples**

Address Type	MAC Address (Hex)
IPoS Return Broadcast	03 00 01 01 00 00

8  
9 **4.9.1.3.5 Return Group Addressing**

---

10 Return group addresses are used for messages sent to one specific group of IPoS  
11 terminals that are assigned to this group. The return group addresses are also  
12 monitored by IPoS terminals that were activated on that inroute group or are  
13 considering becoming active on that inroute group. The grouping is implemented  
14 to provide a scalable approach of forwarding information so that a single IPoS  
15 terminal does not need to process all the return group addresses in the system.

16 Examples of return group address are given in table 4.9.1.3.5-1.

**Table 4.9.1.3.5-1. IPoS Return Group MAC Address Examples**

Address Type	Group Number	MAC Address (Hex)
IPoS Return Group	Group 1	03 00 01 00 00 01
	Group 2	03 00 01 00 00 02

17  
18 **4.9.1.3.6 Unicast Conditional Access**

---

19 The hub uses unicast conditional access addresses to send control messages,  
20 designated as conditional access information, to individual IPoS terminals.  
21 Conditional access information, e.g., decryption keys, permits IPoS terminals to  
22 access different multicast streams.

23 The MAC unicast conditional access addresses are identical to the unicast traffic  
24 MAC address. Examples of unicast conditional access addresses are given in  
25 table 4.9.1.3.6-1.

**Table 4.9.1.3.6-1. IPoS Unicast Conditional Access MAC Address Examples**

Address Type	IPoS Terminal Serial Number	MAC Address (Hex)
IPoS Unicast Conditional Access	Serial number 1	02 00 0A 00 00 01
	Serial number 256	02 00 0A 00 01 00

1

#### 4.9.1.3.7 Multicast Conditional Access

---

2

3 The hub uses multicast conditional access addresses to send conditional access  
 4 information to a group of IPoS terminals. The MAC multicast conditional access  
 5 addresses are identical to the multicast traffic MAC addresses. An example of a  
 6 multicast conditional access address is given in table 4.9.1.3.7-1.

**Table 4.9.1.3.7-1. IPoS Multicast Conditional Access Address Examples**

Address Type	Multicast Address	MAC Address (Hex)
IPoS Multicast Conditional Access	225.2.3.4	01 00 5E 02 03 04
	239.221.204.1	01 00 5E 6D CC 01

7

#### 4.9.1.4 Outroute Logical Channels

---

8

9 This subsection describes the formats in the logical channels used for forwarding  
 10 IPoS specific control and user information from the hub to the IPoS terminals  
 11 and their associated PCs.

12 Logical channels are defined by the type of information and the addressing  
 13 associations made among the access points to the MAC layer and the IPoS  
 14 terminals receiving the information. The definition of logical channels isolates  
 15 the higher layer's delivery of information from the peculiarities of the MAC and  
 16 PHYs.

17 Outroute logical channels are identified by the PID in the multiplexing sublayer  
 18 and the IPoS MAC address that indicates the type and destination of the  
 19 information.

20 According to the submultiplexer PID, IPoS logical channels are divided into:

- 21 • Traffic channels
- 22 • Control channels

23 MAC addressing defines three types of connectivity for the logical channel:

- 24 1. Point-to-point connections, defined with a unicast address, to deliver  
 25 information to a single IPoS terminal
- 26 2. Point-to-multipoint connections, defined with a multicast address, to  
 27 deliver the same information to a group of IPoS terminals

1 3. Broadcast connectivity to deliver the same information to all IPoS  
2 terminals in the system

3 Table 4.9.1.4-1 provides a list of logical channels with examples of their  
4 corresponding MAC and multiplexing layer addresses.

**Table 4.9.1.4-1. Classification of IPoS Logical Channels**

Type of Channel	Logical Channel Designation	MAC Address	PID (default)
Traffic	Unicast traffic	02 00 XX XX XX XX	0x0004
Traffic	Multicast traffic	01 00 5E XX XX XX	0x0004
Control	Superframe Numbering Broadcast	03 00 00 00 00 02	0x0003
Control	Return Broadcast	03 00 00 00 00 01	0x0003
Control	Return Group	03 00 01 00 XX XX	0x0003
Control	Unicast conditional access	02 00 XX XX XX XX	0x0003
Control	Multicast conditional access	01 00 5E XX XX XX	0x0003

5

6 User information and control messages are embedded inside the datagram section  
7 of the outroute MAC format as described in the following subsections. The  
8 routing and filtering of packets at the receiving IPoS terminal are made based on  
9 the PID and the MAC addresses.

10 The control messages format has been defined to be implemented easily and is  
11 flexible enough to accommodate the future signaling needs of the IPoS system.  
12 The first byte, the Frame\_type field, in all control message formats identifies the  
13 particular message.

#### 14 **4.9.1.4.1 Unicast Traffic Channels**

---

15 Unicast traffic channels transport user traffic and IP datagrams inside the  
16 datagram\_section of the IPoS MAC structure. The targeted individual IPoS  
17 terminal is designated in the unicast traffic address in the MAC header.

18 The content of the datagram\_section following the MAC header depends on  
19 whether or not scrambling is enabled in the IPoS MAC header.

20 If scrambling is enabled, then the first 8 bytes immediately following the MAC  
21 header contain:

- 22 • Initialization vector, first 7 bytes of the payload. This field is used for  
23 the decryption of the datagram.
- 24 • Sequence number, byte eight of the payload. This field is specific to  
25 each IPoS terminal and is used to determine the packet priority and  
26 detect out-of-sequence packets.

27 If scrambling is disabled, the IP datagram, including the IP header and payload,  
28 immediately follow the MAC header.

#### 1 **4.9.1.4.2 Multicast Traffic Channels**

---

2 Multicast traffic channels are used for the distribution of multicast streams to  
3 groups of authorized IPoS terminals. The multicast information is conveyed to  
4 those groups of PCs inside the datagram section of MAC PDUs identified in the  
5 multicast address in the MAC header.

6 The hub distributes a list of keys for multicast traffic periodically. If the IPoS  
7 terminal is enabled to receive the multicast address, then the IPoS terminal will  
8 enable the appropriate IP multicast MAC addresses it is authorized to receive.

#### 9 **4.9.1.4.3 Superframe Numbering Channel**

---

10 This channel provides a timing reference and identification for the satellite  
11 transponder over the dedicated MAC superframe numbering address. Only one  
12 type of control message, designated the Superframe Numbering Packet (SFNP),  
13 is carried in this channel.

14 Two SFNPs are sent by the hub every 360 msec for redundancy purposes. IPoS  
15 terminals shall have separate state machines to track the two SFNPs. Only one  
16 SFNP will actively control timing, but the IPoS remote will be able to transition  
17 to the other SFNP when necessary.

18 The following rules shall be used in processing the SFNP at the IPoS terminals:

- 19 • No transmission will be allowed if the IPoS terminal PHY is not  
20 synchronized; this will not affect the IPoS remote's ability to acquire  
21 network timing.
- 22 • Both SFNPs will be monitored, if present, but a change in selection will  
23 be made only after receiving three consecutive valid SFNPs from the  
24 same source.
- 25 • Network timing is declared as in-sync only after receiving three  
26 consecutive valid SFNPs from a timing source and having the local  
27 timing match within eight clock cycles of the 10 MHz clock reference  
28 used at the hub to generate the timing of the SFNPs. This will typically  
29 require four superframe times.
- 30 • Network timing is declared as out of sync after receiving two  
31 consecutive SFNPs from the selected timing source and having the local  
32 timing off by more than 16 clocks.
- 33 • Network timing is declared as out of sync and the network timing source  
34 becomes unselected after not receiving any SFNPs for three superframe  
35 times.
- 36 • Network timing is declared as out of sync and the network timing source  
37 becomes unselected after not receiving two consecutive SFNPs for five  
38 superframe times.

- 1                                   • Network timing is declared as out of sync and the network timing source  
2                                   becomes unselected after not receiving three consecutive SFNPs for  
3                                   seven superframe times.

#### 4   **4.9.1.4.4   Return Broadcast**

---

5                                   This logical channel is used to distribute control messages to all IPoS terminals.  
6                                   The following control messages are transmitted over this channel:

- 7                                   • Inroute Group Definition Packet (IGDP). This message defines available  
8                                   return channel groups and resources available on each group.
- 9                                   • Inroute Command/Ack Packet (ICAP). This message contains a list of  
10                                  commands to be sent to the IPoS terminal from the hub.

#### 11   **4.9.1.4.5   Return Group Logical Channels**

---

12                                  The return group logical channels are used for control messages sent to specific  
13                                  IPoS terminals assigned to a group. The return group logical channels are also  
14                                  monitored by IPoS terminals that were recently active on that inroute group or  
15                                  are considering becoming active on that inroute group. The grouping is  
16                                  implemented to provide a scalable approach to transmitting control messages.

17                                  The message types received over the return logical channels are:

- 18                                  • Bandwidth Allocation Packet (BAP): This message contains the  
19                                  bandwidth allocation and the allocation of the bursts to each IPoS  
20                                  terminal in the group.
- 21                                  • Inroute Acknowledgment Packet (IAP): This message contains a  
22                                  bitmask indicating which bursts in the frame were successfully received  
23                                  at the hub.
- 24                                  • Inroute Command/Ack Packet (ICAP): This message contains a list of  
25                                  commands and explicit acknowledgments sent to IPoS terminals from  
26                                  the hub.
- 27                                  • Inroute Timing Feedback Packet (ITFP): This message contains feedback  
28                                  on the timing accuracy with which the Hub received an Inroute packet.
- 29                                  • Inroute Signal Receive Power Feedback Packet (ISFP): This message  
30                                  contains the power at which the Hub received an Inroute packet.
- 31                                  • Inroute Timing Poll Packet (ITPP): This message contains a request from  
32                                  the Hub to the IPoS Remote Terminal for its current timing information.
- 33                                  • Mesh Command and Acknowledgment Packet (MCAP): This message  
34                                  contains a bitmask indicating which mesh communication bursts in the  
35                                  frame were successfully received at the Mesh Resource Controller.

36

1 It is important to note that if an inroute group advertises that it has Aloha or  
2 unallocated ranging bursts, the inroute group must have some number of those  
3 bursts defined every frame for the next 10 frames. Furthermore, the number of  
4 bursts should be evenly spread across all frames in the superframe. Failure to  
5 meet this requirement will result in higher collision rates and increased user  
6 latency.

#### 7 **4.9.1.4.6 Unicast Conditional Access Channel**

---

8 Unicast conditional access channels are used by the hub to send periodic control  
9 messages containing decryption keys and other conditional access information to  
10 specific IPoS terminals with enabled MAC addresses. The rate at which the  
11 Conditional Access messages are sent is controlled by parameters in the hub.

12 Only one type of command, designated Periodic Adapter Conditional Access  
13 Update (PACAU), is sent over this channel.

#### 14 **4.9.1.4.7 Multicast Conditional Access Channel**

---

15 Over this channel, the hub sends periodic control messages containing mappings  
16 of multicast keys to the list of multicast MAC addresses included in the PACAU.

17 Only one type of command, designated Periodic Element Broadcast (PEB) is sent  
18 over this channel. PEB commands are sent continuously to support relatively  
19 quick notification in the event of a key change and/or the addition of new IPoS  
20 terminals.

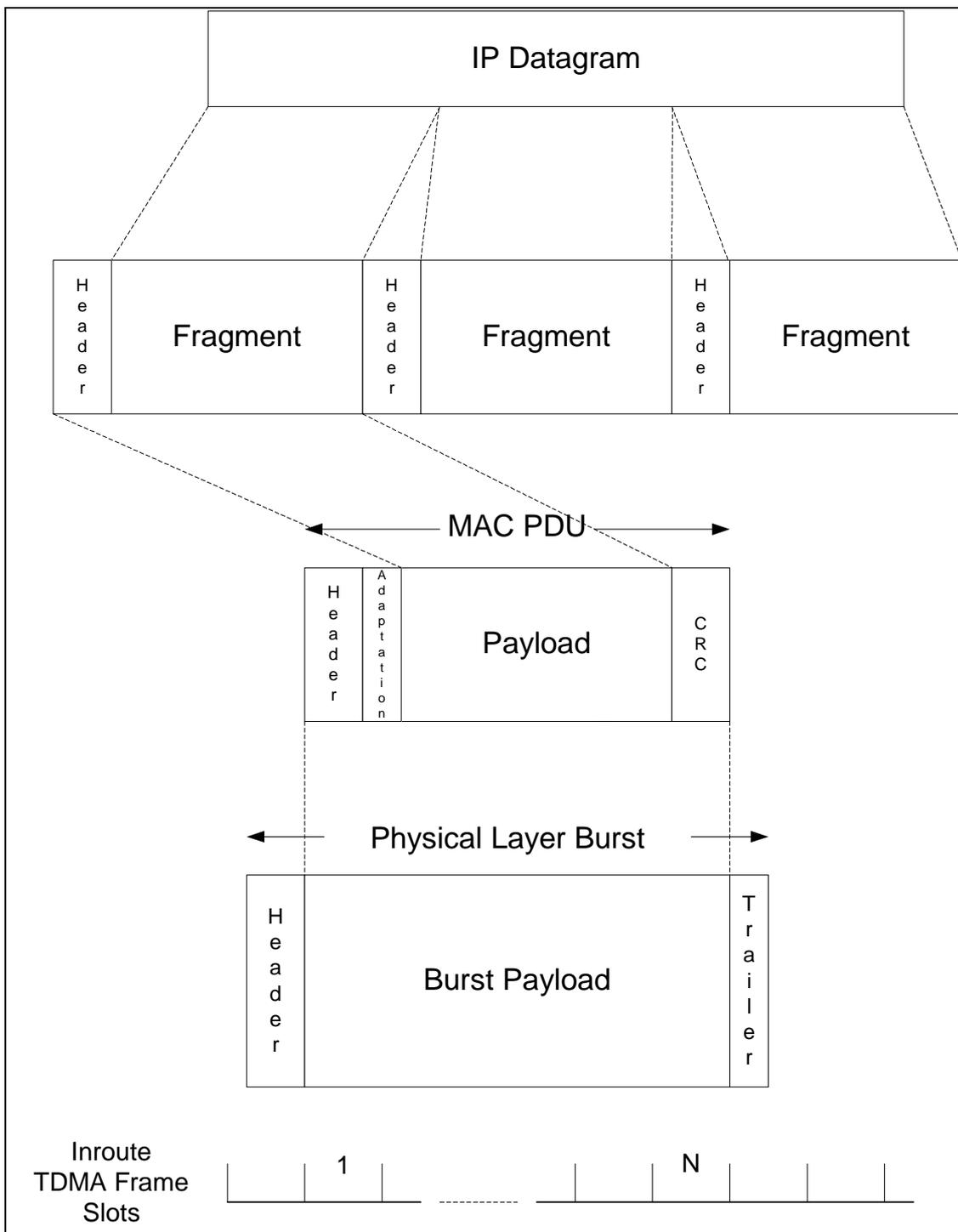
### 21 **4.10 Inroute MAC Sublayer**

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22 The inroute in IPoS is significantly different from the outroute direction because  
23 of the need to optimize transmission over highly asymmetric satellite links. The  
24 inroute MAC adapts user and control information into generic byte-oriented  
25 streams that map the higher order information into the TDMA frame format  
26 defined by the IPoS PHY over the inroute direction.

27 The information from individual IPoS terminals to the hub over the inroute  
28 channels is structured as one or more MAC PDUs. Each MAC PDU is  
29 transmitted over the payloads of a block of consecutive slots associated to a time  
30 interval defined by the inroute bandwidth allocation procedure. Each assigned  
31 interval consists of a sequence of slots within the multifrequency TDMA  
32 structure defined at the PHY.

33 Figure 4.10-1 illustrates the segmentation and encapsulation of higher order  
34 information, through the inroute protocol layers to the payload of the TDMA  
35 bursts, defined at the PHY.



1  
2  
3  
4

**Figure 4.10-1. Inroute MAC Encapsulation of Datagrams**

1 User level IP datagrams are segmented at the input of the IPoS terminal DLC into  
 2 one or more MAC PDUs, or datagram fragments, which are buffered until  
 3 successfully transmitted over the inroute link. The inroute MAC layer  
 4 encapsulates the information to be transmitted into the byte stream formed by the  
 5 payload of the bursts transmitted by the IPoS remote.

6 Proper recovery of the inroute information at the hub requires a reliable, in order,  
 7 processing of the payload of the group of bursts used to transmit the IP datagram.  
 8 To resolve problems due to data loss on the inroute, the SLC provides an  
 9 acknowledgment procedure.

10 The burst payload size of each of the bursts transmitted by the IPoS remote varies  
 11 with the number of effective slots,  $N_s$ , used in the inroute transmission, the  
 12 transmission rate, and FEC encoding in the inroute carrier. The payloads defined  
 13 by the PHY for the different types of bursts are given in table 4.10-1

**Table 4.10-1. Burst Payloads**

Burst Type	BurstPayload Size (Bytes)
BTCH256_1/3TB	$10^* N_s$
BTCH256_1/2TB	$15^* N_s$
BTCH256_2/3TB	$20^* N_s$
BTCH256_4/5TB	$24^* N_s$
BTCH512_1/3TB	$10^* N_s$
BTCH512_1/2TB	$15^* N_s$
BTCH512_2/3TB	$20^* N_s$
BTCH512_4/5TB	$24^* N_s$
BTCH1024_1/3TB	$10^* N_s$
BTCH1024_1/2TB	$15^* N_s$
BTCH1024_2/3TB	$20^* N_s$
BTCH1024_4/5TB	$24^* N_s$
BTCH2048_1/3TB	$10^* N_s$
BTCH2048_1/2TB	$15^* N_s$
BTCH2048_2/3TB	$20^* N_s$
BTCH2048_4/5TB	$24^* N_s$
BTCH4096_1/2TB	$15^* N_s$
BTCH4096_2/3TB	$20^* N_s$
BTCH4096_4/5TB	$24^* N_s$
BTCH6144_1/2TB	$15^* N_s$
BTCH6144_2/3TB	$20^* N_s$
BTCH6144_4/5TB	$24^* N_s$
ATCH256_1/2LDPC	$15^* N_s$
ATCH256_2/3LDPC	$20^* N_s$
ATCH256_4/5LDPC	$24^* N_s$
ATCH256_9/10LDPC	$27^* N_s$
ATCH512_1/2LDPC	$15^* N_s$
ATCH512_2/3LDPC	$20^* N_s$
ATCH512_4/5LDPC	$24^* N_s$
ATCH512_9/10LDPC	$27^* N_s$
ATCH1024_1/2LDPC	$15^* N_s$
ATCH1024_2/3LDPC	$20^* N_s$
ATCH1024_4/5LDPC	$24^* N_s$

**Table 4.10-1. Burst Payloads**

Burst Type	BurstPayload Size (Bytes)
ATCH1024_9/10LDPC	27* N <sub>s</sub>
ATCH2048_1/2LDPC	15* N <sub>s</sub>
ATCH2048_2/3LDPC	20* N <sub>s</sub>
ATCH2048_4/5LDPC	24* N <sub>s</sub>
ATCH2048_9/10LDPC	27* N <sub>s</sub>

1

## 2 **4.10.1 Inroute Logical Channels**

---

3

Two logical channel types are defined in the inroute direction:

4

- Unallocated channels aka Aloha Channels: These are slots or groups of slots designated to be shared by multiple IPoS terminals using a random access procedure. The unallocated channels are primarily used for control messages in the inroute direction. Piggybacking of user data with control messages is supported in the Aloha channels.

5

6

7

8

9

- Allocated channels: These are slots or a sequence of slots in an allocated time interval that are dedicated to one specific IPoS terminal for the transmission of user information.

10

11

12

The following subsections define the MAC structures for both types of logical channels.

13

### 14 **4.10.1.1 MAC Formats for Unallocated Channels**

---

15

The unallocated channels are mainly used to transfer control messages in the inroute direction. Also, user datagram can be sent using the unallocated channel. The most prevalent control messages sent over the unallocated logical channels are as follows.

16

17

18

- Bandwidth Allocation Request (BAR)
- Ranging Request

19

20

The MAC structures used over the unallocated logical channels consist of four sections:

21

1. MAC header

22

2. Adaptation field

23

3. Payload or datagram bytes

24

4. Trailer field

25

26

The adaptation field is particularly used to convey the control messages. The description of adaptation field and thus the control message specification is provided in section 4.12.4.

27

28

29

1 The encapsulation of the datagram in the inroute MAC PDU for unallocated  
2 channels is shown in table 4.10.1.1-1.

**Table 4.10.1.1-1. Inroute MAC PDU Format**

Field Name	Field Length (Bytes)	Comments
Header	9 byte	
Adaptation	0 to M	Can vary from 0 to M byte
Payload	P	P number of user bytes
Trailer field	T	For Turbo Code, the trailer field is BCH code and T=5. For LDPC code, the trailer field is CRC-16 and T=2

3  
4 The format of trailer field in the MAC PDU depends on the coding used in the  
5 PHY. Also, the inroute MAC structure might include an Adaptation field that is  
6 used to convey control information to the hub.

#### 7 **4.10.1.1.1 MAC Header for Unallocated Channels**

---

8 The MAC header for unallocated burst is shown in **Error! Reference source not**  
9 **found.**

**Table 4.10.1.1.1-1. MAC Header for Unallocated Channel**

Field Name	Field Length (Bits)
Backlog_indicator	1
Adaptation_indicator	1
Version	2
Extended Version Present	1
Adaptation_Length	1
Bandwidth Request Type	1
Serial_number	25
Aloha CRC	8
Extended Version	8
Backlog	24

10

11 The description of the fields in the MAC header is the following:

- 12
- 13 • Backlog\_indicator: This flag indicates the presence of the Backlog field. Set to '1' to indicate the presence of backlog.
  - 14 • Adaptation\_indicator: This field indicates the presence/absence of the Adaptation field. Set to '0' to indicate that an Adaptation field is present.
  - 15
  - 16 • Version: This field identifies the version of the protocol. The IPoS terminal shall specify a value of 4 for the version number. Since two bits
  - 17

- 1 cannot represent message version 4, the following Extended Version  
2 Present field is used and this version field is set to '00'.
- 3 • Extended Version Present: A value of zero indicates there is no extended  
4 version field. A value of 1 indicates one more byte is added for the  
5 version number. The value of this field will be '1' to represent message  
6 version  $\geq 4$ .
- 7 • Adaptation\_Length: Indicates the number of bytes used by the  
8 Adaptation field if the Adaptation\_indicator is set. A value of 0 indicates  
9 that the Adaptation\_Length field is 2 bytes long; a value of 1 indicates  
10 that the Adaptation\_Length field is 1 byte long.
- 11 • Bandwidth Request Type: This bit indicates the type of bandwidth  
12 requested. Valid values are: 0 – Star bandwidth request; 1 – Mesh  
13 bandwidth request. A star only terminal shall set this field to 0.
- 14 • Serial\_number: This field contains an IPoS terminal's 25-bit serial  
15 number.
- 16 • Aloha CRC: CRC of unallocated burst header bytes starting from the  
17 backlog indicator till and including backlog field (if present). The Aloha  
18 CRC byte itself is treated as zero while calculating the CRC. CRC is  
19 calculated and filled in by the Remote Terminal if IGDP message (refer  
20 to section 4.12.6) indicates that Hub expects this byte to be present in  
21 unallocated message . The Hub would calculate the CRC on the same  
22 bytes in incoming unallocated bursts and discard the ones on which CRC  
23 check fails.
- 24 • Extended Version: This is the most significant 8 bits of the version  
25 number, the least 2 significant bits are obtained from the version field.  
26 Should the 'Extended Version Present' field be set to '0', then this field  
27 will be set to 0.
- 28 • Backlog: This field has three bytes. The first two bytes, which provides  
29 the total backlog in bytes, is encoded as a floating point number with a 2  
30 bit exponent field and a 14 bit mantissa, and will be rounded up by the  
31 remote terminal. The backlog is indicated by
- 32 
$$4^{\text{Backlog}[15:14]} \times \text{Backlog}[13:0] \times 2.$$
- 33 This yields an even number up to 2 MB, which is the maximum  
34 reasonable queue size to be tracked since this will fully occupy a 2MSPS  
35 inroute for 2 seconds. The third byte contains the highest priority for  
36 which there is a backlog in the two high-order bits and the remainder of  
37 the byte identifies the percentage in 1/64 units (the value is  
38  $((n+1)/64) \times \text{backlog}$  where "n" is the number provided.

39

40

#### 1 **4.10.1.1.2 Payload**

---

2 A remote terminal can send user information over the Payload field of inroute  
3 unallocated logical channels designated for Aloha transmission. The inroute user  
4 information, or IP datagrams, shall be segmented as defined in subsection 4.10.2.  
5 There is not a relationship between the datagram boundaries and the boundaries  
6 of the Payload field in the MAC format for unallocated inroute channels.

7 Depending on the configured length, the Payload field might contain a segment  
8 of an IP datagram or multiple IP datagrams.

#### 9 **4.10.1.1.3 Trailer Field**

---

10 For turbo code inroutes, the BCH code is used over the Trailer field for the  
11 purpose of detecting errors occurring in the transmission of MAC PDU over the  
12 unallocated channels. The definition of BCH code is in section 3.4.3.1.1.

13 At the hub, the BCH code is used to correct and detect the error in the MAC  
14 PDU. MAC PDUs with errors are dropped, but statistics of the CRC failures are  
15 retained by the hub.

16 For LDPC inroutes, the CRC-16 is used over the Trailer field..

17 The CRC-16 is calculated with the following polynomial:

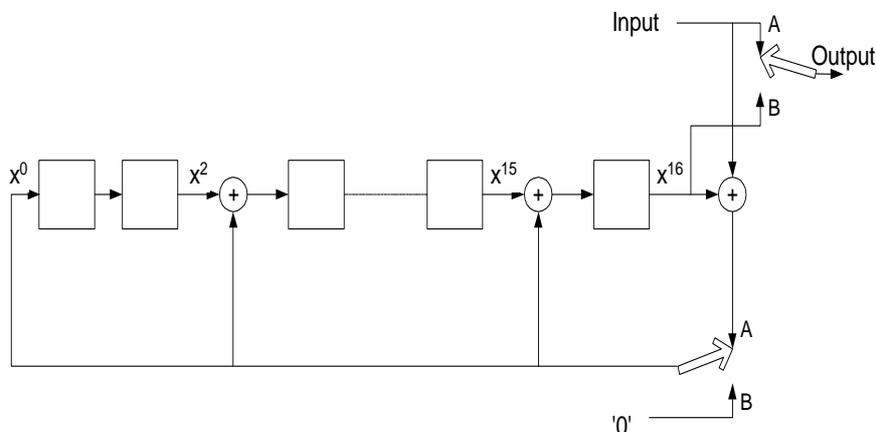
$$18 \quad x^{16} + x^{15} + x^2 + 1$$

19 The preset (initial) value is 0x0000.

20 The following steps describe the operation of the calculation of the CRC-16 by  
21 the IPoS terminal:

- 22 • Before CRC processing, each delay element is set to its initial value '0'.
- 23 • The switches are set in position A.
- 24 • The entire MAC PDU, with the exception of the CRC field, is shifted  
25 and simultaneously transmitted through the shifted datagram, starting  
26 from the IP source address field, passing through the shift register cells  
27 with the connections of the CRC-16 polynomial and simultaneously  
28 transmitted to the output.
- 29 • The content of the shift register after passing the last bit is the CRC-16,  
30 which is appended in the trailer field of the MAC PDU.
- 31 • The switches are moved to position B.
- 32 • The shift register is clocked 16 times, and the content of the shift register  
33 is transmitted to the output, starting with the bit at the end of the shift  
34 register.

1 Figure 4.10.1.1.6-1 shows a typical implementation of the logic used to calculate  
 2 CRC-16.



3  
 4 **Figure 4.10.1.1.3-1. CRC-16 Calculation**

5 At the hub, the CRC is computed in an identical manner on the received data.  
 6 MAC PDUs with an invalid CRC-16 are dropped, but statistics of the CRC  
 7 failures are retained by the hub.

8 **4.10.1.2 MAC Formats for Allocated Channels**

9 The MAC format used to encapsulate user information over allocated channels  
 10 contains the same four-section structure of a MAC PDU for unallocated  
 11 channels:

- 12 1. MAC header
- 13 2. Adaptation field
- 14 3. Payload or IP datagram fragment
- 15 4. Trailer field

16 The Adaptation field for allocated channels serves the same purposes and  
 17 includes the same options as does the Adaptation field for unallocated channels  
 18 described in section 4.12.4.

19 The encapsulation of the datagram in the inroute MAC PDU for allocated  
 20 channels is shown in table 4.10.1.2-1.

**Table 4.10.1.2-1. Inroute MAC PDU Format**

Field Name	Field Length (Bytes)	Comments
Header	7 byte	
Adaptation	0 to M	Can avry from 0 to M byte
Datagram bytes	P	P number of bytes
Trailer Field	T	For Turbo Code, the trailer field is BCH code and

		T=5. For LDPC code, the trailer field is CRC-16 and T=2
--	--	---

1  
2 The trailer field in the MAC PDU depends on the coding type used in the PHY.  
3 The inroute MAC structure might include an Adaptation field that is used to  
4 convey control information to the hub and also is used for padding the MAC  
5 PDU to the combined payload of the group of inroute bursts.

#### 6 **4.10.1.2.1 MAC Header for Allocated Channels**

7 The MAC header for sending IP datagrams over the inroute allocated channels is  
8 shown in Table 4.10.1.2.1-1.

**Table 4.10.1.2.1-1. MAC Header for Allocated Channels**

Field Name	Field Length (Bits)
Backlog_indicator	1
Adaptation_indicator	1
Start_of_new_IPdatagram	1
Bypass Reliable Link Layer (RLL) facility	1
Traffic_priority	2
Reserved	1
Adaptation_length	1
Reserved	4
Sequence_number	20
Backlog	24

9

10 The description of the fields in the MAC header for allocated channels is the  
11 following:

- 12 • Backlog\_indicator: This flag indicates the presence of the Backlog field.  
13 Set to '1' to indicate the presence of backlog.
- 14 • Adaptation\_indicator: This field indicates the presence/absence of the  
15 Adaptation field. Set to '0' to indicate Adaptation field is present.
- 16 • Start\_of\_new\_IPdatagram: This field indicates if the following datagram  
17 is the start of a new IP datagram or the continuation of a previous IP  
18 datagram. A value of 1 indicates that the start of a new IP datagram  
19 follows; a value of 0 indicates that a continued IP datagram follows.
- 20 • Bypass Reliable Link Layer: A value of 1 indicates that the datagram at  
21 the beginning of the burst does not utilize the reliable link layer, i.e. no  
22 link layer acknowledgment is required.

- 1                   • Traffic\_priority: This field indicates the priority level of the datagram at  
2                   the beginning of the burst. Note that a preempted datagram may  
3                   continue in the burst, and this continuing datagram may be at a different  
4                   priority level than the datagram at the beginning of the burst. This field  
5                   allows up to four priorities with the value 0 indicating the highest  
6                   priority.
- 7                   • Reserved: This field is set to the value 0 and ignored by the hub.
- 8                   • Adaptation\_length: This field indicates the number of bytes used for the  
9                   length of the Adaptation field if the Adaptation field is present. The  
10                  value '0' indicates that the number of bytes used for the length of the  
11                  Adaptation field is 2 bytes. The value '1' indicates that the length of the  
12                  Adaptation field is in a single byte.
- 13                  • Sequence\_number: This field is used for the retransmission protocol.  
14                  This is the byte address of the first byte of the encapsulated payload or IP  
15                  fragment.
- 16                  • Backlog: This 3-byte field supports prioritized backlog information.  
17                  The first two bytes provides the total Backlog in bytes. It is encoded as a  
18                  floating point number with a 2-bit exponent field and a 14-bit mantissa  
19                  and shall be rounded up by the IPoS terminal. The Backlog shall be  
20                  indicated by  
21                  
$$4^{\text{Backlog}[15:14]} \times \text{Backlog}[13:0] \times 2.$$
  
22                  This shall yield an even number up to 2M, which is the maximum  
23                  practicable queue size to be tracked since this will fully occupy a 2MSPS  
24                  inroute for 2 seconds. The third byte contains the highest priority for  
25                  which there is a backlog in the two high-order bits and the remainder of  
26                  the byte identifies the percentage (of the backlog that belongs to the  
27                  priority indicated by the two higher-order bytes) in 1/64 units (the value  
28                  is  $((n+1)/64)*\text{backlog}$  where n is the number provided).

#### 29    **4.10.1.2.2   Trailer Field**

---

30                   The Trailer field for MAC PDUs over allocated channel is the BCH code for  
31                   turbo-coding and CRC-16 for LDPC coding described in subsection 4.10.1.1.3.

#### 32    **4.10.2        Inroute Segmentation**

---

33                   This subsection defines the segmentation that might take place in the inroute  
34                   direction to divide higher level units of information, user IP packets, or control  
35                   messages into one or more fragments that fit into the datagram\_bytes section of  
36                   the MAC PDUs. The mapping of IP packets into multiple MAC PDUs provided  
37                   by inroute segmentation is intended to allow an efficient distribution of inroute  
38                   capacity among the population of IPoS terminals.

39                   To support the reassembling of all the fragments generated by the IPoS terminals  
40                   at the hub, fragmentation delimiters are defined for the inroute direction. These

- 1 delimiters shall be used on the inroute allocated channels depending on the  
2 following factors:
- 3 • Start of a new IP datagram for a given priority at the start of a burst.  
4 Also, the start of a new IP datagram for a given priority offset in the  
5 burst if the priority for the new IP datagram is the same as the priority for  
6 the IP datagram at the beginning of the burst.
  - 7 • Start of a new IP datagram for a given priority offset in the burst. The  
8 new IP datagram that is starting offset in the burst is from a different  
9 priority than the IP datagram at the beginning of the burst.
  - 10 • Continuation of an IP datagram for a given priority at the start of a burst.
  - 11 • Continuation of an IP datagram for a given priority offset in the burst.  
12 The continuing IP datagram that is offset in the burst is from a different  
13 priority than the IP datagram at the beginning of the burst.
  - 14 • Continuation of a packet that does not use reliable link layer facility at  
15 the start of a burst.

16 The appropriate fragmentation is part of the payload section of the MAC PDU  
17 and shall always be present before the start of the datagram. This presence is  
18 independent of whether the fragment is starting at the beginning of an IP  
19 datagram or offset in the IP datagram.

#### 20 **4.10.2.1 Start Fragmentation Header – Beginning of MAC PDU**

---

21 The start fragmentation header described in this subsection shall be used when a  
22 new IP datagram for a given priority starts at the beginning of a MAC PDU or if  
23 a new IP datagram starts offset in the MAC PDU and the preceding datagram  
24 was from the same priority. For this start fragmentation header, the  
25 Start\_of\_new\_IPDatagram field shall be set to '1'. The datagram CRC is  
26 calculated at the terminal before any header compression. At the hub, the CRC  
27 check is done after header decompression.

#### 28 **4.10.2.1.1 Start Fragmentation Header – Beginning of MAC PDU**

---

29 Table 4.10.2.1.1-1 shows the payload of MAC PDU consisting of the start  
30 fragmentation header followed by the rest of the IP datagram fragment.

**Table 4.10.2.1.1-1. Start Fragmentation Header – Beginning of MAC PDU**

Field Name	Field Length (Bits)
Start_of_new_IPdatagram	1
Bypass RLL	1
Traffic_priority	2
Datagram_counter/CRC	12
Protocol_version	4
Header_length	4
Type_of_service	8
Reserved	2
Protocol_Type	3
Length	11
Rest_of_datagram	N×8

1

2

3

The description of the fields for the start fragmentation header for the new IP datagrams is:

4

5

6

7

- Start\_of\_new\_IPdatagram: This field indicates if the following datagram is the start of a new IP datagram or the continuation of a previous IP datagram. A value of '1' indicates that the start of a new IP datagram follows; a value of '0' indicates that a continued IP datagram follows.

8

9

- Bypass RLL: A value of 1 indicates that the datagram at the beginning of the burst does not utilize RLL.

10

11

- Traffic\_priority: Used to allow up to four priorities, with the value 0 indicating the highest priority.

12

13

14

- Datagram\_counter/CRC: This field shall be filled with the 12-bit CRC (CRC-12) described in subsection 4.10.2.5. The CRC-12 shall be calculated by the IPoS terminal before header compression.

15

- Protocol\_version: This field takes the value 4 for IPv4.

16

- Header\_length: This field in IP shall be the IP header length.

17

- Type\_of\_service: This field in IP shall be the type of service.

18

19

- Reserved: This field shall be set to the value 0 by IPoS terminal and ignored by the hub.

20

21

22

- Length: This field shall be used to indicate the length of the datagram, starting with the protocol version field. This field is 11 bits long because the maximum datagram is less than 2000 bytes on the IPoS system.

23

24

- Rest\_of\_datagram: The value of P is derived from the Length field, where  $P = \text{Length in bytes from Length field} - 4 \text{ bytes}$ .

25

## 1 **4.10.2.2 Start Fragmentation Header – Offset in MAC PDU**

2 The start fragmentation header described in this subsection shall be used when a  
3 new IP datagram for a given priority starts offset in a MAC PDU, and it is from a  
4 different priority than the preceding datagram. For this start fragmentation  
5 header, the Start\_of\_new\_IPDatagram field shall be set to '1'.

### 6 **4.10.2.2.1 Start Fragmentation Header – Offset in MAC PDU**

7 **Error! Reference source not found.** shows the payload of the MAC PDU  
8 consisting of the Start Fragmentation header followed by the rest of the IP  
9 datagram fragment.

**Table 4.10.2.2.1-1. Start Fragmentation Header Offset –  
in MAC PDU**

Field Name	Field Length (Bits)
Start_of_new_IPdatagram	1
Bypass RLL	1
Traffic_priority	2
Datagram_counter/CRC	12
Sequence_number	24
Protocol_version	4
Header_length	4
Type_of_service	8
Reserved	2
Protocol_Type	3
Length	11
Rest_of_datagram	Px8

10

11

12

The description of the fields for the start fragmentation header for the new IP datagrams is the following:

13

14

15

16

- Start\_of\_new\_IPdatagram: This field indicates if the following datagram is the start of a new IP datagram or the continuation of a previous IP datagram. A value of 1 indicates that the start of a new IP datagram follows; a value of 0 indicates that a continued IP datagram follows.

17

18

- Bypass RLL: A value of 1 indicates that the datagram at the beginning of the burst does not utilize RLL/

19

20

- Traffic\_priority: Used to allow up to four priorities, with the value 0 indicating the highest priority.

21

22

23

24

- Datagram\_counter/CRC: This field shall be filled with the 12-bit CRC (CRC-12) described in subsection 4.10.2.5. The CRC-12 shall be calculated by the IPoS remote before header compression. The Sequence Number field shall not be included in the CRC calculations.

25

26

27

- Sequence\_number: This field shall contain the 24-bit sequence number for the given priority. The sequence number is used to support the retransmission protocol if the real-time traffic bit is not set. The inserted

- 1 Sequence\_number field shall not be considered part of the original  
 2 stream, so the 3 bytes used by this field should not affect the "running"  
 3 sequence number.
- 4 • Protocol\_version: This field takes the value 4 for IPv4.
  - 5 • Header\_length: This field in IP shall be the IP header length.
  - 6 • Type\_of\_service: This field in IP shall be the type of service.
  - 7 • Reserved: This field shall be set to the value 0 by IPoS terminal and  
 8 ignored by the hub.
  - 9 • Length: This field shall be used to indicate the length of the datagram  
 10 starting with the protocol version field. This field is 11 bits long because  
 11 the maximum datagram is less than 2000 bytes on the IPoS system.
  - 12 • Rest\_of\_datagram: The value of P is derived from the Length field, ,  
 13 where  $P = \text{Length in bytes from Length field} - 4$  bytes.

#### 14 **4.10.2.3 Continuation Fragmentation Header – Beginning of MAC PDU**

15 The continuation fragmentation header described in this subsection shall be used  
 16 when an IP datagram for a given priority continues at the beginning of a MAC  
 17 PDU. For this continuation fragmentation header, the Start\_of\_new\_IPDatagram  
 18 field header shall be set to '0'.

##### 19 **4.10.2.3.1 Continuation Fragmentation Header – Beginning of MAC**

20 Table 4.10.2.3.1-1 shows the payload of the terminals MAC PDU consisting of  
 21 the continuation fragmentation header followed by the rest of the IP datagram  
 22 fragment. Note that the Sequence\_number field does not exist in this  
 23 fragmentation header; the sequence number for the datagram is provided by the  
 24 MAC header.

**Table 4.10.2.3.1-1. Continuation Fragmentation Header – Beginning of MAC PDU**

Field Name	Field Length (bits)
Start_of_new_Ipdatalogram	1
Bypass RLL	1
Traffic_priority	2
New IP offset	1
Reserved	1
New IP offset pointer	10
Rest_of_datagram	$P \times 8$

25  
 26 The description of the fields for the start fragmentation header for the new IP  
 27 datagrams follows:

- 28 • Start\_of\_new\_IPdatagram: This field indicates if the following datagram  
 29 is the start of a new IP datagram or the continuation of a previous IP

- 1 datagram. A value of 1 indicates that the start of a new IP datagram  
 2 follows; a value of 0 indicates that a continued IP datagram follows.
- 3 • Bypass RLL: A value of 1 indicates that the datagram at the beginning  
 4 of the burst does not utilize RLL.
  - 5 • Traffic\_priority: Used to allow up to four priorities, with the value 0  
 6 indicating the highest priority.
  - 7 • New IP offset: A value of 1 indicates that a new IP datagram starts offset  
 8 in this burst. A value of 0 indicates that no new IP datagram start offset  
 9 in the burst.
  - 10 • Reserved: This field is set to the value 0 and ignored by the hub.
  - 11 • New IP offset pointer: This field provides the offset, in bytes, where the  
 12 new IP datagram begins. The offset is from the beginning of this  
 13 continued IP datagram header. Assumes that maximum burst size is less  
 14 than 2<sup>10</sup> bytes, (1024).
  - 15 • Rest of datagram: The value of P is derived from the Length field, where  
 16 P = Length in bytes from Length field – 4 bytes.

17 **4.10.2.4 Continuation Fragmentation Header – Offset in MAC PDU**

---

18 The continuation fragmentation header described in this subsection shall be used  
 19 when an IP datagram for a given priority start continues at the offset in a MAC  
 20 PDU. For this continuation fragmentation header, the Start\_of\_new\_IPDatagram  
 21 field in the MAC PDU header shall be set to '0'.

22 **4.10.2.4.1 Continuation Fragmentation Header – Offset in MAC**

---

23 Table 4.10.2.4.1-1 shows the payload of the terminal MAC PDU consisting of  
 24 the continuation fragmentation header followed by the rest of the IP datagram  
 25 fragment.

**Table 4.10.2.4.1-1. Continuation Fragmentation Header – Offset in MAC PDU**

Field Name	Field Length (bits)
Start_of_new_IpdDatagram	1
Bypass RLL	1
Traffic_priority	2
Reserved	4
Sequence_number	24
Rest_of_datagram	P×8

26  
 27 The description of the fields for the start fragmentation header for the new IP  
 28 datagrams follows:

- 29 • Start\_of\_new\_IPdatagram: This field indicates if the following datagram  
 30 is the start of a new IP datagram or the continuation of a previous IP

- 1 datagram. A value of 1 indicates that the start of a new IP datagram  
2 follows; a value of 0 indicates that a continued IP datagram follows.
- 3 • Bypass RLL: A value of 1 indicates that the datagram at the beginning  
4 of the burst does not utilize RLL.
- 5 • Traffic\_priority: Used to allow up to four priorities, with the value 0  
6 indicating the highest priority.
- 7 • Reserved: This field is set to the value 0 and ignored by the hub.
- 8 • Sequence\_number: This field shall contain the 24-bit sequence number  
9 for the given priority. The sequence number is used to support the  
10 retransmission protocol if the real-time traffic bit is not set. The inserted  
11 Sequence\_number field shall not be considered part of the original  
12 stream, so the 3 bytes used by this field should not affect the "running"  
13 sequence number.
- 14 • Rest\_of\_datagram: The value of P is derived from the Length field, ,  
15 where  $P = \text{Length in bytes from Length field} - 4 \text{ bytes}$ .

#### 16 **4.10.2.5 Continuation RLL Bypass IP Datagram —Start of Burst**

---

17 IP packets that bypass RLL feature would be allowed to span multiple bursts.  
18 This requires the use of sequence numbers and resumption headers on packets. In  
19 case of a burst loss for packets that use Reliable Link Layer (RLL), the hub and  
20 remote achieve synchronization by 'GO back N' protocol. Since packets from  
21 queues that bypass reliable link layer are not retransmitted, a new mechanism is  
22 needed to re-synchronize hub and remote. The hub should be able to extract any  
23 good CBR packet that might exist in a burst. Since CBR packets are always in  
24 the beginning of a burst one of the two following scenarios can occur after a  
25 burst loss.

- 26 • New datagram / start of a burst

27 The hub would discard any datagram that are in progress for RLL bypass Queue  
28 and act on the new datagram. Also the hub would adjust its expected to sequence  
29 number to be the sequence number in the new received datagram.

- 30 • Resumed datagram / start of a burst.

31 If the sequence number in the burst header does not match what the hub is  
32 expecting, indicating lost bursts, the hub does not know the in-progress IP  
33 datagram ends and a new one begins. The continuation fragmentation header  
34 described in this subsection is used for the resynchronization between the hub  
35 and remote in this situation. This header will only be used for RLL bypass data,  
36 as the "GoBackN" retransmission protocol handles the normal priority case.

37

38

**Table 4.10.2.5-1. Continuation Fragmentation Header – Offset in MAC PDU**

Field Name	Field Length (bits)
Start_of_new_IPdatagram	1
Bypass RLL	1
Traffic_priority	2
New IP offset	1
Reserved	1
New IP offset pointer	10
Rest_of_datagram	P×8

1

2

3

The description of the fields for the start fragmentation header for the new IP datagrams follows:

4

5

6

7

- Start\_of\_new\_IPdatagram: This field indicates if the following datagram is the start of a new IP datagram or the continuation of a previous IP datagram. A value of 1 indicates that the start of a new IP datagram follows; a value of 0 indicates that a continued IP datagram follows.

8

9

- Bypass RLL: A value of 1 indicates that the datagram at the beginning of the burst does not utilize RLL.

10

11

- Traffic\_priority: Used to allow up to four priorities, with the value 0 indicating the highest priority.

12

13

14

- New IP offset: A value of 1 indicates that a new IP datagram starts offset in this burst. A value of 0 indicates that no new IP datagram start offset in the burst.

15

- Reserved: This field is set to the value 0 and ignored by the hub.

16

17

18

19

- New IP offset pointer: This field provides the offset, in bytes, where the new IP datagram begins. The offset is from the beginning of this continued IP datagram header. Assumes that maximum burst size is less than  $2^{10}$  bytes, (1024).

20

21

- Rest of datagram: The value of P is derived from the Length field, where  $P = \text{Length in bytes from Length field} - 4 \text{ bytes.}$

22

#### **4.10.2.6 Datagram CRC Calculation**

23

24

25

26

27

28

This subsection details how to perform the CRC-12 calculation in the Datagram\_counter/CRC field of the fragmentation header. The Datagram Counter/CRC field shall be filled in initially with a 12-bit datagram counter for non-real-time traffic and with zero for real-time traffic. The datagram counter is specific to each traffic priority and does not include real-time traffic within a priority.

29

30

The purpose of the Datagram\_counter field is to detect loss of synchronization between the IPoS terminals and the hub. This ensures uncorrupted reassembly,

1 correct destination addresses, correct decompressed packet length, and no loss of  
2 datagrams.

3 The CRC-12 is calculated with the following polynomial (0xF01):

$$4 \quad x^{12} + x^{11} + x^3 + x^1 + 1$$

5 The preset (initial) value is 0xFFFF.

6 The following steps describe the operation of the calculation of the CRC-12 by  
7 the IPoS terminal:

- 8 1. Before CRC processing, each delay element is set to its initial value '1'.
- 9 2. The datagram, starting from the IP Source Address field passes through  
10 the CRC with the initial vector set to the returned CRC value from  
11 step 1. The initial 12 bytes of the IP header are skipped over.
- 12 3. A trailer consisting of the IPoS terminal serial number (32 bits),  
13 Hybrid/IP Gateway IP address, and original IP length passes through the  
14 CRC with the initial vector set to the returned CRC value from step 2  
15 above.
- 16 4. After shifting the last bit of the trailer into the CRC-12, the output of all  
17 delay elements is read and the final CRC value is stored in the Datagram  
18 CRC field of the Datagram\_counter/CRC field.

19 Failures on the CRC-12 shall be considered as synchronization failures. The hub  
20 shall force the IPoS terminal to the inactive state to initiate resynchronization. If  
21 the CRC-12 failure occurred on a datagram that was designated as real-time  
22 traffic, the resynchronization mechanism will not be employed, and the IPoS  
23 terminal will remain in the Active state.

