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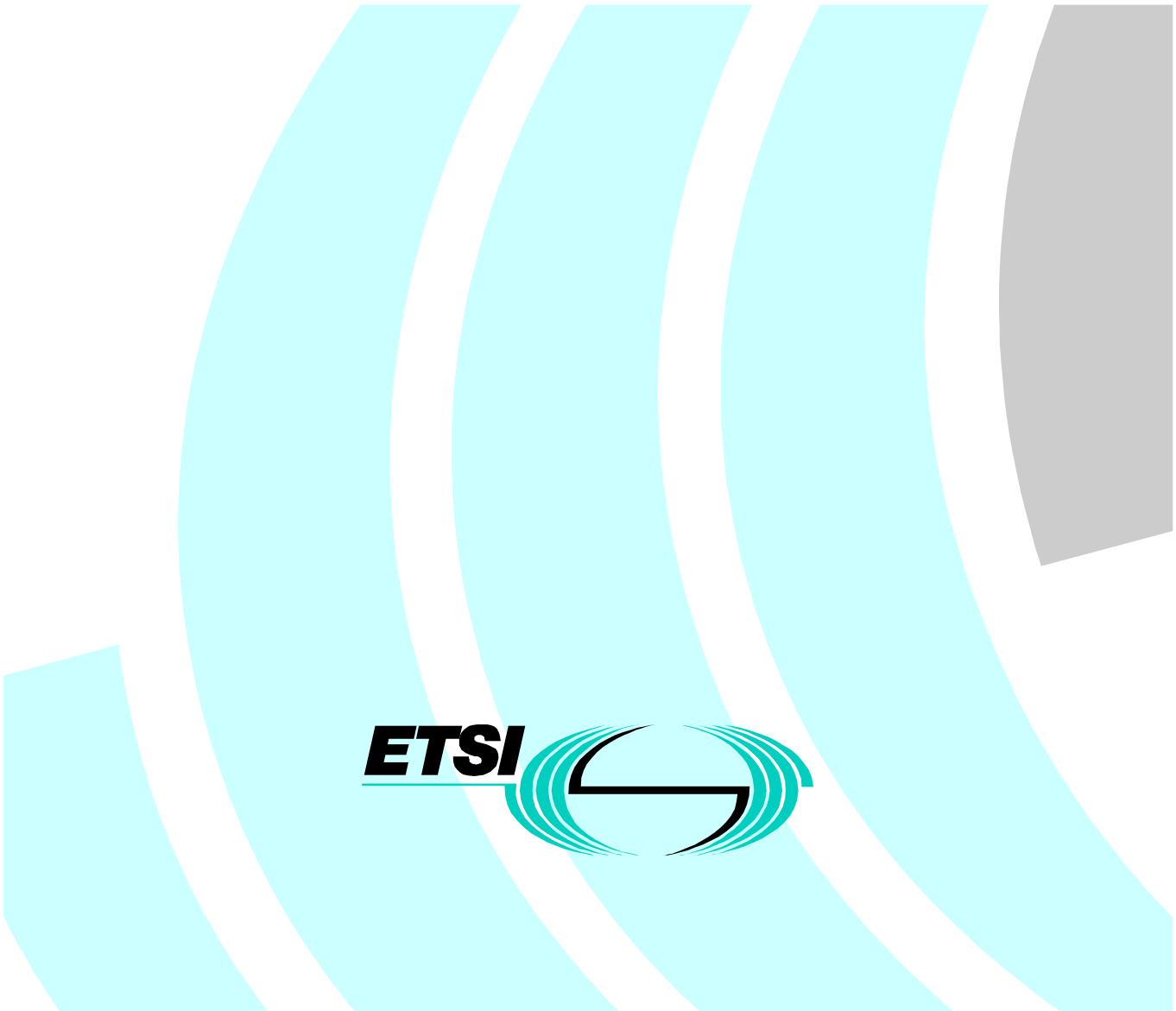
Technical Report

Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); Analysis of existing roaming