#### 24 **4.10.2.7 Error Handling**

---

25 Should there be any protocol error, any priority error, any de-compression error  
26 or datagram CRC error on data receive via the IPoS Inroute, a Compression  
27 History Reset command is sent to the Remote Terminal by the IPoS Hub. Upon  
28 its reception, the Remote Terminal shall reset the Datagram Counter and  
29 Sequence Numbers that are associated with priority queues excepting CBR.  
30 Finally, the Remote Terminal shall acknowledge the Compression History Reset  
31 command via the transmission of a Compression Reset Ack adaptation.

### 32 **4.11 MAC Procedures**

---

#### 34 **4.11.1 System Timing**

---

35 There are two system timing models available for use in the IPoS System:

- 37 • Open Loop Timing

- 1                   • Closed Loop Timing.

2                   The decision to use Open-Loop or Closed-Loop Timing is one that is taken at the  
3                   IPoS Hub. The rationale for using each timing system is beyond the scope of this  
4                   document.

5                   Either Open-Loop or Closed-Loop Timing can be used for Mesh communications  
6                   by a mesh capable IPoS terminal. For mobile IPoS terminal, Closed-Loop  
7                   Timing is mandatory. An IPoS mesh terminal uses this procedure to synchronize  
8                   its transmission timing with the IPoS hub for its star or hub-spoke mode of  
9                   communication. However, it shall perform additional timing procedure to  
10                  synchronize transmission timing with peer mesh terminals so that transmitted  
11                  bursts are received correctly at the peer mesh receivers. This procedure is  
12                  described in section 4.11.10.9.

### 13   **4.11.1.1    Open Loop Timing**

#### 14   **4.11.1.1.1   Overview**

---

15                  The IPoS system uses a star topology with the hub at the center of the star and  
16                  the remote terminals at the points of the star. The hub sends a continuous DVB  
17                  TDM (time division multiplexing) data stream to the satellite for broadcast to all  
18                  the remote terminals in the coverage region. The remote terminals use TDMA to  
19                  access shared inroute channels for transmissions through the satellite to the hub.  
20                  TDMA requires that each remote terminal transmit its data bursts to the satellite  
21                  for relay to the hub such that the bursts start within a narrow window of time, the  
22                  aperture, within a specified burst of a particular frame at the hub.

23                  In the IPoS system with open loop timing, this aperture is 125 μs for assigned  
24                  traffic bursts and Aloha bursts and 2 msec for ranging bursts (see subsection  
25                  3.4.4.1). The propagation time from a remote terminal to the hub through the  
26                  satellite can vary by more than 10 msec from one remote terminal to another,  
27                  depending on the position of the particular remote terminal on the Earth. This  
28                  variation requires that each remote terminal execute procedures to determine  
29                  exactly when it should transmit a data burst so that it will arrive at the hub within  
30                  the proper 125 μs aperture.

31                  Figure 4.11.1.1.1-1 shows the timing relationships between the hub and a remote  
32                  terminal. A vertical line on the figure shows what is happening at the hub (at the  
33                  top) and at the remote terminal (at the bottom) at the same time. The horizontal  
34                  axis is marked in 45 msec units – the duration of an inroute frame. The hub is a  
35                  constant reference for all IPoS system timing and frequency, and the remote  
36                  terminals must establish an accurate time reference relative to the hub's fixed  
37                  standard<sup>2</sup>. Note that:

$$38 \quad T_{HO} = T_{H-S} + T_{S-R} + T_{RO} + T_{R-S} + T_{S-H}$$

1

where:

2

$T_{HO}$ : hub offset time (time between the intended or ideal time of transmission of  $SFNP_N$  at the hub and the start of reception of frame N at the hub)

3

4

5

6

$T_{H-S}$ : propagation time from hub to satellite (same value as  $T_{S-H}$ )

7

8

$T_{S-R}$ : propagation time from satellite to remote terminal (same value as  $T_{R-S}$ )

9

10

11

$T_{RO}$  remote terminal offset time (Time between "ideal" receipt of  $SFNP_N$  at a remote and the transmit time for the start of transmission for frame N at this remote)

12

13

14

15

$T_{R-S}$ : propagation time from remote terminal to satellite

16

17

$T_{S-H}$ : propagation time from satellite to hub

18

19

$SFNP_N$ : Superframe numbering packet that marks Frame N  
(Superframe number =  $\text{int}(N/8)$ )

20

21

22

The hub-to-satellite round-trip time,  $T_{H-S} + T_{S-H}$ , can also be written as  $T_{H-S-H}$ .

23

Then:

24

$$T_{HO} = T_{H-S-H} + T_{S-R} + T_{RO} + T_{R-S}$$

25

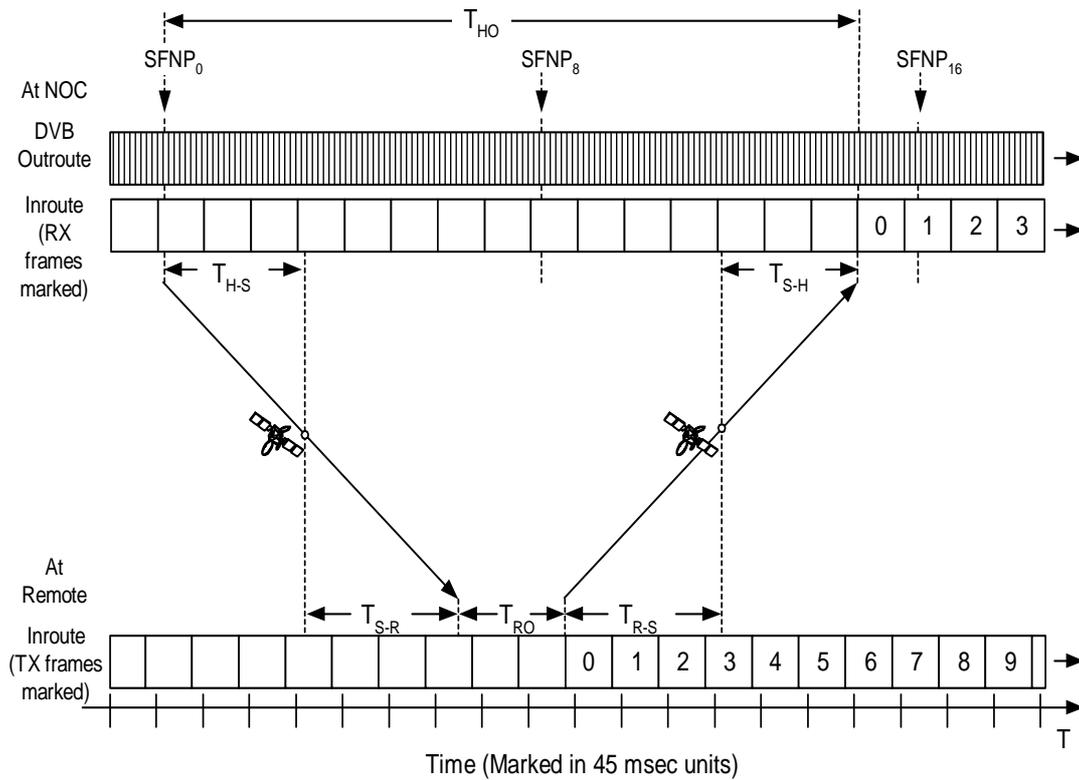
26

If a remote transmits at the end of its  $T_{RO}$  interval, the hub will receive the burst in the first burst position within the frame. If the remote is assigned to transmit at a burst position later in the frame, it shall delay of its transmission by the corresponding number of time slot intervals.

27

28

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1  
2

3 **Figure 4.11.1.1-1. IPoS System Timing Relationships**

4  
5  
6  
7  
8  
9  
10  
11

The DVB outroute does not have any time marker that a remote terminal can use to synchronize its time reference with the hub's. However, the remote terminals must establish a time reference that is sufficiently aligned to the hub's time reference so that bursts arrive within the aperture. To provide this timing reference, the hub transmits an SFNP on the outroute once every superframe (eight frames, or 360 msec.). Table 4.12-4 in this section shows the format of the SFNP containing a frame number (not a superframe number), so the frame number in successive SFNPs increments by 8.

12  
13  
14  
15  
16  
17  
18  
19

As Figure 4.11.1.1-1 shows, the hub starts the inroute TDMA frame one time interval specified in the Hub\_timing\_offset field in the SFNP message, T<sub>HO</sub>, after it transmits the SFNP. Although the SFNP gives the value of T<sub>HO</sub> in use, T<sub>HO</sub> remains constant for a given system after it starts initial operation. T<sub>HO</sub> must be set large enough that an SFNP can be received by a terminal that is farthest from the satellite, have that terminal do some processing (say two frames worth), then transmit a data burst in time to be received back at the hub at the start of the frame number given in the SFNP packet. A typical value for T<sub>HO</sub> is 695 msec.

20  
21  
22  
23

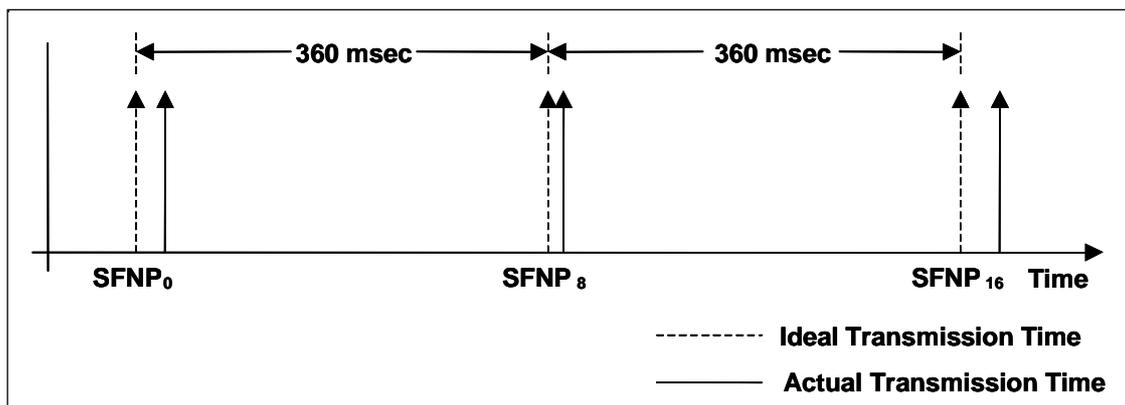
When a remote terminal has established its timing reference, T<sub>RO</sub>, by ranging (see subsection 4.11.2), it will have determined its value for T<sub>RO</sub> well within ± 62.5 μs of its exact current value. This allows the remote terminal to transmit a burst at the right time to fall within a 125 μs aperture at the hub.

1 Each of the following subsections describes specific procedures related to  
2 establishing and maintaining the proper value of  $T_{RO}$  at a remote terminal.

### 3 **4.11.1.1.2 Variation in SFNP Transmission Time**

4 The hub has a time reference, accurate to 1 part in  $10^7$ , which allows the hub to  
5 determine when each new superframe (eight frames or 360 msec) starts. The hub  
6 tries to transmit the SFNP at exactly the start of every superframe. However,  
7 because of processing delays in the hub and because the DVB outroute transport  
8 packets are not synchronized with the hub's frame timing, the hub cannot  
9 transmit the SFNP at exactly the right time. The SFNP is always transmitted a  
10 little bit later than the "ideal," exact, 360 msec tick time. In addition, the amount  
11 of time that the SFNP is delayed from the ideal time varies slightly with each  
12 SFNP transmission.

13 Figure 4.11.1.1.2-1 shows an example of the ideal transmissions, the dotted lines,  
14 and the actual transmissions, the solid lines (with the delay from the ideal  
15 exaggerated). Although the delay and delay variation are small compared to the  
16 360 msec superframe time, they are large compared to the accuracy that the  
17 remote terminals need to synchronize their timing with the hub's.



18

19 **Figure 4.11.1.1.2-1. "Ideal" and Actual SFNP Transmission Time at the Hub**

20 To allow remote terminals to correct for this variation, which occurs each time  
21 the hub transmits an SFNP, there is equipment at the hub measuring the time  
22 delay between the "ideal" exact time when the SFNP should have been  
23 transmitted (the start of the superframe) and the time when it was actually  
24 transmitted. The measured delay is provided by the hub to the remote terminals  
25 in the SFNP. Then the next SFNP gives the time that the previous SFNP was  
26 delayed from its "ideal" transmission time in the packet's Local SFNP Delay  
27 field. The remote terminals subtract this value from the time at which they  
28 received the previous SFNP to determine when it would have been received if the  
29 hub could have sent it at exactly the right time. This is the reference point that a  
30 remote terminal uses for its inroute frame timing calculations.

### 1 **4.11.1.1.3 Timing Variation between Hub and Remote Terminal**

---

2 The frequency/timing source at the remote terminal has a less accurate timing  
3 reference than specified for hub in 4.11.1.1.2. In IPoS the calibration of the  
4 remote terminal frequency/timing source is provided by the hub's frequency  
5 timing reference by comparing the time interval between received SFNPs with  
6 the elapsed time interval measured at the remote terminal local timing.

7 Remote terminals shall determine the corrections needed to their local reference  
8 by measuring a scaling factor that is the ratio of the interval between SFNPs, as  
9 received by the remote terminal, to 360 msec generated with the local timing of  
10 the remote terminal. Multiplying the local timer by the scaling factor remote  
11 terminals correct the timing variations in their timing sources.

12 The remote terminals shall continually recalculate the time scaling factor to  
13 remove the drift in their local frequency/timing reference.

### 14 **4.11.1.1.4 Superframe Synchronization**

---

15 The IPoS hub transmits two timing streams for redundancy. Terminals shall  
16 monitor both streams but only process one of them. This is described in section  
17 4.11.1.1.7. The hub transmits an SFNP once every superframe for each timing  
18 stream. A remote terminal processes each timing stream independently, as  
19 follows:

- 20 • The remote has synchronized to a stream if, having started  
21 unsynchronized, both of the following conditions are true:
  - 22 – Four consecutive valid SFNPs have been received.
  - 23 – After receiving consecutive valid SFNPs from the same timing  
24 stream, the local timing matches within eight clock ticks.

25 Once a remote terminal has synchronized to a stream, synchronization is defined  
26 "to be lost" if any of the following conditions is true:

- 27 • Two consecutive SFNPs have been received with the local timing off by  
28 more than 16 clock ticks.
- 29 • No valid SFNP is received for three consecutive superframes.
- 30 • Two consecutive valid SFNPs have not been received for five  
31 superframe times.
- 32 • Three consecutive valid SFNPs have not been received for seven  
33 superframe times.

34 When an IPoS terminal has lost synchronization or moves to "out of sync" state,  
35 it shall perform sync recovery procedure and shall not transmit until it reacquires  
36 the synchronization. The re-sync procedure is the same as the initial sync  
37 procedure.

1 Annex A shows these conditions in a state diagram format.

#### 2 **4.11.1.1.5 Compensation for Satellite Distance Variations**

---

3 Although the IPoS system uses a geosynchronous satellite, the position of the  
 4 satellite is not perfectly fixed, as seen from a point on the earth. Because the  
 5 satellite cannot be kept in a perfect orbit, the satellite moves slightly in azimuth  
 6 and elevation as well as distance, as seen from both the hub and the remote  
 7 terminals. This satellite movement changes the round-trip time between the hub  
 8 and the remote terminals (i.e., the values of  $T_{H-S-H}$ ,  $T_{S-R}$ , and  $T_{R-S}$  defined in  
 9 subsection 4.11.1.1.1). If there were no compensation for satellite movement,  
 10 when the round-trip time from the hub to a particular remote decreased, the  
 11 remote would receive its SFNPs earlier, and thus transmit its bursts to the hub  
 12 earlier, relative to the frame timing at the hub. Furthermore, the hub would  
 13 receive the bursts from the remotes earlier, relative to the frame timing at the  
 14 remote, because of the reduced return distance from the remote to the hub. These  
 15 effects would cause the hub to receive the remote's bursts earlier in the frame  
 16 than before – possibly before the start of the receive aperture at the hub.  
 17 Conversely, if the round-trip distance from the hub to a remote were to increase,  
 18 the hub would receive that remote's bursts later, possibly after the end of the  
 19 receive aperture. Therefore, the IPoS system has a mechanism for adjusting the  
 20 transmit timing at the remote terminals to compensate for changes in round-trip  
 21 time from the hub to the remotes.

22 It is not practical to measure the changes in the hub-to-remote round-trip times  
 23 for *every* remote separately. Fortunately, the primary change in satellite position  
 24 that affects round-trip times is movement closer to, or farther from, the Earth. As  
 25 a first order approximation, this distance change is the same for the hub as for all  
 26 of the remotes. The distance change is actually slightly different for each remote  
 27 terminal and for the hub, but compensating for the "common mode" distance  
 28 change is sufficient to allow all the remote terminal bursts to fall within the hub's  
 29 receive apertures for the geosynchronous satellite required by the IPoS system  
 30 (see subsection 2.2.1).

31 To determine the change in the distance (or actually, propagation time) from the  
 32 hub to the satellite and back, the hub constantly measures the round-trip time  
 33 through the satellite between itself and a collocated remote terminal and sends  
 34 this measured time to the remotes in the SFNP. The current hub-to-satellite-to-  
 35 hub time,  $T_{H-S-H}$ , is the Echo SFNP Delay field from the current SFNP minus the  
 36 Local SFNP Delay field from the previous SFNP. A remote terminal can  
 37 calculate the change in  $T_{H-S-H}$  since it last ranged by subtracting the current  $T_{H-S-H}$   
 38 value from  $T_{H-S-H}$  at the time ranging was last completed. From  
 39 subsection 4.12.1.1.1, a remote terminal's remote offset time,  $T_{RO}$ , is:

$$40 \quad T_{RO} = T_{HO} - T_{H-S-H} - (T_{S-R} + T_{R-S})$$

41 The change in  $T_{RO}$  caused by the change in distance to the satellite is:

$$42 \quad \Delta T_{RO} = - \Delta T_{H-S-H} - \Delta(T_{S-R} + T_{R-S})$$

43  $T_{HO}$  is a constant, so it does not change. Since it is assumed that the change in  
 44 hub-to-satellite-to-hub time,  $\Delta T_{H-S-H}$ , is, to a good approximation, the same as the

1 change in the remote-to-satellite-to-remote time,  $T_{S-R} + T_{R-S}$ , then this equation  
2 can be rewritten as:

$$3 \quad \Delta T_{RO} = - 2\Delta T_{H-S-H}$$

4 Thus, a remote terminal should constantly modify the value that it determined for  
5 the remote offset time,  $T_{RO}$ , the last time it ranged, by twice the change in  $T_{H-S-H}$   
6 from the last time it ranged. For example, suppose that when the remote terminal  
7 last ranged, the  $T_{H-S-H}$  was 258,317  $\mu\text{s}$  and the value of  $T_{RO}$  (determined  
8 accurately by ranging) was 98,921  $\mu\text{s}$ . Then suppose that, at some later time, an  
9 SFNP packet shows that  $T_{H-S-H}$  has changed to 258,307  $\mu\text{s}$ . Then the remote  
10 terminal should set the  $T_{RO}$  value that it is using to 98,941  $\mu\text{s}$ . That is:

$$11 \quad \Delta T_{H-S-H} = - 10 \mu\text{s}, \text{ or } \Delta T_{RO} = - 2\Delta T_{H-S-H} = +20 \mu\text{s}$$

12 So, the remote terminal should *increase* its  $T_{RO}$  value by 20  $\mu\text{s}$  to 98,941  $\mu\text{s}$ .  
13 That is, the remote terminal should transmit its bursts 20  $\mu\text{s}$  *later* relative to the  
14 receipt of the "ideal" SFNP than it did when it last ranged. It is clear that if  $T_{H-S-H}$   
15 decreases by 10  $\mu\text{s}$ , the remote should send its bursts 20  $\mu\text{s}$  later than before.  
16 This is effectively increasing the total hub-to-remote-to-hub time so that the total  
17 remains the same. The change in  $T_{H-S-H}$  is multiplied by 2 because there is also a  
18 remote-to-satellite-to-remote path in the hub-to-remote round-trip path, and its  
19 time has changed by about the same amount as  $T_{H-S-H}$ .

#### 20 **4.11.1.1.6 Resuming Operation After Interruption**

---

21 It is necessary for an IPoS remote terminal to restart operation after an indefinite  
22 interruption without having to range again as long as the site and satellite  
23 locations have not changed. That means that the remote has to have a way to  
24 determine the current value of  $T_{RO}$  that it should use to time its transmissions  
25 based on the current distance to the satellite. Since remote terminals store the  
26 values of  $T_{RO}$  and  $T_{H-S-H}$  in nonvolatile memory when they last ranged, they can  
27 calculate their current values for  $T_{RO}$  using the stored values and the current  
28  $T_{H-S-H}$  value contained in the latest SFNPs. The formula for calculating the  
29 current value of  $T_{RO}$  is:

$$30 \quad T_{RO(\text{current})} = T_{RO(\text{at last ranging})} - 2 (T_{H-S-H(\text{at last ranging})} - T_{H-S-H(\text{current})})$$

31 After reinitializing the value of  $T_{RO}$  according to the previous calculation, the  
32 remote terminals should resume the  $T_{RO}$  updating process described in  
33 subsection 4.11.1.1.5.

#### 34 **4.11.1.1.7 Timing Redundancy**

---

35 The system timing function is critical to the operation of the IPoS. Therefore the  
36 IPoS standard contains an option for the hub to use redundant timing facilities to  
37 generate two independent timing "streams." When this option is implemented,  
38 the hub sends two SFNPs every superframe, one for each superframe timing  
39 stream. The SFNPs are marked with the ID of the timing stream, 0 or 1. Each  
40 remote processes the two timing streams independently with regard to  
41 superframe synchronization (see Annex A). If the terminal is in synchronization

1 with either of the streams, the terminal is declared to be in superframe  
2 synchronization, and the terminal uses that stream for its timing calculations. If  
3 the terminal loses synchronization on the online stream but maintains superframe  
4 synchronization on the other stream, it switches its timing calculations to the  
5 alternate stream. If the remote terminal is out of superframe synchronization on  
6 both timing streams, then the terminal is deemed to be out of superframe  
7 synchronization.

## 8 **4.11.1.2 Closed Loop Timing**

### 9 **4.11.1.2.1 Overview**

---

10 Closed Loop timing process enables the IPoS hub to feedback timing corrections  
11 to IPoS terminals and the IPoS terminals apply the received timing corrections.

12 Closed Loop timing has two sub-modes governed by whether  $T_{H-S-H}$  can be  
13 measured or not. The use of a particular sub-mode is signaled to the Remote  
14 Terminal via the SFNP timing message. These two submodes are called  
15 “Estimated  $T_{H-S-H}$  Closed-Loop Timing” and “Measured  $T_{H-S-H}$  Closed-Loop  
16 Timing”.

17 The procedure to measure  $T_{H-S-H}$  for “Measured  $T_{H-S-H}$  Closed Loop-Timing” is  
18 described in section 4.11.1.1.5, For “Estimated  $T_{H-S-H}$  Closed Loop-Timing”,  
19  $T_{H-S-H}$  is estimated by a procedure at the IPoS hub that polls certain active fixed  
20 IPoS terminals to obtain their normalized change in time offset time ( $T_{RO}$ ) to  
21 estimate the satellite movement variations at the hub and synthesize the estimated  
22 echo timing which is being sent via the SFNP timing message. A mobile IPoS  
23 terminal is not polled by the hub.

24 The Closed Loop timing procedure, in any of the above modes, enables the  
25 inroute system to use shorter unique word aperture. An IPoS mobile terminal  
26 shall always use the Closed Loop timing procedure, i.e. this type of terminal will  
27 not work if the system does not support Closed Loop timing.

28 Estimated  $T_{H-S-H}$  Closed Loop timing is generally used in networks where it is not  
29 possible or not cost effective for the IPoS hub to receive its own outoute  
30 transmission and thus cannot measure  $T_{H-S-H}$ .

31 The Closed Loop Timing feature has three parts. Namely,

- 32
- 33 • A procedure to obtain closed loop timing feedbacks in remote terminals  
34 from the IPoS hub when terminals send inroute data on allocated  
35 channels.
- 36
- 37 • Measurement of  $T_{H-S-H}$  or Estimation of  $T_{H-S-H}$ . The detailed procedure  
38 for estimation of  $T_{H-S-H}$  is described in annex section A.3.
- 39
- 40 • A procedure to send a burst on an unallocated large aperture slot and  
41 receive a timing correction from the IPoS hub. This special burst is  
42 called “Bootstrap Aloha” and its usage is specified in subsequent  
43 subsections.

1

## 2 **4.11.1.2.2 Bootstrap Aloha**

---

3 “Bootstrap Aloha” is a burst sent on the unallocated contention channel using  
4 large 2 ms aperture window. The burst contents are similar to those of  
5 unallocated ranging bursts. However, unlike an unallocated ranging burst the  
6 IPoS Hub does not allocate any ranging bandwidth to a terminal upon receiving a  
7 “Bootstrap Aloha” burst. A terminal can expect to receive an assign id pertaining  
8 to stream bandwidth in response to its “Bootstrap Aloha”

9 Usage of BootstrapAloha is very common in IPoS mobile applications. An IPoS  
10 mobile terminal always uses the “Bootstrap Aloha” burst as the first message to  
11 become active in the stream mode for sending inroute user data.

## 12 **4.11.1.2.3 Close-Loop Timing Procedures – Estimated $T_{H-S-H}$**

---

13 The IPoS Hub advertizes either a nominal or a derived estimated hub-satellite-  
14 hub propagation delay ( $T_{H-S-H}$ ) via the SFNP timing packets to Remote  
15 Terminals. The use of a particular delay is signaled to the Remote Terminal via a  
16 field in the SFNP message and depends on the Closed-Loop Timing system  
17 states. The Closed-Loop timing system states are specified in A3.1. The nominal  
18 hub-satellite-hub propagation delay is calculated assuming that the Satellite is at  
19 the center of the satellite station keeping box.

20 When the nominal  $T_{H-S-H}$  is advertised, upon first use or not having sent any  
21 Inroute data for  $T_{IDLE}$  minutes (where  $T_{IDLE}$  is set to one hour for a 125 $\mu$ s and  
22 proportionally less for smaller apertures), the Remote Terminal transmits a  
23 “Bootstrap Aloha” message on the IPoS Unallocated ranging Channel that uses a  
24 longer aperture . In response, the IPoS Hub should transmit an Inroute Timing  
25 Feedback Packet containing the timing correction. If an Inroute Timing Feedback  
26 Packet is not received within the number of Superframes defined within  
27 ‘Bootstrap Aloha random back off’ field of the SFNP message, the Remote  
28 Terminal re-transmits its ‘Bootstrap Aloha’ Message. Upon reception of the  
29 Inroute Timing Feedback Packet, the Remote Terminal assumes it is  
30 synchronized and is ‘active’.

31 Once active, the Remote Terminal only uses the closed-loop timing feedback for  
32 its timing adjustment. The IPoS hub measures Unique Word Timing Offset on  
33 every stream burst. Once the error or timing drift crosses a threshold value, then  
34 the IPoS hub sends a message to the IPoS terminal containing a timing correction  
35 as the closed loop timing feedback. If the Remote Terminal is inactive for a time  
36 period which is less than  $T_{IDLE}$ , it uses its last timing correction to send the first  
37 message on the IPoS Unallocated Channel that uses 125 $\mu$ s aperture. Refer to  
38 2.6.3.3 for the description of various types of IPoS inroute channels.

39 The IPoS hub polls a pool of active fixed remote terminals to obtain their timing  
40 corrections over a period from a uniform reference point. With these timing  
41 correction feedbacks received from Remote terminals, the IPoS hub estimates  $T_{H-}$   
42  $s-H$  by averaging those timing feedbacks. Once the estimated delay is available,  
43 the system transitions to a state where the estimated hub-satellite-hub  
44 propagation delay is advertised. In this state, the Remote terminal always uses the

1 estimated echo delay to send the first message on the IPoS Unallocated Channel  
2 that uses 125 $\mu$ s aperture. The IPoS terminal shall use this channel even it were  
3 idle for more than  $T_{IDLE}$  minutes. The IPoS hub acknowledges the terminal  
4 message by sending Aloha Acknowledgement command (see section 4.13.7.2)  
5 and includes a timing correction along with the acknowledgment. Upon  
6 reception of the acknowledged packet, the Remote Terminal assumes it is  
7 synchronized and is 'active'. Again once active, the Remote Terminal only uses  
8 the closed-loop timing feedback for its timing adjustment.

9

#### 10 **4.11.1.2.4 Closed Loop Procedures – Measured $T_{H-S-H}$**

---

11 This submode shall be used in IPoS mobile applications. However, this mode can  
12 also be used in fixed applications.

13 If the Closed-Loop timing is enabled and the fixed or mobile Remote Terminal  
14 has no data to transmit, then it uses the SFNP message for frame timing  
15 adjustment.

16 If the Closed-Loop timing is enabled and the fixed or mobile Remote Terminal  
17 has data to transmit on this Inroute, it only uses Inroute Timing Feedback Packet  
18 for its timing adjustment and ignores the estimated  $T_{H-S-H}$  value present in the  
19 SFNP message.

20 When inactive the fixed terminal sends the first message on the IPoS Unallocated  
21 Channel that uses 125  $\mu$ s aperture, but the mobile terminal sends the first  
22 message on the IPoS Unallocated ranging Channel (Bootstrap Aloha) that uses  
23 large 2 ms aperture. When active both fixed and mobile terminals use 125  $\mu$ s  
24 aperture.

### 25 **4.11.2 Remote Terminal Ranging**

---

26

#### 27 **4.11.2.1 Purpose**

---

28 The ranging process accomplishes the following:

- 29 • Determines accurately the remote offset time,  $T_{RO}$  (see figure 4.11.1.1-1),  
30 that the remote terminal should use to time its inroute transmissions.
- 31 • Enables a remote terminal to determine what types of available inroutes  
32 (transmission rates and coding methods) it is capable of operating within  
33 its current location and configuration.
- 34 • Determines the transmit power setting that the remote terminal should  
35 use for each type of inroute that is available and with which it is capable  
36 of operating.

37 A remote terminal executes the ranging process the first time that it operates at a  
38 particular site with a particular satellite, and each time a new inroute group type  
39 (transmission rate and coding) is made available to it.

## 1 **4.11.2.2 Preparation for Ranging**

---

2 Before a remote terminal begins the ranging process, it must:

- 3 1. Acquire the outroute using the configured outroute frequency and  
4 symbol rate (see subsection 3.8.1.1).
- 5 2. Synchronize its transmit frequency reference with the satellite outroute  
6 frequency so that it can transmit on inroutes with the required frequency  
7 accuracy.
- 8 3. Wait for superframe synchronization (see Annex A).
- 9 4. Wait for three additional superframe times after achieving superframe  
10 synchronization to be sure that it has received and stored a full cycle of  
11 IGDPs (see subsection 4.12.6).
- 12 5. Estimate the distance from its location to the satellite center of box using  
13 the configured values for site latitude and longitude and satellite  
14 longitude (see subsection 4.13). The remote terminal converts this  
15 distance to propagation time,  $T_{S-R}$  (which is the same as  $T_{R-S}$ ).

- 16 6. Estimate the value of  $T_{RO}$  using the formula given in subsection  
17 4.11.1.1.1:

$$18 \quad T_{HO} = T_{H-S-H} + T_{S-R} + T_{RO} + T_{R-S}.$$

- 19 7. This formula can be rearranged to:

$$20 \quad T_{RO} = T_{HO} - T_{H-S-H} - (T_{S-R} + T_{R-S}).$$

- 21 8. Since  $T_{S-R} = T_{R-S}$ , This can also be written as:

$$22 \quad T_{RO} = T_{HO} - T_{H-S-H} - 2T_{S-R}.$$

23 The values for  $T_{HO}$  and  $T_{H-S-H}$  are known from the superframe numbering  
24 packets, and  $T_{S-R}$  was estimated in step 5, above. The remote terminal cannot  
25 determine  $T_{S-R}$  exactly since it does not know its own site location and the  
26 satellite location exactly. Therefore this is a first estimate for  $T_{RO}$ . The ranging  
27 process will help the remote terminal to determine the value of  $T_{RO}$  more  
28 precisely.

## 29 **4.11.2.3 Ranging Order**

---

30 Remote terminals typically receive multiple IGDPs describing different inroute  
31 groups. All of the inroutes in a particular group have the same transmission rate  
32 and coding method, and if spreading is enabled, then the same spreading factor.  
33 Keeping spreading aside, each combination of symbol rate and coding method  
34 (Turbo or LDPC) in Table 3.4.4.1-1 requires a separate inroute group. If adaptive  
35 coding is not enabled, then each combination of symbol rate, coding method and  
36 FEC coding rate in Table 3.4.4.1-1 requires a separate inroute group. The number  
37 of groups could be 38 if all types of inroute in Table 3.4.4.1-1 are supported.  
38 There may be multiple inroute groups that have the same transmission rate, FEC

1 coding rate and coding method. The remote terminal performs the ranging  
2 process (see subsection 4.11.2.4) on one inroute group of each different inroute  
3 type in the ascending order of Table 3.4.4.1-1 as follows;

- 4 • Starting with 256 ksps 1/3 Turbo/BCH inroute and through all turbo  
5 coded inroutes if turbo coded inroutes are present in the network
- 6 • Starting with 256 Ksps 1/2 LDPC/CRC inroute and through all LDPC  
7 inroutes if the terminal is LDPC capable and LDPC inroutes are present  
8 in the network

9 If the IPoS terminal is capable of both Turbo and LDPC inroute transmission, it  
10 shall perform the above two procedures separately.

11 The remote terminal skips the ranging process for any inroute type that is not  
12 available (i.e., no IGDP was received for an inroute of that type), or if the  
13 terminal is not capable of transmitting on that type of inroute or capable but not  
14 configured to use. For example, if a particular terminal were not capable of  
15 transmitting using LDPC coding, it would skip inroute groups of LDPC coding.  
16 The remote terminal terminates the ranging process when any of the following  
17 occurs:

- 18 1. The ranging process on this group type fails (see subsection 4.11.2.5).
- 19 2. The Ranging Acknowledgment command received at the end of the  
20 ranging process for a particular inroute has a Received  $E_b/N_0$  field whose  
21 value is less than the  $E_b/N_0$  Switchup field in the IGDP (see subsection  
22 4.12.6) for this inroute group.
- 23 3. The ranging process was attempted on the last group of inroute types  
24 above, number 5.

25 Additionally, the IPoS terminal may optionally support a 'Single Rate Ranging'  
26 mode. In this mode, the terminal is permitted to range on only the most robust  
27 combination of symbol rate and FEC, and shall be able to calculate a transmit  
28 power value for all symbol and FEC rates from that ranging session that is  
29 accurate to within a 0.5 dB.

#### 30 **4.11.2.4 Ranging Process**

---

31 This subsection describes the steps that a remote terminal and the hub use to  
32 range on an inroute group of a specified type, transmission rate, and coding  
33 method.

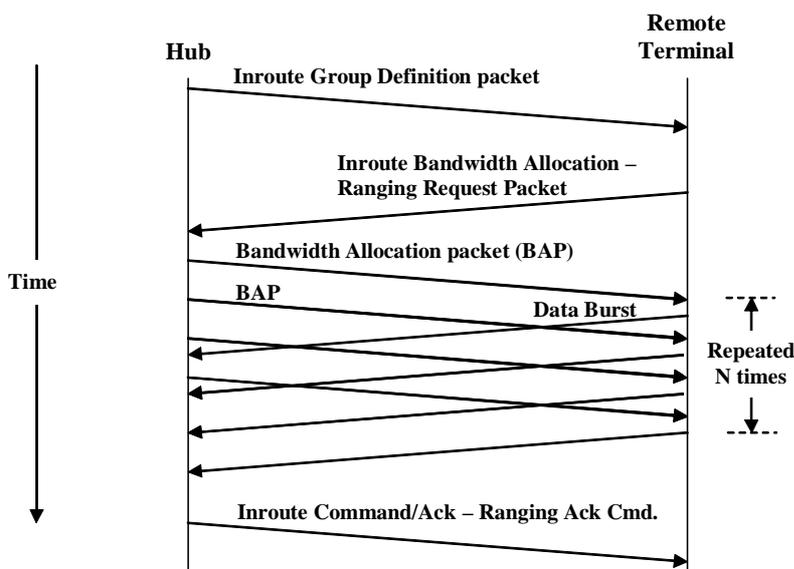
34 The steps are:

- 35 1. The remote terminal:
  - 36 1.1. Selects an inroute group of the desired type, if there is more than  
37 one group of that type.

- 1  
2  
3 1.2. Randomly selects an unallocated ranging logical channel from those whose location (frequency and burst position within a frame) are described in IGDPs.
- 4  
5  
6  
7 1.3. Transmits an inroute unallocated packet with a Ranging Request message at a default starting power level in the selected unallocated ranging logical channel. The transmission time is based on the initial estimate for  $T_{RO}$  (see subsection 4.11.2.2).
- 8  
9  
10  
11 1.4. Responds to ranging BAPs received from the hub by sending null data bursts or outstanding data, if any, in the assigned locations. If the remote terminal receives no response to its Ranging Request, it increases its power and goes back to Step 1.1.
- 12 2. The hub:
  - 13 2.1. Receives the Ranging Request message from the remote.
  - 14  
15  
16  
17  
18 2.2. Sends a series of BAPs (see subsection 4.12.8 for BAP message definition) to the remote specifying an inroute, frame number, burst location, and burst length of the ranging burst that the remote should send. The remote responds to each allocation by sending a single ranging burst with the prescribed characteristics.
  - 19  
20  
21  
22  
23  
24 2.3. Receives each ranging burst that the remote terminal sends and measures the time between the start of the aperture at the hub and the receipt of the packet from the remote. This aperture is about 2 msec long (compared to the 125  $\mu$ s aperture that the hub uses for assigned data bursts and Aloha bursts from remote terminals that have already ranged).
  - 25  
26 2.4. Stops sending BAPs to the remote and waits for the last ranging burst to be received.
  - 27  
28 2.5. Averages the times between the start of the aperture and the receipt of the ranging burst for each ranging burst that the remote sent.
  - 29  
30  
31  
32 2.6. Sends this average time to the remote, in units of 0.1  $\mu$ s, in the Timing Adjustment field of the Ranging Acknowledgment command portion of an ICAP (see subsection 4.12.7 for ICAP message description).
- 33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43 3. The remote terminal receives the Ranging Acknowledgment command packet from the hub and increases or decreases its original estimate of  $T_{RO}$  so that the Timing Adjustment field would be a predetermined fixed value if the remote were to transmit another ranging burst. This predetermined value is a function of the inroute transmission rate and coding method. So, for example, if the predetermined value should be 500  $\mu$ s, and the Timing Adjustment field value is 12,345 (or 1,234.5  $\mu$ s, since the time is specified in 0.1  $\mu$ s units), then the remote terminal should decrease its value for  $T_{RO}$  by 734.5  $\mu$ s (1,234.5  $\mu$ s–500  $\mu$ s) so that its bursts will arrive at the hub 500  $\mu$ s after the start of the receive aperture or 734.5  $\mu$ s earlier than originally estimated.

- 1                   4. The remote terminal stores the current values of  $T_{RO}$  and the round-trip
- 2                   time from the hub to the satellite,  $T_{H-S-N}$ , in nonvolatile memory. The
- 3                   remote terminal needs these values to compensate for changes in distance
- 4                   to the satellite and to resume operation after an interruption
- 5                   (see subsections 4.11.1.1.5 and 4.11.1.1.6).
  
- 6                   5. The remote terminal adjusts transmit power such that the
- 7                   Received  $E_b/N_0$  figure contained within the Ranging Acknowledgment
- 8                   command is equal to the  $E_b/N_0$  target field contained within the IGDP
- 9                   associated with the inroute group to which the IPoS remote is ranging.

Figure 4.11.2.4-1 shows the message sequence used in the remote terminal ranging process as described above. The remote terminal uses the information in the IGDP to select an unallocated ranging slot. The remote terminal then sends a Ranging Request packet in this slot. If the request is successful, the hub sends a series of BAPs; the remote terminal transmits a null burst in each of the assigned slots. When the hub has determined the timing correction and power adjustment that the remote terminal should use, it sends this information to the remote terminal in a Ranging Ack command.



**Figure 4.11.2.4-1 Message Sequence for Remote Terminal Ranging**

#### 4.11.2.5 Failure Conditions

There are four failure conditions that a remote terminal can encounter when attempting to range on a particular inroute type:

1. There are no unallocated ranging logical channels defined in any of the inroute groups of the desired type.
2. The remote terminal continues to retransmit Ranging Requests at higher and higher power until it has received no response at its maximum power.

- 1                                   3. The remote terminal stops receiving bandwidth allocations after making  
2                                   a Ranging Request but receives no Ranging Acknowledgment command  
3                                   (4.12.7.1) after a timeout period.
- 4                                   4. The Received  $E_b/N_0$  field in the Ranging Acknowledgment command  
5                                   received from the hub is below the  $E_b/N_{0\_min}$  field in the IGDP for this  
6                                   inroute group.

7                                   If ranging fails, the remote terminal ends the overall ranging process described in  
8                                   subsection 4.11.2.4. If ranging has not been successful on any of the available  
9                                   inroute types, the terminal waits for a timeout period and then retries the overall  
10                                  ranging process from the beginning.

### 11   **4.11.3    Inroute Group Selection by IPoS Remotes**

---

12                                  The ranging process helps the terminal to determine which symbol rate and FEC  
13                                  rate it can operate and the margins. When Adaptive Inroute Selection (AIS)  
14                                  feature is not present in the network, the remote terminal shall pick an inroute  
15                                  group that supports the "best" available inroute type in terms of throughput.

16                                  When AIS is enabled in the network, the IPoS terminal shall select the inroute  
17                                  group using the AIS procedure described in 4.11.8.

### 18   **4.11.4    Inroute Data Transmission Sequence**

---

#### 19   **4.11.4.1    Overview**

---

20                                  As subsection 4.4.3 describes, the IPoS system does not use the concept of a user  
21                                  access session. Once a remote terminal has completed the start-up procedure  
22                                  (see subsection 4.4.2), it is always ready to transmit or receive data. An  
23                                  operational terminal can receive IP packets from an outroute at any time. It can  
24                                  also receive packets to be transmitted on the inroute at any time, but if it is idle  
25                                  (i.e., has not transmitted data on the inroute for some period of time), it must  
26                                  follow procedures for becoming active, sending data, and then returning to the  
27                                  Idle state. The following subsections describe these procedures.  
28

#### 29   **4.11.4.2    Bandwidth Request and Acknowledgment**

---

##### 30   **4.11.4.2.1   Aloha Logical Channel Selection**

---

31                                  If a remote terminal has just started operation or if it has transmitted data and  
32                                  returned to the Idle state, it must request a bandwidth assignment from the hub  
33                                  before it can transmit data on the inroute. To do this, it follows these steps:  
34

- 35                                  1. Selects an inroute group that contains one or more logical channels for  
36                                  Aloha bursts.
- 37                                  2. Randomly selects *two* specific Aloha logical channels (defined by their  
38                                  carrier frequency and timeslots) on which to transmit an Aloha BAR.  
39                                  These logical channels may be on the same inroute channel or they may

1 be on different channels, but they must be sufficiently separated in time  
2 to allow the remote terminal to retune the inroute transmit frequency and  
3 transmit two bursts.

#### 4 **4.11.4.2.2 Aloha Request Transmission**

---

5 Once the IPoS terminal has selected two Aloha logical channels on which to  
6 transmit its bandwidth request, it sends the *same* BAR in the two logical  
7 channels. The only difference in the contents of the two bursts is the fields that  
8 indicate the frame and slot numbers in which the burst was transmitted and the  
9 CRC. Sending the bandwidth request twice is called Diversity Aloha. This  
10 technique decreases the likelihood that *both* requests will collide with other  
11 Aloha requests while keeping approximately the same Aloha channel throughput  
12 as a single-transmission logical Aloha channel.

13 The following fields are of particular importance in the Aloha requests:

- 14 • Remote Serial Number: This is how the hub identifies the remote  
15 terminal and how it determines the unicast MAC address used in data  
16 packets sent to this terminal.
- 17 • Backlog: This tells the hub how much data the remote terminal has  
18 remaining to be sent. This helps the hub allocate inroute bandwidth to  
19 terminals in proportion to the amount of data that they have to send.
- 20 • Encapsulated Datagrams: The terminal can send the first segment of the  
21 data that it has to send within the Aloha request itself. If the Aloha  
22 logical channels are configured to be large enough, the remote terminal  
23 may be able to send a complete transaction within the Aloha burst,  
24 depending on the application.
- 25 • Reset Indication: This Adaptation field gives the hub the remote  
26 terminal's IP address and the IP address of the IP packet processor within  
27 the hub, which should receive the packets from this remote. This second  
28 address is set in the terminal's Initial Configuration parameters (see  
29 subsection 4.13). The reset indication adaptation field contains IPoS  
30 remotes capabilities.

#### 31 **4.11.4.2.3 Bandwidth Request Acknowledgment**

---

32 If the hub receives either of the remote terminals' two Aloha requests, it sends a  
33 single ICAP acknowledging receipt of one of the Aloha packets. The Aloha  
34 Acknowledgment command can acknowledge receipt of Aloha packets from a  
35 number of terminals in a single packet. Then, each remote terminal has to search  
36 each Aloha Acknowledgment command to see if its serial number is listed. If it  
37 is listed, the hub has received the Aloha request successfully.

38 If a remote terminal does not receive an ICAP acknowledging receipt of one its  
39 two Aloha transmissions within a timeout period, the terminal waits a random  
40 time (a random exponential backoff) and then transmits its Aloha request again.

### 1 **4.11.4.3 Bandwidth Allocation**

---

2 When the hub receives an Aloha bandwidth request from a remote terminal, it  
3 will begin sending the remote terminal BAPs, designating a frame number,  
4 starting slot number, and burst duration where the terminal may transmit. The  
5 hub sends BAPs for inroute frame N such that the remote terminal will always  
6 receive the BAP at least two frames before it needs to transmit data in response  
7 to the allocation arriving at the hub in frame N. The exact "lead time" between  
8 receipt of the BAP and the inroute frame being allocated depends on the value of  
9  $T_{HO}$   
10 (see subsection 4.11.1.1).

11 The hub typically sends one or more BAPs every frame time, 45 msec, allocating  
12 bandwidth for a particular frame, N, in the future. A BAP can assign bandwidth  
13 to more than one terminal that is using the same inroute group, so each remote  
14 terminal has to check each BAP to see if there is an allocation for an AssignID  
15 that matches the one that the terminal received when its Aloha bandwidth request  
16 was acknowledged.

17 The hub has to determine how to assign the inroute bandwidth based on the  
18 Aloha requests that it has received from remote terminals and the amount of data  
19 (shown in the Backlog field) that each remote terminal has to be sent. The hub  
20 generally assigns more bandwidth to terminals that have the highest backlog.  
21 However, the hub may give priority to remote terminals that have small amounts  
22 of data remaining since this data may be part of a short interactive transmission.  
23 If a terminal's backlog goes to zero, the hub does not immediately stop allocating  
24 bandwidth to the terminal. Depending on Configuration parameters, the hub may  
25 assign bursts at increasing intervals, say every other frame, then every fourth  
26 frame, etc., which allows the terminal to resume data transmission without  
27 having to send an Aloha burst. When the hub has not given a remote terminal a  
28 bandwidth assignment for a configurable number of frames, it moves the remote  
29 terminal's state to Idle and stops sending bandwidth assignments altogether until  
30 it receives another Aloha request from the terminal.

### 31 **4.11.4.4 Inroute Data Transmission**

---

32 A remote terminal must transmit a burst for each bandwidth allocation that it  
33 receives. If it has data to send, it sends as much of it as it can in the allocated  
34 burst. If it receives an allocation and has no data to send, it sends a null data  
35 packet. When the remote terminal is sending inroute data, it sends a Backlog  
36 field so that the hub will be able to judge how much bandwidth to allocate to this  
37 terminal.

38 A remote terminal sends the initial byte sequence number and the number of data  
39 bytes in each data burst that it sends. The byte sequence number starts at zero in  
40 the Aloha burst that requests bandwidth and in the next burst increases by the  
41 number of data bytes sent in the previous data burst. The byte sequence number  
42 field is 16 bits or 24 bits long depending on terminal's class and may roll over, if  
43 necessary. The hub sends an IAP for each inroute frame with a bitmap matching  
44 the corresponding BAP, indicating which bursts were received with correct  
45 CRCs. If a terminal receives an IAP indicating that its transmission for that burst

1 was not received correctly at the hub, or if the remote does not receive an IAP  
2 within 16 frame times after it transmits a burst, it resends the data in the missed  
3 burst with the same byte sequence number as the one in the missed burst. Note  
4 that because the remote terminal receives varying burst assignments, it may be  
5 forced to send more bytes than were contained in the missed burst. The hub must  
6 detect the duplication and discard the duplicated bytes. When the remote  
7 resumes transmission, it continues from where it left off and transmits normally.  
8 This selective transmission scheme allows the invalid transmission to resume  
9 quickly and efficiently when the hub misses an inroute burst.

10 Note that the retransmission in acknowledged operation is on a burst-by-burst (or  
11 segment-by-segment) basis – not on an IP packet basis. The ensured delivery on  
12 the inroute operates below the level of the IP Packet Reassembly function.

#### 13 **4.11.4.5 Transition to Idle State**

---

14 If a remote terminal does not receive a BAP with an assignment for its AssignID  
15 for a configurable number of consecutive frames, it transitions to the Idle state.  
16 This means that if the terminal currently has data to be transmitted or receives  
17 data in the future to be transmitted on the inroute, it will have to send another  
18 Aloha request as described above, starting with subsection 4.11.4.2.1, before it  
19 can resume sending data on the inroute.

20 While in the Idle state, the remote terminal prepares for the next ranging or  
21 Aloha access by obtaining the parameters every fourth frame in the superframe.  
22 These parameters will allow random-weighted selection among all the inroute  
23 groups advertised over the outroute. The selection of the inroute group involves  
24 the following initial steps:

- 25 1. Receive and process the IGDP messages.
- 26 2. Select the inroute groups that have transmission rates and coding  
27 methods supported by the terminal.
- 28 3. Eliminate any inroute groups that do not contain the type of unallocated  
29 channel, ranging or Aloha, required by the remote terminal. A value 0 in  
30 the Ranging\_metric field indicates that the inroute group is unavailable  
31 for ranging; a value 0 in the bandwidth (Aloha)\_metric indicates that the  
32 inroute group is not available for Aloha requests.

#### 33 **4.11.5 Contention Channel Access Procedures**

---

34 Contention access procedures are used by the remote terminals to transmit over  
35 the inroute unallocated logical channels defined in subsection 4.10.1. These  
36 unallocated logical channels are made up of slots or group of slots within the  
37 inroute physical channels. The IGDP sent by the hub specifies the current  
38 locations (frequency and timeslots) of these unallocated channels. The  
39 unallocated channels are shared by multiple remote terminals on a contention  
40 basis, also designated as Slotted Aloha or random access.

1 Two types of structures are defined in IPoS for access on the inroute unallocated  
2 channels depending on whether the unallocated channels are designated for  
3 ranging or Aloha BARs. The communications procedure for accessing these two  
4 types of unallocated channels is the same contention access procedure described  
5 below despite the different burst lengths, apertures, and MAC formats that might  
6 be used for accessing these two types of unallocated channels.

7 When a remote terminal needs to transmit over an unallocated channel, it uses the  
8 following steps:

- 9 1. Performs a weighted selection based on the value of the metric field that  
10 pertains to the type of unallocated channel, Ranging\_metric or  
11 Bandwidth (Aloha)\_metric, to select an inroute group on which to  
12 transmit.
- 13 2. If a ranging channel is required, the remote terminal selects one of the  
14 defined ranging slots randomly. If an Aloha channel is required, the  
15 remote terminal selects two of the defined traffic slots randomly, with the  
16 constraint that the second slot does not overlap with the first in time and  
17 that the time separation between slots is sufficient to allow the terminal  
18 to change transmit frequencies, if required.
- 19 3. The terminal transmits the Ranging Request or BAR into the selected  
20 timeslot(s).
- 21 4. The remote terminal waits for the ICAP from the chosen group and for  
22 the inroute frame(s) in which the burst(s) were transmitted.
- 23 5. If the transmission was for ranging, the ICAP shows whether the hub  
24 received the Ranging Request. If the ICAP indicates that the hub has  
25 received the Ranging Request, the remote terminal proceeds to execute  
26 the ranging process as described in subsection 4.11.2.4. If the ICAP  
27 indicates that the hub did not receive the Ranging Request, the remote  
28 terminal goes back to step 1 after a time delay that is a random  
29 exponential delay whose parameters are contained within the IGDP.
- 30 6. If the burst is an Aloha BAR, the ICAP shows whether or not the hub has  
31 received either of the two Aloha transmissions. If the ICAP indicates  
32 that the hub has received any of them, the remote terminals proceed to  
33 execute the data transmission process as describe in subsection 4.11.4.4.  
34 If the IAP indicates that the hub did not receive either of the two Aloha  
35 bursts, the terminal goes back to Step 1 after a time delay that is a  
36 random exponential delay whose parameters are contained within the  
37 IGDP.

#### 38 **4.11.6 Packet Filtering Procedures**

---

39 The IPoS outroute may contain a great deal of information that is not intended to  
40 be processed by a given remote terminal. To reduce the remote terminal's  
41 processing load, packet filters may be applied to the outroute to discard transport  
42 streams that are not intended for a particular remote terminal.

- 1 Packet filters are applied in the following order:
- 2 1. Filters to discard outroute packets that are not sent on transport streams  
3 associated with PSI tables and outroute logical control and traffic  
4 channels supported in the IPoS system as defined in subsection 4.8.2.
- 5 2. Filters to discard outroute packets that do not contain one of the  
6 following MAC addresses:
- 7 a) The remote terminal's unique unicast address (see  
8 subsection 4.9.1.3.1)
- 9 b) The multicast address to which the remote terminal might be  
10 configured to process multicast groups (see subsection 4.9.1.3.2)
- 11 c) The superframe numbering address (see subsection 4.9.1.3.3)
- 12 d) The return broadcast address (see subsection 4.9.1.3.4)
- 13 e) The return group address for the group with which the terminal is  
14 active (see subsection 4.9.1.3.5)
- 15 f) The unicast conditional access address unique to the remote terminal  
16 (see subsection 4.9.1.3.6)
- 17 g) The multicast conditional access address for the group with which  
18 the terminal is active (see subsection 4.9.1.3.7)
- 19 All other outroute packets shall be processed by the remote terminals to see if  
20 further processing is required.

#### 21 **4.11.7 Outroute Adaptive Coding and Modulation (ACM)** 22 **Procedures**

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23 The availability of multiple coding and modulation schemes in DVB-S2  
24 standards paves the way to allow different modulation and error protection levels  
25 to be used and changed on a frame-by-frame and user-by-user basis. This, when  
26 combined with the use of a return channel to achieve a closed loop feedback can  
27 provide Adaptive Coding and Modulation. ACM allows a system to dynamically  
28 vary the modulation and coding (MODCOD) of the outroute to be optimized for  
29 each individual remote terminal depending on its link condition. Figure 4.11.7-1  
30 depicts the ACM procedure.



**Figure 4.11.7-1 Adaptive Coding and Modulation**

IPoS ACM procedures consist of the following:

- Outroute channel estimation: IPoS remote monitors the quality of its DVB-S2 outroute reception and performs link quality estimations.
- MODCOD selection: IPoS remote determines the optimal MODCOD for the current outroute link conditions.
- MODCOD request: IPoS terminal conveys to the IPoS Hub its optimal MODCOD.

**4.11.7.1 Outroute Channel Estimation**

The Es/No estimator in the IPoS terminal shall estimate the received link quality to an accuracy that is less than equal to 0.2 dB. The estimation procedure at the IPoS terminal is outside the scope of this specification.

**4.11.7.2 MODCOD Selection**

IPoS remote's MODCOD selection process is also known as link adaptation procedure. The link adaptation procedure attempts to maximize the availability requirements by changing the modulation scheme, the code rate or both in response to varying propagation losses and impairments on the outroute. The optimal MODCOD selection process is accomplished by monitoring outroute SINR and comparing the averages outroute SINRs with the threshold SINRs, of all available MODCODs, in the trajectory table.

A trajectory table (shown in 4.11.7.2-1) is an ordered list of MODCODs (modulation and coding rate pair) and their minimum, ingress and egress thresholds and the ordering is done in descending order of minimum thresholds required.

**Table 4.11.7.2-1. Example of an ACM Trajectory Table**

Modulation	Code Rate	Minimum SINR (dB)	Ingress SINR (dB)	Egress SINR (dB)
8PSK	8/9	10.69	12.20	11.69
8PSK	5/6	9.35	11.10	10.35
8PSK	3/4	8.00	10.00	9.10
8PSK	2/3	5.73	8.50	6.73
QPSK	2/3	3.10	3.60	4.10
QPSK	1/2	1.00	1.50	2.00

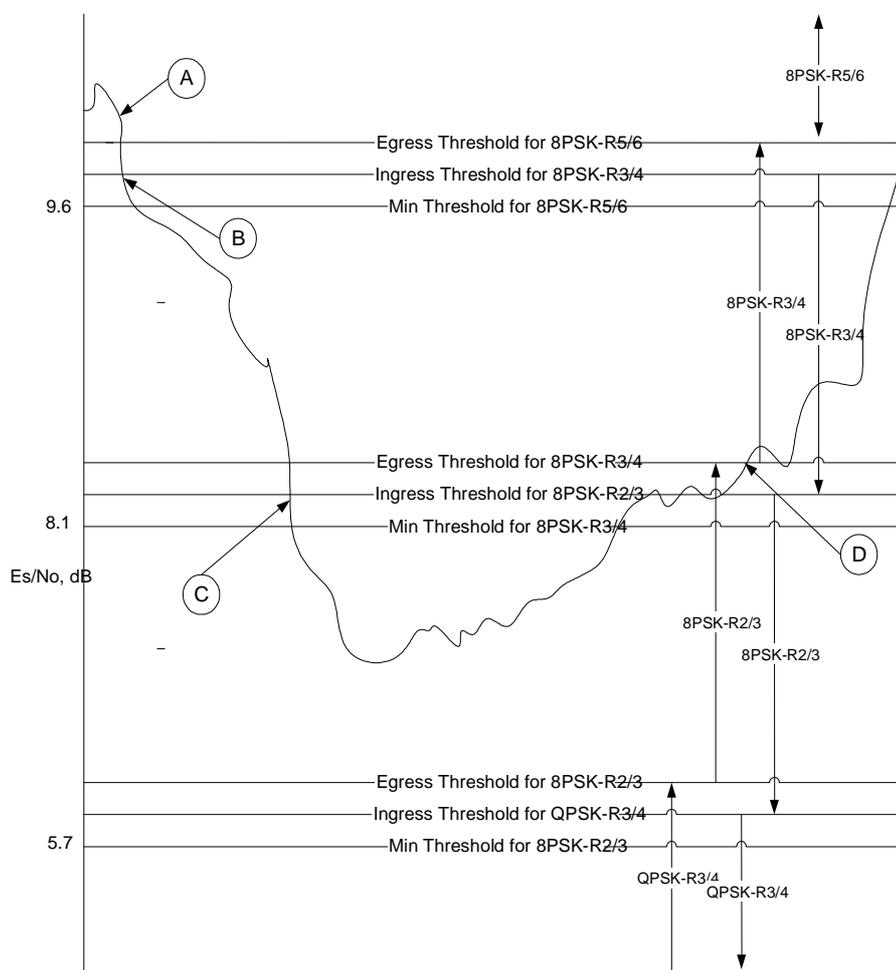
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An exemplary MDOCOD selection procedure is described next using Figure 4.11.7.2-1. The Ingress and Egress thresholds provide hysteresis to aid in avoiding ping-pong effect of selection between adjacent MODCODs.



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6

**Figure 4.11.7.2-1 MODCOD Selection Ingress and Egress**

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If the slope of the SINR is negative, the ingress thresholds are used, and if positive the egress thresholds are used.

1 The thresholds are the minimum threshold for a particular MODCOD which is  
2 the operating point to achieve a  $10^{-7}$  PLR, the ingress threshold which is the  
3 fallback threshold and the egress threshold which is fall forward threshold. At  
4 startup, the IPoS terminal selects the least robust MODCOD whose egress  
5 threshold value is less than or equal to the current averaged outroute SINR.  
6 Referring to Figure 4.11.7.2-1, if a fade profile is as shown the IPoS terminal  
7 would start out at 8PSK R5/6 at point (A). The remote terminal would operate at  
8 this rate until the measured SINR falls below the ingress threshold for 8PSK  
9 R3/4 at point (B). At this point terminal selects MODCOD 8PSK R3/4 and  
10 requests from the Hub 8PSK R3/4 modulation and coding henceforth. If the fade  
11 continues and falls below the ingress threshold for 8PSK R2/3 at point (C), the  
12 terminal would request MODCOD for 8PSK 2/3, and henceforth. If the fade  
13 starts decreasing as shown and the SINR crosses the egress threshold of the  
14 8PSK R $\frac{3}{4}$  (D) the terminal would select MODCOD 8PSK R3/4. The egress and  
15 ingress thresholds are selected in order to provide appropriate hysteresis to prevent  
16 a terminal from thrashing between adjacent MODCODs in the trajectory table  
17 due to instantaneous scintillation and SINR measurement errors.

### 18 **4.11.7.3 MODCOD Request**

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19 MODCOD request loop consists of the following processes:

- 20 • IPoS terminal sends MODCOD (the currently selected optimal  
21 MODCOD) change request to the IPoS Hub on the inroute.
- 22 • Hub realizes user requested MODCOD and applies the new MODCOD  
23 on its traffic henceforth.
- 24 • Terminal receives traffic on the new requested MODCOD.

25 The IPoS terminal requests its optimal MODCOD from the Hub by sending an  
26 ACM message via the adaptation field of an inroute burst. The ACM message  
27 contains the requested MODCOD value and the current averaged outroute SINR.  
28 The ACM message or MODCOD request can be sent by a terminal either on an  
29 unallocated channel using Aloha access method or on an allocated channel using  
30 stream access method.

31 Whenever an IPoS terminal decides to request a specific MODCOD from the  
32 Hub, it can be in any one of the following states with respect to its inroute  
33 TDMA allocations.

- 34 • The terminal has an active session on the inroute and is sending inroute  
35 data
- 36 • The terminal is idle on the inroute.

37 When an IPoS terminal is active on the inroute and the terminal determines it  
38 needs to send a new MODCOD request, the terminal sends the request on the  
39 next allocated inroute burst using an adaptation header. In the case MODCOD  
40 change is from a lower to a higher protection, the terminal must defer sending a  
41 MODCOD change request for at least a configurable number of frames of not

1 receiving a stream allocation and may send the MODCOD change request  
2 anytime using an Aloha burst after the configurable number of frames or longer  
3 of not receiving a stream allocation. This Aloha burst contains the requested  
4 MODCOD and SINR values and that is transmitted even when the terminal has  
5 an active TDMA session.

6 When an IPoS terminal is idle but the current SINR measurement needs a new  
7 MDOCOD request, it may send the MODCOD request using an Aloha burst on  
8 an unallocated channel or waits for user data to be queued up and sends the  
9 MODCOD request with the ALOHA bandwidth request message.

10

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## 12 **4.11.8 Adaptive Coding**

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13 Adaptive Coding feature provides the ability to receive bursts from different  
14 coding rates on a single inroute using a particular coding method at the IPoS  
15 demodulator. With adaptive coding an inroute group is composed of inroutes at a  
16 specified symbol rate (e.g. 256 Ksps) and coding method (Turbo or LDPC), and  
17 at a specific symbol rate, and spreading factor for a spreading enabled group.  
18 When an IPoS terminal transmits on an inroute from an inroute group that  
19 supports Adaptive Coding, the terminal transmits at the best coding rate that it  
20 can achieve at this time. For some remotes this may be rate 2/3 and for other  
21 remotes this may be rate 4/5.

22 An adaptive coding inroute group specifies the symbol rate, coding method,  
23 spreading factor if spreading is used and coding rate for the default rate which is  
24 normally the most robust coding rate. An IPoS terminal using Adaptive coding  
25 ranges on the default coding rate (for example rate 1/2) and must estimate the  
26 ranging parameters such as transmission power for the other coding rates (e.g.  
27 2/3 and 4/5) within an accuracy of 0.2 dB.

28 Adaptive coding is supported on both Turbo and LDPC inroutes. Adaptive  
29 Coding support can be enabled or disabled at per inroute group level. The IPoS  
30 Hub advertises adaptive coding support on a group via the Inroute Group  
31 Definition (IGDP, refer to 4.12.6) message. An IPoS terminal supporting adaptive  
32 coding shall use this feature on that inroute group. An IPoS terminal not  
33 supporting adaptive coding shall use the default coding rate advertised in the  
34 IGDP message.

## 35 **4.11.9 Adaptive Inroute Selection (AIS) and Closed Loop 36 Power Control (CLPC) Procedures**

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37 Adaptive Inroute Selection (AIS) feature enables an IPoS terminal to select an  
38 optimal symbol rate, FEC coding rate, and transmission power for its inroute  
39 transmission as a function of a configured trajectory table and information it  
40 learns about its transmission from a closed loop power control (CLPC) algorithm.

1 AIS provides an inroute Trajectory Table that specifies the inroute rates and the  
2 required inroute power threshold for each rate.

3 Each IPoS remote terminal independently decides the most optimal symbol rate,  
4 FEC code rate, and power level to satisfy the QoS requirements. An IPoS  
5 terminal using AIS monitors the outroute fade in conjunction with the inroute  
6 power feedback to make decisions on when to ingress (fallback) or egress (switch  
7 up) to inroute rates in the Trajectory Table. The terminal uses the outroute SINR  
8 measurement to estimate its uplink fade, and the inroute SINR feedback from the  
9 IPoS hub to update its power control loop. Terminals adjust their power every  
10 inroute frame. The IPoS hub measures the inroute SINR and feeds the  
11 measurement per frame per inroute burst via the "Inroute SINR Feedback  
12 Packet" to the appropriate remote.

13 The following terminal procedures are important for the correct operation of  
14 AIS/CLPC:

- 15 • Ranging
- 16 • Selection of an optimal inroute rate with an optimal power to send Aloha  
17 bandwidth request message for becoming active on a stream inroute
- 18 • While active on stream inroutes, continuously update transmission  
19 powers using CLPC
- 20 • While active on stream inroutes, selection of a new ingress or egress rate  
21 to track weather change.

22 The following elements are involved to achieve the above procedures:

- 23 • Trajectory table
- 24 • Outroute SINR measurement to estimate the uplink attenuation
- 25 • Inroute SINR feedback

#### 26 **4.11.9.1 Trajectory Table**

---

27 AIS trajectory table is an ordered list of allowable symbol rate-code rate pairs.  
28 Each entry of the trajectory table corresponding to a symbol rate-code rate pair  
29 contains the minimum and target in-route SINR threshold, and inroute coding  
30 method which is either Turbo with BCH trailer or LDPC with CRC-16 trailer. A  
31 trajectory table may contain inroute rates with both Turbo and LDPC coding  
32 methods. An IPoS terminal supporting only Turbo coded inroutes uses Turbo  
33 coded with BCH trailer inroutes from the trajectory table. An IPoS terminal  
34 supporting both Turbo and LDPC inroutes uses either Turbo coded with BCH  
35 trailer inroutes or LDPC coded with CRC-16 inroutes depending on the coding  
36 method with which this terminal is configured.

37 In the event a terminal needs to fallback to a lower rate or switch up to a higher  
38 rate, it finds out the appropriate rate that exists in the trajectory table. A choice of  
39 a more robust symbol-code rate pair, than the one being used, triggers an ingress

1 (fallback) request. A choice of a less robust symbol-code rate pair triggers an  
2 egress (switch up) request.

3 A few examples of Trajectory Tables follow. A different trajectory table may be  
4 required for a specific scenario. Some example scenarios are whether Adaptive  
5 Coding to be used or maximum spectral efficiency to be achieved or maximum  
6 throughput to be required.

7 When Adaptive Coding is enabled, the trajectory table is an ordered list of the  
8 highest symbol rate and least robust code rate to the lowest symbol rate and most  
9 robust code rate. This ordered list groups like symbol rate and switches code rate  
10 before changing the symbol rate. These tables ensure that the remote will switch  
11 down using code rates before switching symbol rate, to remain in the same  
12 inroute group. One such trajectory table is shown in Table 4.11.9.1-1.

13 **Table 4.11.9.1-1. Inroute Trajectory Table – Adaptive is enabled**

Symbol Rate (Ksps)	Code Rate	Minimum SINR (dB)	Target SINR (dB)
1024	4/5	67.50	69.50
1024	2/3	65.50	67.50
1024	1/2	62.90	64.90
512	1/2	59.89	61.89

14  
15 When Adaptive Coding is disabled, the procedure is based on maximizing either  
16 the spectral efficiency or the throughput. Table 4.11.9.1-2 and 4.11.9.1-3 show  
17 examples of trajectory tables that maximize spectral efficiency and throughput  
18 respectively.

19 **Table 4.11.9.1-2. Inroute Trajectory Table – Maximize Spectral Efficiency**

Symbol Rate (Ksps)	Code Rate	Minimum SINR (dB)	Target SINR (dB)
1024	4/5	67.50	69.50
512	4/5	64.49	66.49
256	4/5	61.48	63.48
256	2/3	59.18	61.18

20  
21 **Table 4.11.9.1-3. Inroute Trajectory Table – Maximize Throughput**

Symbol Rate (Ksps)	Code Rate	Minimum SINR (dB)	Target SINR (dB)
1024	4/5	67.50	69.50
1024	2/3	65.50	67.50
1024	1/2	62.90	64.90
512	1/2	59.89	61.89

22  
23 **4.11.9.2 Outroute Measurement**

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24 The outroute-downlink SINR is continuously measured at the IPoS remote  
25 terminals. This is used by the terminal to estimate the inroute-uplink attenuation.

1 The estimation procedure of the inroute attenuation from the outroute fade  
 2 obtained from downlink SINR measurement is outside of the scope of the IPoS  
 3 specification. However, an IPoS terminal shall estimate the attenuation within  
 4 accuracy of 0.2 dB. One method could be to compute the short-term and the  
 5 long-term averages of the outroute SINR using short-term and long-term filters  
 6 respectively, where the long-term filter tracks the clear sky outroute SINR and  
 7 the short-term filter tracks the atmospheric attenuation and scintillation. The  
 8 outroute-downlink fade is then calculated by subtracting the short-term average  
 9 from the long-term average SINRs and finally the inroute-uplink fade is  
 10 estimated from the outroute fade using a conversion factor.

### 11 **4.11.9.3 Inroute SINR Feedback**

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12 The link layer of IPoS hub receives the inroute SINR measurement from the  
 13 physical layer. This measurement is done on a per frame per inroute burst basis.  
 14 The link layer feeds back the measured SINR to the terminal on the outroute.

15 When Closed Loop Power Control is enabled on an inroute group, the IPoS Hub  
 16 provides SINR estimation on every received Aloha or stream burst to the remote  
 17 terminals. For unallocated bursts, the Aloha Acknowledgement ICAP IPoS  
 18 message from the hub contains the estimated SINR value. For allocated (stream)  
 19 bursts, the Inroute SINR Feedback Packet (ISFP) is used by the Hub to send the  
 20 SINR estimation.

### 21 **4.11.9.4 Ranging**

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22 During installation, the ranging is done at maximum power on the most robust  
 23 symbol rate-code rate pair advertized on the Inroute Group Definition packet.  
 24 Once commissioned, the IPoS terminal receives the AIS trajectory table. If  
 25 "Single Rate Ranging" feature is enabled, then ranging is done only on the most  
 26 robust symbol rate-code rate pair, and the ranging parameter for all other symbol-  
 27 code rate pairs in the trajectory table are derived theoretically from the  
 28 measurement of the most robust pair used for ranging. If "Single Rate Ranging"  
 29 feature is not enabled, then the IPoS terminal ranges through all symbol rate-code  
 30 rate pairs in the trajectory table.

31 The outroute SINR is averaged during ranging. After a successful ranging, the  
 32 following parameters are obtained.

- 33 1.  $\frac{E_s}{N_0}(s_R, c_R)$  Inroute ranged  $E_s/N_0$  for the symbol rate-code rate pair  
 34 (SR, CR) used for ranging
- 35 2.  $PCW_R$  Power control word used for ranging
- 36 3.  $\left[ \frac{C}{N} \right]_{OR}^{R-avg}$  Average value of the outroute SINR

37 The ranging parameters for the other symbol-code rate pairs in the trajectory  
 38 table is derived as

$$\frac{E_s}{N_o}(s,c) = \frac{E_s}{N_o}(s_R,c_R) + \left[ \left[ \frac{E_s}{N_o}(s,c) \right]_{IR}^{\min} - \left[ \frac{E_s}{N_o}(s_R,c_R) \right]_{IR}^{\min} \right]$$

$$\left[ \frac{C}{N_o}(s,c) \right]_{IR}^R = \left[ \frac{E_s}{N_o}(s,c) + (10 \cdot \log_{10}(s_R) - 10 \cdot \log_{10}(s)) \right] + 10 \cdot \log_{10}(s)$$

1

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### 3 **4.11.9.5 Power Adjustment**

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When an IPoS terminal has an active inroute data session on an allocated stream channel, it receives the SINR feedback from the hub corresponding to each allocated burst sent on the inroute. The terminal calculates the power control error as the difference between the target SINR threshold in the trajectory for the symbol rate and code rate pair on which burst has been sent and the SINR value received from the Hub.

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A power control process runs in the IPoS terminal which tracks power control error using digital filters and calculates the change in power relative to the ranged value for the desired symbol rate-code rate pair. Based on the calculated power change, the terminal determines its transmission power for the next frame. As this procedure is implementation dependent, it is outside of the scope of this specification. However, an IPoS terminal shall determine its transmission power within a specified accuracy such that the measured Es/No at the hub for its transmitted bursts shall be +0.2 dB compared to the desired value.

18

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If the IPoS terminal cannot meet the threshold defined in the trajectory table for the current symbol rate-code rate pair even after adjusting power or it is eligible to meet threshold for a less robust symbol rate-code rate pair, it executes ingress or egress procedure as specified in subsection 4.11.9.6.

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### **4.11.9.6 Inroute Rate Egress or Ingress**

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This procedure is called "Link Adaptation" procedure which determines the optimal symbol rate and code rate an IPoS remote terminal shall transmit its inroute bursts. A choice of a more robust symbol rate-code rate pair, than the one being used, triggers an ingress request. A choice for a less robust symbol rate-code rate pair triggers an egress request.

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If the atmospheric condition deteriorates, the terminal receives lower Es/No measurement from the Hub and adjusts power to combat the fade. When there is no more room for power adjustment, the following procedures are executed by the terminal.

32

33

1. Select the first row of the trajectory table. Let its symbol rate-code rate pair be  $(s,c)'$

34

35

36

2. If the target  $C/N_o$  of this new symbol rate-code rate pair  $(s,c)'$  is smaller than the target  $C/N_o$  of the current rate symbol rate-code rate pair  $(s,c)$ , then proceed to step 5, otherwise proceed to step 3

- 1 3. If there are more rows in the the trajectory table, then proceed to step 4,  
2 otherwise  $(s,c)$  represents the most robust symbol rate-code rate pair; no  
3 further transitions are allowed
- 4 4. Select the next row of the trajectory table. Let its symbol rate-code rate  
5 pair be  $(s,c)'$  and jump to 2
- 6 5. After applying an appropriate hysteresis select the symbol rate-code rate  
7 pair  $(s,c)'$  for transmission. If the change is only in the coding rate and  
8 adaptive coding is enabled, then the terminal starts transmitting on the  
9 new code rate remaining on the same inroute channel and using its  
10 existing bandwidth allocations. Otherwise, the terminal goes inactive and  
11 sends bandwidth request through Aloha on a new inroute group

12 The IPoS terminal computes power change from the Hub SINR feedback as  
13 specified in subsection 4.11.9.5. It also maintains a cumulative power change  
14 value. When the atmospheric condition starts improving, the following  
15 procedures are observed in the IPoS terminal to select a less robust symbol rate-  
16 code rate pair.

- 17 1. If this change in power is positive, then select the first row of the  
18 trajectory table. Let its symbol rate-code rate pair be  $(s,c)'$
- 19 2. If the target  $C/N_o$  of this new symbol rate-code rate pair  $(s,c)'$  is larger  
20 than the target  $C/N_o$  of the current rate symbol rate-code rate pair  $(s,c)$ ,  
21 then proceed to step 3, otherwise jump to step 5
- 22 3. If the change in power is greater than the absolute difference in the target  
23  $C/N_o$ 's of  $(s,c)'$  and  $(s,c)$ , in the trajectory table, then proceed to step 4,  
24 otherwise go to step 5
- 25 4. After applying some hysteresis select the symbol rate-code rate pair  
26  $(s,c)'$  for transmission. If the change is only in the coding rate and  
27 adaptive coding is enabled, then the terminal starts transmitting on the  
28 new code rate remaining on the same inroute channel and using its  
29 existing bandwidth allocations. Otherwise, the terminal goes inactive and  
30 sends bandwidth request through Aloha on a new inroute group)
- 31 5. If there are more rows in the trajectory table, then proceed to step 6,  
32 otherwise  $(s,c)$  represents the least robust symbol rate-code rate pair; no  
33 further transitions are allowed
- 34 6. Select the next row of the trajectory table. Let its symbol rate-code rate  
35 pair be  $(s,c)'$  and jump to step 2

#### 36 **4.11.9.7 Aloha Channel Selection**

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37 The Aloha transmission may be due to a symbol rate or code rate change as seen  
38 in subsection 4.11.9.6 or may be due to any other reasons such as the IPoS  
39 terminal requests bandwidth to become active after an idle period. An IPoS  
40 terminal executes the following procedure to select the symbol rate-code rate pair  
41 for its Aloha transmission in the context of AIS.

- 1 1. If the Aloha transmission is due to egress or ingress then proceed to step
- 2 2. If the Aloha transmission is due to any other reason then jump to step
- 3 3
- 4 2. Send an Aloha transmission on the symbol rate-code rate pair requested
- 5 by the egress or ingress procedure
- 6 3. Select the first row of the trajectory table. Let its symbol rate-code rate
- 7 pair be  $(s,c)$ '
- 8 4. Compute transmission power using the target SINR threshold of  $(s,c)$ ,
- 9 ranged SINR on  $(s,c)$ ' and power control tracking filter. Since this
- 10 procedure is implementation dependent, the detail is outside of the scope
- 11 for this specification.
- 12 5. If the calculated transmission power indicates maximum power, then
- 13 jump to step 7, otherwise proceed to step 6
- 14 6. Send an Aloha transmission on  $(s,c)$ '
- 15 7. If there are more rows in the trajectory table, then proceed to step 8,
- 16 otherwise  $(s,c)$ ' represents the least robust symbol rate-code rate pair; no
- 17 further transitions are allowed
- 18 8. Select the next row of the trajectory table. Let its symbol rate-code rate
- 19 pair be  $(s,c)$ ' and jump to step 4.

## 20 4.11.10 Mesh Procedures

### 21 4.11.10.1 Mesh Link Layer Connectivity

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22 Figure 4.11.10.1-1 below shows the link layer connectivity of two Mesh  
23 Terminals and an IPoS hub. A DVB-S2 outroute is transmitted by the Hub. Each  
24 IPoS terminal has a single MF-TDMA transmitter which it uses to send inroute  
25 traffic to both the Hub (star) and other terminals (mesh). Each terminal also has  
26 an MF-TDMA receiver capable of receiving inroute user traffic from other  
27 terminals (mesh). The MF-TDMA receiver may listen to multiple inroutes at the  
28 same time. The Hub has a set of inroute MF-TDMA receivers for receiving  
29 (star) remote site to hub traffic sent by the terminals. In addition to receiving the  
30 star traffic, the Hub also listens to the mesh bursts sent by the terminals to extract  
31 mesh related inroute signaling information, provide feedback for closed loop  
32 power control, etc. The Mesh Resource Controller in the Hub coordinates mesh  
33 connectivity between terminals providing information to the terminals as to  
34 which inroutes to listen to to receive mesh data from other terminals.

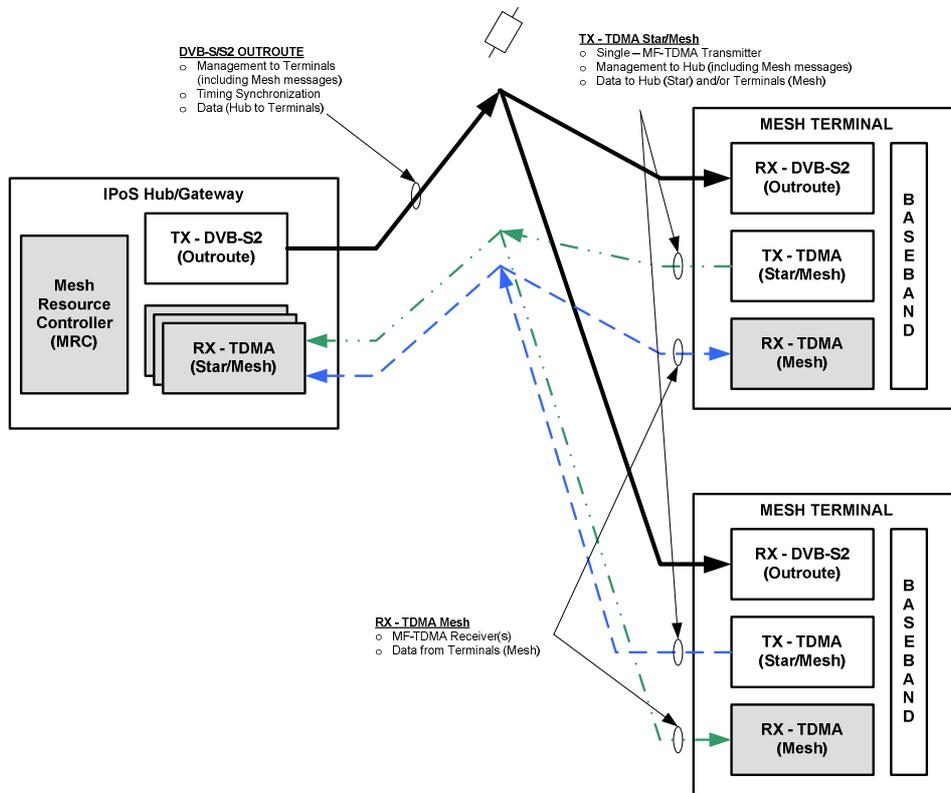


Figure 4.11.10.1-1 IPoS Star and Mesh Tx and Rx Connectivity

4.11.10.2 Mesh Message Types

IPoS uses two levels of messages pertaining to mesh operation.

- Terminal level messages are used to synchronize information between a terminal and the Mesh Resource Controller with respect to a terminal's properties and configuration.
- Mesh connection specific messages are used to setup and tear down mesh connections.

All messages include the explicit or implicit identity of the sender and receiver. In general, there are positive and negative responses for each message. All negative responses include an appropriate, very specific error indication. All messages include a sequence number field which can be used (when necessary) to detect duplicate responses when messages are delayed. The sender can set the field using whatever mechanism it wants to use. The receiver simply echoes the value back to the sender when it sends its response message. Also, as is typical, a response timer (with appropriate retry limits) is used to protect against lost messages.

Mesh messages from the terminals to the MRC are sent as adaptation headers in the IPoS MAC headers. Mesh messages may be sent in any type of burst

1 allocation, star or mesh, Aloha or stream, as long as there is enough room for the  
2 entire message.

3 Mesh messages from the MRC to the terminals are sent via Mesh  
4 Command/Acknowledgement Packet (MCAP). A terminal searches the MCAP  
5 packet for its serial number to find messages sent by the MRC to itself. A special  
6 serial number (e.g. all zeroes) is used to indicate an MRC message which is  
7 addressed to all of the terminals using this MRC. MCAP messages are sent using  
8 inroute group level MAC addressing

9 The detailed format of the various over the air mesh messages is provided in  
10 section 4.12.

### 11 **4.11.10.3 Mesh Registration**

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12 The Mesh Remote Terminal is pre-configured with the identity of other Mesh  
13 Remote Terminals that form the egress points for mesh communications. This is  
14 done by using a Community of Interest (COI) group concept.

15 A Community of Interest group is a logical set of terminals which need to  
16 connect to each other via mesh. In order for two terminals to be allowed mesh  
17 communication with each other, the terminals must belong to a common COI  
18 group. A terminal may belong to more than one COI group.

19 Once the COI groups have been determined, the terminals then are divided into  
20 subgroups. A subgroup is a set of terminals where the (COI) connectivity rules  
21 are exactly the same for each terminal in the subgroup. For example, Mesh  
22 Terminals A1 and A2 cannot be in the same subgroup as Mesh Terminal A if the  
23 latter is allowed to connect to Mesh Terminal B while the former are not. In  
24 general, the number of subgroups required is equal to the number of unique  
25 combinations of groups.

26 Once the subgroups are determined, a COI plan is defined for each subgroup. A  
27 Community of Interest (COI) plan defines the set of (COI) connectivity rules for  
28 a subgroup. The connectivity rules are used by the MRC to enforce connectivity  
29 restrictions. A terminal is configured with its COI subgroup/plan number.

30 Before a terminal can send or receive mesh traffic, the terminal must register  
31 with the Mesh Resource Controller (MRC) in the IPoS hub. The registration  
32 information sent to the MRC includes the following:

- 33 • The serial number of the terminal
- 34 • The terminal's community of interest plan number which is pre-  
35 configured in the terminal.
- 36
- 37 • The number of simultaneous inroutes that the terminal can receive at the  
38 symbol rate of the Inroute Group associated with the terminal's Plan
- 39 • A list of the IPv4 subnets supported at the remote site by the terminal

1 The following events trigger a terminal to register with the MRC.

- 2
- Terminal startup
  - 3 • An error occurs which indicates that the terminal and MRC are out of  
4 sync
  - 5 • The MRC solicits a terminal to register by sending a Register Now  
6 message to the terminal

7 At MRC startup (and whenever any relevant MRC parameter changes, etc.), the  
8 MRC sends a Register Now message to all of the terminals. The MRC repeats  
9 the Register Now message at one second intervals for N seconds. The MCAP  
10 packet is used to send the Register Now message and is sent using the inroute  
11 group's multicast address. Thus, if there is more than one inroute group  
12 supported by this Hub, the MRC also repeats the Register Now message for each  
13 inroute group.

14 The Register Now message includes a timestamp value. The timestamp is  
15 generated when the first Register Now message (for the first inroute group) is  
16 sent. Subsequent Register Now messages (sent to the same or other inroute  
17 groups) include the same timestamp as the original Register Now message,  
18 allowing terminals to determine that the messages are duplicates and, thus, only  
19 react once. The MRC may also send a unicast Register Now message to a  
20 terminal if it detects that the MRC and the terminal may be out of sync.

21 Whenever a terminal receives a Register Now message addressed to it, it deletes  
22 any in progress mesh connections it currently has and enters the [mesh]  
23 Registration State. Once the terminal has successfully registered, it enters the  
24 [mesh] Ready State. Terminal and MRC behavior with respect to operation  
25 while in the Registration and Ready States is discussed in the following sections  
26 and with an example message flows as shown in 4.11.10.2-1

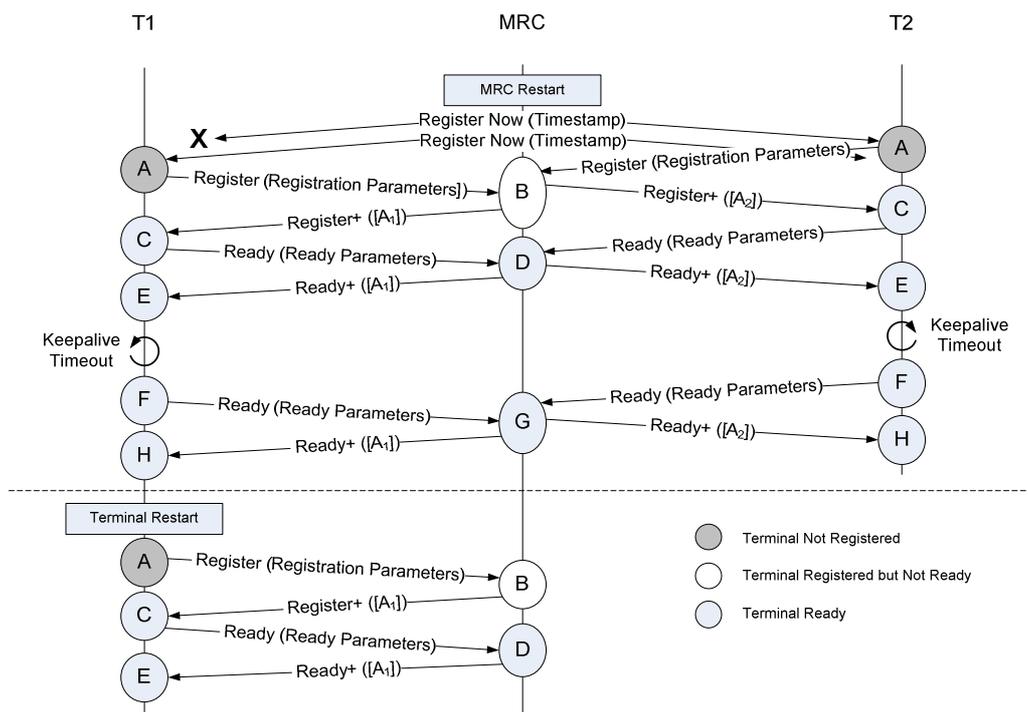


Figure 4.11.10.2-1 Mesh Terminal Registration Message Flow

### 4.11.10.3.1 Mesh Registration State Processing

The IPoS mesh registration state processing involves the following steps.

- Step A: When a mesh terminal enters the [mesh] Registration state, it starts a Registration timer. To avoid problems when all of the terminals need to register at the same time, the terminal sets the Registration timer to a random interval in between defined minimum and maximum values. When the Registration timeout occurs, the terminal sends a Register message to the MRC and restarts the Registration timer.
- Step B: When the MRC receives the Register message, it stores the terminal's information, sets the terminal's current state to Registered, responds with a positive response to the Register message and starts the Waiting for Ready timer for the terminal. The Register message response includes an Assign ID or list of the terminal's Assign IDs (one per transmitter serial number). If the MRC receives an invalid Register message, i.e. one or more of the parameters in the message is not valid, the MRC responds with a negative response to the Register message with an error indicating which specific parameter is invalid.
- Step C: When the terminal receives the positive response to the Register message, it exits the [mesh] Registration State, sends a Ready message to the MRC and starts a Response timer for the message, and enters the [mesh] Ready State. A Ready message includes the same information as a Register message. If the terminal receives no response to a Register message, i.e. a registration timeout occurs, the terminal retransmits the

1 Register message. After the first N retries (where N is defined by  
2 Registration Retries parameter), the terminal starts backing off the retry  
3 interval until a maximum backoff value is reached. If the terminal  
4 receives a negative response to its Register message, it sets its  
5 Registration timer to the maximum backed off value and periodically  
6 retries registration.

7 • Step D: When the MRC receives the Ready message, it sets the  
8 terminal's current state to Ready, stops the Waiting for Ready timer,  
9 starts the Health Check timer for the terminal and responds with a  
10 positive response to the Ready message. If the MRC receives an invalid  
11 Ready message, i.e. one or more of the parameters in the message is not  
12 valid, the MRC responds to the Ready message by sending a (unicast)  
13 Register Now message to the terminal. If the MRC does not receive a  
14 Ready message after sending a positive response to a Register message,  
15 the MRC sets the terminal's mesh state back to Not Registered, and it  
16 does not send Register now message to the terminal.

17 • Step E: When the terminal receives the positive response to the Ready  
18 message, it stops the message Response timer and starts its Keepalive  
19 timer. If the terminal receives no response to a Ready message, i.e. a  
20 (terminal level) response timeout occurs, the terminal retransmits the  
21 Ready message. After N consecutive retries (where N is defined by the  
22 Message Retries parameter) without receiving a response, the terminal  
23 deletes all of its in progress mesh connections and re-enters the  
24 Registration State.

#### 25 **4.11.10.3.2 Mesh Ready State Processing**

---

26 The IPoS mesh ready state processing involves the following steps. The MRC  
27 expects the type of terminal, and the COI plan number values to always be the  
28 same in a Ready message as they were in the last Register message received from  
29 a terminal.

30 • Step 1: While in the [mesh] Ready state, the terminal periodically sends a  
31 Ready message to the MRC and starts a Response timer for the message.  
32 The periodicity of the Ready message is configurable.

33 • Step 2: When the MRC receives the Ready message, it updates its  
34 information for the terminal, restarts the Health Check timer for the  
35 terminal and responds with a positive response

36 • Step 3: When the terminal receives the positive response to the Ready  
37 message, it stops the message Response timer and restarts the Keepalive  
38 timer.

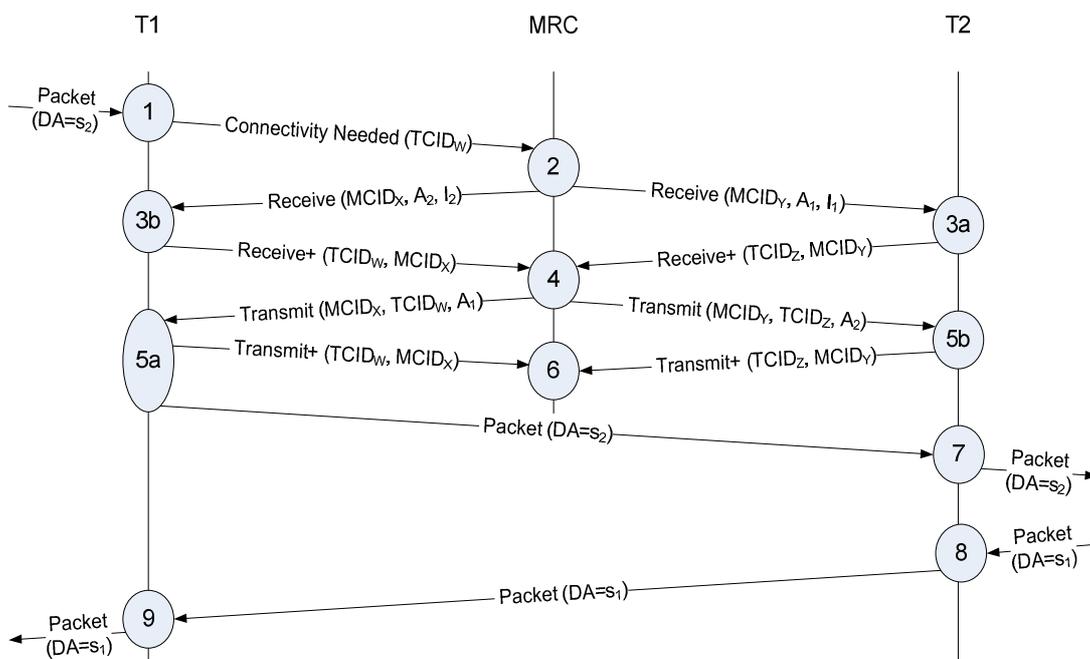
39 Note that [mesh] Ready state processing occurs continuously, independent from  
40 any mesh connection activity. Even when mesh connections are in progress, the  
41 terminal continues to periodically send Ready messages.

42

1 **4.11.10.4 Mesh Connection Setup**

2 A Mesh connection setup procedure is described using an example message flow  
 3 as shown in Figure 4.11.10.4-1 where Terminal T1 initiates a connection setup  
 4 with Terminal T2. S<sub>1</sub> and S<sub>2</sub> are subnets of Terminal T1 and T2 respectively.

5



6  
7

**Figure 4.11.10.4-1 Mesh Connection Setup Message Flow**

8

9 • Step 1: In this example, a packet arrival trigger is used to indicate  
 10 bidirectional connectivity with packets which arrive before transmit  
 11 connectivity is available. A packet is destined to address s<sub>2</sub>, (Destination  
 12 Address, DA = s<sub>2</sub>) which belongs to subnet S<sub>2</sub>. Terminal 1 (T1) assigns a  
 13 Transmitter [Mesh] Connection ID (TCID<sub>w</sub>) for the connection, and the  
 14 transmit and receive Member ID fields are both set to 0. T1 then sends a  
 15 Connectivity Needed message for s<sub>2</sub> to the MRC and starts a Response  
 16 timer for the message. Bidirectional connectivity is indicated in the  
 17 Connectivity Needed message. A unidirectional connection can also be  
 18 created.

19 • Step 2: When the MRC receives the Connectivity Needed message, it  
 20 looks up which terminal (Terminal 2) supports the subnet that contains  
 21 address s<sub>2</sub>. The MRC then checks the status of Terminal 1 (T1) and  
 22 Terminal 2 (T2) and determines if they can each listen to each other. For  
 23 bidirectional connectivity request, the MRC only sets up the required  
 24 mesh connection if both directions can be accommodated. If one  
 25 terminal can listen to the other but not vice versa, the connection is not  
 26 set up. When MRC determines that both mesh connections can proceed,  
 27 it assigns a Mesh Connection ID to each terminal (MCID<sub>x</sub> for T1 and  
 28 MCID<sub>y</sub> for T2, where X and Y are not equal). The MRC then sends a

- 1 (bidirectional) Receive message to T2 with a value of  $A_1$  for the source  
2 Assign ID and a value of  $I_1$  for the source transmit inroute. In parallel,  
3 the MRC sends a (bidirectional) Receive message to T1 with a value of  
4  $A_2$  for the source Assign ID and a value of  $I_2$  for the source transmit  
5 inroute. If the terminal receives no response to a Connectivity Needed  
6 message, which can happen if the Connectivity Needed message or the  
7 response to this message is lost, the terminal assigns a new TCID to the  
8 connection and retransmits the Connectivity Needed message. After N  
9 retries, the terminal assumes that mesh connection setup was  
10 unsuccessful. When a terminal receives a negative response to a  
11 Connectivity Needed message, it changes the transmit and receive state  
12 of the mesh connection to Blocked and starts a Block connection timer.  
13 When the Blocked Connection timer expires, the terminal deletes the  
14 mesh connection or resends the Connectivity Needed message
- 15 • Step 3a: When T2 receives the Receive message, it assigns a  $TCID_z$  for  
16 the connection and sets up its mesh receiver to listen to the indicated  
17 terminal ( $A_1$ ) via that terminal's transmit inroute ( $I_1$ ). The current  
18 receive state is set to Active and, because bidirectional connectivity was  
19 indicated in the Receive message, the current transmit state is set to Pending.  
20 (For a unidirectional Receive message, the transmit state would be set to  
21 Unused). At this point, T2 starts looking for  $A_1$  in the Bandwidth  
22 Allocation Packets being sent by the Hub and opens apertures wherever  
23  $A_1$  is assigned mesh bandwidth in order to receive the mesh packets sent  
24 by T1. T2 sends a positive Receive response message to the MRC. If T2  
25 rejects the Receive message, i.e. the MRC receives a negative response  
26 to the Receive message, mesh connection setup is considered  
27 unsuccessful. The MRC changes the state of the peer's (T1) mesh  
28 connection to 'closing' and sends a Release Connection message to the  
29 peer (T1). The MRC deletes the mesh connection for the terminal which  
30 sent the negative response and does not send a Release Connection  
31 message to the terminal which responded with the negative response  
32 since the negative response itself indicates that the terminal will delete  
33 the mesh connection.
  - 34 • Step 3b: In parallel, when T1 receives the Receive message, it changes  
35 the current receive state to Active and records the Assign ID ( $A_2$ ) and  
36 transmit inroute ( $I_2$ ) of the peer. T1 also sets up its mesh receiver to  
37 listen to the indicated terminal via its transmit inroute ( $I_2$ ). At this point,  
38 T1 starts looking for  $A_2$  in the Bandwidth Allocation Packets and opens  
39 apertures wherever  $A_2$  is assigned mesh bandwidth in order to receive the  
40 mesh packets sent by T2. T1 sends a positive Receive response message  
41 to the MRC. If T1 rejects the Receive message, i.e. the MRC receives a  
42 negative response to the Receive message, mesh connection setup is  
43 considered unsuccessful. The MRC changes the state of the peer's (T2)  
44 mesh connection to 'closing' and sends a Release Connection message to  
45 the peer (T2). The MRC deletes the mesh connection for the terminal  
46 which sent the negative response and does not send a Release  
47 Connection message to the terminal which responded with the negative  
48 response since the negative response itself indicates that the terminal will  
49 delete the mesh connection.



- 1                   • Step 8: T2 receives (from the local LAN) a packet destined to an address
- 2                   (s<sub>1</sub>) that T2 determines is a mesh destination and T2 determines that it
- 3                   already has a mesh connection with a transmit state of Active for the
- 4                   subnet (S<sub>1</sub>) which includes address s<sub>1</sub>. Therefore, T2 simply transmits
- 5                   the packet (on mesh bandwidth allocated to A<sub>2</sub>).
  
- 6                   • Step 9: T1 receives (from inroute I<sub>2</sub>) the packet, after reassembling the
- 7                   burst(s), sent by T2. T1 checks each mesh packet it receives to see if the
- 8                   destination subnet is S<sub>1</sub>. If so, it processes the packet, i.e. forwards it. If
- 9                   the destination subnet is not S<sub>1</sub>, T1 discards the packet.

10                   The IPoS hub polices the number of connection requests made by a terminal. If

11                   the terminal has used all of the connections it either can or is allowed to use, the

12                   hub will continuously reject the connection request.

13                   **4.11.10.5 Mesh Connection Teardown**

---

14                   A release mesh connection can be triggered from an IPoS mesh terminal or from

15                   the MRC.

16                   **4.11.10.5.1 Mesh Connection Release – Terminal Triggered**

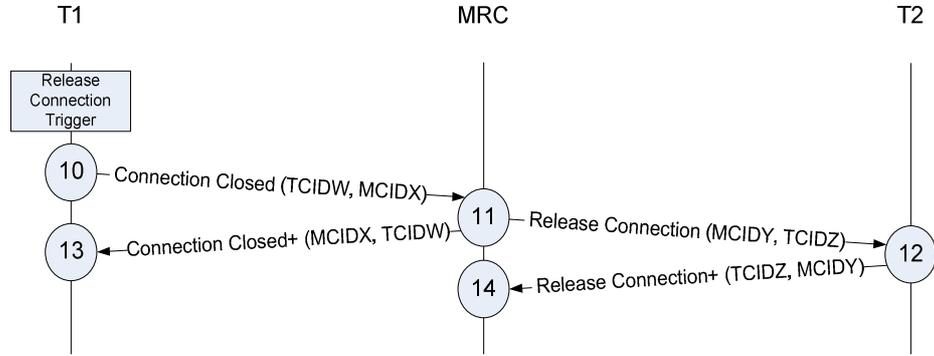
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17                   A Mesh connection release procedure triggered from a mesh terminal is

18                   described using an example message flow as shown in Figure 4.11.10.5.1-1. The

19                   example illustrated in Figure 4.11.10.5.1-1 is an extension of the example

20                   illustrated in Figure 4.11.10.4-1.



21

22                   **Figure 4.11.10.5.1-1 Mesh Connection Release Message Flow**

- 23
- 24
- 25                   • Step 10: T1 sends a (bidirectional) Connection Closed message to the
- 26                   MRC. At this point, T1 also stops opening apertures for the bursts
- 27                   assigned to A<sub>2</sub> (and, thus, stops receiving packets from T2). T1 also sets
- 28                   the current transmit state and the current receive state of the mesh
- 29                   connection for subnet S<sub>2</sub> to Closing and starts a Response timer for the
- 30                   Connection Closed message.

- 1                   • Step 11: When the MRC receives the Connection Closed message from
- 2                   T1, it sends a positive response to the Connection Closed message to T1
- 3                   and sets the current state for the subnet  $S_1$  to subnet  $S_2$  direction for the
- 4                   connection to Closed. The MRC then sends a (bidirectional) Release
- 5                   Connection message to T2 and starts a Response timer for the message.
- 6                   The MRC sets the current state for the subnet  $S_2$  to subnet  $S_1$  direction to
- 7                   Closing.
  
- 8                   • Step 12: When T2 receives the Release Connection message, it sets both
- 9                   the current transmit state and current receive state for the connection to
- 10                  Closed and stops looking for burst assignments for  $A_1$  (and stops
- 11                  receiving packets from T1). T2 sends a positive Release Connection
- 12                  response message to the MRC.
  
- 13                 • Step 13: When T1 receives the Connection Closed positive response, it
- 14                 sets both the current transmit state and current receive state for the
- 15                 connection to Closed.
  
- 16                 • Step 14: When the MRC receives the Release Connection response
- 17                 message from T2, it sets the current state for the subnet  $S_2$  to subnet  $S_1$
- 18                 direction for the connection to Closed.

#### 4.11.10.5.2 Mesh Connection Release – MRC Triggered

A release connection trigger might also occur at the MRC. In general, all MRC release connection triggers are related to recovery from errors. When an MRC release connection trigger occurs, the MRC may send a Release Connection message to each terminal (as illustrated in Figure 4.11.10.5.2-1).

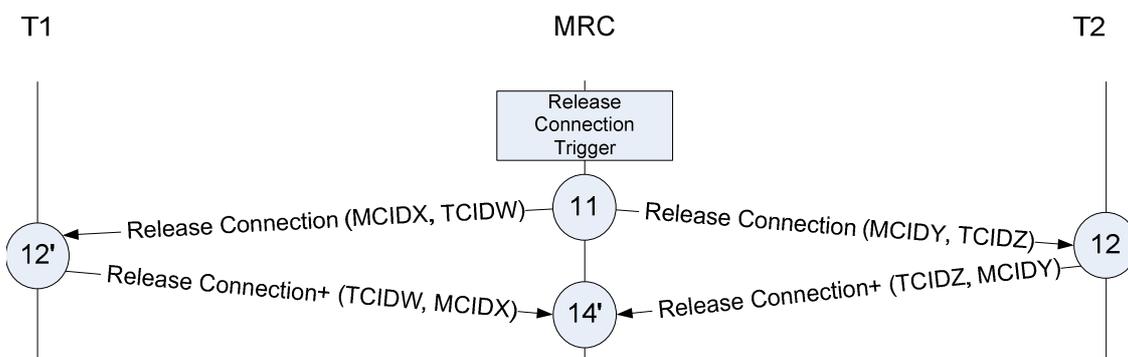


Figure 4.11.10.5.2-1 MRC Release Connection Triggered

#### 4.11.10.6 Mesh bandwidth Allocation

When an IPoS Mesh Terminal has any mesh traffic to send and does not have mesh bandwidth already allocated to it, the terminal uses variable mechanisms that depend on if the Remote Terminal is active with star bandwidth or has no

1 assigned bandwidth at all. If the Remote Terminal is already active with star  
2 bandwidth, an adaptation header will be used to request the mesh bandwidth.

3 If the Remote Terminal is inactive and only needs to request mesh bandwidth, an  
4 Aloha burst is transmitted with the 'Bandwidth Request Type' set to request  
5 Mesh capacity.

6 When a Remote Terminal already has allocated Mesh bandwidth and  
7 subsequently requires Star bandwidth or vice versa, the additional bandwidth is  
8 requested via an adaptation header called Adaptation Supplemental Bandwidth  
9 Request. The response to the adaptation supplemental bandwidth request is  
10 conveyed via an ICAP message (refer to section 4.12) directed to the requesting  
11 Remote Terminal.

12 An IPoS Mesh Terminal assumes that the hub would not provide it with  
13 conflicting allocations between mesh and star. The mesh and star assignments are  
14 given on the same frequency.

15 The IPoS Hub can assign star and mesh bandwidth on different frequencies. For  
16 such a case,, the IPoS terminal shall be able to switch btween frequencies with  
17 keeping one frame gap in between. The IPoS hub skips one frame in between star  
18 and mesh assignment on different frequencies.

19 An Assign\_ID is a 16-bit field. IPoS partitions the Assign\_ID space so that  
20 Assign\_ID intended for mesh resource allocation can be distinguished from Star  
21 Assign\_ID. The space is divided in half and the most significant bit is set to 1 to  
22 represent a Mesh Assign\_ID. Table 4.11.10.6-1 defines the partitioning of  
23 Assign\_ID field range.

24 **Table 4.11.10.6-1. Assign ID Field Range**

Assign ID range	Star or Mesh
1 – 32767	Star
32768 – 65534	Mesh

25  
26 The IPoS Hub uses assign ID from the Star assign ID space (1 – 32767) in the  
27 BAP message when allocating star bandwidth in response to an Aloha request  
28 with a pure serial number. On the other hand, it uses assign ID from the mesh  
29 assign ID space (32768 – 65534) in the BAP message when allocating mesh  
30 resources in response to an Aloha request with mesh bit set (most significant bit  
31 is set to 1) in the serial number field.

### 32 **4.11.10.7 Mesh Traffic Transmission**

---

33 The IPoS Remote Terminal determines if the destination of the received IP  
34 packet is a star destination or a mesh destination. If the destination is a star  
35 destination, the packet is sent to the Hub on the star inroute. If the destination is a  
36 mesh destination i.e. destined to another mesh terminal, the terminal checks to

1 see if there is an existing mesh connection to the destination mesh terminal.  
2 Three possibilities exist:

- 3 1. No such connection exists
- 4 2. A connection exists but it has not yet reached the stage where the  
5 terminal state is active
- 6 3. A connection exists and its transmit state is Active

7 For the first case, the terminal determines if the connectivity to the destination is  
8 allowed or not. If connectivity is allowed then the IPoS mesh terminal initiates a  
9 mesh connection to the destination according to the clause in subsection  
10 4.11.11.2. If connectivity is not allowed, the user IP packet is discarded.

11 For the second case, the mesh connection setup process is already in progress and  
12 so the terminal queues the packet to be sent once connection setup completes.

13 For the third case, the terminal transmits the packet. If the arrival of packet  
14 require more bandwidth, the terminal shall request for extra bandwidth, If the  
15 extra bandwidth cannot be granted by the Hub, the IPoS terminal shall either  
16 queue packets, in which case packet latency increases and ultimately queue  
17 overflows or selectively discard incoming packets.

#### 18 **4.11.10.8 Mesh Traffic Reception**

---

19 The IPoS Mesh Terminal listens to IGDP messages and opens the MAC address  
20 corresponding to its IQoS-assigned group. On that MAC address, bandwidth  
21 allocation packets are received from the IPoS Hub.

22 The terminal parses Bandwidth Allocation Packets (BAPs) sent by the Hub  
23 looking for Assign IDs of interest. In addition to its own Assign ID (which  
24 indicates star and mesh bandwidth allocations for the terminal's own transmitter),  
25 the terminal looks for the Assign IDs listed in its Mesh Receive Inroute list.  
26 Wherever it finds a burst assignment for one of its receive Assign IDs associated  
27 with one of the inroutes it is currently listening to, the Mesh Terminal opens a  
28 burst aperture to receive what is transmitted by the peer terminal in that burst  
29 allocation.

30 The Remote Terminal assembles all Mesh IP traffic and discards IP packets that  
31 are not destined to the subnets supported by the Remote Terminal. It also  
32 discards its own transmitted IP packets.

#### 33 **4.11.10.9 Mesh Timing Synchronization**

---

34 This section describes the maintenance of time synchronization at the mesh  
35 receiver.

##### 36 **4.11.10.9.1 Frame Timing Synchronization**

---

37 The frame and slot structure for the mesh transmission and reception is the same  
38 as used in star mode. After a mesh terminal and the IPoS Hub achieve the timing

1 synchronization using the scheme defined in section 4.11.1, the terminal  
2 transmissions at mesh mode are all synchronized at the satellite. Each burst  
3 requires a synchronization sequence. The TDMA mode synchronization point is  
4 on the satellite transponder.

5  
6 Each mesh remote terminal shall have a local Super Frame Pulse (SFP)  
7 generator. It is based on an inexpensive oscillator, so it does not have the same  
8 intrinsic stability as for the Hub. The terminal shall maintain a hardware frame  
9 number count and a software frame number count.

10  
11 The local SFP generator produces a superframe pulse once every eight frames.  
12 After the remote terminal locks to the inroute frame timing and synchronizes its  
13 inroute software frame number with the Hub, the local SFP pulse production  
14 instant has to be adjusted so that this pulse is generated at inroute frames M,  
15 M+8, M+16 and so on, where M is divisible by 8. Below is a description of the  
16 procedure which ensures SFP generation on frames that are divisible by 8.

17  
18 The terminal shall count hardware frame numbers from 0 to 7 and then rolls back  
19 to 0. The start point is random. The SuperFrame pulse is generated on every  
20 occurrence of frame number 0.

21  
22 The hardware frame number 0 may not correspond to inroute frame numbers that  
23 are divisible by 8.

24  
25 At every frame processing time, the terminal shall record the current hardware  
26 frame number. The terminal shall delay the SFP pulse before it reaches the mesh  
27 receiver of the terminal. The delay (Tsd) should be such that the SFP pulse in the  
28 receiver aligns with the frame numbers that are divisible by 8. For example, the  
29 inroute software frame number and the hardware frame number, when the  
30 terminal locks to the inroute frame timing are 56 and 5. At inroute frame number  
31 59, the SFP pulse shall be generated. In order to align the SFP with the next 0  
32 modulo 8 frame number, Tsd will be  $(64 - 59) * 45000$  microseconds. In  
33 essence, Tsd is nothing but the current hardware frame number when the system  
34 frame number is 0 modulo 8.

35  
36 In addition to the delay Tsd as mentioned above, another delay component shall  
37 be considered by the terminal that arises because the Hub SFP and the locally  
38 generated SFP has a phase offset between them.

39  
40 The remote SFP is the time that the remote would launch burst 0 of the  
41 superframe corresponding to the SFP, if it were assigned that burst. All bursts it  
42 transmits shall be relative to the SFP in time.

43  
44 Here are some definitions:

45  
46  $T_h$  = Absolute time of a superframe pulse at the hub.

47  $T_{h-1}$  = Absolute time of the previous superframe pulse at the hub.

48  $T_r$  = Absolute time of the superframe pulse in the remote terminal's uplink  
49 section corresponding to  $P_{h-1}$ .

50  $T_m$  = Absolute time of the same superframe pulse delivered by the remote  
51 terminal to its mesh receiver.

1  $D_{sh}$  = Instantaneous delay from satellite to hub (or vice versa). It changes with  
 2 satellite movement.  
 3  $D_{sr}$  = Instantaneous delay from satellite to remote (or vice versa). It changes with  
 4 satellite movement and remote terminal movement (if mobile).  
 5 STO = Space Timing Offset.  
 6  $S_i$  = Superframe interval (360 ms)  
 7  $T_{S-R}$  = propagation time from satellite to remote terminal (same value as  $T_{R-S}$ )  
 8  $T_{R-S}$  = propagation time from remote terminal to satellite

9  
 10 The terminal shall have its outroute frame timing locked to the inroute frame  
 11 timing with a phase offset.

12  
 13 This can be described algebraically by:

14  $T_r = T_{h-I} + STO - (D_{sh} + D_{sr})$   
 15  $T_h = T_{h-I} + S_i$

16  
 17 If the remote terminal transmits a burst at time  $T_r$ , after experiencing a total  
 18 satellite propagation delay of  $(D_{sh} + D_{sr})$ , the burst will arrive at time  $T_{h-I} + STO$ ,  
 19 which is exactly when the hub expects it. Solving the above equation for  $T_h$ , we  
 20 have:

21  
 22  $T_h = T_r + S_i - STO + (D_{sh} + D_{sr})$

23  
 24  $T_m$  is frequency locked to  $T_{h-I}$  with a phase offset. The Phase offset depends on  
 25  $D_{sh}$  vs.  $D_{sr}$ . If  $D_{sr}$  is the same as  $D_{sh}$ , a given burst will hit the remote at exactly  
 26 the same time as it hits the hub. If  $D_{sr}$  is less, the burst will hit the remote sooner,  
 27 so the SFP phase will have to be advanced. If  $D_{sr}$  is more, the burst will be  
 28 received by the remote later, so the SFP phase will have to be retarded.

29 Algebraically:

30  
 31  $T_m = T_h + D_{sr} - D_{sh}$

32  
 33  $T_h$  does not exist directly at the remote, only  $T_r$ . So we substitute for  $T_h$  in the  
 34 above equation and get:

35  $T_m = (T_r + S_i - STO + D_{sh} + D_{sr}) + D_{sr} - D_{sh}$

36  $T_m = T_r + S_i - STO + 2 D_{sr}$

37  $T_m - T_r = S_i - STO + 2 D_{sr}$

38  
 39 The terminal shall delay its SFP by an amount as follows;

40  
 41 Total SFP delay =  $T_{sd} + (T_m - T_r)$

42  
 43 The remote terminal, at occurrence of every inroute frame, provides the mesh  
 44 receiver with the burst time plan for a receive frame whose number is the same as  
 45 the current frame number. For example, at inroute frame N+16, the terminal  
 46 generates a burst time plan for the receive frame N+16. At frame N+16, the  
 47 terminal sends a frame control message with frame number given by  $\{N+16 -$   
 48  $(T_{R-S} + T_{S-R}) \text{ div } 45000\}$ . The burst demodulator needs the burst time plan at least  
 49 8 frames ahead. As nearly half of the STO has elapsed when the remote terminal  
 50 generates the burst time plan for the same receive frame as compared to the Hub,  
 51 the STO shall be configured as at least 16 frames.

1

2

3

## 4.12 Message Functional Definition and Contents

5

### 4.12.1 General

7

The requirements in this section are common to all exchanges of information over the IPoS air interface; they are intended to preserve the bit ordering, content, and length of the messages and their information elements.

8

9

The information received by the DLC from higher layers and transmitted to the PHY consists of sequences of bytes, or octets, with an integral number of bytes in the sequence.

10

11

12

### 4.12.2 Packet Order of Presentation

13

14

15

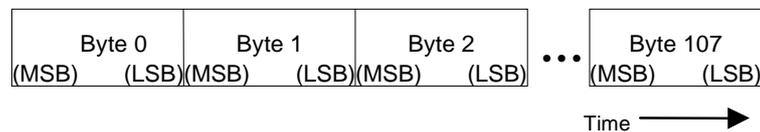
16

17

18

19

The order of presentation or transmission of both outroute and inroute IPoS packets by the remote terminals is in consecutive byte number, starting with byte 0 (header) and ending with the last byte, N. The remote terminal transmit order of presentation of the bits within each byte of a packet is MSB first (bit 7) and LSB last (bit 0). The packets are transmitted in order as shown by the direction of transmission in figure 4.12.2-1.



20

**Figure 4.12.2-1. Packet Byte and Bit Order of Presentation**

21

22

23

24

25

In DVB-S2 ACM mode, the outroute packets received at the remote may be out of sequence due to the hub queuing handling of code rate or modulation change. The remote shall be able to re-sequence packets received out of order. This resequencing needs to be done without requesting retransmission.

26

27

28

29

30

Because of adaptive modulation and code rate change and multiple priority queues existing in front of the outroute modulator, a single IP packet may be segmented into multiple coding queues and the transmission may not be in contiguous MPEG packets. The IPoS remote shall be capable of reassembling outroute packets which do not arrive in contiguous MPEG packets.

31

### 4.12.3 Order of Bits Within a Field

32

33

34

The order of bits within a field shall be "big-endian" as illustrated in figure 4.12.3-1.

(MSB) Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	(LSB) Bit 0	Byte
								N
				$2^7$	$2^6$	$2^5$	$2^4$	N+1
$2^3$	$2^2$	$2^1$	$2^0$					N+2
								N+3

**Figure 4.12.3-1. Order of Bits Within a Field**

Field values represented in hexadecimal (hex) notations that have four consecutive bits, or data nibble, are represented by a single character, X, from 0 to F (base 16). A 1-byte field value is represented by two nibbles as 0xXX, and a 2-byte value by four nibbles, with a leading zero in the form 0xXXXX. The hex representation of a 13-bit binary field might take values from 0x0000 to 0x1FFF.

Binary fields are represented by the corresponding string of zeros and ones with single quotation marks and the left-most bit, representing the MSB, e.g., '101001'.

Decimal values are presented in their natural format, e.g., 5.

#### 4.12.4 Adaptation Field

The Adaptation field serves two purposes:

1. The first is to provide management and control information along with the MAC header. Some examples of management and control information are remote configuration information or Ranging Request.
2. The second purpose is padding. The Adaptation field is adjusted to ensure that the MAC PDU fits the aggregated payloads of the group of bursts exactly

The Adaptation field, when present, is defined by the first 4 bytes after the MAC header:

- The first two bytes indicates the total length of the Adaptation field in bytes.
- The third and fourth bytes are a bitmask defining which, if any, of the optional Adaptation fields described in the following subsections are present.

The adaptation fields are encoded in order (left-to-right) according to the adaptation bitmask. For example, if the adaptation bitmask indicated that the Reset, ACM Modcod, and Star QoS adaptation fields were present, the adaptation information section would encode the Reset adaptation first, followed by the ACM Modcod adaptation, and lastly the Star QoS adaptation.

An optional one (1) byte CRC can be inserted to cover the adaptation length and adaptation bitmask fields. The adaptation CRC does *not* cover the adaptation

1 information. The terminal includes the adaptation CRC if the selected inroute  
 2 group's IGDP message indicates that the adaptation CRC is supported. The  
 3 terminal indicates in the Reset adaption field if adaptation CRC is being sent by  
 4 the terminal. The adaptation CRC byte is inserted in-between the adaptation  
 5 length and bitmask fields.

6 The following subsections define the optional Adaptation fields that would be  
 7 defined in the adaptation bitmask.

#### 8 **4.12.4.1 Reset Indication**

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9 When bit 7 in the first byte bitmask field of the Adaptation field is set to '1' by  
 10 the IPoS terminal, the Reset Indication option is included in the Adaptation field.  
 11 The information elements and meaning in the Reset Indication options are given  
 12 inTable 4.12.4.1. -1.

**Table 4.12.4.1. -1. Reset Indication Format**

Field Name	Field Length (Bits)	Description
Reserved	16	Shall be transmitted as 0 and ignored on reception
Capabilities Bitmask	16	A bitmask of features supported by the terminal. The bitmask is as follows:  0x0000 - None 0x0001 – Closed Loop Power 0x0002 – Closed Loop Timing 0x0004 – Single Rate Ranging 0x0008 - Generalized load balancing 0x0010 - Mesh Communication 0x0020 - Spreading Support 0x0080 – Adaptation CRC on version 4 stream messages  Others are reserved for future use.
DstIP	32	This shall be the IP address of the default hub that the IPoS terminal has been configured to use at commissioning time.

#### 13 **4.12.4.2 Ranging and Ranging Reason Adaptation**

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14 When bit 6 in the first byte bitmask of the Adpatation field is set to '1' by the  
 15 IPoS terminal, the Ranging Request option is included in the Adaptation field.  
 16 The Ranging adaptation is sent on the unallocated (Aloha) ranging burst to  
 17 request ranging and on every allocated ranging burst.

18 If the Ranging Reason adaptation bit is set (bit 2 of the first byte bitmask field) in  
 19 the adaptation bitmask, then the Ranging adaptation also includes the reason why  
 20 the ranging has been initiated.

1 The information elements and meaning in the Ranging Request option are given  
 2 in table 4.12.4.2-1.

**Table 4.12.4.2-1. Ranging Request and Reason Format**

Field Name	Field Length (Bits)	Description
Ranging Done	1	This bit is set on every ranging burst transmitted during the final ranging session.
SQF	8	This field contains the current receive DEMOD SQF value.
Power_Setting		The current power setting of the terminal
Time_offset	8	This field is used to indicate the local timing offset (in the timing unit of 0.1 microsecond) that is being used to transmit the ranging packet. Values greater than 255 will be truncated.
Ranging Reason	8	The reason why the terminal is ranging this rate. This field is only provided when the Ranging Reason adaptation bit is set. Valid reasons include: <ul style="list-style-type: none"> <li>• 1 – Distance to satellite changed</li> <li>• 2 – No Terminal-to-Satellite (BnD) delay</li> <li>• 3 – Need to range at a new rate</li> <li>• 4 – Different transmitter version</li> <li>• 5 – Ranging ID has changed</li> <li>• 6 – Network (Satellite) change</li> <li>• 7 – NOC initiated (Invalidate = 1)</li> <li>• 8 – New ranging algorithm</li> <li>• 9 – Terminal forced ranging</li> <li>• 10 – <i>Not Used</i></li> <li>• 11 – NOC initiated (Invalidate = 0)</li> <li>• 12 – Transmit radio calibration</li> </ul>

---

3 **4.12.4.3 ACP Request**

4 When bit 5 in the first byte bitmask field is set to '1' by the IPoS Remote  
 5 Terminal, the ACP option is included in the Adaptation field. The ACP  
 6 adaptation field is sent when the terminal needs to request an ACP test.

7 The information elements and meaning in the ACP adaptation option are given in  
 8 Table 4.12.4.3-1.

**Table 4.12.4.3-1. ACP Adaptation Format**

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Field	Bits	Description
Installer ID	16	If the Remote Terminal performs an automatic ACP measurement this field will contain "0". If the ACP is initiated from the Hub, this ID will be "NOC". If the Remote Terminal User initiates an ACP, this will be "SELF". Otherwise, this ID is supplied by the host attached to the Remote Terminal.
Version Number	2	The protocol version of the ACP request. Shall be set to '0'
Longitude	14	The Longitude of the antenna location in network byte order. Unit is 0.1 degree.
Reserved	2	Shall be set to '0'
Latitude	14	The Latitude of the antenna location in network byte order. Unit is 0.1 degree.
Requested Queue	2	The queue or type of ACP test requested. Valid values are: 0 – Pointing/Manual Request 1 – Validate/Automatic Request 2 – Revalidate Request
Reserved	5	Shall be set to '0'
Regional ACP request indicator	1	One bit to indicate the format of the ACP request. 1 indicates regional ACP request format, and 0 indicates Class A Terminal support.
SQF	8	The outroute SQF of the terminal.

2

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#### **4.12.4.4 Reset ACK**

4

When bit 3 in the first byte bitmask field is set to '1' by the IPoS Remote Terminal, Reset ACK option is included in the Adaptation field.

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6

This option is included to inform the IPoS Hub that the Remote Terminal has reset its Datagram Counter and Sequence Numbers for all the traffic priorities except those that bypass reliable link layer(RLL).

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#### **4.12.4.5 DVB-S2 ACM Message**

10

The IPoS Remote Terminal sends a request to the Hub indicating what modulation and code rate the Hub should use on the Outroute for Unicast traffic when it determines a change is necessary. The Remote Terminal uses the

11

12

- 1 adaptation field of the MAC header for modulation and code rate change  
 2 indication purposes.
- 3 When bit 1 in the first byte bitmask field of the Adaptation field is set to '1' by  
 4 the IPoS Remote Terminals, the modulation and coding rate Indication option is  
 5 included in the Adaptation field. The information elements and meaning in the  
 6 DVB-S2 ACM message option is given in Table 4.12.4.5-1.

**Table 4.12.4.5-1. DVB-S2 MOCOD Indication Format**

Field Name	Field Length (Bits)	Description
ModCod	8	This field provides the code for the requested modulation and coding rate. The meaning of each code is defined in Table 4.13.4.5-2
Terminal SINR	16	The averaged outroute SINR (Es/No) at the terminal. Units are in 0.1 dB.

**Table 4.12.4.5-2. DVB-S2 MOCOD**

ModCod	Modulation	FEC Code	Inner Code Rate
1	QPSK	LDPC+BCH	1/4
2	QPSK	LDPC+BCH	1/3
3	QPSK	LDPC+BCH	5/12
4	QPSK	LDPC+BCH	1/2
5	QPSK	LDPC+BCH	3/5
6	QPSK	LDPC+BCH	2/3
7	QPSK	LDPC+BCH	3/4
8	QPSK	LDPC+BCH	4/5
9	QPSK	LDPC+BCH	5/6
10	QPSK	LDPC+BCH	8/9
11	QPSK	LDPC+BCH	9/10
12	8-PSK	LDPC+BCH	3/5
13	8-PSK	LDPC+BCH	2/3

14	8-PSK	LDPC+BCH	$\frac{3}{4}$
15	8-PSK	LDPC+BCH	5/6
16	8-PSK	LDPC+BCH	8/9
17	8-PSK	LDPC+BCH	9/10
18	16APSK	LDPC+BCH	2/3
19	16APSK	LDPC+BCH	$\frac{3}{4}$
20	16APSK	LDPC+BCH	4/5
21	16APSK	LDPC+BCH	5/6
22	16APSK	LDPC+BCH	8/9
23	16APSK	LDPC+BCH	9/10
24	32APSK	LDPC+BCH	$\frac{3}{4}$
25	32APSK	LDPC+BCH	4/5
26	32APSK	LDPC+BCH	5/6
27	32APSK	LDPC+BCH	8/9
28	32APSK	LDPC+BCH	9/10

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#### 2 4.12.4.6 Timing Poll Response

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In response to a Timing Poll Packet, the Remote Terminal transmits a Timing Poll Response as defined in Table 4.12.4.6-1. When bit 0 in the first byte bitmask field is set to '1' by the IPoS Remote Terminal, the Timing Poll Response option is included in the Adaptation field. Please see Appendix A.3 for some of the terminologies related to Close Loop Timing used here.

8

**Table 4.12.4.6-1. Timing Poll Response**

Field Name	Field Length (Bits)	Description
Reserved	1	Shall be set to '0'
Ranged in Initial Bootstrap or Outage	1	Indicates if the terminal ranged in either 'Initial Bootstrap' or 'Hub Outage' mode.
T <sub>RO</sub> correction	14	This field represents half of the timing correction of a

		<p>Remote Terminal between the time when polled and the reference point.</p> <p>Which is <math>\{T_{RO (last\ corr)} - T_{RO (Reference)}\}/2</math></p> <p>This field is set to zero when the "T<sub>H-S-H</sub> Bootstrap ON" bit is set to true in the SFNP message and the Remote Terminal has yet to set reference values.</p> <p>The most significant bit of this field represents the sign bit.</p> <p>1 – negative value 0 – positive value</p> <p>The next 13-bits represent the absolute value of the correction.</p>
Reference T <sub>H-S-H</sub>	24	<p>This field represents the reference T<sub>H-S-H</sub> of a Remote Terminal.</p> <p>This field is set to T<sub>H-S-H (Current)</sub> (equals to T<sub>H-S-H (Nominal)</sub>) when the "T<sub>H-S-H</sub> Bootstrap ON" bit is set to true in the SFNP message and the Remote Terminal has yet to set reference values.</p>

1 **4.12.4.7 Supplementary Bandwidth Request**

2 The Supplemental Bandwidth Request (SBR) adaptation field is sent when the  
3 mesh terminal has an active mesh connection and requires additional bandwidth  
4 for star traffic or has an active star session and requires additional bandwidth for  
5 mesh traffic. The SBR adaptation is only sent by mesh Terminals when there is  
6 an active mesh connection or an active star session. When Bit 7 of the second  
7 byte bitmask of the Adpation field is set, SBR adaptation is indicated. The  
8 information elements and meaning in the SBR option is given in Table 4.12.4.7-  
9 1.

10 **Table 4.12.4.7-1. Supplementary Bandwidth Request**

Field Name	Field Length (Bits)	Description
Message Version	4 bits	This field indicates the message version for the Supplemental Bandwidth Request. This version will use a version field of 0.
Reserved	3	Preset to 0
Bandwidth Request Type	1	0 – Star bandwidth 1 – Mesh bandwidth

11 **4.12.4.8 Mesh Adaptation**

12 Mesh Terminals send Mesh Message adaptation field when the terminals need to  
13 provide mesh related information to the MRC. When Bit 5 of the second byte

1 bitmask of the Adpatation field is set, Mesh adaptation is indicated. There are  
 2 numerous mesh adaptation message types, and each type is prefixed with the  
 3 common mesh adaptation header shown in Table 4.12.4.8-1 below.

4 **Table 4.12.4.8-1. Mesh Adaptation**

Field Name	Field Length (Bits)	Description
Message Type	4	This field indicates the type of (sub) message that is provided in the Mesh Message adaptation header. See Table 4.12.4.9-2 for an enumeration of possible message type.
Message Version	4	This field indicates the message version for the corresponding Mesh Message.
Message	N	Depends in the message type.

5

6 The Mesh Message adaptation header can be sent on either *Star* or *Mesh* bursts.  
 7 This includes both Aloha (for *Star*) as well as Allocated bandwidth depending on  
 8 what type of bandwidth is available when the message needs to be sent. The valid  
 9 Message Types are enumerated in Table 4.12.4.8-2 below.

10 **Table 4.12.4.8-2. Mesh Message Type**

Value	Message Type	Description/Note
1	Register	This is a <b>terminal</b> level message that is used to register the terminal with the Mesh Resource Controller (MRC).
2	Ready	This is a <b>terminal</b> level message this is used to inform the MRC that this terminal is (still) in a Ready state. This is essentially a 'Keep-Alive' message to inform the MRC of the terminal's health.
3	Unregister	This is a <b>terminal</b> level message that is used to unregister the terminal with the Mesh Resource Controller (MRC).
4	Connectivity Needed	This is a <b>per-connection</b> level message that is used to request a new mesh connection.
5	Open Connection Response	This is a <b>per-connection</b> level message that is used to acknowledge successful reception of an Open Connection message from the MRC. In section 4.11.10.4 (where Mesh Connection Setup procedure is described), terminologies "Receive" and "Tranmsit" messages sent from MRC to terminals are synonomous with "Open Connection" message, "Receive Response" and "Transmit Response" messages from terminals to MRC are are synonomous with "Open Connection Response" message.
6	Connection Closed	This is a <b>per-connection</b> level message that is used to inform the MRC that the terminal has closed (torn-down) the indicated active mesh connection.
7	Release Connection Response	This is a <b>per-connection</b> level message that is used to acknowledge successful reception of a Release Connection message from the MRC.
8	Bandwidth Change Request	This is a <b>per-connection</b> level message that is used to request a bandwidth allocation change for the supplied mesh connection.

11

1 **4.12.4.8.1 Register Adaptation**

2 The Register message is sent to inform the MRC of the terminal's configuration  
 3 and capabilities. The information elements and meaning in the Register  
 4 adaptation option is given in Table 4.12.4.8.1-1.

**Table 4.12.4.8.1-1. Register Adaptation**

Field Name	Field Length (Bits)	Description
Mesh Terminal ID	8	A value of zero (0) is sent by the Mesh Terminal.
Flags	4	Bitmask of indicators used to inform the MRC of details regarding the Register Message. The least-significant bit (0x1) is used to tell the MRC to delete any previous connections it may have on record. The most 3-significant bits are reserved.
Reason	4	The reason why the terminal is registering. Valid enumerated reasons include: <ul style="list-style-type: none"> <li>• 1 – Initial Registration</li> <li>• 2 – Not used</li> <li>• 3 – Terminal Information Change</li> <li>• 4 – IP Subnet Change</li> <li>• 5 – COI Identifier Change</li> <li>• 6 – Not used</li> <li>• 7 – Response to 'Register Now' Message</li> </ul>
Message ID Number	8	A registration message number that is used to synchronize registration events between the terminal and MRC. The registration message number is incremented by one (1) each time a register message is sent.
Terminal Serial Number	24	The serial number of the terminal.
COI ID	8	The Community of Interest (COI) Identifier associated with the terminal
Reserved	88	Reserved, Shall be set to 0.
Number Of Terminals (T)	8	A value of one (1) shall be sent by a meshterminal.
List of Terminal Information	32T	T is always 1. The least 24 significant bits are set as the terminal serial number.
Number of Subnets (S)	8	The number of subnets ( <b>S</b> ) that the terminal supports.
List of Subnets	40S	A list of <b>S</b> subnets that are supported by the terminal. The format of Subnets is outside of the scope for this document.

5

#### 1 4.12.4.8.2 Ready Adaptation Message

2 The Ready message is sent to inform the MRC that the terminal is (still) ready to  
 3 accept mesh connections. The Ready message is essentially a heartbeat message  
 4 and no specific content is currently required to be included in this message. The  
 5 information elements and meaning in the Ready adaptation option for mesh  
 6 Terminals is given in Table 4.12.4.8.2-1.

**Table 4.12.4.8.2-1. Ready Adaptation**

Field Name	Field Length (Bits)	Description
Reserved	8	Shall be set to '0'

7

#### 8 4.12.4.8.3 Unregister Adaptation Message

9 The Unregister message is sent to inform the MRC that the terminal is no longer  
 10 able to accept or participate in any mesh connections.

11 The information elements and meaning in the Unregister adaptation option for  
 12 meshTerminals is given in Table 4.12.4.8.3-1.

**Table 4.12.4.8.3-1. Unregister Adaptation**

Field Name	Field Length (Bits)	Description
Reserved	8	A value of zero (0) shall be sent by the mesh terminal.
Unregister Reason	8	A reason code for why the terminal is unregistering. Valid values include: <ul style="list-style-type: none"> <li>• 1 –Mesh feature is disabled</li> <li>• 2- Not used</li> </ul>

#### 13 4.12.4.8.4 Connectivity Needed Adaptation Message

14 The Connectivity Needed message is sent to the MRC to request a new mesh  
 15 connection. The information elements and meaning in the Connectivity Needed  
 16 adaptation option for meshTerminals is given in Table 4.12.4.8.4-1.

**Table 4.12.4.8.4-1. Connectivity Needed Adaptation**

Field Name	Field Length (Bits)	Description
Terminal Connection ID (TCID)	16	A Terminal Connection Identifier (TCID) that is used for each mesh connection. The TCID may be incremented by one (1) for each new connection request and "rolls over" after 65,535.
Connection Type	4	The type of mesh connection requested. Valid values include: <ul style="list-style-type: none"> <li>• 1 – Activity Triggered, the arrival of an IP packet</li> </ul>

		<p>triggers the establishment of a mesh connection</p> <ul style="list-style-type: none"> <li>• 2 – Permanent Active-Open, where connection initiator do not need to wait for an IP packet to initiate a mesh connection</li> <li>• 3 – Permanent Passive-Open, where a mesh terminals waits to accept a permamnent mesh connection</li> <li>• 4 – Application Requested, the application can request for a mesh connection by sniffing protocols. For example, an application protocol sniffing module may sniff Session Initiation Protocol (SIP) and initiates a mesh connection</li> </ul>
Connection Direction	4	<p>The connectivity direction of the mesh connection requested.</p> <ul style="list-style-type: none"> <li>• 1 – Bidirectional</li> <li>• 2 – Transmit Only</li> <li>• 3- Receive Only</li> </ul>
Reserved	16	Shall be set to all zeros and ignored by the receiver
Destination IP Subnet	40	The Destination IP subnet from the packet that triggered the Mesh Connection Request. Format is not specified in this specification.
Source IP Subnet	40	The Source IP subnet of the originating (requesting) terminal. Format is not specified in this specification.

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#### 2 **4.12.4.8.5 Open Connection Response Adaptation Message**

3 The Open Connection Response message is sent from the terminal to the MRC to  
 4 inform the MRC that it successfully received the Open Connection message from  
 5 the MRC. The information elements and meaning in the Open connection  
 6 response adaptation option for mesh Terminals is given in Table 4.12.4.8.5-1.

7 **Table 4.12.4.8.5-1. Open Connection Response Adaptation**

Field Name	Field Length (Bits)	Description
Response Indicator	1	Indicates if the terminal is able to accept the new connection. A value of <b>1</b> indicates that the terminal is able to accept the connection. A value of <b>0</b> indicates that the terminal is unable to accept the connection.
Reason	2	When the <i>Response Indicator</i> field indicates the connection cannot be established, the Reason field provides an enumerated reason why the connection cannot be established. When the <i>Response Indicator</i> field indicates the connection can be established, the Reason field is not used.
Terminal Connection ID	16	A Terminal Connection Identifier (TCID) that is used for each mesh connection. For the originating terminal, this

(TCID)		is the same TCID that was sent in the associated <i>Connectivity Needed</i> message. For the peer terminal, that did not initiate the connection, a new TCID is created at the peer terminal.
MRC Connection ID (MCID)	16	The MCID that was provided by the MRC in the associated Open Connection Message.

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#### 2 **4.12.4.8.6 Connection Closed Adaptation Message**

3 The Connection Closed message is sent from the terminal to the MRC to inform  
4 the MRC that the associated mesh connection should be closed. For the  
5 Connection Closed message, the *terminal* decides to close the connection.

6 The information elements and meaning in the Connection Closed adaptation  
7 option for mesh Terminals is given in Table 4.12.4.8.6-1.

8 **Table 4.12.4.8.6-1. Connection Closed Adaptation**

Field Name	Field Length (Bits)	Description
Reason	2	An enumerated value providing the reason why the connection is being closed.
Terminal Connection ID (TCID)	16	A Terminal Connection Identifier (TCID) that is used for each mesh connection. This is the terminal specific TCID that was created at the originating terminal or the peer terminal.
MRC Connection ID (MCID)	16	The MCID for the mesh connection that should be closed.

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#### 10 **4.12.4.8.7 Release Connection Response Adaptation Message**

11 The Release Connection Response message is sent from the terminal to the MRC  
12 to inform the MRC that successfully received the Release Connection message.

13 The information elements and meaning in the Release Connection adaptation  
14 option for mesh Terminals is given in Table 4.12.4.8.7-1.

15 **Table 4.12.4.8.7-1. Release Connection Response Adaptation**

Field Name	Field Length (Bits)	Description
Reason	2	An enumerated value providing the reason why the

		connection is being released.
Terminal Connection ID (TCID)	16	A Terminal Connection Identifier (TCID) that is used for each mesh connection. This is the terminal specific TCID that was created at the originating terminal or the peer terminal.
MRC Connection ID (MCID)	16	The MCID that was provided by the MRC in the associated Release Connection Message.

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#### 4.12.4.8.8 Bandwidth Change Request Adaptation Message

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The Bandwidth Change Request (BCR) message is sent from the terminal to the MRC to inform the MRC that the terminal needs an adjustment to its bandwidth allocation.

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The information elements and meaning in the Bandwidth Change adaptation option for mesh Terminals is given in Table 4.12.4.8.8-1.

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**Table 4.12.4.8.8-1. Bandwidth Change Request Adaptation**

Field Name	Field Length (Bits)	Description
Terminal Connection ID (TCID)	16	A Terminal Connection Identifier (TCID) that is used for each mesh connection.
MRC Connection ID (MCID)	16	The MCID whose bandwidth to be adjusted.
Bandwidth Requested	16	The total amount of bandwidth, in bytes, that is requested for the associated mesh connection.

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#### 4.12.4.9 Bandwidth Allocation Request

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A remote terminal indicates to the hub that the unallocated Aloha transmission is a BAR packet by setting the Backlog\_indicator to '0' and setting the Adaptation\_indicator fields in the MAC header to '1'. Under these conditions, the terminal announces to the hub that there is a nonzero backoff request for bandwidth.

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#### 4.12.5 Outroute Message

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Each outroute message is sent by the Hub encapsulated within a pseudo IP/UDP header of 28 bytes. From an IPoS terminal perspective, the length field of the UDP header is only significant. The Hub sends all zeros for other IP/UDP fields.

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### 1 **4.12.5.1 Superframe Numbering Packet**

2 SFNP contains measurements of the propagation time from the hub to the  
 3 satellite and current propagation time in the hub. By using these times in  
 4 combination with its own propagation time to the satellite, an IPoS terminal  
 5 using open-loop timing is able to calculate the time at which it should transmit a  
 6 data packet such that it is received by the hub at the required time. Additionally,  
 7 the SFNP identifies the IPoS network to which the IPoS terminal is connected.

8 The information elements in the SFNP are shown in table 4.12.5.1-1.

**Table 4.12.5.1-1. SFNP Message Format**

Field Name	Field Length (Bits)
Frame_type	8
Timing_source	1
Version	7
Frame_number	16
Local_SFNP_delay	32
Echo_SFNP_delay	32
SFNP_interval	32
Hub_timing_offset	32
Satellite Network Code	2
Frequency	15
Longitude	15
Secure Mode	1
No ACP Required	2
Reserved	1
Ranging_identifier	4
NOC ID	4
Modulator	4
NOC Delay Offset	8
Reserved	1
T <sub>H-S-H</sub> Bootstrap ON	1
Bootstrap Mode	1
Spot Beam ID	5
Bootstrap Aloha random back off	16
Known NOC Satellite Delay	N*32

9

10 The following is a description of the fields in the SFNP:

- 11
- Frame\_type: Set to 0x01 by the hub, this field indicates an SFNP
  - Timing\_source: Set to '0' or '1' by the hub, it is used to distinguish the timing source at the hub (there are two for redundancy) generating this SFNP. Terminals shall monitor both the timing sources, if present and select one randomly. A change in selection shall only be made by terminals after receiving three consecutive valid SFNP from the same source. In the case one timing source is down, terminals shall select non-optionally the one that is up.
- 12  
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- 1                   • Version: This field is set by the hub to indicate the return channel  
2                   protocol version supported by the hub. This document describes  
3                   version 1. If an IPoS terminal does not recognize a particular version of  
4                   the message, it shall not transmit or use any of these incoming packets  
5                   related to the return channels. For the Closed Loop Timing – Estimated  
6                   Echo Delay, the version number 4 is used which indicates to the IPoS  
7                   terminal that it is a new formatted SFNP message which replaces the true  
8                   echo value with either the nominal or the estimated value. An IPoS  
9                   terminal not supporting closed loop timing cannot transmit if version 4 is  
10                  indicated.
- 11                 • Frame\_number: This counter shall be incremented by eight by the hub  
12                   for every superframe and shall be used to identify global timing. It will  
13                   wrap every 49 minutes.
- 14                 • Local\_SFNP\_delay: The value in this field is set by the hub to indicate  
15                   the data propagation time at the hub. A value of 0 will be used to  
16                   indicate that the value is unknown. IPoS terminals require two  
17                   consecutive SFNPs to be able to interpret this field.
- 18                 • Echo\_SFNP\_delay: The value in this field is set by the hub and used by  
19                   IPoS terminals in the calculation of the round-trip delay from the hub to  
20                   the satellite. The value of 0 will be used to indicate that the value is  
21                   unknown for the previous superframe. IPoS terminals require two  
22                   consecutive SFNPs to be able to interpret this field.
- 23                 • SFNP\_interval: The value in this field is set by the hub to indicate the  
24                   elapsed time between this SFNP and the previous one. IPoS terminals  
25                   shall use this information to adjust for any differences between their  
26                   local measurement clock and the clock used by the timing units at the  
27                   hub. The value of 0 shall be used to indicate to the IPoS remote that the  
28                   value is unknown for the previous superframe. IPoS terminals are  
29                   required to receive three consecutive SFNPs to be able to interpret this  
30                   field.
- 31                 • Hub\_timing\_offset: The value in this field is set by the hub to indicate  
32                   the number of milliseconds between the IPoS outroute SFNP and the  
33                   time that the first frame from the superframe will be received at the hub.
- 34                 • Satellite Network Code: This field shall be transmitted by the IPoS hub  
35                   as value '00' and confirmed by the IPoS remote upon reception. The 2  
36                   bits in this field, plus the Frequency and Longitude fields, are intended as  
37                   a method of confirming that the correct satellite network is being  
38                   monitored.
- 39                 • Frequency: Set by the hub to the frequency of the outroute transponder.  
40                   The frequency is measured in 100 kHz units.
- 41                 • Longitude: Set by the hub to the longitude of the satellite. Bit 14 is the  
42                   West/East\_ indicator, bits 13 through 6 are the degrees, and bits 5  
43                   through 0 are the minutes.

- 1                   • Secure Mode: If set to one, secure commands are allowed to Remote  
2                   Terminals (specifically memory read and write) from the host driver on  
3                   the user end-system.
- 4                   • No ACP Required: If set to one, indicates that ACP is not required on  
5                   this Outroute Satellite Transponder.
- 6                   • Reserved: Shall be transmitted by the hub as '0' and ignored upon  
7                   reception at the IPoS terminals.
- 8                   • Ranging\_Identifier: The value in this field is set by the Hub and shall be  
9                   stored by the IPoS Remote Terminal when performing a ranging  
10                  operation. If the received Ranging\_identifier does not match the  
11                  previously saved value, then the ranging information is invalid. The  
12                  Ranging\_identifier value is only changed to force all terminals to re-  
13                  range to recover from some catastrophic error.
- 14                  • NOC ID: This value is used to indicate the Hub identifier (ID). This  
15                  field is used to support geographically redundant Hubs. Each Hub that  
16                  supports the same network (network is defined to be the satellite &  
17                  transponder) must have its own unique NOC ID. If the network does not  
18                  support geographically redundant Hubs, then the NOC ID field should be  
19                  set to zero (0). If the network supports geographically redundant Hubs,  
20                  the NOC ID field should be between 1 – 15 inclusive.
- 21                  • Modulator: This value shall indicate the type of modulator used for the  
22                  outroute satellite transponder.
- 23                  • NOC Delay Offset: This field is the offset into the packet (in 8 bit) of  
24                  the Hub delay table. It will be used to allow addition of future fields,  
25                  while maintaining backward compatibility.
- 26                  • Reserved: Shall be transmitted by the hub as '0' and ignored upon  
27                  reception at the IPoS terminals.
- 28                  •  $T_{H-S-H}$  Bootstrap ON: Set to 1 during Bootstrap period when terminals  
29                  need to go to Bootstrap Aloha mode. Otherwise set to 0.
- 30                  • Bootstrap Mode: This field is only relevant if the previous field  $T_{H-S-H}$   
31                  Bootstrap ON is set to 1. This field is set to 1 if the TU perceives a Hub  
32                  outage type of bootstrapping scenario. Otherwise set to 0 which means a  
33                  network startup bootstrap mode.
- 34                  • Spot Beam ID: The spot beam id to which this timing unit belongs. This  
35                  field is set to all zeros when the system is not a spot beam system.
- 36                  • Bootstrap Aloha random back off: A non-zero value expressed in  
37                  number of superframes indicates to terminals that they should randomize  
38                  their initial back off before sending Bootstrap Aloha messages.

- 1 • Known NOC Satellite delays: (Optional) To accommodate
- 2 geographically redundant Hubs, these values indicate the known satellite
- 3 delay for each of the Hubs at a given time of day. Since the satellite has
- 4 a diurnal drift, the satellite drift is the same at a particular time from day
- 5 to day. The satellite delay is measured once at a given time at each of
- 6 the Hubs. The satellite delay for this field is defined to be the (Echo
- 7 SFNP Delay – Local SFNP Delay). The value of N is determined from
- 8 the length of the SFNP. N can not be larger than 15 since the NOC ID
- 9 field is 4 bits long.

#### 4.12.5.2 Timing Correction Poll Packet

---

The IPoS Hub can poll IPoS Remote Terminals that support CLT for Timing information using the TCPP (Timing Correction Poll Packet), the format of which is shown in Table 4.12.5.2-1 and 4.12.5.2-2. Only active terminals are being polled by the IPoS Hub. A few superframes before the scheduled polling time the IPoS Hub observes the list of terminals being allocated with bandwidth on a frame and selects some of the terminals from the list as the polling candidates. A TCPP message sent right after the BAP contains polling requests for multiple terminals.

**Table 4.12.5.2-1. Timing Polling Packet**

Field Name	Field Length (Bits)	Description
Frame Type	8	Set to a value of 11 to indicate a Timing Polling packet.
Number_of_entries	8	The value in this field is the number of entries (N) in the following Polling_records field.
Polling_records	N*16	Array of N records each representing the identity of the polled Remote Terminal. As defined in 4.12.5.2-2.

**Table 4.12.5.2-2. Timing Polling Record**

Field Name	Field Length (Bits)	Description
Assign ID	16	This is an ID used in BAPs. A Remote Terminal uses this ID to find the timing correction. Assign Ids are sorted in ascending order.

### 1 4.12.5.3 Timing Feedback Packet

2 In IPoS networks consisting of Terminals that have been configured for Closed-  
 3 Loop Timing, the IPoS Hub can send a message called Inroute Timing Feedback  
 4 Packet (ITFP) to the Remote Terminal that provides feedback on the timing  
 5 accuracy of Inroute packets. This message is sent after the IAP message. The  
 6 format of this packet is defined by table 4.12.5.3-1 and 4.12.5.3-2.

**Table 4.12.5.3-1. Timing Feedback Packet**

Field Name	Field Length (Bits)	Description
Frame_type	8	Set to a value of 10 to indicate a Timing feedback packet.
Number_of_entries	8	The value in this field is the number of entries (N) in the following Timing Correction records field.
Timing_correction_records	N*24	Array of N records each representing the Timing correction feedback for a Remote Terminal. This record is sorted by Assign ID with the fields defined in the following table.

7

**Table 4.12.5.3-2. Timing Correction Field Format**

Field Name	Field Length (Bits)	Description
Assign ID	16	This is an ID used in BAPs. A Remote Terminal uses this ID to find its correction.
Reserved	1	Shall be set to 0 and ignored upon reception.
Timing Correction	7	The most significant bit represents the direction of the correction  The least 6-significant bits specify the absolute value of the drift (in microsecond unit) from the center of the aperture  Note that Hub sends the timing correction to a Remote Terminal only if its timing drift crosses a configured threshold from the center in either direction. If the drift is greater than the threshold

**Table 4.12.5.3-2. Timing Correction Field Format**

		in positive direction from the center, the most significant bit is set to 1 to signify that the correction to be made at Remote Terminal is negative (Terminal needs to transmit burst early). On the other hand, if the drift is greater than the threshold in negative direction from the center, the most significant bit is set to 0 to signify that the correction to be made at the Remote Terminal is positive.
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1

2 **4.12.6 Inroute Group Definition Packet (IGDP)**

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3 IGDP messages are used to define the inroute logical on an inroute channel group  
 4 and to determine which carriers of inroute channel groups are for user traffic and  
 5 for request/ranging. Inroute channel groups are used to allow for load sharing  
 6 among a number of inroute channels and to minimize the outroute bandwidth  
 7 required to control the inroute channel bandwidth allocation. Inroute channel  
 8 groups also limit the amount of information that needs to be cached or processed  
 9 by the IPoS terminals.

10 All IPoS terminals on the same outroute carrier shall receive all IGDP messages  
 11 sent on this outroute and ignore IGDP messages intended for other inroute  
 12 groups. IPoS terminals shall discard the content of those messages that are not  
 13 received again after three superframe intervals. The inroute group tables created  
 14 in the IPoS terminals from the information elements of all IGDP messages should  
 15 be almost static, with the exception of the metrics.

16 **4.12.6.1 IGDP message**

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17 The information elements of IGDP message are given in Table 4.12.6.1-1.

**Table 4.12.6.1-1 IGDP Message Format**

Field Name	Field Length (Bits)
Frame_type	8
Inroute_group_ID	7
Frequency_offset	5
Return_channel_type	4
Has serial number range	1
Sequence number for RLL traffic	1
Aloha CRC	1
Inroute/Outroute overlay	1
Reserved	4
Ranging_metric/LDPC	8
Ranging_backoff	4

Ranging_retries	4
Ranging_max_backoff	16
Bandwidth (Aloha)_metric/LDPC	16
Small_Aloha_backoff	4
Small_Aloha_retries	4
Overhead Slots for Normal Aperture	4
Overhead Slots for Reduced Normal Aperture	4
Aloha_max_backoff	16
E <sub>b</sub> /N <sub>o</sub> _switchup	8
E <sub>b</sub> /N <sub>o</sub> _target	8
E <sub>b</sub> /N <sub>o</sub> _min	8
Frequency band	4
Resrvd	4
Reserved	16
Rain fade rate backoff	16
Symbol rate	16
FEC type	4
Adaptation CRC	4
Closed Loop Timing	1
Closed Loop Power	1
Adaptive Coding	1
Ranging aperture size	8
Ranging Payload Size	4
ESS (Enhanced Secure Signaling) <sup>3</sup> Encryption	1
ESS Outroute Authentication	1
ESS Inroute Authentication	1
Reserved	1
Mesh support	3
Spreading Factor	5
ESS Key Set Version	16
Base Frequency	32
Reserved	8
Park Frequency	24
Encoding Type	4
IGDP Message Version	4
Ranging_Metric for LDPC	8
Bandwidth_Metric for LDPC	16
Reserved	6
Serial number starts	26
Reserved	6
Serial number ends	26
Frequency_table	N×24
ESS Auth Code	16

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2

The description of the fields in the IGDP is the following:

3

- Frame-type: Set to 2 to indicate an IGDP.

<sup>3</sup> Please see Annex B.3 for Enhanced Secure Signaling

- 1                   • Inroute\_group\_ID: This field is set by the hub to provide an identifier  
2                   for each inroute group. This identifier shall be unique across all IPoS  
3                   inroute groups that are available to a set of IPoS outroutes.
  
- 4                   • Frequency\_offset: Set to 13 by the hub. This field provides the offset  
5                   into the packet (in 16-bit words) of the Frequency\_table field from the  
6                   start of the Aloha\_max\_backoff field. It shall be used to allow addition  
7                   of future fields while maintaining backward compatibility.
  
- 8                   • Return\_channel\_type: This field is always set to 7 and indicates that two  
9                   separate fields, "Symbol Rate" and "FEC type" represent full symbol  
10                  rate in units of Ksps and FEC rate.
  
- 11                  • Has serial number range: If set to one, this indicates that a serial number  
12                  range to disable is present after the fixed portion of IGDP payload and  
13                  before the frequency table.
  
- 14                  • Sequence number for RLL bypass traffic: This bit is set to 1 to indicate  
15                  that the hub supports sequence numbers on RLL bypass traffic.
  
- 16                  • Aloha CRC: This bit is set to 1 if IPoS Hub expects Aloha CRC byte to  
17                  be present in unallocated bursts.
  
- 18                  • Outroute-Inroute overlay: If this bit sets to 1, this indicates that Inroute  
19                  channels overlay Outroute channels. If it is set to 0, FDM is used.
  
- 20                  • Reserved: Set by the hub to the value 0 and ignored on reception.
  
- 21                  • Ranging\_metric/LDPC: Ranging metric is defined as the minimum of  
22                  number of non allocated and allocated ranging inroutes. This metric is  
23                  used by the remote for random selection of a Return channel group when  
24                  performing Nonallocated Ranging. A value of 0 means Nonallocated  
25                  Ranging is not currently available on this Return Channel Group. This  
26                  metric is used for random weighted selection of a Return channel Group  
27                  when performing Nonallocated Ranging. It should be based on the  
28                  number of Nonallocated Ranging bursts defined, and the collision rate on  
29                  those bursts. A value of 0 means Nonallocated Ranging is not currently  
30                  available on this Return channel Group. For LDPC inroute type, this  
31                  field combined with the "Bandwidth (Aloha) Metric" field, are used to  
32                  indicate when an IGDP is advertising an LDPC inroute group. An inroute  
33                  is LDPC if Ranging Metric = 0, Bandwidth (Aloha) Metric = 0 and  
34                  Encoding Type is 1 (LDPC).
  
- 35                  • Ranging\_backoff: This is the number of maximum frames the remote  
36                  waits before retransmission of unallocated ranging request after the  
37                  Ranging Retires have been exceeded. After the ranging retires have been  
38                  exceeded, the remote continues to attempt to recover in the background.  
39                  The "Ranging Backoff" parameter is used for the first or initial random  
40                  backoff for the unallocated ranging request retransmission, after that  
41                  truncated, binary exponential backoff algorithm is used. This value is the  
42

- 1 upper limit for the backoff algorithm. This is the number of frames  
 2 (minus one) for the initial random backoff for the ranging transmission  
 3 prior to allocation of ranging bandwidth. It is expected to be 4 for the  
 4 initial system.
- 5 • Ranging\_retries: The value in this field indicates the number of times  
 6 (minus one) that a packet retransmission shall be attempted using the  
 7 initial random backoff before the IPoS terminal exits the ranging  
 8 procedure.
  - 9 • Ranging\_max\_backoff: After the ranging retries have been exceeded,  
 10 the transmission is aborted, but the IPoS remote shall continue to attempt  
 11 to recover in the background. This value is the upper limit for the  
 12 truncated, binary exponential backoff algorithm that the IPoS remote  
 13 shall use.
  - 14 • Bandwidth (Aloha)\_metric/LDPC: Bandwidth metric of a group is  
 15 defined as the difference between the maximum configured users  
 16 supported in a group and the current actual number of active users on  
 17 that group. The number for the maximum configured users is obtained by  
 18 multiplying the number of currently locked inroutes with the bandwidth  
 19 metric factor (i.e, the number of users supported in one inroute by  
 20 average) configured for the group. A value of 0 indicates an unavailable  
 21 inroute group or no aloha defined. This metric is used for random  
 22 weighted selection of a Return channel Group when going active. It  
 23 should be based on a ratio of the number of return channels available for  
 24 user traffic to the active number of users. This is used to ensure that  
 25 users are evenly distributed between inroute groups. A value of zero  
 26 indicates an unavailable inroute group or no aloha defined. For LDPC  
 27 inroute type, this field combined with the "Ranging Metric" field, are  
 28 used to indicate when an IGDP is advertising an LDPC inroute group.  
 29 An inroute is LDPC if Ranging Metric = 0, Bandwidth (Aloha) Metric =  
 30 0 and Encoding Type is 1 (LDPC)
  - 31 • Small\_Aloha\_backoff: This field indicates the number of frames (minus  
 32 one) for the initial random backoff for the small Aloha transmission.
  - 33 • Small\_Aloha\_retries: This field shall indicate the number of times  
 34 (minus one) that a packet retransmission is attempted using the initial  
 35 random backoff before the IPoS terminal exits the Aloha procedure.
  - 36 • Overhead slots for normal aperture: This field represents the overhead  
 37 slot for the Aloha burst. The Aloha overhead slot is fixed and is as  
 38 specified in the following table.

Symbol rate (ksps)	Overhead Slot for Aloha
256	1
512	1
1024	2
2048	3

4096	5
6144	7

1

2

3

4

- Overhead Slots for Reduced Normal Aperture: This field represents the overhead slot for the narrow aperture Stream burst (Reduced Normal aperture) with the usage of closed loop timing.

Symbol rate (ksps)	Overhead Slot for Stream
256	1
512	1
1024	2
2048	3
4096	3
6144	3

5

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- Aloha-max\_backoff: This is the number of maximum frames the remote waits before retransmission of small ALOHA after the Small Aloha Retires have been exceeded. After the Small Aloha retires have been exceeded, the remote continues to attempt to recover in the background. The "Small Aloha Backoff" parameter is used for the first or initial random backoff for the Small Aloha request retransmission, after that truncated, binary exponential backoff algorithm is used. This value is the upper limit for the backoff algorithm. After either Aloha Retries have been exceeded, the transmission is aborted, but the terminal will continue to attempt to recover in the background. This value is an upper limit for the truncated, binary exponential backoff algorithm.

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- $E_b/N_o$ \_switchup: This field indicates the inroute  $E_b/N_o$  value required to attempt ranging up to the next available inroute symbol rate. Ranging to higher rates is done only if they are available.  $E_b/N_o$  values are indicated in 0.1 dB units.

21

22

23

- $E_b/N_o$ \_target: This field is set by the hub to indicate the desired (target) inroute  $E_b/N_o$  value for ranging on this inroute group.  $E_b/N_o$  values are indicated in 0.1 dB units.

24

25

26

- $E_b/N_o$ \_min: This field is set by the hub to indicate the minimum inroute  $E_b/N_o$  value required for ranging on this inroute group.  $E_b/N_o$  values are indicated in 0.1 dB units.

27

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30

- Frequency band: Specifies the frequency band for this group. 0 – Ku, 1 – Ka, 2 – C, 3 – custom). When the frequency band is defined as custom then the base frequency and park frequency are defined elsewhere in the IGDP.

31

- Reserved: Set by the hub to the value 0 and ignored on reception.

32

- Reserved: Set by the hub to the value 0 and ignored on reception.

- 1                   • Rain fade rate backoff: This field specifies the number of frames the  
2 remote should backoff at the lower rate before switching back to the  
3 preferred rate. This gives a maximum backoff value of approximately 49  
4 minutes.
- 5                   • Symbol rate: Specifies inroute symbol rate in 100 sps (Symbol Per  
6 Second) units.
- 7                   • FEC type: 0 – No FEC specified, 1- R1/3, 2 – R½, 3 – R2/3, 4 – R4/5
- 8                   • Adaptation CRC: Terminals shall also not put an Adaptation CRC on an  
9 inroute group operating if this bit is 0. Terminals may put an Adaptation  
10 CRC on an inroute group operating on if this bit is 1.
- 11                  • Closed loop Timing: This bit is set to 1 if closed loop timing is supported  
12 on this group, otherwise set to 0. The non closed loop timing aware  
13 Remote Terminal ignores this field.
- 14                  • Closed loop power: This bit is set to 1 if closed loop power is supported  
15 on this group, otherwise set to 0. The non closed loop power aware  
16 Remote Terminal ignores this field.
- 17                  • Adaptive Coding: This bit is set to 1 if Inroute Adaptive Coding is  
18 supported in this group, otherwise set to 0. The non adaptive coding  
19 aware Remote Terminal ignores this field
- 20                  • Ranging aperture size: The number of slots that make up the aperture  
21 size in a ranging burst. The ranging burst is placed in the BAP when a  
22 ranging burst is assigned in either the Unallocated or Allocated inroutes.  
23 The Ranging Burst Size = Ranging Aperture Size + Payload Slot Size +  
24 Overhead Slot Size.
- 25                  • Ranging Payload Size: This field represents the minimum payload size  
26 slots. This parameter is applicable for inroute rates above 2Mpsps. The  
27 minimum is 3 slots, and the maximum is 7 slots.
- 28                  • ESS Encryption: Applicable for Enhanced Signaling Security (ESS), a  
29 value of 1 means inroute group is encrypted and value 0 means no  
30 encryption is used. An ESS unaware terminal shall ignore this field.
- 31                  • ESS Outroute Authentication: Value of 1 means outroute control and  
32 management messages are authenticated, value of 0 means no outroute  
33 control and management message is authenticated. An ESS unaware  
34 terminal shall ignore this field.
- 35                  • ESS Inroute Authentication: Value of 1 means inroute control and  
36 management messages are authenticated, value of 0 means no inroute  
37 control and management message is authenticated. An ESS unaware  
38 terminal shall ignore this field.

- 1                   • Mesh Support: 0 if Mesh is not supported 2 if mesh is supported. Other  
2                   values are reserved.
  
- 3                   • Spreading Factor: This field represents the spreading factor supported in  
4                   this group which is 1...MAX\_SPREAD\_FACTOR. Spread Factor 1  
5                   means spreading is disabled. An IPoS terminal not supporting spreading  
6                   shall ignore this field.
  
- 7                   • ESS Key Set Version: This field represents the ESS Key Set version in  
8                   use on the IPoS hub as an unsigned 2-byte Big Endian integer, or 0 if  
9                   ESS is not in use. An ESS unware terminal shall ignore this field.
  
- 10                  • Base Frequency: This defines in 100's of Hz the base frequency of this  
11                  inroute group. The IPoS Hub advertises the base frequency for Ku, Ka  
12                  and C bands through this field , and therefore is only used by the  
13                  terminal when the frequency band is set to Custom.
  
- 14                  • Reserved: Set by the hub to the value 0 and ignored on reception.
  
- 15                  • Park Frequency: This defines in 100's of Hz a frequency that the remote  
16                  should set its transmitter to when it is not transmitting. This is defined as  
17                  an offset from the Base Frequency.
  
- 18                  • Encoding Type: A value of '1' indicates LDPC.
  
- 19                  • IGDP Message Version: This is set to '1'.
  
- 20                  • Ranging Metric for LDPC: This field is used when the Inroute Group is a  
21                  new type of encoding such as the LDPC encoding. The original value of  
22                  the "Ranging Metric" should be set to "0" along with the "Bandwidth  
23                  (Aloha) Metric". "Ranging Metric" is defined as the minimum of  
24                  number of non allocated and allocated ranging inroutes. This metric is  
25                  used by the remote for random selection of a Return channel group when  
26                  performing Nonallocated Ranging. A value of 0 means Nonallocated  
27                  Ranging is not currently available on this Return Channel Group. It  
28                  should be based on the number of Nonallocated Ranging bursts defined,  
29                  and the collision rate on those bursts.
  
- 30                  • Bandwidth (Aloha) Metric for LDPC: This field is used when the Inroute  
31                  Group is a new type of encoding such as the LDPC encoding. The  
32                  original value of the "Ranging Metric" should be set to "0" along with  
33                  the "Bandwidth (Aloha) Metric". "Bandwidth (Aloha) Metric of a group  
34                  is defined as the difference between the maximum configured users  
35                  supported in a group and the current actual number of active users on  
36                  that group. The number for the maximum configured users is obtained by  
37                  multiplying the number of currently locked inroutes with the bandwidth  
38                  metric factor (i.e, the number of users supported in one inroute by  
39                  average) configured for the group. A value of 0 indicates an unavailable  
40                  inroute group or no aloha defined. This metric is used for random  
41                  weighted selection of a Return channel Group when going active. It  
42                  should be based on a ratio of the number of return channels available for

- 1 user traffic to the active number of users. This is used to ensure that  
 2 users are evenly distributed between inroute groups.
- 3 • Reserved: Set by the hub to the value 0 and ignored on reception.
  - 4 • Serial number starts: Start of serial number range to disable (inclusive)
  - 5 • Reserved: Set by the hub to the value 0 and ignored on reception.
  - 6 • Serial number ends: End of serial number range to disable (inclusive)
  - 7 • Frequency\_table: This field indicates the frequency used to transmit on  
 8 each of the inroute carriers in the group. There is an upper bound of no  
 9 more than 4,000 inroute carriers within an inroute channel. The upper  
 10 bound for the number of return channels in each return channel group is  
 11 based on the limit of the number of burst allocations in the BAP since  
 12 only a single BAP message is sent for each inroute group. If an inroute  
 13 is not used, then its bandwidth will be allocated to a reserved AssignID  
 14 from the BAP. The frequency is encoded as:
- 15 C band Frequency = 5.85 GHz + value \* 100 Hz
- 16 Ku band: Frequency = 14 GHz + value \* 100 Hz
- 17 Ka band Frequency = 29.5GHz + value \* 100 Hz
- 18 • ESS Auth Code: This 16 bit authentication hash is present at the end of  
 19 the IGDP message if ESS is enabled on this group.

## 20 4.12.7 Inroute Command and Acknowledgment Packet 21 (ICAP)

---

22 The ICAP message is used to convey an inroute acknowledgment that explicitly  
 23 acknowledges Aloha and ranging transmissions over the unallocated inroute  
 24 channels as well as sending commands to IPoS terminals. The ICAP messages  
 25 are multicast to reduce outroute bandwidth.

26 The information elements in the ICAP are given in table 4.12.7-1.

**Table 4.12.7-1. ICAP Message Format**

Field Name	Field Length (Bits)
Frame_type	8
Number_of_entries	8
Offset_table	N×16
Command/Acknowledgment	M×8

27  
 28 The description of the fields and their values in the ICAP are as follows:

- 29 • Frame-type: Set to a value of 5 to indicate an ICAP
- 30 • Number\_of\_entries: The value in this field is the number of entries in  
 31 the following Offset\_table field.

- 1                                   • Offset\_table: This is a table of offsets where each of the variable sized  
2                                   Command/Acknowledgment fields begins. The size should be known  
3                                   based on the Command field. Each offset is an 11-bit value and starts  
4                                   from the beginning of the Offset\_table. The value of N is the number of  
5                                   entries. Note that since the offset is 11 bits, there are 5 reserved bits for  
6                                   each entry.
- 7                                   • Command/Acknowledgment: This is a list of commands or  
8                                   acknowledgments sorted by SerNr with the fields defined in the  
9                                   following subsections. No more than one command or acknowledgment  
10                                  can be sent to an IPoS terminal per packet.

11                                  The following subsections describe the commands that can be contained within  
12                                  an ICAP.

### 13   **4.12.7.1    Ranging Acknowledgment Command**

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14                                  Table 4.12.7.1-1 gives the fields and description of the Ranging  
15                                  Acknowledgment command.

**Table 4.12.7.1-1. Ranging Acknowledgment Command**

Field Name	Field Length (Bits)	Description
SerNr	26	Set by the hub to the serial number of the IPoS remote in this field.
Command	5	A value of 0 shall indicate a Ranging (and Unallocated Ranging) Acknowledgment command from the IPoS hub. When an IPoS remote is using allocated ranging, it may not receive ranging acknowledgments for each frame, but the encapsulated datagrams will be acknowledged within the IAP. The hub shall transmit this acknowledgment upon the inroute group multicast address.
Reserved	1	Should be transmitted as 0 and ignored on reception.
Timing_adjustment	16	This is a signed 16-bit field indicating the number of $\mu$ s by which to adjust the burst timing. The IPoS terminal shall alter its burst timing by the value commanded by this field.
Received_ $E_b/N_o$	16	This is an unsigned 16-bit field that indicates the received $E_b/N_o$ value at the hub at the previous ranging cycle.
Frame_number	16	This 16-bit field is the frame number to acknowledge. This is the frame number on which the terminal sent its request.

### 16                                  17   **4.12.7.2    Aloha Acknowledgment Command**

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18                                  Table 4.12.7.2-1 gives the fields and description of the Aloha Acknowledgment  
19                                  command.

**Table 4.12.7.2-1. Aloha Acknowledgment Command**

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Field Name	Field Length (Bits)	Description
SerNr	26	The Hub transmits the serial number of the Remote Terminal in this field.
Command	5	A value of 1 indicates an Aloha Acknowledgment. Only one of the diversity Aloha packets will be acknowledged. This acknowledgment is sent upon the Inroute group's multicast address.
Reset	1	If this bit is set, it indicates that no prior state information on the Remote Terminal was maintained by the Hub. This will cause the Remote Terminal to transmit its source and destination IP addresses.
Extended Ack	1	If this bit is set, Aloha acknowledgement command is extended and contains timing and power feedback. Otherwise, it does not contain them.
Inroute_group_ID	7	This is the Inroute group, where future bandwidth will be allocated. The Inroute type for this group must be the same type that was used in the Aloha packet.
AssignID	16	This is an ID used in BAPs. A value of 0 will acknowledge the data without assigning any bandwidth.
Frame_number	16	This 16 bit field is the frame number to acknowledge. This is the last field in the message if the Extended Ack bit is set to 0.
Reserved	2	Shall be set to 0
SINR Feedback present	1	Indicates whether the SINR feedback field is present in the remainder of the message. 0 – not present 1 – present
Timing Feedback present	1	Indicates whether the timing feedback field is present in the remainder of the message. 0 – not present 1 – present

Version	4	Aloha Acknowledgement message version number. Version number 0 is used for this message.
Timing Feedback on which Aloha	1	<p>Set to 1 if the feedback corresponds to the normal small Aloha.</p> <p>Set to 0 if the feedback corresponds to the ranging Aloha</p> <p>If this bit is not set, the f15 bit timing feedback field titled Timing Feedback on Ranging Aloha is included as the next field.</p> <p>If this bit is set, the 7-bit timing feedback field titled Timing feedback on Normal Aloha is included in the next field.</p> <p>This field will not be present if the "Timing Feedback present" field is set to 0.</p> <p>The following two fields, Timing Feedback on ranging Aloha and Timing Feedback on normal Aloha, are mutually exclusive. Not both of them are present at the same time.</p>
Timing Feedback on ranging Aloha	15	<p>This value specifies when UW was detected relative to rising edge of UW aperture.</p> <p>This field is present if the "Timing Feedback present" bit is set to 1 and also the "Timing Feedback on which Aloha" field is set to 0.</p>
Timing Feedback on normal Aloha	7	<p>The most significant bit represents the direction of the correction.</p> <p>1 – negative correction</p> <p>0 – positive correction</p> <p>The least 6-significant bits specify the absolute value of the timing offset (in unit of microsecond) from the center of aperture.</p> <p>This field is present if the "Timing Feedback present" bit is set to 1 and also the "Timing Feedback on which Aloha" field is set to 1.</p>
SINR Feedback	8	<p>This 8-bit field provides received SINR value of the burst. The value is specified in units of one-tenth of dB. Supported range is from 0 to 25.5 dB.</p> <p>This field will not be present if the "SINR Feedback present" field is set to 0</p>

### 1 **4.12.7.3 Disable/Enable IPoS Terminal Command**

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2 Table 4.12.7.3-1 gives the fields and description of the Disable/Enable IPoS  
3 Terminal command

**Table 4.12.7.3-1. Disable/Enable IPoS Terminal Command**

Field Name	Field Length (Bits)	Description
SerNr	26	The hub transmits the serial number of the IPoS terminal in this field.
Command	5	A value of 2 indicates a Disable/Enable IPoS Terminal Transmitter command – When disabled, the IPoS terminal will not transmit again until it is explicitly enabled from the hub. This setting is stored in nonvolatile memory on the IPoS terminal. There is no acknowledgment to this command.
Enable	1	Set to 1 if enable, set to 0 for disable.

4

### 5 **4.12.7.4 Start Ranging Command**

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6 Table 4.12.7.4-1 gives the fields and description of the Start Ranging command.

**Table 4.12.7.4-1. Start Ranging Command**

Field Name	Field Length (Bits)	Description
SerNr	26	The hub transmits the serial number of the IPoS remote in this field.
Command	5	A value of 3 indicates a Start Ranging command. The IPoS terminal is informed that is required to range by having ranging bursts allocated. This command is implicitly acknowledged by the IPoS terminal ranging.
Invalidate	1	If this bit is set, the IPoS terminal will invalidate its prior ranging information and revert to the defaults.
Reserved	1	This field is set by the hub to '0' and shall be ignored by the IPoS remote.
Inroute_group_ID	7	This is the inroute group where the hub will allocate bandwidth to the IPoS terminal. This will imply the use of the associated inroute type when initiating ranging.
Reserved	16	This field is set by the hub to '0' and shall be ignored by the IPoS remote.

7

8

1 **4.12.7.5 Go Active Command**

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2 Table 4.12.7.5-1 gives the fields and description of the Go Active command.

**Table 4.12.7.5-1. Go Active Command**

Field Name	Field Length (Bits)	Description
SerNr	26	The hub transmits the serial number of the IPoS terminal in this field.
Command	5	A value of 4 indicates a Go Active command. IPoS remotes will look for allocated bursts on the specified inroute group and transmit on the ones allocated to them. This command is only accepted if the IPoS remote is inactive and has already successfully ranged for the inroute type. This command is implicitly acknowledged by the act of transmitting.
Force_switch	1	If this bit is set, this will force a remote terminal to switch its inroute group.
Reserved	1	Should be transmitted as '0' and ignored on reception.
Inroute_group_ID	7	This is the inroute group where future bandwidth will be allocated.
AssignID	16	This is an ID used in the BAP.
FEC Rate	4	Specifies the FEC rate targeted on the destination inroute group. The FEC rates $\frac{1}{2}$ , $\frac{1}{3}$ and $\frac{4}{5}$ are coded as 2,3, and 4 respectively.
Reserved	4	Shall be set to 0 and ignored on reception.

3

4 **4.12.7.6 Change Inroute Group Command**

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5 Table 4.12.7.6-1 gives the fields and description of the Change Inroute Group  
6 command.

**Table 4.12.7.6-1. Change Inroute Group Command**

Field Name	Field Length (Bits)	Description
SerNr	26	The hub transmits the serial number of the IPoS terminal in this field.
Command	5	A value of 5 indicates a Change Inroute Group command. This command is only accepted if the IPoS terminal is active. This command is implicitly acknowledged by the act of using the new inroute group.
Reserved	2	Should be transmitted as 0 and ignored upon reception.

**Table 4.12.7.6-1. Change Inroute Group Command**

Field Name	Field Length (Bits)	Description
Inroute_group ID	7	This is the ID of the inroute group where future bandwidth will be allocated. The inroute type for this group must be the same type that is currently in use.
AssignID	16	This is an ID used in the BAP. A value of 0 can be used to force an IPoS terminal to become inactive.
FEC Rate	4	Specifies the FEC rate targeted on the destination inroute group. The FEC rates 1/2, 1/3 and 4/5 are coded as 2,3, and 4 respectively.
Reserved	4	Should be set to 0 and ignored on reception.

1  
23 **4.12.7.7 Reset Terminal Command**

4 Table 4.12.7.7-1 gives the fields and description of the Reset Terminal command.

**Table 4.12.7.7-1. Reset Terminal Command**

Field Name	Field Length (Bits)	Description
SerNr	26	The hub transmits the serial number of the IPoS remote in this field.
Command	5	A value of 7 indicates a Reset Terminal command. This command forces the IPoS terminal to reboot within 10 seconds of receiving the command. This delay is included to debounce multiple copies of the command that may have been sent for redundancy. No attempt shall be made to shut down gracefully such as going inactive or informing the hub. There is no acknowledgment to this command.
Reserved	1	Should be transmitted as 0 and ignored upon reception.

5

6 **4.12.7.8 Send Test Pattern Command**

7 This ICAP message pertains to ordering a terminal to send a Test Pattern.

8 **Table 4.12.7.8-1. Send Test Pattern Command**

Field	Bits	Description
SerNr	26	This is the Serial Number of the IRU
Command	5	A value of 6 indicates a Send Test Pattern Command
Reserved	2	Should be transmitted as 0 and ignored on reception

<b>Frequency Band</b>	<b>3</b>	.
		Ku = 0 (Default), Ka = 1, C = 2,
Pattern	4	The value of 0 terminates the test. The test should also be terminated if the Send Test Pattern Command is not repeated within 300 frame times. The enabling and disabling of test patterns will <b>not</b> coincide with frame boundaries.
Frequency	24	C band Frequency = 5.85 GHz + value * 100 Hz Ku band: Frequency = 14 GHz + value * 100 Hz Ka band Frequency = 29.5GHz + value * 100 Hz
Base Frequency	32	This is the base frequency of the band. This field is only valid if the frequency band is set to Custom. The IPoS Hub will transmit the base frequency for Ku, Ka and C bands but this should be ignored by the terminal

1

## 2 4.12.8 Bandwidth Allocation Packet

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3 IPoS terminals receive one BAP message each frame from the inroute group  
4 from which they are currently expecting to receive bandwidth. The IPoS  
5 terminal needs to scan the entire list in the Burst\_allocation\_record to derive the  
6 following elements needed in order to be able to transmit data and process  
7 acknowledgments:

- 8 • Inroute Group: Since the IPoS terminal can be monitoring two inroute  
9 groups it will need to confirm the inroute group based on the MAC  
10 address of the message and process only the BAP messages for which it  
11 expects to use bandwidth.
- 12 • Inroute Index: Computed as the cumulative Burst\_offset divided by the  
13 slot size of a frame. It is used as an index into the Frequency\_table of  
14 the Inroute Group Definition message.
- 15 • Frame Number: This element comes directly from the Frame\_number  
16 field of the message.
- 17 • BurstId: This is the 4 LSBs of the index into the  
18 Burst\_allocation\_record.
- 19 • Burst Offset: The cumulative burst offset starts at 0 and increases with  
20 the each Burst\_size. The burst offset is the cumulative burst offset  
21 modulo the slot size of a frame.
- 22 • Burst Size: This element comes directly from the  
23 Burst\_allocation\_record and will never cross a frame boundary.
- 24 • Acknowledgment Offset: This is the index into the entry's burst  
25 allocation table.

1 The format of the BAP message is given in table 4.12.8-1.

**Table 4.12.8-1. BAP Message Format**

Field Name	Field Length (bits)
Frame_type	8
Frame_number	16
Burst_allocation_record	24xN

2

3

The description of the fields and their values in the BAP is as follows:

4

- Frame-type: Set to 3 to indicate a BAP.

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- Frame\_number: This field indicates the Frame\_number that is allocated in this message. The value of this field shall be a future frame number with respect to the current Frame\_number; the difference is a fixed offset that allows the IPoS terminals to respond to changes in allocation.

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- Burst\_allocation\_record: This is a list of all the burst allocations for each inroute. The format of each Burst\_allocation\_record is defined in table 4.12.8-2. The list contains all the bursts in a frame, and a frame for each inroute carrier in the group. The list is limited to no more than 489 entries, since IP datagrams are limited to 1500 bytes. It is important that the list of Burst\_allocation\_record is well ordered since the IPoS terminal performs a linear search.

**Table 4.12.8-2. Format of the Burst\_allocation\_record**

Field Name	Field Length (bits)	Description
AssignID	16	This is a unique identifier used to indicate to which IPoS terminal the bandwidth was allocated. The value of 0 is used to indicate small Aloha (and nonallocated ranging) bursts, and a value of 1 is used to indicate large Aloha bursts. The value of 0xFFFF will be used to indicate bandwidth that is not assigned.
Ranging	1	This indicates whether the burst is allocated for normal (value = '0') or ranging bursts (value = '1'). While an IPoS terminal is ranging it will still be able to send encapsulated datagrams over the inroute. An active user may have ranging turned on/off to test or fine tune the value with minimal impact on performance.
Final_burst	1	If the value is '1', this is the final burst that is being assigned to this remote for the current session.
Burst_size	6	Size (in slots) of this burst, including the aperture and burst overhead.

16

## 4.12.9 Inroute Acknowledgment Packet

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The IAP message is used to explicitly acknowledge each inroute packet for assigned bandwidth with a good CRC or BCH, regardless of the presence of any encapsulation data. Besides allowing for faster recovery from inroute packet errors, this will also allow measurement of the inroute packet error rate at the IPoS remote. Aloha and nonallocated ranging packets are acknowledged explicitly.

If the IAP is lost, the IPoS terminal will retransmit the packet automatically except for any RLL bypassed data that was in the lost burst. The loss of the IAP for a particular inroute group is detected when the next IAP packet is received or, if no IAP is received, for four frame times.

The information elements in the IAP message are given in table 4.12.9-1.

**Table 4.12.9-1. IAP Message Format**

Field Name	Field Length (bits)
Frame_type	8
Frame_number	16
ACK	N

The description of the fields and their values in the IAP is as follows:

- **Frame\_type:** A value of 4 indicates an IAP.
- **Frame\_number:** This field indicates the frame number for which the acknowledgment applies and must be less than the current frame number.
- **ACK:** This field is a bitmap that matches the entries for this frame in the burst allocation table of the BAP. To determine what was acknowledged, IPoS terminals must determine which bursts were assigned to them from the BAP and remember what data was transmitted during those bursts. The value of N is derived from the length of the IP datagram and will match the value of N from the associated BAP.

## 4.12.10 Inroute Signal Receive Power (SINR) Feedback Packet (ISFP)

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In a population of Terminals that *are* employing Closed Loop Power Control feature, the ISFP message is used to explicitly acknowledge each Inroute packet for assigned bandwidth with a good CRC or BCH, regardless of the presence of any encapsulation data *and* provide a measurement of the power received at the Hub to facilitate the Closed Loop Control Feature.

The information elements in the ISFP message are given in table 4.12.10-1.

**Table 4.12.10-1. ISFP Message Format**

Field Name	Field Length (bits)
Frame_type	8
Frame_number	16
SINR Feedback Record	8*N

The description of the fields and their values in the ISFP is as follows:

- Frame\_type: A value of 8 indicates an ISFP.
- Frame\_number: This field indicates the frame number for which the acknowledgment applies and must be less than the current frame number.
- SINR Feedback\_Record: This is a list of all SINR feedbacks for each Inroute within a group. The format of each SINR\_Feedback\_Record is defined in table 4.12.10-2 The list contains all the bursts in a frame, and a frame for each Inroute carrier in the group.

**Table 4.12.10-2. SINR Field Format**

Field Name	Field Length (bits)
SINR Feedback	8

- SINR\_Feedback: This 8-bits field provides received Es/No value of the burst. The value is specified in units of one-tenth of dB. Supported range is from 0 to 25.5 dB.

### **4.12.11 Mesh Command And Acknowledment Packet (MCAP)**

Mesh messages from the MRC to the terminals are sent via a Mesh Command/Acknowledgement Packet (MCAP). The MCAP message provides responses to terminal and connection level message that are sent from the terminals to the MRC. The MCAP message may also provide unsolicited messages to terminals. The MCAP packet is formatted similar to the ICAP packet with multiple MRC messages embedded in the MCAP packet. A terminal searches the MCAP packet for its serial number to find messages sent by the MRC to itself. Unlike an ICAP message, the MCAP message supports a "broadcast" message that is destined to all terminals on the network. A special serial number of all zeros is used to indicate an MRC message which is addressed to all of the terminals using this MRC. MCAP messages are sent using inroute group level MAC addressing. In some cases, the MRC may need to duplicate a message to send it each inroute group supported by its Hub.

The information elements in theMCAP are given in table 4.12.11-1.

**Table 4.12.11-1. MCAP Message Format**

Field Name	Field Length (bits)
Frame_type	8
Number of Entries	8
Offset Table	N*16
Command And Acknowledgment	M*8

1  
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The description of the fields and their values in the MCAP is as follows:

- Frame-type: Set to a value of 32 to indicate an MCAP
- Number\_of\_entries: The value in this field is the number of entries in the following Offset\_table field.
- Offset\_table: This is a table of offsets where each of the variable sized Command/Acknowledgment fields begins. The size should be known based on the Command field. Each offset is an 11-bit value and starts from the beginning of the Offset\_table. The value of N is the number of entries. Note that since the offset is 11 bits, there are 5 reserved bits for each entry.
- Command/Acknowledgment: This is a list of commands or acknowledgments sorted by SerNr with the fields defined in the following subsections. No more than one command or acknowledgment can be sent to an IPoS Remote Terminal per packet.

Each MCAP command (entry) shares a common format for the first four (4) bytes. This common format contains the terminal serial number followed by the command identifier. The format of these bytes is given in 4.12.11-2.

**Table 4.12.11-2. MCAP Sub-Command Common Header**

Field Name	Field Length (bits)
Serial Number	26
Command	5
Reserved	1

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20  
21  
22  
23  
24  
25  
26  
27

The description of the fields and their values in the MCAP common header is as follows:

- Serial Number: This field indicates the serial number of the terminal that the message is directed to.
- Command: This field indicates the MCAP command. Valid command values are described in Table 4.12.11-3.

The valid MCAP commands and acknowledgments (entries) are given in 4.12.11-3.

**Table 4.12.11-3. MCAP Message Format**

Value	Message Type	Description/Notes
1	Register ACK	This is a <b>terminal</b> level message. The MRC sends a Register ACK to acknowledge successful receipt of a Register message that was sent from the terminal.
2	Ready ACK	This is a <b>terminal</b> level message. The MRC sends a Ready ACK to acknowledge successful receipt of a Ready message that was sent from the terminal.
3	Register Now	This is a <b>terminal</b> level message. The MRC may send a Register Now message to all terminals or individual terminals. The MRC would send a Register Now message to all terminals after a MRC restart. The MRC may send a Register Now message to individual terminals if the MRC and the terminal became out of sync.
4	Unregister ACK	This is a <b>terminal</b> level message. The MRC sends an Unregister ACK to acknowledge successful receipt of an Unregister message that was sent from the terminal.
5	Connectivity Needed ACK	This is a <b>per-connection</b> level message. The MRC <i>may</i> send a Connectivity Needed ACK in response to a Connectivity Needed message from the terminal.
6	Open Connection	This is a <b>per-connection</b> level message. Assuming a bidirectional mesh connection, the MRC sends an Open Connection message to the originating terminal and the peer terminal. The Open Connection message is sent in response to a Connectivity Needed message
7	Connection Closed ACK	This is a <b>per-connection</b> level message. The MRC sends a Connection Closed ACK to acknowledge successful receipt of a Connection Closed message that was sent from the terminal. The Connection Closed ACK is sent to the terminal that requested the connection be closed.
8	Release Connection	This is a <b>per-connection</b> level message. The MRC sends a Release Connection message to inform a terminal to end (release) a mesh connection. Unlike the Connection Closed ACK message, the Release Connection is an unsolicited message sent to a terminal.
9	Bandwidth Change Request ACK	This is a <b>per-connection</b> level message. The MRC sends a Bandwidth Change Request ACK to acknowledge successful receipt of a Bandwidth Change Request message that was sent from the terminal.

1    **4.12.11.1    Register ACK Message**

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2           Register ACK message is sent from the MRC to the terminal in response to a  
3           Register message sent from the terminal. The Register ACK message provides a  
4           list of Assign IDs that should be used for mesh connection. For a standalone  
5           terminal, only one (1) Assign ID is provided. For a Mesh Gateway terminal, a  
6           number of Assign IDs are provided. The message details are given in Table  
7           4.12.11.1-1.

**Table 4.12.11.1-1. Register ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Register ACK message is directed to.
Command	5	A value of 1 indicates a Register ACK command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Register ACK message.
Response Indicator	1	Indicates if the terminal has successfully registered (ACK) or not (NAK) with the MRC. A value of 1 indicates an ACK and a value of 0 indicates a NAK.
Reason	7	When the <i>Response Indicator</i> field indicates the terminal did <b>not</b> register with the MRC, the Reason field provides an enumerated reason why the terminal could not register.
Message ID	8	Used to verify that the acknowledgement corresponds to the latest Register message sent, other the terminal should ignore the ack.
Number of Assign IDs (N)	8	The number of Assign IDs that follow.
Assign IDs	16N	Provides a list of N Assign IDs that should be used for mesh communication.

8

9    **4.12.11.2    Ready ACK Message**

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10           Register ACK message is sent from the MRC to the terminal in response to a  
11           Ready message sent from the terminal. The message details are given in Table  
12           4.12.11.2-1.

**Table 4.12.11.2-1. Ready ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Ready ACK message is directed to.
Command	5	A value of 2 indicates a Ready ACK command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Ready ACK message.
Response Indicator	1	Indicates if the MRC has successfully acknowledged (ACK) the Ready message sent from the terminal. A value of <b>1</b> indicates an ACK and a value of <b>0</b> indicates a NAK. The MRC may send a NAK if the terminal is currently not registered with the MRC.
Reason	7	When the <i>Response Indicator</i> field indicates a <b>NAK</b> , the Reason field provides an enumerated reason why the MRC did not successfully acknowledge the Ready message from the terminal.

### 1 4.12.11.3 Register Now Message

2 The Register Now message is sent from the MRC to a terminal or all terminals  
 3 when the MRC becomes out of sync with a terminal(s). This message is sent to  
 4 all terminals if the MRC resets. In this case, the Serial Number field is set to a  
 5 'special' all zeros (0) value. A Register Now message may be sent to an  
 6 individual terminal if the MRC and terminal get out of sync. The message details  
 7 are given in Table 4.12.11.3-1.

**Table 4.12.11.3-1. Ready ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Register Now message is directed to. This field is set to all zeros (0) if the Register Now message is intended for all terminals using this MRC.
Command	5	A value of 3 indicates a Register Now command.

**Table 4.12.11.3-1. Ready ACK Message**

Field Name	Field Length (Bits)	Description
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Register Now message.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Reason	7	Indicates the reason why the Register Now message is sent. Possible values include: <ol style="list-style-type: none"> <li>1. The MRC was restarted (Sent on MRC startup)</li> <li>2. Invalid Ready Message received at the MRC</li> <li>3. Connection message received at the MRC for an unregistered terminal</li> </ol>
Message Timestamp	32	The timestamp, expressed in Unix time (number of seconds since midnight January 1, 1970), when the Register Now message was initially sent. The terminal uses the Message Timestamp field to determine when a duplicate Register Now message has been sent that the terminal has already responded to.

1 **4.12.11.4 Unregister ACK Message**

---

2 Register ACK message is sent from the MRC to the terminal in response to a  
3 Unregister message sent from the terminal. The message details are given in  
4 Table 4.12.11.4-1.

**Table 4.12.11.4-1. Unregister ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Unregister ACK message is directed to.
Command	5	A value of 4 indicates a Ready ACK command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Unregister ACK message.

**Table 4.12.11.4-1. Unregister ACK Message**

Field Name	Field Length (Bits)	Description
Response Indicator	1	Indicates if the MRC has successfully acknowledged (ACK) the Unregister message sent from the terminal. A value of <b>1</b> indicates an ACK and a value of <b>0</b> indicates a NAK.
Reason	7	When the <i>Response Indicator</i> field indicates a <b>NAK</b> , the Reason field provides an enumerated reason why the MRC did not successfully acknowledge the Unregister message from the terminal.

1 **4.12.11.5 Connectivity Needed ACK Message**

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2 The Connectivity Needed ACK message may be sent to a terminal in response to  
3 a Connectivity Needed message sent from the originating terminal.

4 If the MRC is able to service the connection request, the MRC typically does not  
5 send a Connectivity Needed ACK to the terminal. Rather the MRC sends an  
6 Open Connection message to the terminal, which the terminal uses as an implicit  
7 ACK to the Connectivity Needed request. However, if the MRC is unable to  
8 service the connection request, the Connectivity Needed ACK message indicates  
9 the appropriate error condition. The message details are given in  
10 Table 4.12.11.5-1.

**Table 4.12.11.5-1. Connectivity Needed ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Connectivity Needed ACK message is directed to.
Command	5	A value of 5 indicates a Ready ACK command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Connectivity Needed ACK message.

**Table 4.12.11.5-1. Connectivity Needed ACK Message**

Field Name	Field Length (Bits)	Description
Response Indicator	1	Indicates if the Connectivity Needed message can be serviced (ACK) or not (NAK). A value of <b>1</b> indicates an ACK and the connection request was successful. A value of <b>0</b> indicates a NAK and the following Reason field provides the reason why the connection could not be serviced.
Reason	7	If the <i>Response Indicator</i> indicates that the connection could not be established, this field indicates the reason why the connection could not be established.
Terminal Connection ID (TCID)	16	The Terminal Connection Identifier (TCID) that is used by the terminal for each mesh connection.

1 **4.12.11.6 Open Connection Message**

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2 The Open Connection message is sent to a terminal in response to a Connectivity  
3 Needed message for the originating terminal. This message provides the terminal  
4 with information required to receive data from the other (peer) terminal and  
5 information required to transmit data to the peer terminal. The message details  
6 are given in Table 4.12.11.6-1.

7 Note that some of the fields would be zero (0) for a terminal participating in a  
8 unidirectional mesh connection. For example, if a terminal is the transmitting  
9 terminal in a mesh connection, the Peer Assign ID, Peer Transmit Inroute, and  
10 Peer Transmit Inroute Group fields would be 0. Similarly, if a terminal is the  
11 receiving terminal in a mesh connection, the Transmit Assign ID field would be  
12 zero.

**Table 4.12.11.6-1. Open Connection Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Open Connection message is directed to.
Command	5	A value of 6 indicates a Open Connection command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.

**Table 4.12.11.6-1. Open Connection Message**

Field Name	Field Length (Bits)	Description
Version	8	The Version of the Open Connection message.
Connection Type	8	The type of mesh connection requested. Valid values include: <ul style="list-style-type: none"> <li>• 1 – Activity Triggered</li> <li>• 2 – Permanent</li> <li>• 3 – Application Requested</li> </ul>
Terminal Connection ID (TCID)	16	The Terminal Connection Identifier (TCID) that is used by the terminal for each mesh connection. For the Open Connection message sent to the originating terminal, the TCID sent in the Connectivity Needed message is used. For the Open Connection message sent to the peer terminal, a value of 0 is used for the TCID.
MRC Connection ID (MCID)	16	The MCID that is created at the MRC to uniquely identify this mesh connection.
Local Subnet	40	The IP subnet of the local terminal (e.g. the terminal that received this message). Supernet CIDR type addressing is used. The first four (4) bytes are the source IP address and the fifth (5 <sup>th</sup> ) byte is the prefix length
Peer Subnet	40	The IP subnet of the peer terminal. Supernet CIDR type addressing is used. The first four (4) bytes are the source IP address and the fifth (5 <sup>th</sup> ) byte is the prefix length
Peer Assign ID	16	The Assign ID of the peer (other) terminal. This Assign ID is used to identify which bursts the peer terminal is transmitting and to then open apertures for bursts transmitted by the peer terminal.
Peer Transmit Inroute Frequency	32	The Inroute frequency that the peer (other) terminal is transmitting on.
Peer Transmit Inroute Group	8	The Inroute Group that the peer (other) terminal is transmitting on.
Terminal Assign ID	16	The Assign ID for the terminal that should perform the transmitting for this mesh connection.

**Table 4.12.11.6-1. Open Connection Message**

Field Name	Field Length (Bits)	Description
Receive Assign ID	16	The Assign ID for the terminal that should perform the receiving for this mesh connection.
Bandwidth Granted	16	The amount of bandwidth, in bytes, granted for the mesh connection.

1 **4.12.11.7 Connection Close ACK Message**

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2 The Connection Close ACK message is sent to a terminal in response to a  
3 Connection Close message sent from the originating terminal. The Connection  
4 Closed ACK informs the terminal that the requested mesh connection has been  
5 closed at the MRC. The message details are given in Table 4.12.11.7-1.

**Table 4.12.11.7-1. Connection Closed ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Connectivity Closed ACK message is directed to.
Command	5	A value of 7 indicates a Connection Closed ACK command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Connection Closed ACK message.
Response Indicator	1	Indicates if the Connection Closed can be serviced (ACK) or not (NAK). A value of <b>1</b> indicates an ACK and the connection close request was successful. A value of <b>0</b> indicates a NAK and the following Reason field provides the reason why the connection could not be closed.
Reason	7	If the <i>Response Indicator</i> indicates that the connection could not be established, this field indicates the reason why the connection could not be closed.

**Table 4.12.11.7-1. Connection Closed ACK Message**

Field Name	Field Length (Bits)	Description
Terminal Connection ID (TCID)	16	The Terminal Connection Identifier (TCID) that is used by the terminal for each mesh connection.
MRC Connection ID (MCID)	16	The MCID that is created at the MRC to uniquely identify this mesh connection.

1 **4.12.11.8 Release Connection Message**

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2 Typically, the Release Connection message is sent to a (peer) terminal in  
 3 response to a Connection Close message sent from the originating terminal. The  
 4 Release Connection message is an unsolicited message sent from the MRC to a  
 5 peer terminal informing the terminal that the indicated mesh connection has  
 6 been closed at the MRC.

7 The Release Connection message may also be unsolicited to both terminals  
 8 (originating and peer) under some error scenario at the MRC. The message  
 9 details are given in Table 4.12.11.8-1.

**Table 4.12.11.8-1. Release Connection Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Release Connection message is directed to.
Command	5	A value of 8 indicates a Release Connection command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Release Connection message.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Reason	7	This field indicates the reason why the connection should be released.
Terminal Connection ID (TCID)	16	The Terminal Connection Identifier (TCID) that is used by the terminal for each mesh connection.

**Table 4.12.11.8-1. Release Connection Message**

Field Name	Field Length (Bits)	Description
MRC Connection ID (MCID)	16	The MCID that is created at the MRC to uniquely identify this mesh connection.

1 **4.12.11.9 Connection Close ACK Message**

2 The Bandwidth Change Request ACK message is sent to a terminal in response  
 3 to a Bandwidth Change Request message sent from the terminal. The Bandwidth  
 4 Change Request ACK informs the terminal if its bandwidth change request has  
 5 been granted and the terminal's and the terminal's new bandwidth. The message  
 6 details are given in Table 4.12.11.9-1.

**Table 4.13.11.1-9. Bandwidth Change Request ACK Message**

Field Name	Field Length (Bits)	Description
SerNr	26	Serial number of the terminal that the Bandwidth Change Request ACK message is directed to.
Command	5	A value of 9 indicates a Bandwidth Change Request ACK command.
Reserved	1	This field is set by the Hub to '0' and shall be ignored by the IPoS Remote Terminal.
Version	8	The Version of the Bandwidth Change Request ACK message.
Response Indicator	1	Indicates if the Bandwidth Change Request can be serviced (ACK) or not (NAK). A value of <b>1</b> indicates an ACK and the bandwidth change request was successful. A value of <b>0</b> indicates a NAK and the following Reason field provides the reason why the bandwidth could not be adjusted.
Reason	7	If the <i>Response Indicator</i> indicated that the bandwidth could not be adjusted, this field indicates the reason why the bandwidth could not be adjusted.
Terminal Connection ID (TCID)	16	The Terminal Connection Identifier (TCID) that is used by the terminal for each mesh connection.

**Table 4.13.11.1-9. Bandwidth Change Request ACK Message**

Field Name	Field Length (Bits)	Description
MRC Connection ID (MCID)	16	The MCID that is created at the MRC to uniquely identify this mesh connection.
Bandwidth Granted	16	The amount of bandwidth, in bytes, granted for the mesh connection. Note that even if the bandwidth could not be adjusted, this field indicates the current bandwidth allocation rate for the mesh connection.

1

## 2 **4.12.12 Periodic Adapter Conditional Access Update** 3 **(PACAU)**

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4 The hub periodically transmits the PACAU packet containing the decryption  
5 element keys (EKs) used for the decryption of encrypted unicast traffic. The  
6 PACAUs also contain multicast group keys (GKs) for the multicast service  
7 elements for which the transceiver has been enabled. The PACAU can contain  
8 multiple GKs and EKs simultaneously, in which case the Group ID field will  
9 form an array of entries, one of which may be an EK. The PACAU is  
10 individually addressed to each IPoS remote's Unicast Conditional Access  
11 address.

12 For clarity, the PACAU packet has been split into two subsections. The first, the  
13 PACAU header, contains addressing and version information for the PACAU  
14 packet. The second, the PACAU array entry, contains the keys for each group or  
15 element of which the IPoS remote is a member, ordered by group ID. The  
16 PACAU header is defined in table 4.12.12-1, the PACAU payload for the GKs is  
17 given in table 4.12.12-2, and the PACAU payload for the EKs is defined in  
18 table 4.12.12-3.

**Table 4.12.12-1. PACAU Header Format**

Field Name	Field Length (Bits)	Description
PACAUVer	32	Current PACAU version for this IPoS terminal
ICAUVer	32	Current ICAU version for this IPoS terminal
Timestamp	64	ICAU_Request backoff time in seconds that the IPoS remote should randomize before sending an ICAU_Request
SiteID	80	This is the unique Site ID of the IPoS terminal provided to the IPoS remote in this packet.
EEMK	128	EEMK for this IPoS remote

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**Table 4.12.12-2. PACAU Group Key Entry Format**

Field Name	Field Length (Bits)	Description
GroupID	24	Unique GroupID
Version	8	Current crypto version
Crypto Key	64	Crypto Key

1

**Table 4.12.12-3. PACAU Element Key Entry Format**

Field Name	Field Length (Bits)	Description
ElementID	24	Set to 0xFF
Version	8	Current crypto version
Crypto Key	64	Crypto Key

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The PACAU EK payload is distinguished from the PACAU GK payload by the EK's payload Element ID field value being equal to 0xFF.

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### 4.12.13 Periodic Element Broadcast (PEB)

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The hub periodically sends the PEB command providing mapping information that shall be used by the IPoS terminal to map encrypted multicast encryption keys to MAC addresses sent over the unicast conditional access channel. The fields and meanings in the PEB are given table 4.12.13-1.

**Table 4.12.13-1. PEB Format**

Field Name	Field Length (bits)	Description
VersionNumber	32	VersionNumber of PEB
GroupID	24	GroupID of which this element is a member
GroupVersion	8	Crypto version of the group
Number of Entries	16	This field contains the number of MACAddresses to which the PEB applies.
MACAddress	Nx48	This field contains all the MAC addresses to which the PEB applies. N is defined by the value of the Number of Entries field.

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### 4.12.14 DVB-S2 ACM Message

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In DVB-S2 ACM mode, the Hub segment sends out Unicast traffic to an IPoS terminal whose modulation and coding rate can change dynamically depending upon the local condition, e.g. weather.

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The specification defines two mechanisms for the feedback process. The IPoS terminal can take the responsibility to indicate via an ACM message a need for the Hub to use a different modulation and coding rate when it determines an inconsistency between current modulation and coding rate and outroute Es/No

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1 measured at the terminal. Another way can be the IPoS terminal feeds back its  
2 Outroute Signal Quality to the Hub .

3 Irrespective of the feedback mechanism, the IPOS terminal's ACM message is  
4 sent as an inroute MAC PDU (see section 4.10) either on Unallocated or  
5 Allocated channel.

#### 6 **4.12.14.1 Preferred DVB-S2 Outroute ACM Mode**

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7 The IPoS terminal sends a request to the Hub indicating what modulation and  
8 code rate the Hub should use on the outroute for Unicast traffic when it  
9 determines a change is necessary. The terminal uses the adaptation field of the  
10 MAC header for modulation and code rate change indication purposes.

11 When bit 1 (see IPoS section 4.10.1.1.4) in the bitmask field of the Adaptation  
12 field is set to '1' by the IPoS terminal, the modulation and coding rate Indication  
13 option is included in the Adaptation field. The meaning in the modulation and  
14 code rate Indication option are given in table 4.12.12.1-2.

15 During the remote installation, theMODCODs supported by the system shall be  
16 downloaded.

**Table 4.12.14.1-1. DVB-S2 Modulation and Code Rate Indication Format**

Field Name	Field Length (Bits)	Description
ModCod	8	This field provides the code for the requested modulation and coding rate. The meaning of each code is defined in Table 4.12.14.1-2

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**Table 4.12.14.1-2. DVB-S2 Code for Modulation and Code Rate**

3

ModCod	Modulation	FEC Code	Inner Code Rate
1	QPSK	LDPC+BCH	1/4
2	QPSK	LDPC+BCH	1/3
3	QPSK	LDPC+BCH	5/12
4	QPSK	LDPC+BCH	1/2
5	QPSK	LDPC+BCH	3/5
6	QPSK	LDPC+BCH	2/3
7	QPSK	LDPC+BCH	3/4
8	QPSK	LDPC+BCH	4/5
9	QPSK	LDPC+BCH	5/6
10	QPSK	LDPC+BCH	8/9
11	QPSK	LDPC+BCH	9/10
12	8-PSK	LDPC+BCH	3/5
13	8-PSK	LDPC+BCH	2/3
14	8-PSK	LDPC+BCH	3/4
15	8-PSK	LDPC+BCH	5/6
16	8-PSK	LDPC+BCH	8/9
17	8-PSK	LDPC+BCH	9/10
18	16APSK	LDPC+BCH	2/3
19	16APSK	LDPC+BCH	3/4
20	16APSK	LDPC+BCH	4/5
21	16APSK	LDPC+BCH	5/6
22	16APSK	LDPC+BCH	8/9
23	16APSK	LDPC+BCH	9/10
24	32APSK	LDPC+BCH	3/4
25	32APSK	LDPC+BCH	4/5

26	32APSK	LDPC+BCH	5/6
27	32APSK	LDPC+BCH	8/9
28	32APSK	LDPC+BCH	9/10

## 1 **4.13 Configurable Parameters**

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2 The remote terminal needs to have the following data configured locally as part  
3 of its commissioning procedure before it can acquire an outroute and send data:

- 4
- Outroute:
    - 5 – Frequency
    - 6 – Symbol rate
    - 7 – Coding rate
    - 8 – Modulation type
    - 9 – Valid outroute groups for this terminal
  - 10 • Satellite longitude
  - 11 • Longitude and latitude of terminal site
  - 12 • IP address of IP packet processor at the hub
  - 13 • Its own internal IP address within the system

14 The hub must have the encrypted keys configured for every IPoS terminal with  
15 which it will operate and for every multicast stream.

## 1 **ANNEX A - (NORMATIVE): STATE MACHINES**

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2 This annex shows state machines and message sequence diagrams for several of  
3 the processes that IPoS remote terminals execute. These are logical state  
4 diagrams that are intended to illustrate functions; they do not imply a particular  
5 implementation.

### 6 **A.1 Superframe Synchronization**

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#### 7 **A.1.1. State Diagram**

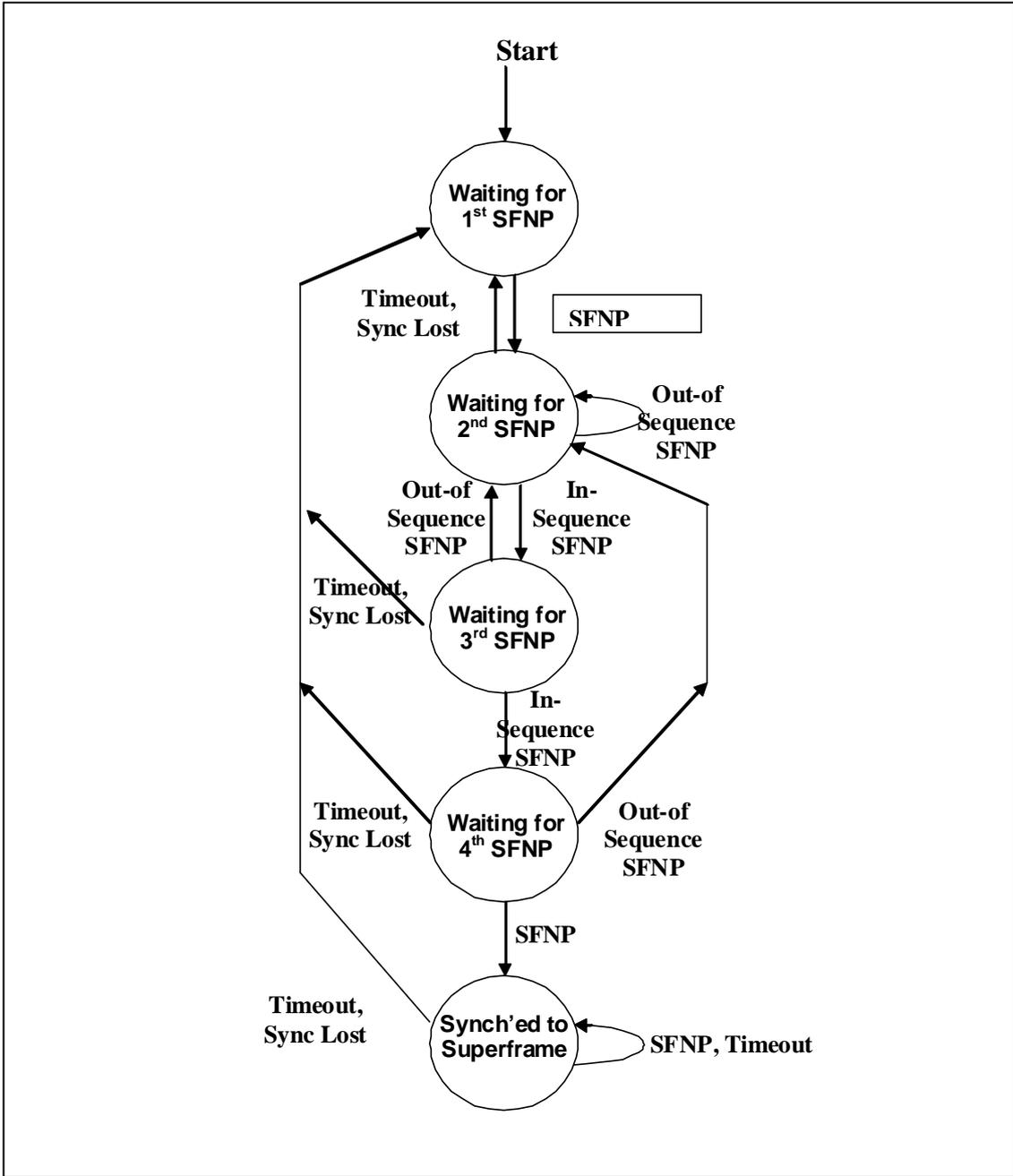
8 Figure A.1.1-1 and the flowcharts in the following subsections show the states  
9 and transitions that embody the superframe synchronization logic that is  
10 described in subsection 4.10.1.4.3. When the terminal acquires or loses  
11 superframe synchronization, it sends a corresponding event to the main remote  
12 terminal state machine that is described in section A.2 of this annex.

13 Under normal conditions, after the terminal starts, the following sequence of  
14 events occurs:

- 15 1. The terminal enters the Waiting for 1<sup>st</sup> SFNP state.
- 16 2. After some period of time, the terminal receives its first SFNP. The  
17 terminal advances to the Waiting for 2<sup>nd</sup> SFNP state.
- 18 3. The terminal receives its second SFNP. If the number on this SFNP  
19 indicates that it is the next SFNP sequence, the terminal advances to the  
20 Waiting for 3<sup>rd</sup> SFNP state. Instead, if the timeout occurs (about  
21 361 msec after the first SFNP was received), this indicates that the next  
22 SFNP was missed and the terminal returns to the Waiting for 1<sup>st</sup> SFNP  
23 state.
- 24 4. The terminal receives its third SFNP, and the sequence number is the  
25 next one expected. The terminal advances to the Waiting for 4<sup>th</sup> SFNP  
26 state.
- 27 5. The terminal receives its fourth SFNP, and the sequence number is the  
28 next one expected. Also the hub timing is within eight clock ticks of the  
29 remote terminal's timing. The terminal enters the Sync'ed-to-  
30 Superframe state and sends a Superframe Sync event to the Main  
31 Terminal state machine.

32 The flowcharts in subsections A.1.2 and A.1.3 show how synchronization events  
33 are processed in the Sync'ed-to-Superframe state.

34



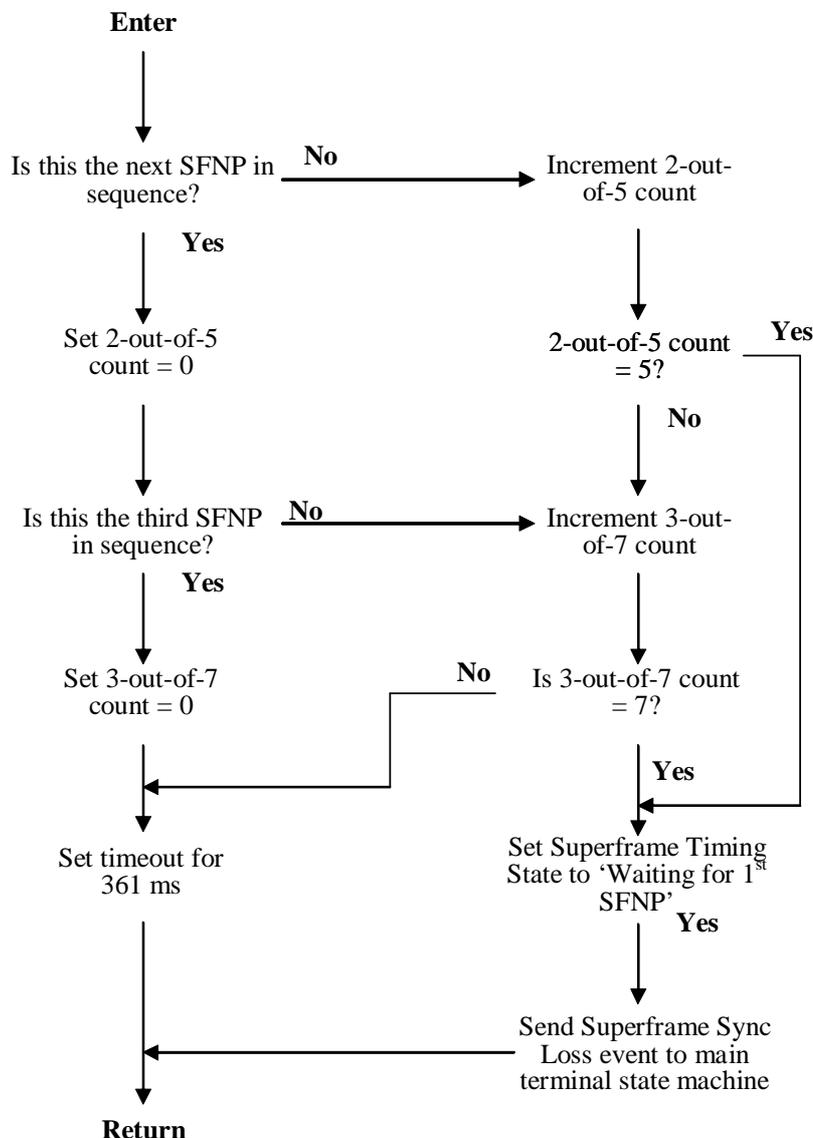
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Figure A.1.1-1. IPoS Terminal Superframe Timing States

**A.1.2 SFNP Processing in Sync'ed-to-Superframe State**

Figure A.1.2-1 shows the processing in the Sync'ed-to-Superframe state when the terminal receives an SFNP. Typically this will be the next SFNP in sequence. The terminal sets the 2-out-of-5 counter to zero indicating that it has been 0 frames since two sequential SFNPs have been received. Furthermore, if this is the 3rd SFNP that has been received in sequence, the terminal sets the

1 3-out-of-7 counter to zero to indicate that it has been 0 frames since three  
 2 sequential SFNPs have been received.



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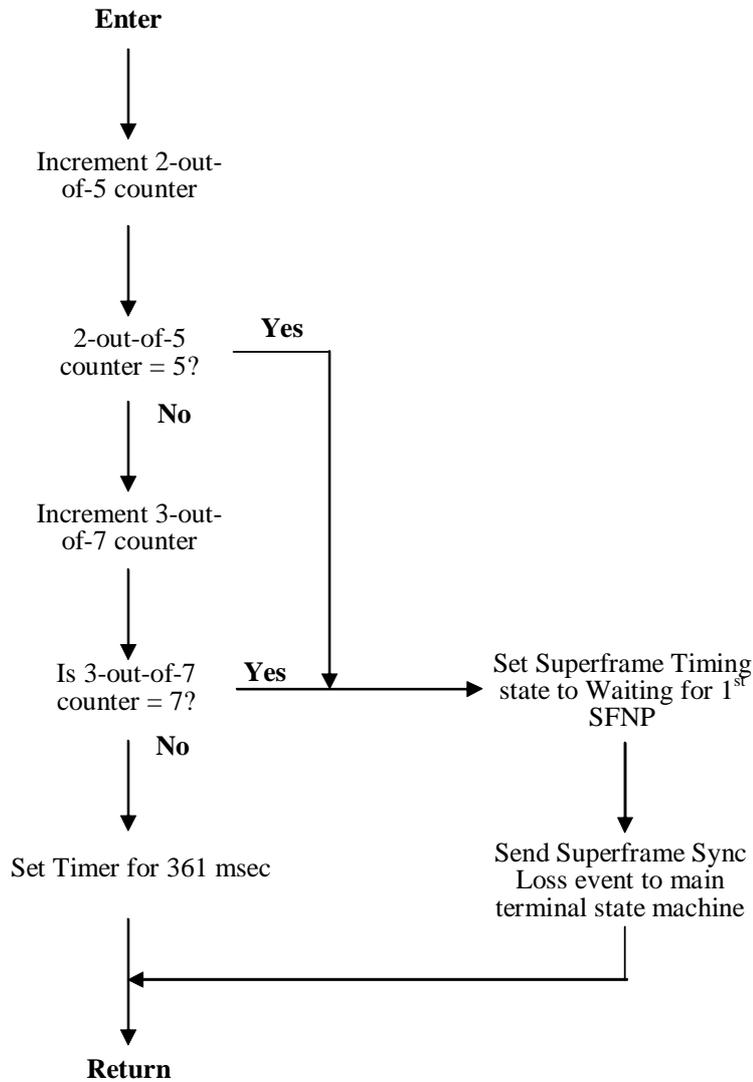
5 **Figure A.1.2-1. Processing for SFNP in Sync'ed-to-Superframe State**

6 **A.1.3 Timeout Processing in Sync'ed-to-Superframe State**

7 Figure A.1.3-1 shows the processing for a timeout received in the Sync'ed-to-  
 8 Superframe state. The timeout is set for 361 msec, 1 msec longer than the  
 9 superframe interval, so a timeout indicates that an SFNP was missed.

10  
 11 For a missed SFNP timeout, the terminal increments both the 2-out-of-5 and  
 12 3-out-of-7 counters to indicate the number of frames missed. If the number of  
 13 frames missed now meets either criterion for superframe sync loss, the state

1 machine sends a sync loss event to the main terminal state machine. Otherwise,  
 2 the terminal waits for the next superframe interval. See Figure A.1.3-1.



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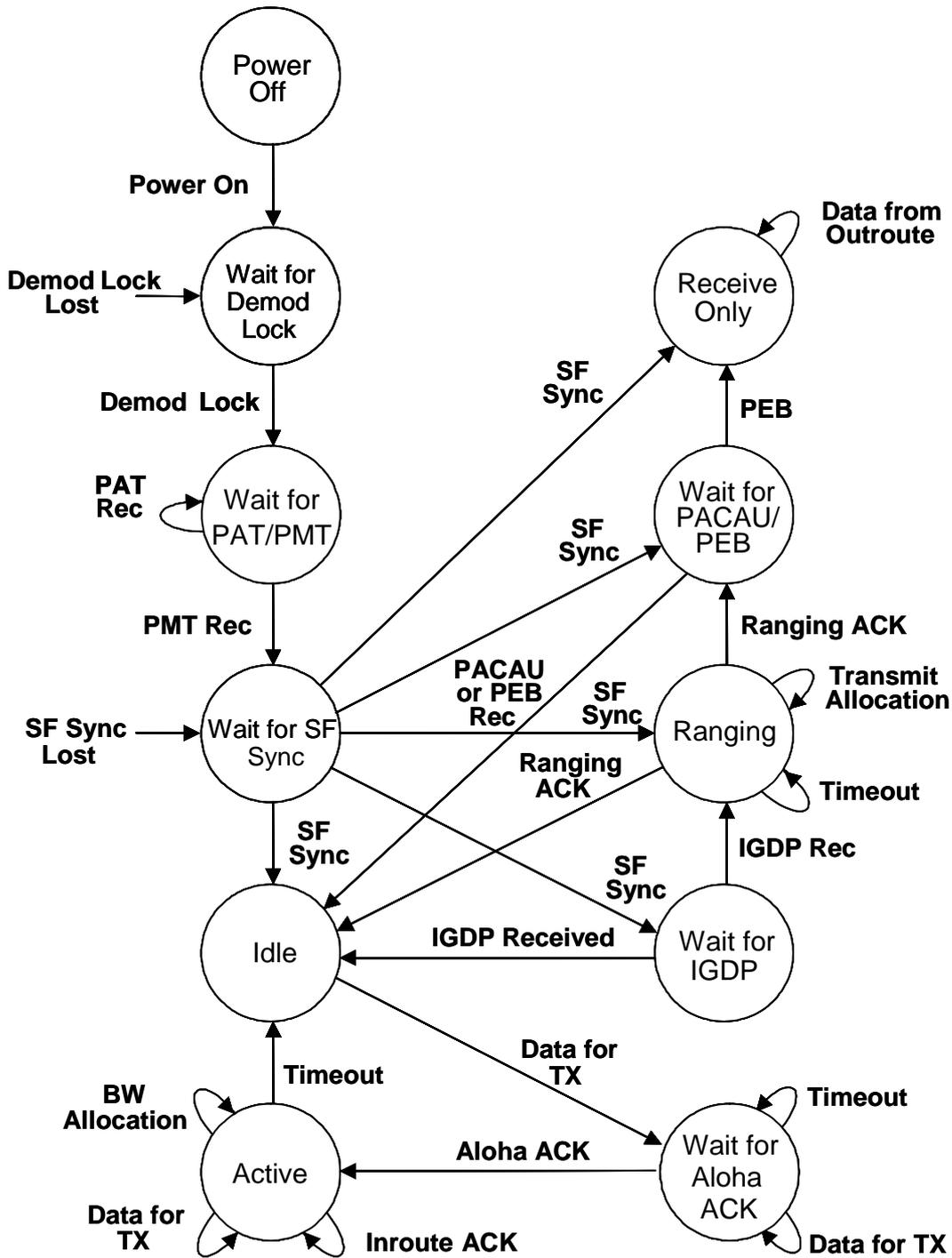
5 **Figure A.1.3-1. Processing for Superframe Timeout in Superframe State**

6 **A.2 Remote Terminal Operating States**

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7 **A.2.1 Normal Operation**

8 This subsection describes the event/state processing for the case where there are  
 9 no errors or failures. Figure A.2.1-1 shows the remote terminal states.



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**Figure A.2.1-1. IPoS Remote Terminal State Diagram**

Assuming that a terminal has already been commissioned, received its encryption keys, and ranged, a terminal might perform the following functions when power is applied:

- 1  
2 1. Enter the frequency and modulation parameters for the demodulator (see subsection A.2.2).
- 3 2. Enter the Wait for Demod Lock state.
- 4 3. After a few seconds, the demodulator locks onto the  
5 outroute, and the terminal enters the Wait for PAT/PMT  
6 state (see subsection A.2.3).
- 7 4. The terminal receives the DVB PAT (Program  
8 Association Table) message. From the PAT the terminal  
9 determines which PID is listed to receive the PMT  
10 (Program Map Table) DVB message  
11 (see subsection A.2.4).
- 12 5. The terminal receives the PMT message and determines  
13 the PIDs to be used for IPoS control messages and data.  
14 The terminal sets the hardware to receive data from these  
15 PIDs and enters the Wait for SF Sync state (see  
16 subsection A.2.5).
- 17 6. While it is in the Wait for SF Sync state, the terminal  
18 processes both SFNPs and IGDPs that it receives (see  
19 subsections A.1 and A.2.6). During this time, the  
20 Superframe Synchronization state machine runs  
21 independently of the terminal's high-level state machine.
- 22 7. The terminal receives a sufficient number of consecutive  
23 SFNPs to declare that superframe synchronization has  
24 been acquired. The terminal enters the Idle state (see  
25 subsection A.2.7). In this state the terminal sends any IP  
26 packets that it receives from the outroute that are  
27 addressed to the terminal (either by unicast or multicast)  
28 through the SI-SAP to the layer above the DLC layer.
- 29 8. When the terminal sends an IP packet through the SI-  
30 SAP to the DLC layer for transmission, the terminal uses  
31 the inroute group selected during idle. The inroute  
32 group must have one or more Aloha request channels.
- 33 9. The terminal sends an Aloha request for bandwidth  
34 along with the first part of the IP packet to be sent to the  
35 hub and enters the Wait for Aloha ACK state (see  
36 subsection A.2.8).
- 37 10. The terminal receives an Aloha Ack message and enters  
38 the Active state (see subsection A.2.9).
- 39 11. The terminal receives successive BAPs.

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- 12. The terminal transmits the remaining IP data, including new IP packets that may have come in since the first one (see subsection A.2.10).
- 13. The terminal runs out of data and stops sending IP data. However, it must send idle bursts for any allocations that it receives.
- 14. The terminal has no data to transmit and receives a configurable number of consecutive frames without receiving a bandwidth assignment (see subsection A.2.11).
- 15. The terminal enters the Idle state.

### A.2.2 Enter Wait for Demod Lock State

Figure A.2.2-1 shows the processing executed when the remote terminal starts up or after it has lost demod lock. The terminal initializes its data buffers and address filters and waits for the demodulator to lock to the outroute.

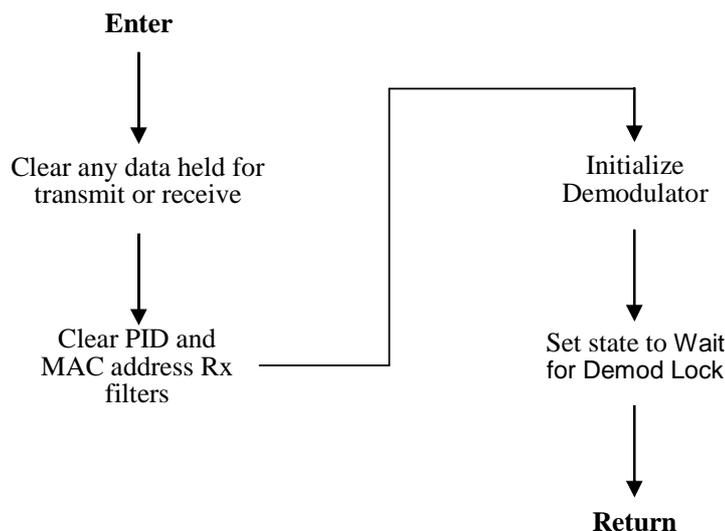
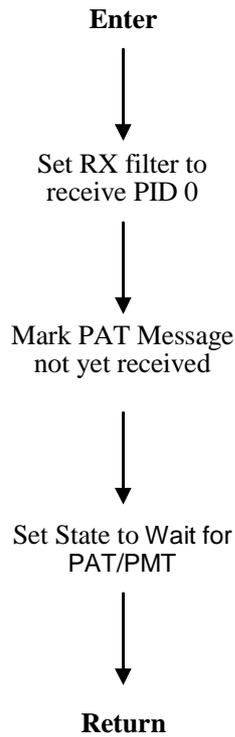


Figure A.2.2-1. Processing for Entering the Wait for Demod Lock State

### A.2.3 Demod Lock Received in Wait for Demod Lock State

Figure A.2.3-1 shows the processing executed when the remote terminal receives demodulator lock when it is in the Wait for Demod Lock state. The terminal sets the receive filter to PID 0, the DVB PID on which PAT and PMT messages are sent. Then the terminal enters the Wait for PAT/PMT state for the first PAT message.

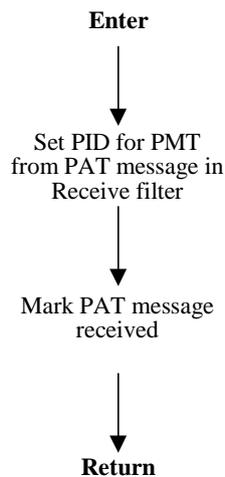


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3 **Figure A.2.3-1. PAT Message Processing in the Wait for PAT/PMT State**

4 **A.2.4 PAT Message Received in Wait for PAT/PMT State**

5 Figure A.2.4-1 shows the processing executed when the remote terminal receives  
 6 a PAT message while it is in the Wait for PAT/PMT state. The PAT message  
 7 gives the terminal the value of the PID on which it should expect to receive the  
 8 PMT message. The terminal sets its receive filter to process this PID.

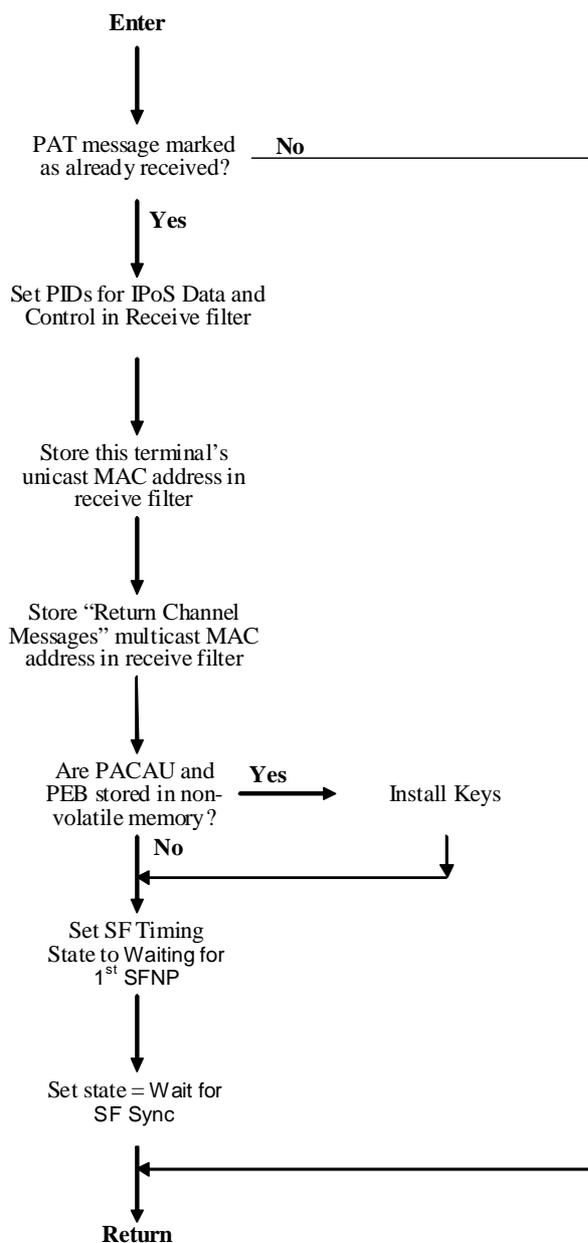


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10 **Figure A.2.4-1. PAT Message Processing in the Wait for PAT/PMT State**

### 1    **A.2.5    PMT Message Received in Wait for PAT/PMT State**

2    Figure A.2.5-1 shows the processing executed when the remote terminal receives  
3    a PMT message while it is in the Wait for PAT/PMT state. The PMT message  
4    gives the terminal the PIDs to use for IPoS data and control messages, and the  
5    terminal sets its receive filter to process these PIDs. If the keys have already  
6    been received, the terminal installs them in the decryption device. The terminal  
7    then sets the state in the Superframe Synchronization state machine  
8    (see subsection A.1) to Wait for SF Sync to begin the process of establishing  
9    superframe synchronization.

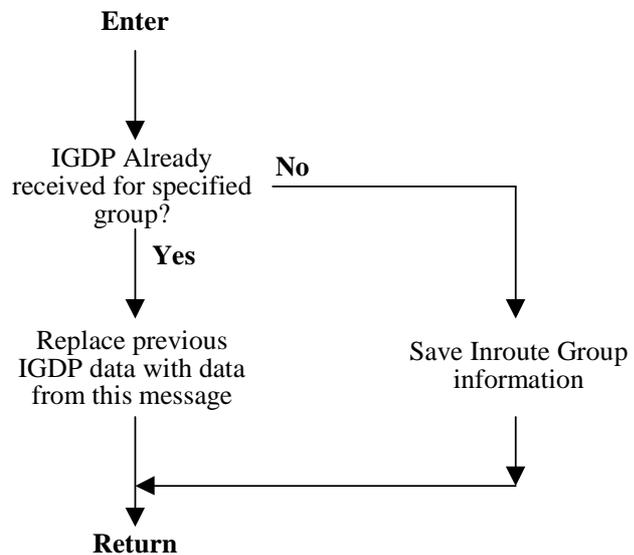


10

11    **Figure A.2.5-1. PMT Message Processing in the Wait for PAT/PMT State**

1 **A.2.6 IGDP Message Received in Wait for SF Sync State**

2 Figure A.2.6-1 shows the processing executed when the remote terminal receives  
 3 an IGDP message while it is in the Wait for SF Sync state. The terminal saves  
 4 any new inroute group information that the message may contain.



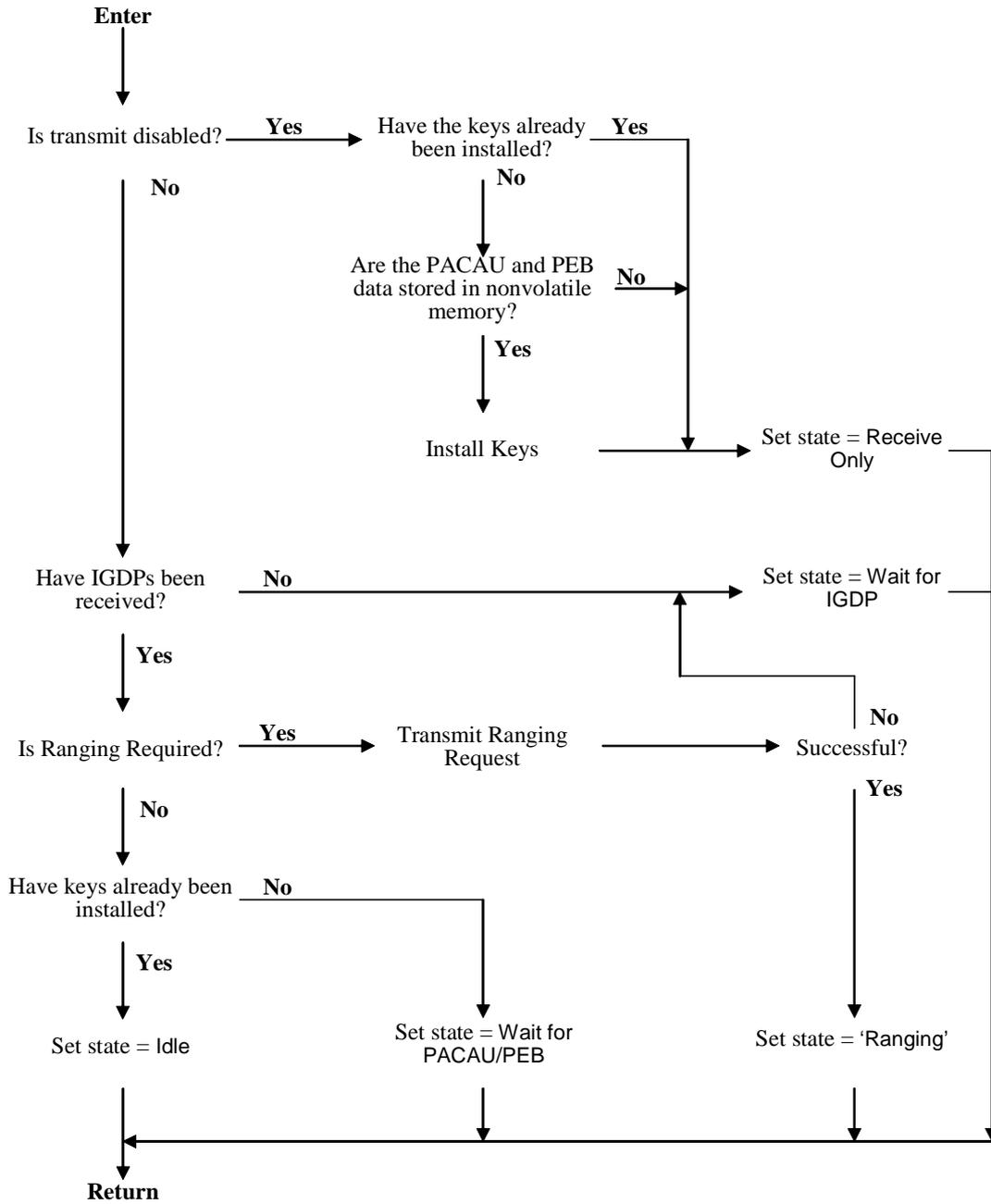
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7 **Figure A.2.6-1. Process IGDP Message Received in the Wait for SF Sync State**

8 **A.2.7 SF Sync Event Received in the Wait for SF Sync State**

9 Figure A.2.7-1 shows the processing executed when the terminal goes into  
 10 superframe synchronization (see subsection A.1) when it is in the Wait for SF  
 11 Sync state. Typically, the processing follows the main line of processing to the  
 12 left of the figure, and the terminal enters the Idle state.

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**Figure A.2.7-1. Process SF Sync Event in the Wait for SF Sync State**

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### **A.2.8 IP Data for Transmission Received in Idle State**

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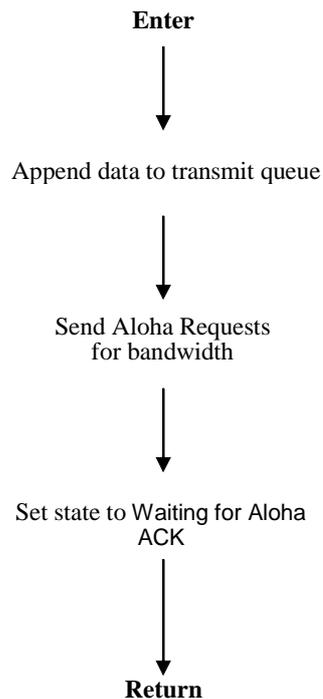
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Figure A.2.8-1 shows the processing executed when the terminal receives IP data for transmission on the inroute when it is in the Idle state. The terminal chooses two Aloha slots, sends a Bandwidth Request message on each of the chosen slots, then enters the Waiting for Aloha ACK state.

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2 **Figure A.2.8-1. Process Data for Inroute Transmission Received in Idle State**3 **A.2.9 Aloha ACK Message Received in Wait for Aloha ACK State**

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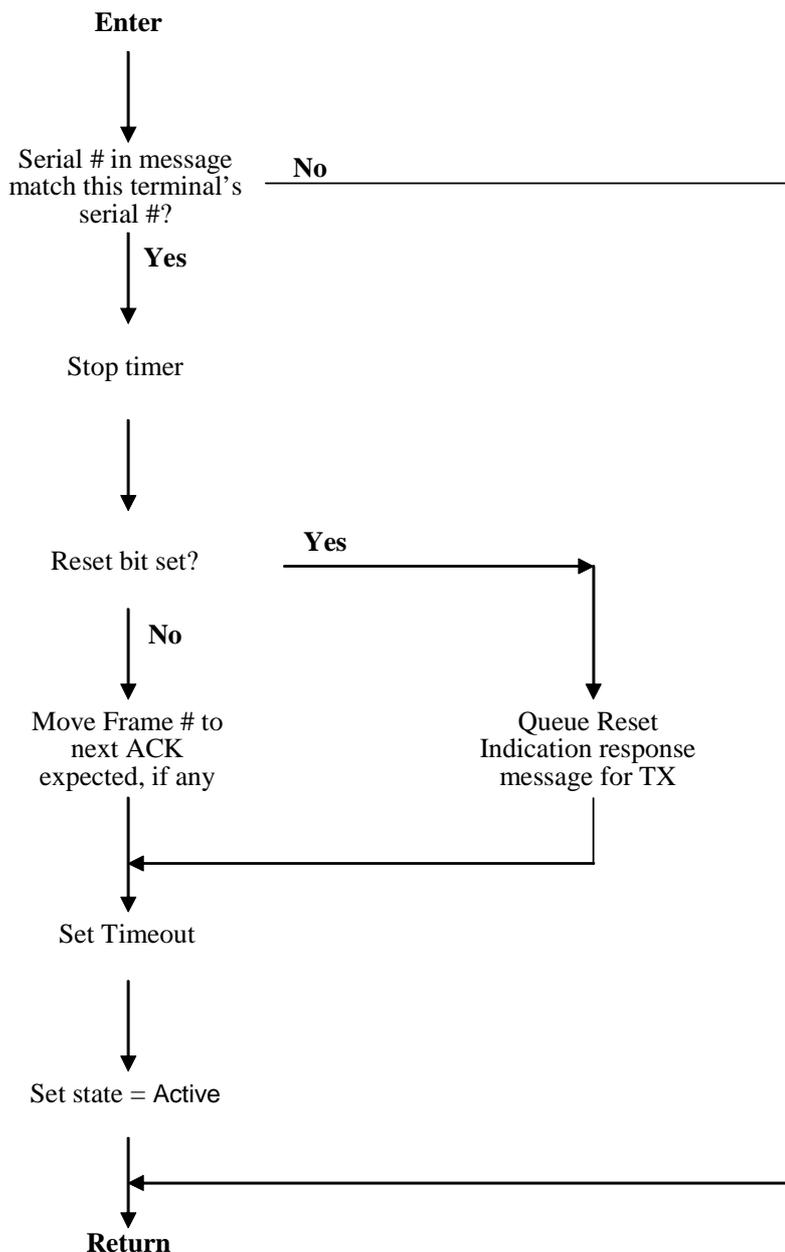
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Figure A.2.9-1 shows the processing executed when the terminal receives an Aloha ACK message while it is in the Wait for Aloha ACK state. Typically, the processing follows the main line of processing to the left of the figure, and the terminal enters the Active state.

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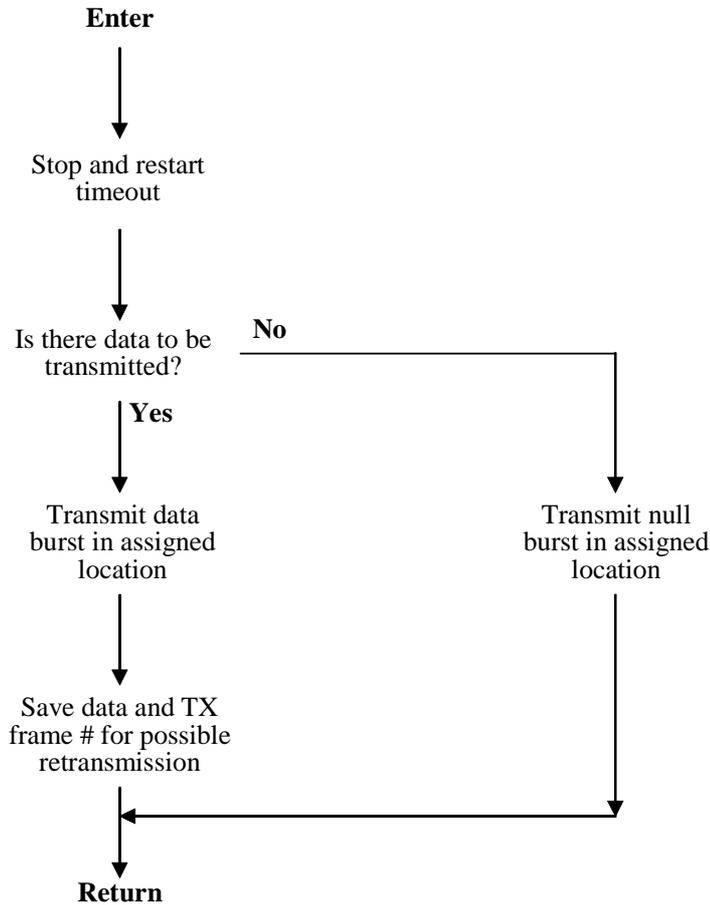
3 **Figure A.2.9-1. Process Aloha ACK Received in Wait for Aloha ACK State**

4 **A.2.10 Bandwidth Allocation Message Received in Active State**

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Figure A.2.10-1 shows the processing executed when the terminal receives a Bandwidth Allocation message when it is in the Active state. If the terminal has data to be transmitted, it transmits it in the assigned slots. If it has no data to transmit, it transmits a null burst in the assigned slots.

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3 **Figure A.2.10-1. Process Bandwidth Allocation Message Received in Active State**

4 **A.2.11 Timeout in Active State**

5 Figure A.2.11-1 shows the processing executed when the terminal receives a  
 6 timeout (a configurable number of consecutive frames without a bandwidth  
 7 allocation) when it is in the Active state. If the terminal has data to be  
 8 transmitted, it must become active again by sending an Aloha Request message.  
 9 Otherwise, the terminal removes the MAC address for the current outroute group  
 10 from the terminal's receive filter so that it will not have to process extraneous  
 11 bandwidth assignment and other messages.

12

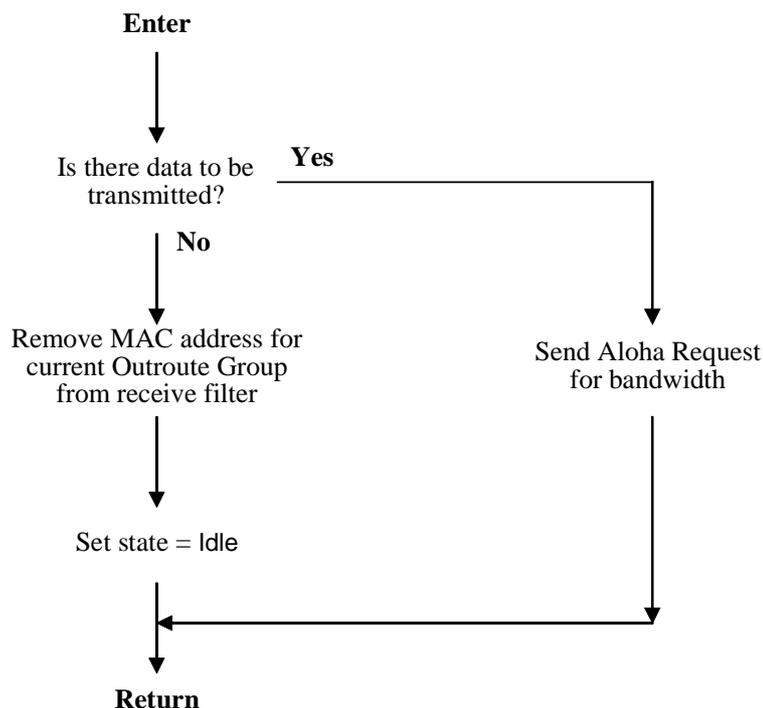


Figure A.2.11-1. Process Timeout in the Active State

## A.3 Closed-Loop Timing

### A.3.1 Closed-Loop Timing States

The entire closed-loop timing procedure is divided into three system states or operational stages, and they are:

- **Initial days of operation (Bootstrap State):** In this state hub-satellite-hub propagation delay ( $T_{H-S-H}$ ) value can not be calculated because not enough remote terminals are installed for obtaining timing corrections from them to estimate the  $T_{H-S-H}$  value. A nominal value is broadcast. A procedure (described later) makes the system transition from initial days of operation to a steady state operation.
- **The steady state operation:** In this state estimated  $T_{H-S-H}$  value is available.
- **Hub outage operation:** Hub outage can be due to many reasons such as one or more Hub components are down or most of the terminals in a network are down, and so Hub may not able to estimate the  $T_{H-S-H}$  value.

A ladder diagram is shown in Figure A.3.1-1 as the reference for the description of state transition procedures in subsequent subsections. Various symbols and notations used in the specification are shown in Table A.3.1-1.

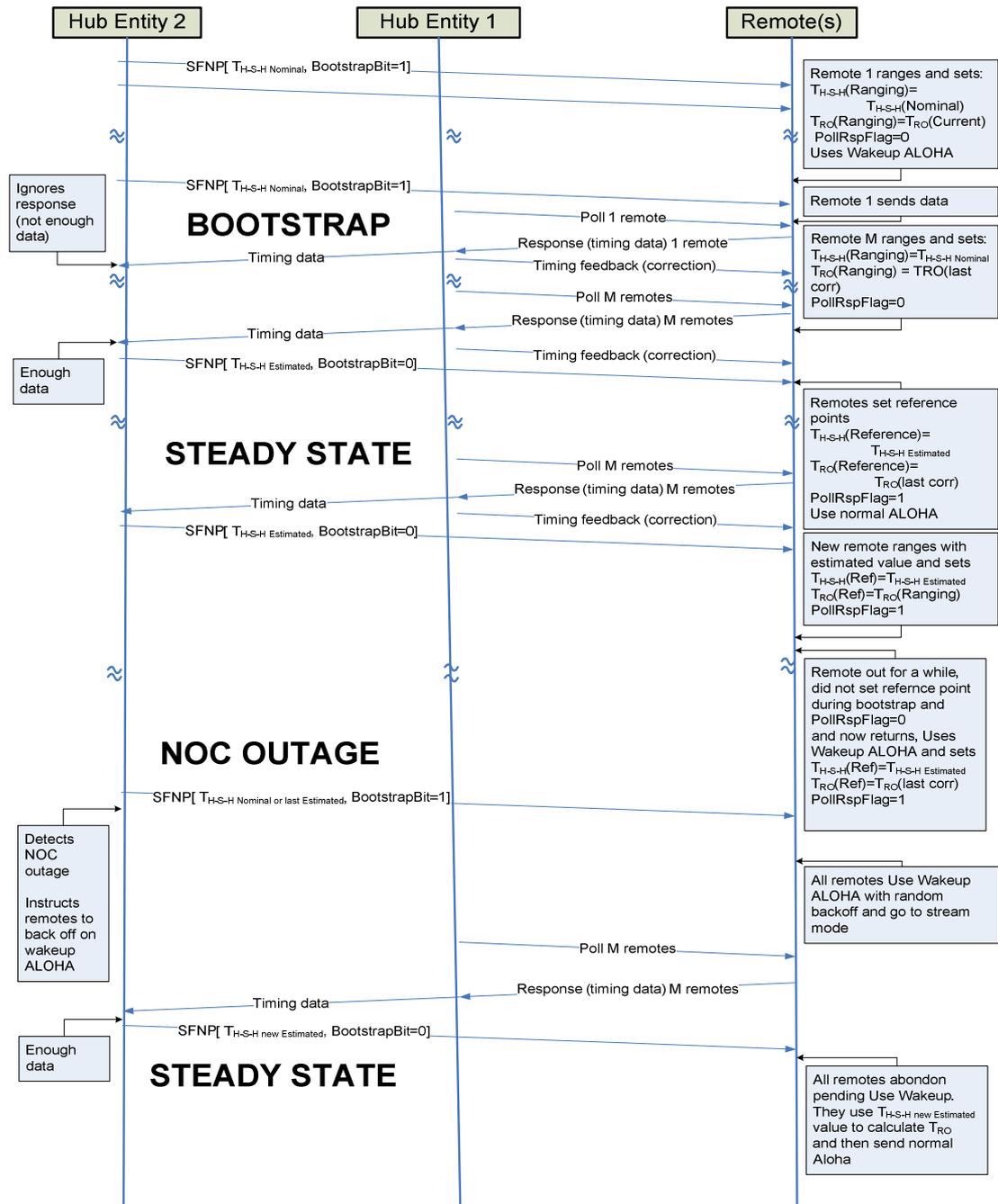


Figure A.3.1-1. Closed Loop Timing States

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Table A3.1-1. Symbols and Notations for Closed Loop Timing

Symbols & notation	Description
$T_{H-S-H}$ (Nominal)	Nominal Hub-Satellite-Hub propagation delay measured when the Satellite is at the center of the box.

Symbols & notation	Description
$T_{H-S-H}$ (Ranging)	The Hub-Satellite-Hub propagation delay saved by a terminal during the ranging time.
$T_{H-S-H}$ (Reference)	The Hub-Satellite-Hub propagation delay saved by a terminal for use as a reference when asked for its timing feedback. Ter
$T_{H-S-H}$ (Current)	The latest Hub-Satellite-Hub propagation delay received by a terminal in the SFNP message
$T_{H-S-Hn}$	The Hub-Satellite-Hub propagation delay transmitted in the nth SFNP message
$T_{RO}$ (Ranging)	Remote terminal offset time calculated after a successful ranging.
$T_{RO}$ (Reference)	$T_{RO}$ saved by a terminal for use as the reference when asked to provide the timing correction feedback.
$T_{RO}$ (last corr)	$T_{RO}$ value after the most recent correction has been made by a terminal
$\Delta T_{RO}$ (C-R)	The difference between the $T_{RO}$ (current) and $T_{RO}$ (Reference). It essentially represents twice the value of Satellite drift as seen by a terminal (assuming the same drift is seen by the terminal and the Hub) between now and the time when the reference $T_{RO}$ was set by that terminal.
PollRspFlag	This is a flag maintained at the terminal which denotes whether this specific terminal should respond to a timing correction request from the Hub.

1

### 2 A.3.2 Initial Days of Operation (Initial Bootstrap State)

3 As shown in the ladder diagram, IPoS Hub entities and multiple terminals  
 4 participate in the procedure that helps the system to reach the steady state of  
 5 operation. Initially the Hub advertises  $T_{H-S-H(nominal)}$  in the SFNP message and sets  
 6 the “ $T_{H-S-H}$  Bootstrap ON” bit to true. It continues to do so until the system  
 7 reaches the steady state. This period is called the “Initial  $T_{H-S-H}$  Bootstrap”  
 8 period.

9 IPoS Hub is configured with two parameters – polling intervals in number of  
 10 superframes ( $N_{Polling\_interval}$ ) and maximum number of terminals ( $M_{max\_polling}$ ) that it  
 11 shall include in its polling message. Hub only polls terminals that are active at  
 12 the scheduled polling time. The number of terminals in a polling message can be  
 13 in the range of 1 to  $M_{max\_polling}$ .

14 A flag called PollRspFlag is initialized to false in all remote terminals before they  
 15 are commissioned. One remote terminal (say, Terminal 1) ranges with the  
 16 nominal  $T_{H-S-H}$  value and saves the following information into the flash:

$$17 \quad T_{H-S-H} \text{ (Ranging)} = T_{H-S-H} \text{ (Nominal)}$$

$$18 \quad T_{RO} \text{ (Ranging)}$$

19 Other terminals also range with the nominal  $T_{H-S-H}$  value. In the meantime,  
 20 terminal 1 requires to send data and uses “Bootstrap Aloha” because the “ $T_{H-S-H}$   
 21 Bootstrap ON” bit is set in the SFNP message and it was idle for more than  $T_{IDLE}$   
 22 minutes.

23 Once hub observes active terminals, it sends polling messages to randomly  
 24 selected terminals (not exceeding  $M_{max\_polling}$  terminals) at the scheduled time.

1 When the “ $T_{H-S-H}$  Bootstrap ON” bit is set in the SFNP message, remote  
 2 terminals respond to the polling message although PollRspFlag may have been  
 3 set to false. Otherwise if the “ $T_{H-S-H}$  Bootstrap ON” bit is set to false, then no  
 4 terminal should respond to a polling message if PollRspFlag is set to false. A  
 5 remote terminal responds with the following information via the adaptation field  
 6 in the inroute burst:

- 7 ○  $T_C = \Delta T_{RO(C-R)}/2$  which is zero because terminal 1 has not yet set  
 8 reference values
- 9 ○  $T_{H-S-H(Current)}$  which is  $T_{H-S-H(Nominal)}$
- 10 ○ PollRspFlag which is false

11 IPoS Hub collects the above timing information from the remote terminal 1 and  
 12 adds the timing offset from the nominal center that is present on the burst  
 13 containing the feedback to  $T_C$ . The Hub is configured with a parameter called  
 14 “Minimum Terminal Feedback Count” ( $Min_{feedback}$ ) required for the correct  
 15 estimation of  $T_{H-S-H}$ . Since feedback from only one terminal (Terminal 1) is  
 16 available (assume  $1 < Min_{feedback}$ ), the timing unit ignores the feedback and does  
 17 not calculate the estimated  $T_{H-S-H}$  value, and continues to provide  $T_{H-S-H(Nominal)}$   
 18 value in the SFNP message.

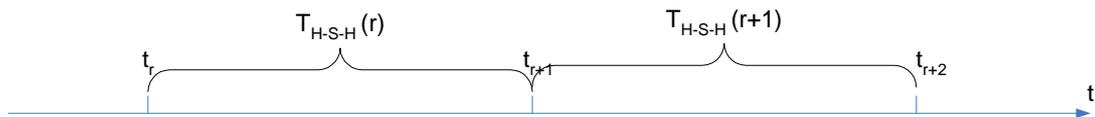
19 As time progresses, more and more terminals are installed, and hub receives  
 20 feedbacks from  $M$  terminals where  $M \geq Min_{feedback}$  and then is able to estimate  
 21 the  $T_{H-S-H}$  value. The estimated  $T_{H-S-H}$  value is now advertised via the SFNP  
 22 message and the “ $T_{H-S-H}$  Bootstrap ON” bit is set to false to mark the transition  
 23 to the steady state.

24 The remote terminals, which had sent the polling responses and observed a  
 25 transition of the “ $T_{H-S-H}$  Bootstrap ON” bit from true to false in the SFNP  
 26 message within a few superframe interval counted from the time when the  
 27 responses are being sent save references as follows:

- 28 ○  $T_{H-S-H(Reference)} = T_{H-S-H(Current)}$
- 29 ○  $T_{RO(Reference)} = T_{RO(last\ corr)}$
- 30 ○ PollRspFlag = true

31 **A.3.3 Steady State Operation (Steady State)**

32 Steady state operation refers to the condition when Hub is up and several  
 33 terminals have been ranged and operational, and estimated  $T_{H-S-H}$  is being  
 34 transmitted in the SFNP messages



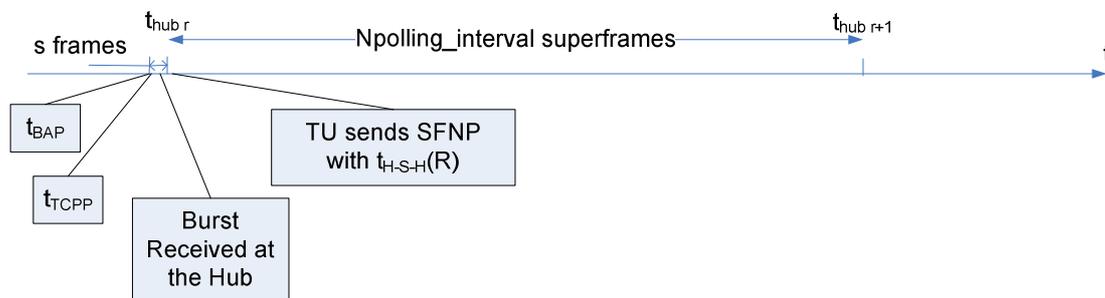
35 **Figure A.3.3-1. Timing Diagram at the Terminal**

36

1 Terminals receive superframe numbering packets which are transmitted from the  
 2 Hub every 360 milliseconds interval period. As shown in the figure A.3.3-1, at  
 3 time  $t_r$ ,  $t_{r+1}$  and  $t_{r+2}$ , terminal has received SFNP packets with hub-satellite-hub  
 4 propagation delay being advertised as  $T_{H-S-H(r)}$ ,  $T_{H-S-H(r+1)}$  and  $T_{H-S-H(r+2)}$ . The  
 5 successive time differences between  $t_r$ ,  $t_{r+1}$  and  $t_{r+2}$  are not 360 ms, instead they  
 6 might be in the order of minutes (this value is close to the configurable polling  
 7 interval parameter). Hence, there are several SFNP packets sent between the time  
 8  $t_r$  and  $t_{r+1}$  with the same  $T_{H-S-H(r)}$  value.

### 9 A.3.3.1 Creating estimated $T_{H-S-H}$ value

10 Steady state operation refers to the condition when Hub is up and several  
 11 terminals have been ranged and operational, and estimated  $T_{H-S-H}$  is being  
 12 transmitted in the SFNP messages



13 **Figure A.3.3.1-1. Timing Diagram at the IPoS Hub**

14 Figure A.3.3.1-1 shows the timing diagram at the IPoS hub. The polling interval  
 15 is  $N_{Polling\_interval}$  superframes. An S frames before the scheduled polling time ( $t_{hubr}$ ),  
 16 the IPoS Hub polls M number of active terminals for their timing corrections. At  
 17 time  $t_{BAP}$  the BAP message is sent and at  $t_{TCPP}$  the polling request is sent from the  
 18 IPoS hub. The k number of terminals out of M whose  $PollRspFlag = true$ , send  
 19 the timing data via the adaptation field.  
 20

21  $T_{H-S-H(Reference)i}$  is the value of  $T_{H-S-H(Reference)}$  for terminal i, where  $i = 1$  to k

22  $T_{RO(Reference)i}$  is the value of  $T_{RO(Reference)}$  for terminal i, where  $i = 1$  to k

23  $T_{RO(last corr)i}$  is the value of  $T_{RO(last corr)}$  for terminal i, where  $i = 1$  to k

24 Feedback from terminal i is shown below:

- 25 ○  $T_{Ci} = \Delta T_{RO(C-R)} / 2 = \{ T_{RO(last corr)i} - T_{RO(Reference)i} \} / 2$
- 26 ○  $T_{H-S-H(Reference)i}$
- 27 ○  $PollRspFlag = true$

28 Hub collects feedback from each terminal i and adds the timing drift ( $T_{OFFi}$ ) to  
 29 the  $T_{Ci}$ , where  $T_{OFFi}$  is the offset measured on the burst containing the feedback  
 30 for terminal i from the center of the aperture,  $Tf_{Ci} = T_{Ci} + T_{OFFi}$ ; where  $i = 1$  to k.  
 31 Then it performs the following:

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- 1                   • Calculate  $T_{H-S-H}$  per remotes as  $T_{H-S-H i} = T_{H-S-H (Reference) i} - T_{f C i}$ ; where  $i = 1$   
2                   to  $k$
- 3                   • Calculate the mean and standard deviation of calculated  $T_{H-S-H i}$
- 4                   • Delete all samples which are  $>$  or  $<$  than  $\pm 3 * STD$  and checks if  
5                   remaining samples  $\geq Min_{feedback}$  and if it is, then proceed to average  
6                   remotes  $T_{H-S-H}$  values as  $T_{H-S-H r} = \sum(T_{H-S-H i}) / k$ ; where  $i = 1$  to  $k$ .

7                   During the steady state period, a new terminal can be installed and ranged or a  
8                   terminal can wake up which had never set its reference point and the PollRspFlag  
9                   is still set to false. The terminal will range using the  $T_{H-S-H}$  value received in the  
10                  last SFNP message and will set references as follows:

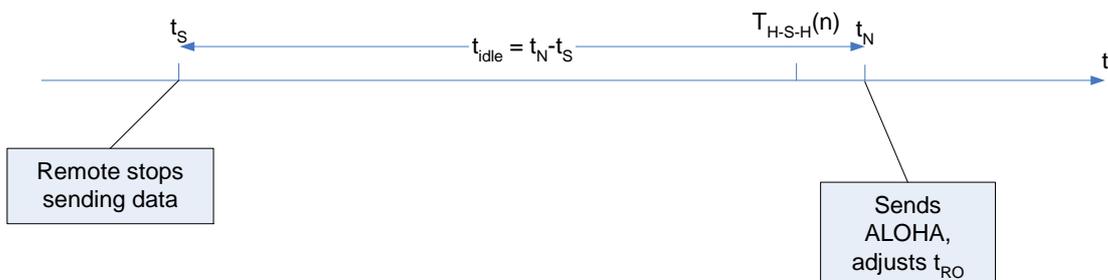
- 11                  ○  $T_{H-S-H (Reference)} = T_{H-S-H (Ranging)}$
- 12                  ○  $T_{RO (Reference)} = T_{RO (Ranging)}$
- 13                  ○ PollRspFlag = true

14                  If a terminal wakes up during steady state after remaining idle for more than  
15                   $T_{IDLE}$  minutes and still has the PollRspFlag set to false, then it uses the “Wake Up  
16                  Aloha” to send the first message. If the idle period is less than  $T_{IDLE}$  minutes, then  
17                  it sends the first message on the IPOs unallocated channel that uses 125  
18                  microseconds aperture. This terminal sets references after receiving the timing  
19                  correction in the Acknowledgement Message corresponding to the “Bootstrap  
20                  Aloha” burst or normal normal aperture unallocated burst according to the  
21                  following rule:

- 22                  ○  $T_{H-S-H (Reference)} = T_{H-S-H (current)}$
- 23                  ○  $T_{RO (Reference)} = T_{RO (last corr)}$
- 24                  ○ PollRspFlag = true

### 25    **A.3.3.2    Using estimated $T_{H-S-H}$ value**

26                  An IPOs terminal uses the estimated  $T_{H-S-H}$  value when it comes out from a  
27                  RESET or was idle (not sending any inroute data) for  $T_{IDLE}$  minutes. While  
28                  terminals are powered up and sending data, they do not use the estimated  $T_{H-S-H}$   
29                  value for their timing adjustment, instead they use the closed loop feedback from  
30                  theHub.



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1 **Figure A.3.3.2-1. Timing Diagram at the terminal and Usage of Estimated  $T_{H-S-H}$**

2 As shown in Figure A.3.3.2-1, at time  $t_s$  a terminal stops sending inroute data. At  
3 time  $t_N$ , the terminal wants to send the first message after an idle period  $t_{idle} = (t_N$   
4  $- t_s)$ , where  $t_{idle}$  is  $> T_{IDLE}$  minutes and is large enough so that if the terminal uses  
5 its last saved  $T_{RO}$ , the Aloha burst may not fall within the 125 microseconds  
6 aperture. This is the time when the terminal uses the estimated  $T_{H-S-H}$  value if its  
7 PollRspFlag is set to true

8 If  $T_{H-S-H(n)}$  is the last estimated value received by the terminal in the SFNP  
9 message, the  $T_{RO}$  value is adjusted according to the following equation  $T_{RO(new)} =$   
10  $T_{RO(Reference)} + \{T_{H-S-H(Reference)} - T_{H-S-H(n)}\} * 2$ ; where  $\{T_{H-S-H(n)} - T_{H-S-H(Reference)}\}$  is  
11 the total Satellite drift observed by the referred terminal between now and when  
12 it had saved its reference point.

13 **A.3.3 Hub Outage Operation (Outage Bootstrap State)**

14 Upon detecting the Hub outage condition (the detection procedure is outside of  
15 the scope of this document) the IPoS Hub sets the “ $T_{H-S-H}$  bootstrap ON” bit to  
16 true and sends the last saved  $T_{H-S-H}$  value or  $T_{H-S-H(Nominal)}$  in the SFNP message.  
17 This state is similar to the initial bootstrap case with the exception that in this  
18 condition many terminals had already set their reference points and there are lot  
19 of terminals might be present in the network. During the initial Bootstrap state no  
20 terminal in the network sets its reference point until moves to a steady state.

21 The terminals send Bootstrap Aloha bursts to send their first messages if were  
22 idle for more than  $T_{IDLE}$  minutes as they see the “ $T_{H-S-H}$  bootstrap ON” bit is set to  
23 true in the SFNP message. A sufficiently large initial random back off value is  
24 advertised in the SFNP message for use by terminals to avoid mass collisions of  
25 Bootstrap Aloha messages.

26 After successfully sending the Bootstrap Aloha burst and receiving timing  
27 correction, gradually more and more terminals become active on stream inroutes,  
28 and respond to the polling requests from the hub. Once the hub receives feedback  
29 from at least  $Min_{feedback}$  number of terminals, it is able to calculate the estimated  
30  $T_{H-S-H}$  value and then turns off the “ $T_{H-S-H}$  bootstrap ON” bit and sends the  
31 estimated  $T_{H-S-H}$  value in the SFNP message As soon as terminals see the  
32 transition of the “ $T_{H-S-H}$  bootstrap ON” bit from true to false, they abandon their  
33 Bootstrap Aloha process while in the middle of the random back off period,  
34 instead they use the new estimated  $T_{H-S-H}$  value in the SFNP message to adjust  
35 their timing and then send their first messages on the IPoS unallocated channel  
36 that uses 125 microseconds aperture.

37

38 A new IPoS terminal installed in the “Outage Bootstrap” state ranges using the  
39  $T_{H-S-H}$  value received in the last SFNP message, but does not set its reference  
40 point until the system moves to the steady state. A terminal ranged and installed  
41 in other states but did not sent its reference point sets the same when the system  
42 state is transitioned from “Outage Bootstrap” to “Steady” satte. A terminal  
43 responds to the polling request even its PollRspFlag is set to false when the “ $T_{H-S-}$   
44  $H$  bootstrap ON” bit is set to true in the “Initial Bootstrap” state. However,

1 terminals do not respond to the polling request when its PollRspFlag is set to  
2 false and the "T<sub>H-S-H</sub> bootstrap ON" bit is set to true in the "Outage Bootstrap"  
3 state.

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## 1 **ANNEX B - (NORMATIVE): IPOS SECURITY**

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### 3 **B.1 Scope**

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4 This document is an annex to the IP over Satellite (IPoS) MAC/SLC Layer  
5 Specification that describes the security procedures supported within IPoS.

6 The purpose of security is to prevent unauthorized access to IPoS services. In  
7 order to fulfill this goal, the following features are supported:

- 8 • Provision for the secure transfer of information to the IPoS subscriber.
- 9 • Provision of secure means for conveying management and control  
10 information.
- 11 • Protection of revenues from the IPoS system.

12 The IPoS security architecture relates to the outroute direction between the IPoS  
13 hub and the IPoS remote terminals. The architecture contains management,  
14 control, and user plane procedures providing the following security services:

- 15 • Protection of the privacy of the content of unicast outroute transmissions.
- 16 • Control of access to multicast services.
- 17 • Prevention of unicast reception by unauthorized receivers.

18 End-to-end service protection extending from the user to the service provider  
19 might be provided on top of satellite IPoS security by a separate mechanism,  
20 typically IPsec.

### 21 **B.2 Security System Architecture**

---

#### 23 **B.2.1 Introduction**

24 The IPoS security architecture relies upon:

- 25 • Decryption keys that only unlock various IPoS services to a database of  
26 authorized users. There is a hierarchy of encryption keys, which  
27 includes key encrypting and keys for protecting the information sent  
28 from the hub to the remote terminals.
- 29 • Procedures for the distribution and update of the keys needed at the IPoS  
30 hub and IPoS remote terminals prior to the encryption/decryption of  
31 information.
- 32 • The actual encryption/decryption of keys, control, and user information  
33 sent over the outroute direction.

## 1 **B.2.2 Database of Authorized Users**

2 IPoS authentication is based on a shared-key scheme where the hub has  
3 knowledge of information derived from a master key (MK) (the effective master  
4 key, EMK) stored at each remote terminal. The hub's information allows the  
5 secure distribution of key material to an IPoS remote.

6 The binding between the remote terminal's MK and the hub's key information  
7 normally takes place during the commissioning of the terminal. During the  
8 registration procedure, the parameters such as hardware serial number, customer  
9 name, and contact information, which identify the remote terminal, are sent to the  
10 IPoS hub out-of band. Once received, the information is stored at the hub and  
11 associated with the EMK information that allows the identification of remote  
12 terminals.

13 From these parameters, the hub's security management entities can determine the  
14 services and types of keys required by each remote terminal as well as the MAC  
15 address associated with the remote terminal over the IPoS remote.

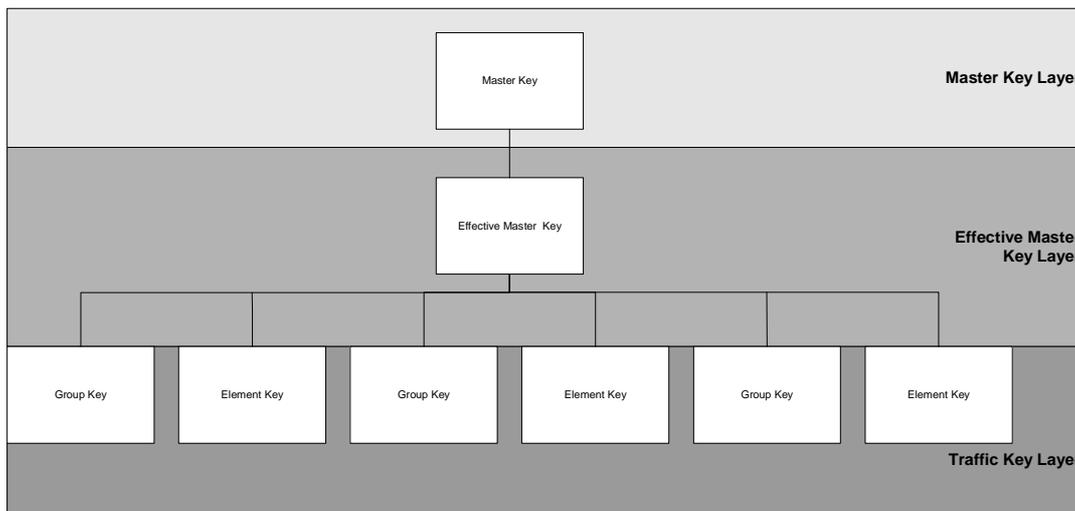
16 Security management entities at the hub create the appropriate messages with the  
17 keys that will be distributed to the remote terminals over the outroute direction.

18 The terminal demonstrates its identity by its knowledge of this MK. This MK  
19 allows the terminals to decrypt the messages sent by the hub with the keys that  
20 will be used to encrypt the information of the various services.

21 The encryption keys are changed periodically to limit the period in which a  
22 service is exposed to security breaches. Authorization to receive services is  
23 revoked at the hub by withholding from a remote the updated keys needed to  
24 decrypt the services.

## 25 **B.2.3 Key Hierarchy**

26 The IPoS security architecture uses a three-layer key hierarchy, which allows  
27 effective management, control, and update of key information for each remote  
28 terminal. The partition of keys into these three layers reduces the complexity of  
29 the IPoS security architecture. In this architecture the keys in the "upper" layers  
30 protect the keys in the "lower" layers, thus increasing the flexibility and security  
31 of the system. The three layers of security architecture are illustrated in  
32 figure B.2.3-1.



1

2

**Figure B.2.3-1. IPoS Security Key Hierarchy**

3

The two upper layers of the key hierarchy contain key-encrypting keys that are used to encrypt the keys of the layer below, e.g., the EMK layer is encrypted under the MK layer and the traffic key (TK) layer is encrypted with the EMK layer. The key-encrypting keys in the MK and EMK layers are 192 bits wide, which are obtained with a triple-DES encryption/decryption operation where each of the 192-bit wide keys consists of three 64-bit blocks of the standard single DES 64-bit block key. The group key (GK) and element key (EK) in the lower TK layer are 64 bits wide and are used to protect user traffic with a single DES block.

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Each layer has keying material, key distribution, and management procedures pertaining to it. These are specified in the following subsections.

13

### 14 **B.2.3.1 Master Key Layer**

The MK layer is the highest level of IPoS security architecture. Every key in the MK layer is unique to each IPoS remote. The MK is a key-decrypting key that decrypts the EMK. The MK is never used to encrypt or decrypt user traffic.

15

16

17

### 18 **B.2.3.2 Effective Master Key Layer**

The EMK resides at the EMK layer. The EMK is specific to each IPoS remote. The EMK is a key-decrypting key. The EMK decrypts TKs that are assigned to that IPoS remote or multicast group. The EMK is never used to encrypt or decrypt user traffic.

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### 23 **B.2.3.3 Traffic Key Layer**

There are two keys resident at the TK layer: the GK and the EK. The GK is used to encrypt data that is addressed to multiple IPoS remotes in multicast groups; the EK is used to encrypt data that is addressed to an IPoS remote's unicast address.

24

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1 Each multicast group has its own key material; therefore, each GK is specific to  
2 an IPoS multicast group. The GK decrypts multicast traffic for a specific  
3 multicast group on the IPoS outroute.

4 The EK is associated with IPoS elements. An IPoS element is the smallest unit  
5 of data that can be controlled by the IPoS security system. IPoS elements are  
6 usually associated with IPoS services. For example, an Internet surfing service  
7 can be viewed as an element. Unicast user's data is encrypted under the EK on  
8 the IPoS outroute.

## 9 **B.2.4 Key Creation**

### 11 **B.2.4.1 Master Key Layer**

12 The MK is created at a separate key creation facility. This facility is normally a  
13 secure facility in close proximity to the manufacturing location of the IPoS  
14 remotes.

15 A single MK is loaded into an IPoS remote by a secure key-loading device. The  
16 key-loading device protects the security of the MK by not allowing the keys to be  
17 loaded in any other remote than the target IPoS remote.

18 Each MK is unique to a single IPoS remote.

19 To guard the security of the MK, the MK is loaded in a secure register at the  
20 remote terminal such that the IPoS remote shall never reveal the value of the  
21 MK.

### 22 **B.2.4.2 Effective Master Key Layer**

23 As part of the key creation process, EMKs for each remote are created.

24 The EMKs are used to make the encrypted effective master key (EEMK).

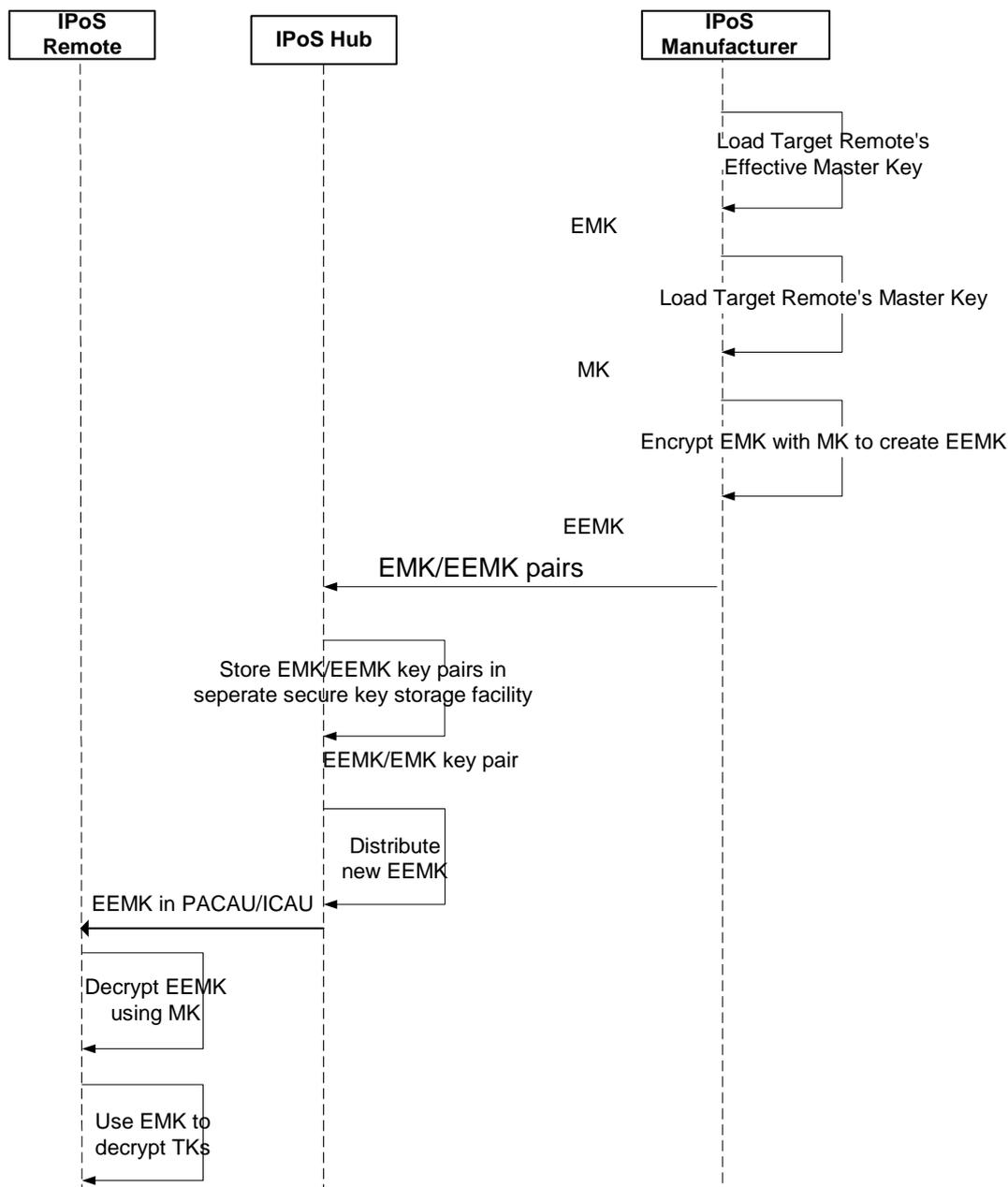
25 The EEMK is created by the separate key creation facility. To create an EEMK,  
26 the separate key creation facility uses one EMK (for the remote that will  
27 eventually receive the EEMK) and then encrypts the EMK with the target IPoS  
28 remote's MK. The EMK and associated EEMK are paired together then stored at  
29 the IPoS hub.

30 The advantage of this system is that, should the key material stored in the IPoS  
31 hub become compromised, the IPoS remote can be rekeyed with another EMK,  
32 re-establishing the integrity of the IPoS security system. Therefore, the  
33 terminal's manufacturer is exclusively responsible for maintaining the security of  
34 the terminal's MK

35 The EEMK can be transmitted from the IPoS hub to the IPoS remote within a  
36 PACAU or ICAU packet (see subsection 4.5 for details of these packets).

37 The MK is used by the IPoS remote to decrypt the EEMK. The result of  
38 decrypting the EEMK with the MK is the EMK, thus securely establishing the  
39 EMK as the shared secret between the IPoS hub and IPoS remote. The EMK is  
40 used to encrypt the TKs at the IPoS hub and to decrypt them at the IPoS remote.

- 1 Therefore, the hub uses a remote's EMK to encrypt the TKs required for the
- 2 services the remote terminal is authorized to receive. The remote terminal uses its
- 3 EMK to decrypt the TKs and thus gain access to those services.
- 4 This process is illustrated in figure B.2.4.2-1.



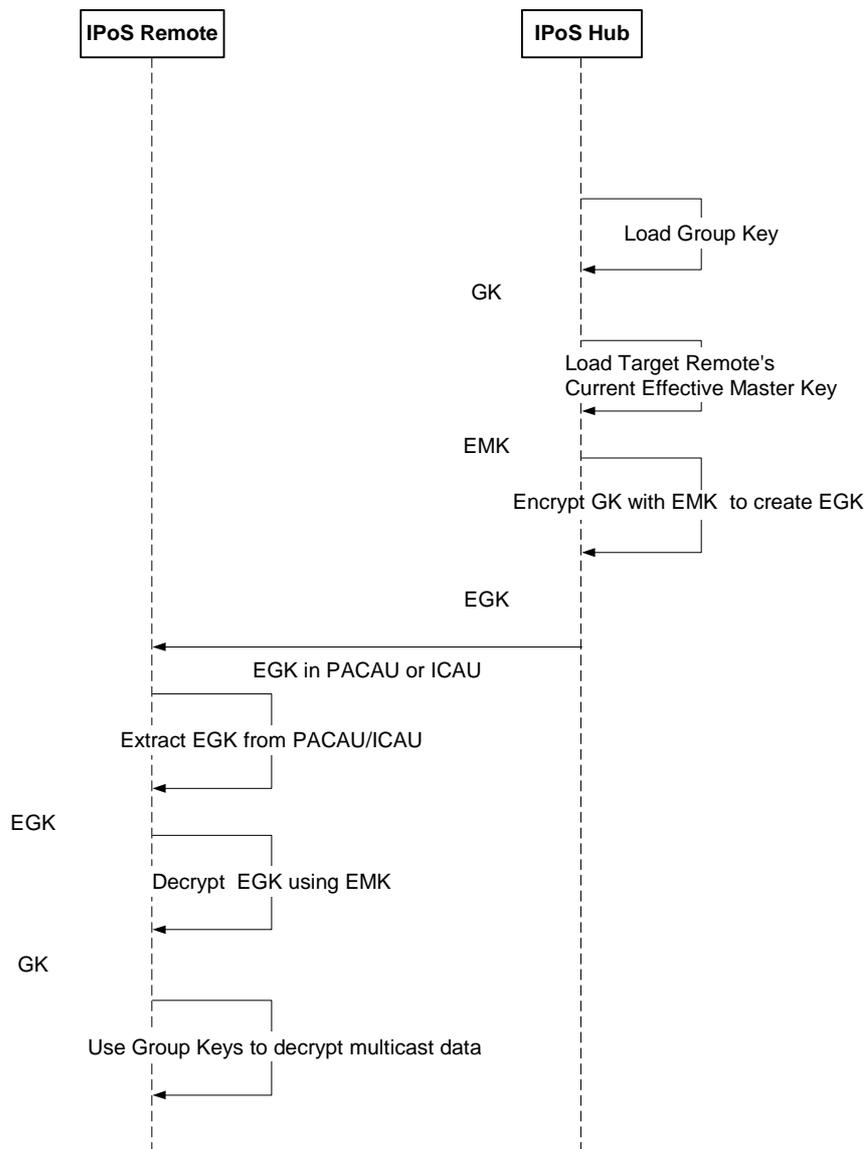
5  
6 **Figure B.2.4.2-1. EEMK Distribution Procedure**

1 **B.2.4.3 Traffic Key Layer**

2 The GKs for each remote are created at the IPoS hub. A GK for each multicast  
 3 group will be created and encrypted under the target IPoS remote's current EMK  
 4 to create the encrypted group key (EGK).

5 Upon reception of the EGK, the IPoS remote shall decrypt the EGK with its  
 6 current EMK to create the GK. Upon success, the GK can be used to decrypt  
 7 multicast data feeds that will be addressed to the remote terminals at the address  
 8 expressed in the Periodic Element Broadcast (PEB) packet.

9 This process is illustrated by figure B.2.4.3-1.



10  
 11 **Figure B.2.4.3-1. Group Key Creation and Distribution Procedure**

12

- 1 Each IPoS unicast data feed has its own key material. This key material is called
  - 2 an EK. Each EK is specific to an IPoS unicast data feed.
  - 3
  - 4 Once these keys have been created, they are encrypted under the target remote
  - 5 terminal's EMK. The result of this encryption is the EEK.
  - 6
  - 7 The EEK is transmitted to the IPoS remote in PACAU or ICAU packets.
  - 8
  - 9 Upon reception of the EEK, the IPoS remote shall decrypt the EEK with its
  - 10 current EMK to create the EK. Upon success, the resultant EK can be used to
  - 11 decrypt unicast user traffic that will be addressed to the IPoS remote.
- This process is illustrated by figure B.2.4.3-2.

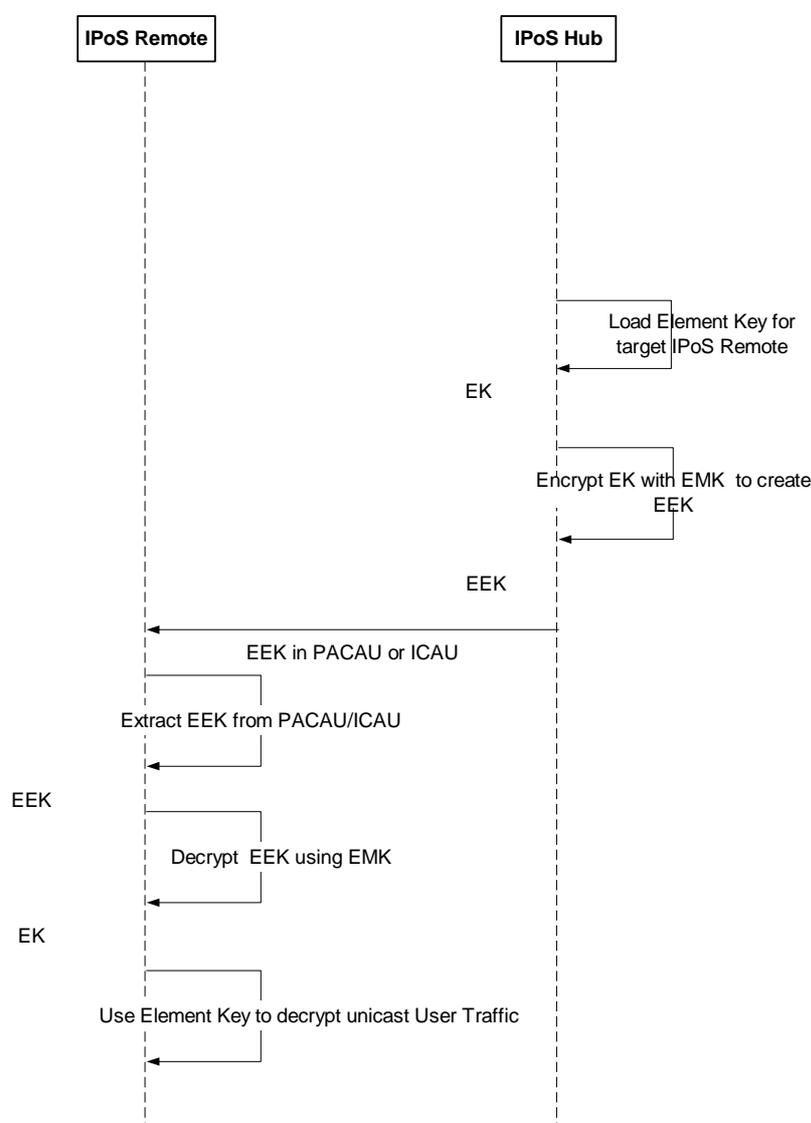


Figure B.2.4.3-2. Element Key Creation and Distribution Procedure

## 1 **B.2.4.4 Key Association Summary**

2 Table B.2.4.4-1 summarizes the encryption of the various keys in the IPoS  
3 security architecture and their association with the different layers.

**Table B.2.4.4-1. Encryption of Keying Association with Each Layer**

Layer	Key	Encryption Key	Product of Encryption	Site of Encryption	Packet Used
Master	MK	N/A	N/A	N/A	N/A
Effective Master	EMK	MK	EEMK	Remote Terminal Manufacturing Site Separate Key Creation Facility	PACAU ICAU
Traffic	EK	EMK	EEK	Hub	PACAU ICAU
	GK	EMK	EGK	Hub	PACAU ICAU

4  
5 Table B.4.4.4-2 summarizes the decryption processes associated to the various  
6 keys.

**Table B.2.4.4-2. Decryption of Keying Association with Each Layer**

Layer	Key	Decryption Key	Product of Decryption	Packet Used
Master	MK	N/A	N/A	N/A
Effective Master	EEMK	MK	EMK	PACAU ICAU
Traffic	EEK	EMK	EK	PACAU ICAU
	EGK	EMK	GK	PACAU ICAU

7

## 8 **B.2.5 Key Distribution**

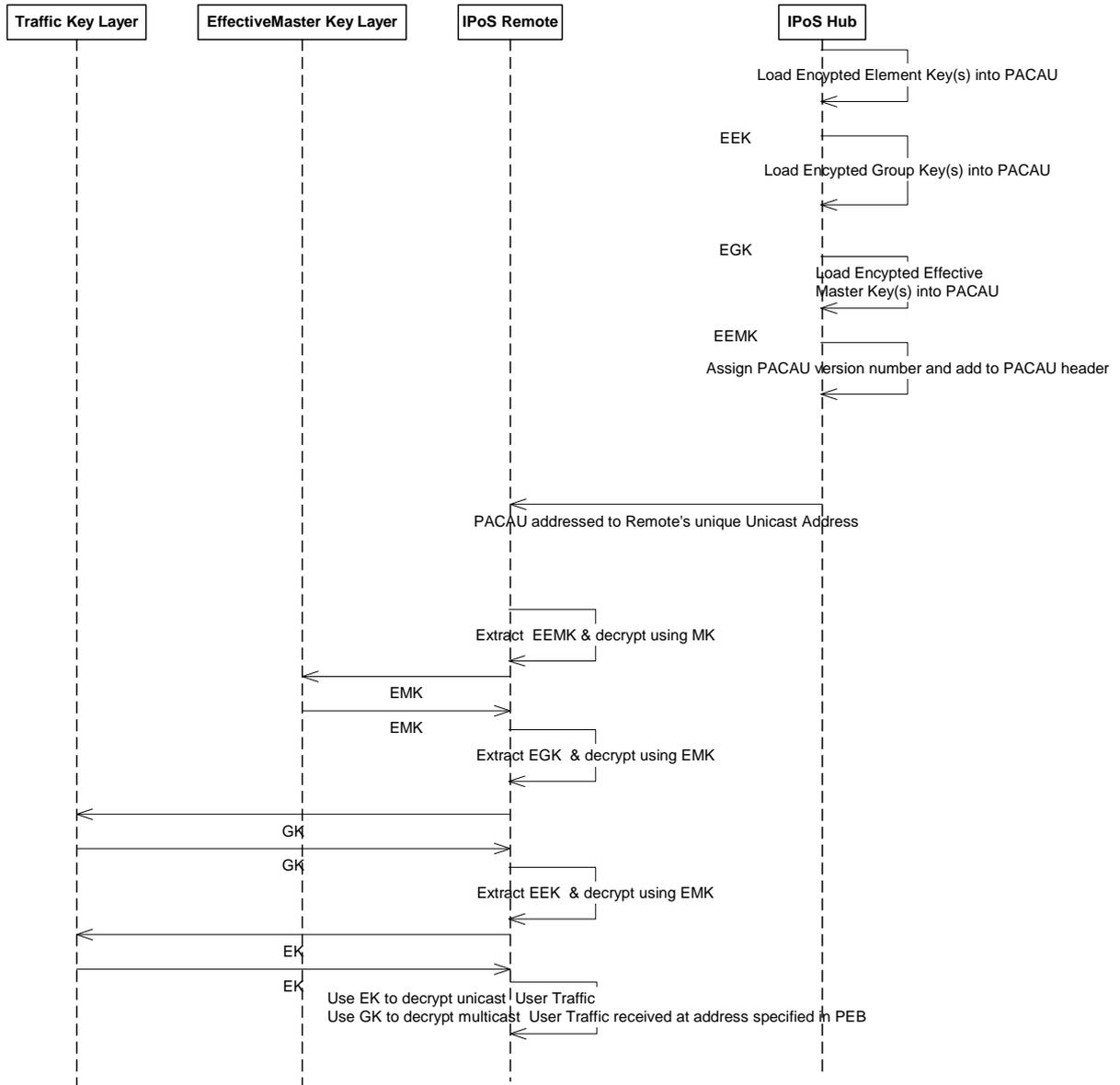
### 9 **B.2.5.1 Introduction**

10 In IPoS, encryption keys are distributed by the hub employing two types of  
11 messages: the PACAU and ICAU. Another message, the PEB, carries the MAC  
12 addresses of each multicast group. The packet types and their functions will be  
13 described within this subsection.

### 14 **B.2.5.2 Periodic Adapter Conditional Access Update Description**

15 The PACAU consists of a header, EEMK, EGKs, and EEK, which the targeted  
16 IPoS remote requires for its authorized services. Subsection 4.13.9 defines the  
17 PACAU header format and the PACAU payload format for GKs and EKs.

18 The PACAU is individually addressed to each IPoS remote using its unicast  
19 MAC address, which is unique to every IPoS remote. Only the IPoS hub can  
20 create and send a PACAU. Figure B.2.5.2-1 shows the creation and distribution  
21 of the PACAU.



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**Figure B.2.5.2-1. PACAU Creation, Distribution, and Association of Keying with Layers**

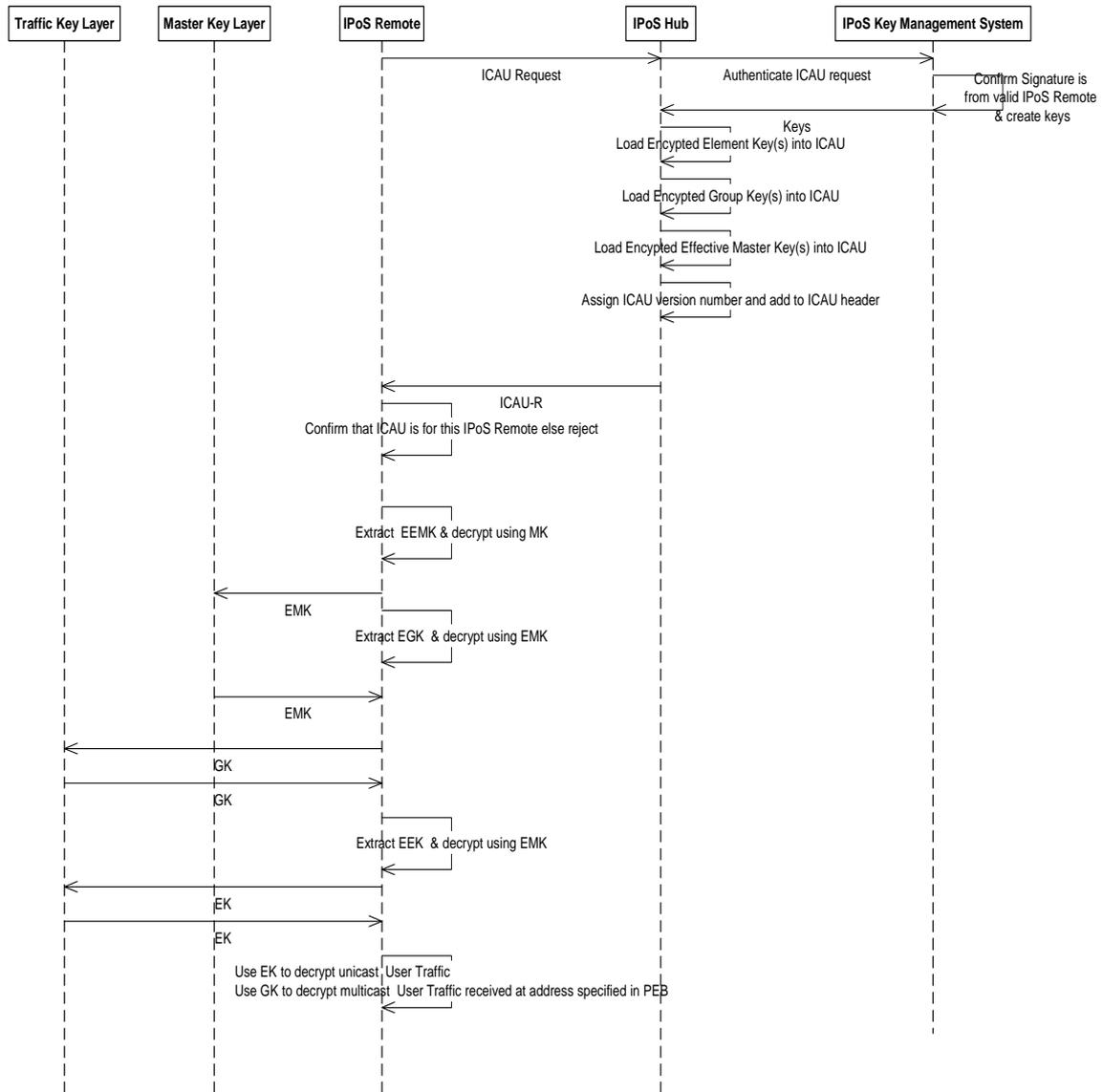
### 1 **B.2.5.3 Interactive Adapter Conditional Access Update Description**

2 The ICAU is sent to an IPoS remote during commissioning to initially provide  
3 the IPoS remote with its keys and is also sent when the IPoS remote requests an  
4 updated ICAU (using the ICAU Request) from the IPoS hub. The ICAU Request  
5 is created when the IPoS remote realizes that its ICAU is out of date and so  
6 requires an update (see subsection B.2.5.5 for update procedures). The ICAU  
7 Request includes a signature from the IPoS remote that is unique to that remote  
8 and that request. (This signature is formed using a process that is critical to the  
9 security of IPoS: therefore, the definition of this signature is only made available  
10 to licensed manufacturers.) Once the ICAU Request has been authenticated by  
11 the IPoS hub, an ICAU Response (ICAU-R) to the IPoS remote is made. The  
12 ICAU-R is individually addressed to each IPoS remote and includes the signature  
13 from the ICAU Request. To authenticate the ICAU-R, the signature must match  
14 that used in the ICAU Request; otherwise, the ICAU-R is ignored.

15 Both the ICAU Request and ICAU-R are sent “out-of-band” only (i.e., not via the  
16 IPoS inroute or outroute). Only the IPoS hub can create and send a valid ICAU-R  
17 as only it has access to the EEMK that forms a part of it.

18 In total, the ICAU-R consists of a header, EEMKs, EGKs, and EEKs, which the  
19 targeted IPoS remote requires for its authorized services. Subsection 4.13.10  
20 defines the ICAU Request format and the ICAU-R format.

21 Figure B.2.5.3-1 illustrates the ICAU Request and ICAU-R process.



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**Figure B.2.5.3-1. ICAU Creation, Distribution, and Association of Keying with Layers**

**1 B.2.5.4****Periodic Element Broadcast Description**

2 The PEB provides the IPoS remote with addressing information about each  
3 multicast group. The PEB is broadcast to the IPoS remotes on their broadcast  
4 MAC address. Only the IPoS hub can create and send a PEB.  
5 Subsection 4.13.11 defines the PEB's format.

**6 B.2.5.5****Procedure for Initial Key Distribution During Registration and Commissioning**

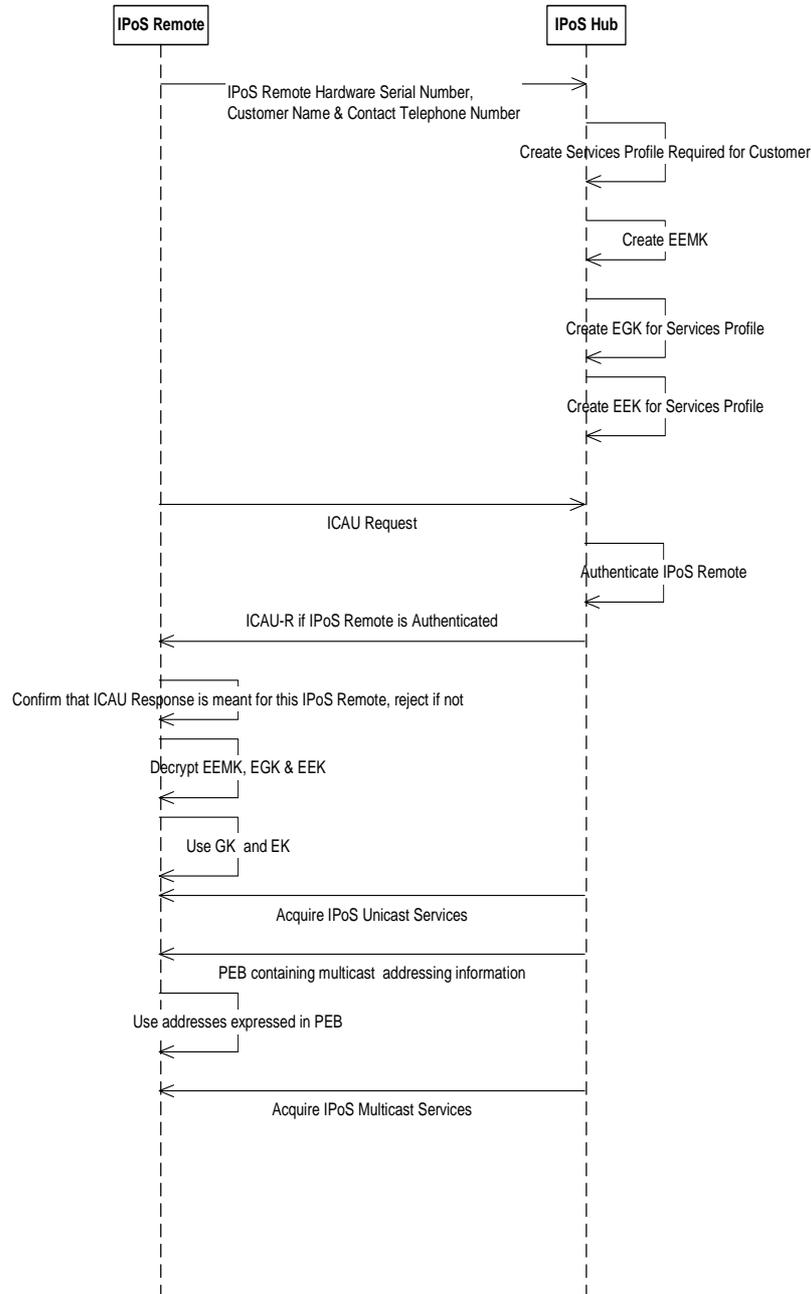
7  
8 During commissioning of the IPoS remote, registration with the IPoS system  
9 takes place. The parameters that are required from the IPoS remote are its  
10 hardware serial number, customer name, and contact information.

11 From these parameters and the set of services the IPoS remote is authorized to  
12 receive, the IPoS hub can determine the set of GKs and EKs that the IPoS remote  
13 will require and the required MAC address to be used to send the keying  
14 information to the IPoS remote.

15 The IPoS remote will then acquire its initial keys by making an "out-of-band"  
16 ICAU Request. The IPoS hub will respond to an authenticated IPoS remote's  
17 ICAU Request with an ICAU Response containing EEMK, EGKs, and EEKs for  
18 the IPoS remote.

19 Once a complete set of valid keys and addresses has been received by the IPoS  
20 remote, it can access IPoS services. See Figure B.2.5.5-1.

21 Any subsequent key updates will be made via the PACAU and PEB.  
22



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**Figure B.2.5.5-1. IPoS Security-Centric View of Information Exchanges During Registration and Commissioning**

### 1 **B.2.5.6 Key Updates During Normal Operations**

2 IPoS uses bulk data encryption (see reference [1], found in subsection 1.4 of this  
3 document). Additionally, the hub Key Management System can update EMKs,  
4 GKs, and EKs at any time.

5 IPoS uses the 2-bit `payload_scrambling_control` field in the outroute MAC  
6 header, with the values defined in subsection 4.9.1.2.1 to indicate whether the  
7 payload is encrypted or not.

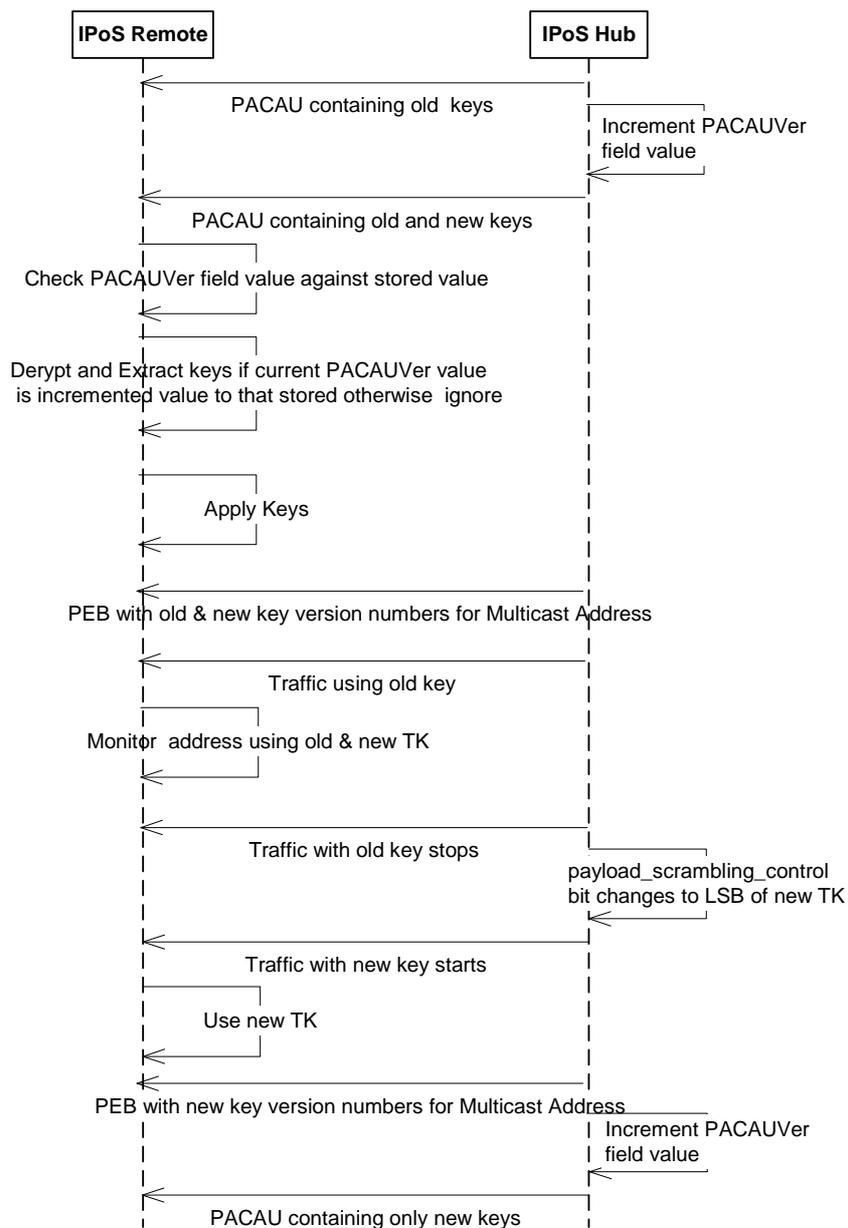
8 TKs are versioned. The hub performs TK updates by distributing the next TK  
9 (with an incremented version number) ahead of time to all authorized users in  
10 order to support hitless encryption during the key update.

11 To update the EMK, GK and EK keys, the PACAU is used.

12 A key update is indicated to the IPoS remote in the PACAU. The PACAU  
13 header contains a `PACAUVer` field that can indicate that a key update has taken  
14 place. Every time the IPoS remote receives a PACAU, it will compare the values  
15 of the new `PACAUVer` field with those it has previously stored.

16 Should the `PACAUVer` field in current PACAUs be different from the  
17 `PACAUVer` stored by the IPoS remote, this indicates that a key update has taken  
18 place, and the IPoS remote will start to update its keys.

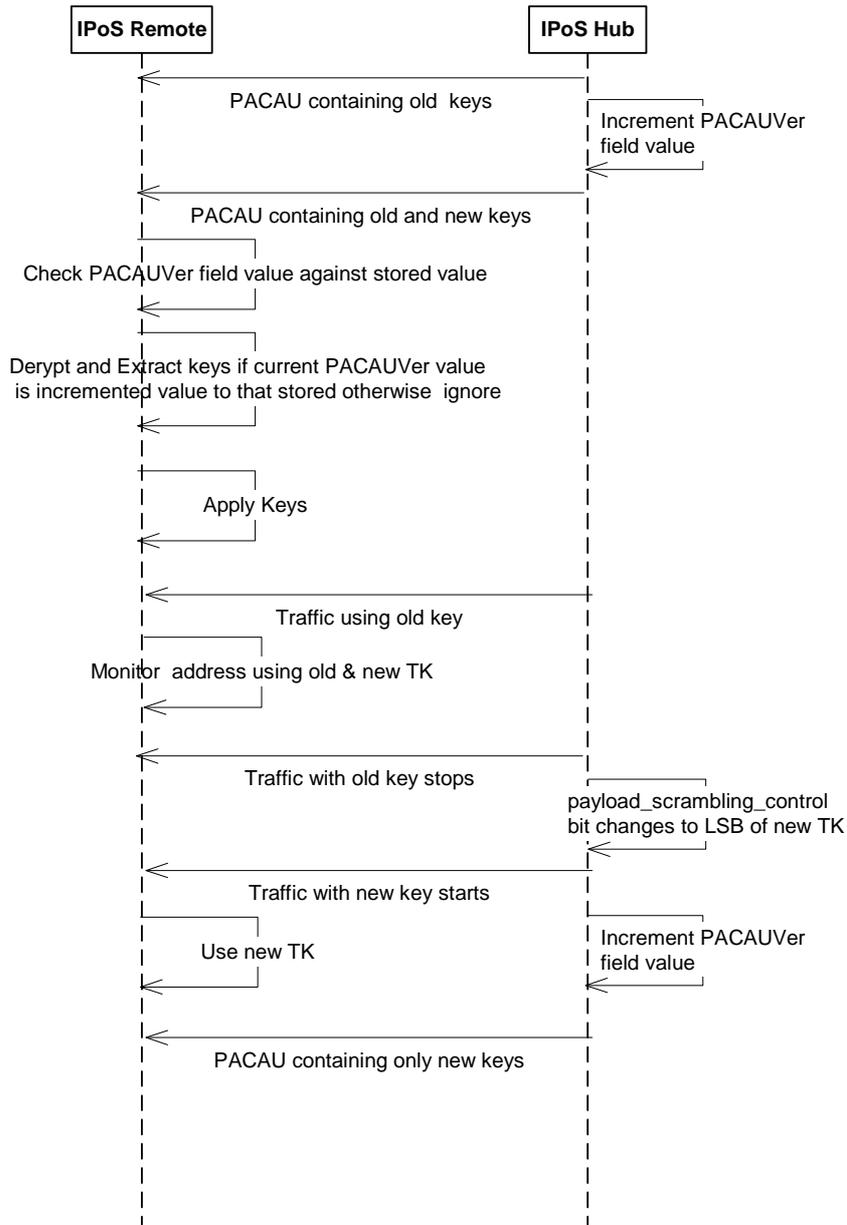
19 If the PACAU has been updated, the new versions of the keys will be embedded  
20 within the PACAU packet. Figure B.2.5.6-1 shows the update of the GKs with  
21 the PACAU.



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**Figure B.2.5.6-1. PACAU Update Notification and Group Key Distribution Procedure**

Figure B.2.5.6-2 shows the update of the EKs with the PACAU. (Note that the PEB is not required to use EKs.)



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**Figure B.2.5.6-2. PACAU Update Notification and Element Key Distribution Procedure**

Once the IPoS remote receives EEMK, EGK, and EEK, and then successfully decrypts them, the keys are loaded into the IPoS remote's secure registry. Each key has a version number that must be preserved as a part of the key update procedure. This version number will be incremented for a new version of a TK. Additionally, a PACAU can be transmitted that has both the current and new TKs embedded within it; in this situation the IPoS remote shall continue to use the current TK and switch to the new key when commanded by the payload\_scrambling\_control field of the data packet.

1 Next, if a GK is being updated, a notification of the multicast address to which  
2 the new key applies will arrive. This notification is in the form of a PEB  
3 specifying that both the old key and new TKs are required to decrypt the  
4 multicast address for the service affected by the key update.

5 When the hub ceases with the old key and begins on the new key, the IPoS  
6 remote will load the new key that pertains to that multicast service and will begin  
7 to decrypt the data.

8 The commencement of transmission of traffic (either unicast or multicast), which  
9 is encrypted under the new TK, is indicated to the IPoS remote by placement of  
10 the new TK's version number's least significant bit (LSB) in the  
11 payload\_scrambling\_control field of the traffic packet.

12 Following the commencement of traffic using the new key, subsequent PEBs and  
13 PACAUs shall contain only the new key for the services (until another rekey is  
14 ordered).

15 If new EMKs are received, the IPoS remote shall immediately install and use  
16 them as required.

## 17 **B.2.6 Payload Encryption/Decryption**

18 At the beginning of each datagram to be transmitted, the IPoS hub determines the  
19 encryption key required to protect the datagram based upon the datagram's MAC  
20 address. This MAC address has previously been allocated to the datagram based  
21 upon the service to which the datagram relates.

22 When the datagram relates to a multicast address and requires protection, it is  
23 encrypted by the IPoS hub with the corresponding GK. The GK is a 64-bit DES  
24 key; traffic encryption in the IPoS uses single DES 64-bit encryption keys.

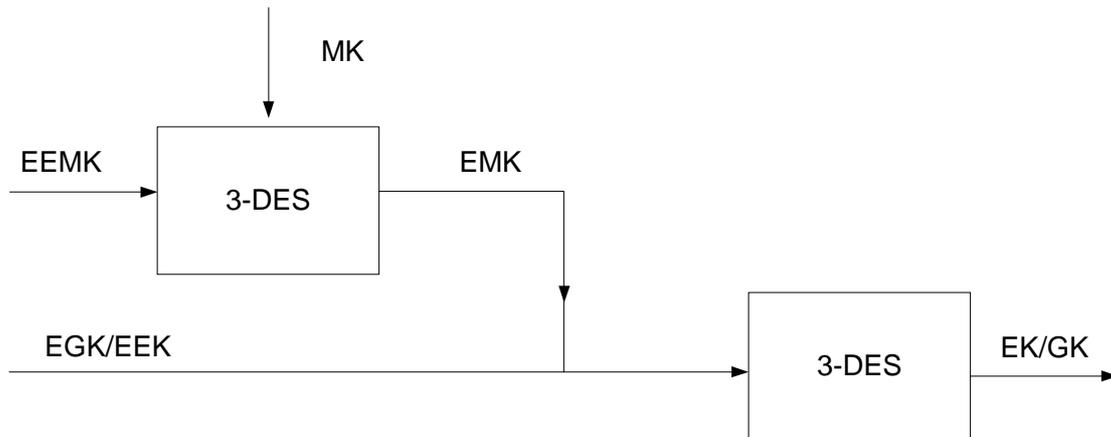
25 When the datagram relates to a unicast address and requires protection, it is  
26 encrypted by the IPoS hub with the corresponding EK. The EK is a 64-bit DES  
27 key; traffic encryption in IPoS uses single DES 64-bit encryption keys.

28 If the datagram does not require protection, it is not encrypted.

29 The EK needed at the remote terminal for decryption of the unicast datagrams is  
30 obtained by receiving the EEMK and EEK made available via the Key  
31 Distribution messages and by decrypting the EK prior to receiving the datagram.

32 The GK needed at the remote terminal for the decryption of the multicast  
33 datagrams is obtained by receiving the EEMK and EGK made available via the  
34 Key Distribution messages and decrypting the EGK prior to receiving the  
35 datagram.

36 The decryption of the EK and GK from the EEMK, EGK, and EEK uses a  
37 triple-DES algorithm and is illustrated in figure B.2.6-1.



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3

### Figure B.2.6-1. Decryption of EK and GK Keys

4

The MAC address to which the encrypted multicast user data packets will be transmitted to the IPoS remote has been made available via PEB messages (described in subsection B.2.5) prior to receiving the datagram.

5

6

7

The header of each datagram is left unencrypted so that the IPoS remote can read the MAC addressing information.

8

9

Triple-DES decryption of the encrypted payload of each received packet is performed at the remote terminal according to the following steps:

10

11

1. Upon reception at the IPoS remote, the remote can use the datagram's destination MAC address. The MAC address to GK mapping information is provided in the PEB packet, and the GK is to be used to decrypt the datagram.

12

13

14

15

2. An EK is identified by an Element\_ID (in a PACAU) or Group\_ID (in a ICAU-R) field value 0x0000FF.

16

17

3. The content of each datagram section contains the 8-byte initialization vector (see subsection 4.10.1.2.2) to the Cipher Block Chaining (CBC) DES decryption mode used in IPoS.

18

19

20

4. Once the remote terminals have selected the appropriate decryption key, the key is loaded into the appropriate register of the DES decryption element.

21

22

23

5. The payload of the received packet is loaded into the input register.

24

6. Unencrypted data is provided by the DES decryptor into the output register.

25

## 1 **B.3 Enhanced Signaling Security**

### 3 **B.3.1 Introduction**

4 The IPoS Enhanced Signaling Security (ESS) feature extends the authentication  
5 and encryption capabilities of the IPoS system security as described before to  
6 include protection of control plane signaling traffic.

### 7 **B.3.2 ESS Traffic**

8 Table B.3.2-1 summarizes the signaling traffic along with their type,  
9 transmission direction and addressing mode that are either encrypted or  
10 authenticated by IPoS ESS.

**Table B.3.2-1. ESS Traffic**

Transmission Direction	Message Type	Addressing	IPoS Original Security	IPoS Enhanced Security
<b>Control Plane</b>				11
				12
<b>Outroute</b>	Control	Multicast	None	Encrypt and Authenticate BAP, ICAP, TFP, TPP messages. Authenticate IGDP message
<b>Inroute</b>	Control Information from terminal as adaptation	Unicast	None	Encrypt/Authenticate IPoS MAC header carrying MODCOD, Ranging, backlog information
				13 14 15 16

### 17 **B.3.3 ESS Overview**

18 Control messages for inroute operation are sent from the IPoS hub to terminals.  
19 These messages are sent using multicast. A different multicast address is used for  
20 each Inroute group (with a special multicast address used to indicate "All Inroute  
21 Groups"). For messages which include terminal specific information (e.g. BAP  
22 messages), the terminals determine which messages are relevant to them by  
23 parsing the messages looking for their serial number and/or current Assign ID.  
24 Messages containing terminal specific information are the primary targets for  
25 IPoS Enhanced Signaling Security.

26 The terminal sends control messages to the IPoS Hub as part of system processes  
27 such as ranging and to request inroute bandwidth. Terminal to IPoS Hub control  
28 signaling are actually sent as information encoded into the IPoS inroute MAC  
29 header. The majority of such information is contained in the IPoS inroute MAC  
30 Adaptation Header, The information in the headers, sent from the remote  
31 terminal to the IPoS Hub, is the control plane signaling, which is a candidate for  
32 encryption and authentication. The ESS security scope is an inroute group.  
33 Outroute and inroute control messages of an ESS enabled inroute group enabled  
34 shall be encrypted and optionally authenticated.

35 AES-256, in counter (CTR) mode is used as the encryption algorithm and  
36 HMAC-SHA-256 is used for authentication for outroute control messages.

1 Each message is encrypted using a unique counter value. The outroute counter is  
2 used to encrypt outroute control messages sent to the IPoS remotes and the  
3 inroute counter is used by the IPoS remote to encrypt inroute IPoS MAC headers  
4 sent to the IPoS hub. Counters used on both inroute and outroute encrypted  
5 traffic shall be 128 bits long. The counter shall not use any part of the message  
6 being encrypted.

### 7 **B.3.3 ESS and Outroute signaling**

8 The IETF's Multicast Security (MSEC) solution (RFC 3740) is the model used  
9 by the IPoS in specifying the encryption/authentication scheme used for outroute  
10 control messages. A per Inroute Group.manual, one-way Group Security  
11 Association (GSA) is created at the Hub, and the key material required for the  
12 GSA is configured into the Hub, as well as the remote terminals.

13 Not all inroute related control messages related to an ESS enabled inroute group  
14 from the IPoS Hub are encrypted and/or authenticated. The IGDP message of an  
15 ESS enabled inroute group is always authenticated, but not encrypted. Otherwise,  
16 IPoS ESS encrypts and optionally authenticates only messages that have  
17 information regarding specific IPoS remote terminals.

18 The following outroute messages related to an ESS enabled inroute group are  
19 encrypted, and optionally authenticated.

- 20 • BAP (Bandwidth Allocation Packet)
- 21 • ICAP (Inroute Command and Acknowledgment Packet)
- 22 • TFP (Timing Feedback Packet)
- 23 • TPP (Timing Poll Packet)

### 24 **B.3.3 ESS and Inroute signaling**

25 The MAC layer headers, both unallocated(Aloha) and allocated (Stream) on an  
26 inroute burst shall be encrypted using AES-256, in CTR mode, and optionally  
27 authenticated with SHA-256 transmitted on an IPoS inroute that belongs to an  
28 ESS enabled inroute group. The IPoS terminal shall always encrypt and  
29 optionally authenticate a static number of bytes (32 bytes) in the header and by  
30 doing this some of the payload in the burst may also be encrypted/authenticated.

31 IPoS ESS shall create a per inroute group, one way unicast inroute security  
32 association (ISA) in the terminal. The key material required for the ISA shall be  
33 configured locally into the VSAT terminals and shall be unique per inroute  
34 group. The same per inroute group keys shall be used by all of the IPoS  
35 terminals. The IPoS Hub needs the same key material used by the terminal to  
36 encrypt traffic so it can decrypt.

### 37 **B.3.4 Key Distribution**

38 In order to perform encryption/authentication on an inroute group the IPoS Hub  
39 and terminal shall require four keys per inroute group. They are:

- 1                   • Outroute control message encryption key
- 2                   • Outroute control message authentication key
- 3                   • Inroute control message encryption key
- 4                   • Inroute control message authentication key

5                   The IPoS ESS specifies a manual key distribution for the AES-256 encryption  
6                   and HMAC-SHA-256 authentication algorithm. This means that, in a remote  
7                   terminal, every encryption and authentication key for every inroute group that  
8                   might be configured for ESS shall be installed. Keys are provided to terminals  
9                   via a configuration process that is outside the scope of this specification.

10                  Below is a sample file format of VSAT key file related to ESS. The syntax is  
11                  line-oriented, with each line consisting of white space, a comment or a key-value  
12                  pair. Comments start with '#' and continue to the end of the line. Key-value pairs  
13                  consist of an upper case key token, and '#' character surrounded by optional  
14                  linear white space, and a value type dependent on the key. Lines are terminated  
15                  by either LF or the CR-LF pair. There can be any number of key sets. Each key  
16                  starts with a version number.

```
17                  #Key file for VSAT
18                  #Generated July 23, 2009
19                  #Key ser 1 for inroute groups = 1, 3
20                  #Generated July 23, 2009
21                  KSV=1
22                  IGP=1
23                  KOE= FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496
24                  KOA=67CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE348
25                  KIE= A3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FE
26                  KIA = CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867
27                  IGP = 3
28                  KOE = 965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA
29                  KOA = B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02
30                  KIE = 45AAE74145AAE74145AAE74145AAE74145AAE74145AAE74145AAE74145AAE741
31                  KIA = C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1
32                  #Key set 2 for inroute_groups = 1, 3
33                  #Generated July 16, 2009
34                  KSV = 2
35                  IGP = 1
36                  KOE = A3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FEA3B496FE
37                  KOA =
38                  KIE =
39                  KIA =
```

1 *KOA = C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1*  
 2 *KIE = B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02*  
 3 *KIA = CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867*  
 4  
 5 *IGP = 3*  
 6 *KOE = 965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA965BA2EA*  
 7 *KOA = B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02B329CD02*  
 8 *KIE = 67CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE34867CAE348*  
 9 *KIA = C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1C248EFA1*  
 10

## 11 **B.3.5 Control Plane ESS Procedures**

### 12 **B.3.5.1 Key set, Encryption and Authentication Information**

13 The IPoS Hub informs the IPoS terminal of the following ESS related  
 14 information via IGDP messages. Such IGDP message is specified in 4.12.6.1.

- 15 • If outroute and inroute control messages of an inroute group shall support  
 16 encryption or not – “ESS Encryption” field in IGDP message
- 17 • If outroute control messages for an inroute group are authenticated –  
 18 “ESS Outroute Authentication” field in IGDP message
- 19 • If inroute control messages are authenticated – “ESS Inroute  
 20 Authentication” field in IGDP message
- 21 • Which key set to use – “ESS Key Set Version” field in IGDP message

22 Any IGDP for inroute groups that are configured for ESS is authenticated. The  
 23 authenticated hash is present at the end of the IGDP message in the “ESS Auth  
 24 Code” field that follows the Frequency Table and the key set index used is in the  
 25 ESS Key Set Version (refer to 4.12.6.3).

26 If the ESS Key Set Version has a value of zero and keys for this inroute group  
 27 are present in the IPoS terminals, then the IGDP message shall be discarded by  
 28 the IPoS terminals. If the ESS Key Set Version has a value of zero and keys for  
 29 this inroute group are not present in the IPoS terminal, then the inroute group is  
 30 not encrypted/authenticated nor is the IGDP message itself authenticated.

### 31 **B.3.5.2 Outroute Messages Encryption and Authentication**

32 The IPoS Hub checks the GSA for the relevant inroute group to determine if the  
 33 outroute control message should be encrypted/authenticated. If so, the message is  
 34 encrypted and optionally authenticated prior to sending over the space-link.

35 In cases where all-IRU messages (Inroute Command/Acknowledgement Packet)  
 36 are encrypted and authenticated, the keys used are from the ESS Inroute Group  
 37 with the lowest encrypted IG ID. These messages are not tied to a specific IG.

38 The IPoS Hub transmits the following outroute control messages to terminals,  
 39 and applies encryption/authentication based on their message types.

- 1 • IGDP message is sent on “all IRU” address to all IPoS remotes and no  
2 encryption is done on this message, only authentication is present.
- 3 • BAP message is specific to an Inroute Group and is encrypted and  
4 optionally authenticated using the key of the encrypted group with the  
5 specific group ID.
- 6 • IAP message is specific to an Inroute group and neither encrypted nor  
7 authenticated
- 8 • ICAP messages that are sent on Inroute Group using Inroute Group  
9 multicast use key of the encrypted group with the specific group ID, and  
10 ICAP messages that are sent on “all IRU” address use the lowest  
11 encrypted Inroute group ID.
- 12 • ISFP messages are neither encrypted nor authenticated
- 13 • TFP message is encrypted and optionally authenticated using the key of  
14 the encrypted group with the lowest encrypted Inroute group ID
- 15 • TPP message is encrypted and optionally authenticated using the key of  
16 the encrypted group with the lowest encrypted Inroute group ID

17 As per RFC 4868, only half of the 32 bytes of authentication is actually  
18 transmitted. The most significant bytes (MSB) of the 32 bytes authentication  
19 hash is transmitted to an IPoS terminal. If both authentication and encryption are  
20 enabled, authentication is provided on top of the encrypted data. The 16 bytes  
21 authentication code is placed at the end of the outroute message.

22 For any message being encrypted, the encryption begins following the message  
23 number (known as “Frame Type”).

24 The authentication hash field in all outroute authenticated control messages is not  
25 part of the authentication hash, however the UDP length field pseudo IP/UDP  
26 header (refer to ) includes the 16 byte authentication code. For example, if the  
27 pseudo IP/UDP header + message + authentication hash field = 100 byte, then  
28 100 byte shall be put in the UDP length field of the pseudo-IP/UDP header but  
29 the actual hash shall be done over 84 byte not to include the hash itself.

30 The outroute counter is used to encrypt outroute control messages sent to the  
31 IPoS remotes. Counters used on both inroute and outroute encrypted traffic shall  
32 be 128 bits long. The counter shall not use any part of the message being  
33 encrypted.

34 The outroute messages are encrypted using AES and the counter shall be  
35 included in every encrypted message. The format of the outroute counter shall be  
36 as follows.

- 37 • Platform startup time (32 bits) – restarted when the IPoS ESS platform  
38 restarts

- 1                   • Frame ID (32 bits) – current inroute frame number when the message is
- 2                   sent
- 3                   • Counter (32 bits) – resets when the platform restarts and increments with
- 4                   every message transmitted
- 5                   • Group ID (8 bits) – the Inroute Group ID that was used in the encryption
- 6                   • Block Counter (24 bits) – count of every 128 bit message packet from
- 7                   start of message and restarts with every new message

8                   Each encrypted outroute control message shall include the 104 bits (13 byte) of

9                   the counter as part of the transmission. Though the counter is actually 128 bits,

10                  the final 24 bits are always zero for every message. The IPoS inroute control

11                  message includes a pseudo 28 bytes IP/UDP header. Not all bytes in the header

12                  are used. Unused Bytes 9 through 24 are used to transmit the outroute counter as

13                  shown below.

```

14 0000 09 81 32 c2 90 01 00 00 00 00 00 00 00 03 00
15 0010 01 00 00 03 03 00 01 00 00 03 58 00 00 00 00
16 0020 45 00 00 00 b6 4a 00 00 xx xx xx xx xx xx xx xx
17 0030 xx xx xx xx xx 00 00 00 00 00 41 00 00 03 b6 4a 00
18 0040 00 88 00 00 14 00 00 14 00 00 14 00 00 14 ff ff
19 0050 02 ff ff 01 00 00 14 ff ff 37 ff ff 0e ff ff 01
20 0060 00 00 14 ff ff 37 ff ff 0e ff ff 01 00 00 14 ff
21 0070 ff 37 ff ff 0e 00 00 00

```

22

23                  The sample message above contains the data bytes of a BAP message (type 3)

24                  transmitted from the IPoS Hub to the terminals on frame 0xb64a. The pseudo- IP

25                  header is underlined. The bytes locations used (marked with “xx”) include the

26                  AES counter.

27

28                  In the IPoS terminal, keys are distributed within a key set.and the key set is

29                  identified by a Key Set Version (KSV) number.

30                  When the terminal selects an Inroute Group to operate on, the appropriate keys

31                  shall be referenced for the selected group if ESS is enabled on that group. The

32                  terminal shall use the KSV as instructed via the IGDP message.in the ESS Ket

33                  set version field for decrypting and authenticating outroute control messages for

34                  that group.

35                  The terminal shall check if the GSA is present for the corresponding inroute

36                  group of an IGDP message. If so, the terminal shall first authenticate the IGDP

37                  message using HMAC-SHA-256. The terminal shall find the 16-byte

38                  authentication code in the ESS Auth Code field at the end of the IGDP message.

39                  The IGDP messages are never encrypted and sent it clear.

40                  When decrypting an outroute packet, the IPoS terminal shall consult the IGDP

41                  information for the Inroute Group to determine if authentication information is

42                  present. The terminal shall only decrypt and/or authenticate those packet types

43                  that are known to be encrypted (BAP, ICAP, TFP, TPP).

1 If authentication is present, the IPoS Terminal shall first authenticate the  
2 encrypted message using HMAC-SHA-256 because the IPoS Hub first encrypts  
3 the message and then applies authentication on top of the encrypted data. The 16-  
4 byte authentication codes are sent at the end of each control message if  
5 authentication is enabled. The terminal shall expect that the UDP length field in  
6 the pseudo IP/UDP header includes the extra value of 16-byte authentication  
7 code.

8 If authentication is successful, the IPoS remote shall decrypt the packet. The  
9 initial counter for decryption shall be obtained from the pseudo-IP/UDP header  
10 as described earlier. Each 128 bit (16 byte) block is decoded individually and the  
11 AES counter portion of the counter is incremented by one (1) for each 16 byte  
12 block of the message.

13 If the decryption/authentication fails, the message shall be simply discarded by  
14 the terminal.

### 15 **B.3.5.6 Inroute Messages Encryption and Decryption**

16 The IPoS terminal shall encrypt and optionally authenticate the first 32 bytes of  
17 an inroute burst associated with an ESS enabled inroute group.

18 When the IPoS terminal is fabricating an inroute burst, it shall create the plaintext  
19 version of the burst data which is not encrypted. After creating the plaintext  
20 version of the burst, the first 32 bytes of the burst shall be encrypted using the  
21 computed counter and associated crypto stream value. The first 16 bytes will  
22 have a Block Counter field value of 0 and the second 16 bytes will have Block  
23 Counter field value of 1.

24 If authentication is required on the inroute bursts (as indicted in the IGDP  
25 message for the group), the authentication digest shall be generated for the 32  
26 bytes of encrypted burst information. The 16 byte authentication digest shall be  
27 provided *before* the encrypted burst header. If both authentication and encryption  
28 are enabled, authentication shall be provided on top of the encrypted data. The  
29 IPoS terminal shall create inroute counters when transmitting inroute bursts to  
30 the IPoS hub. There is a subtle difference in using the inroute and outroute  
31 counters. For outroute messages the IPoS terminal extracts the counter from  
32 packets sent *from* the hub. For inroute messages, the counters are not transmitted  
33 with the message; the IPoS terminal and the Hub shall both create the counter  
34 based on certain rules as captured below.

- 35 • Platform startup time (32 bits) – This is a 32-bit value provided to the  
36 terminal as part of the counter sent on every outroute message that  
37 require encryption. This value changes if the IPoS ESS platform restarts.
- 38 • Frame ID (32 bits) - the 32-bit frame ID received by the terminal in BAP  
39 message as part of the counter for an inroute frame on which remote is  
40 sending a burst
- 41 • Burst Number (16-bits) - the burst number assigned to the remote for use  
42 in transmitting on the inroute. Burst number is derived from its position

- 1 in the BAP. The IPoS Hub and remote both can determine what burst  
2 was used.
- 3 • Frequency (24-b its) - This is a 24-bit value that indicates the channel  
4 frequency, in 100s of Hz, for the inroute that is being transmitted. The  
5 frequency value is provided in the IGDP message sent by the Inroute  
6 Group.
  - 7 • Block Counter (24-bits) - This is a 24-bit value that is incremented for  
8 each 128 bits (16 bytes) of encrypted data. This value is reset to 0 for  
9 each inroute burst. Since only the first 32 bytes (256 bits) of an inroute  
10 burst are encrypted, the AES counter will always be 0 for the first 16  
11 bytes encrypted and 1 for the last 16 bytes encrypted.
  - 12 • As specified earlier the inroute traffic does not include the AES counter.  
13 The counter is recreated by the IPoS Hub based on the information  
14 known by both the IPoS remotes and the Hub. However, the AES  
15 counter used on the outroute traffic shall be transmitted along with the  
16 encrypted message.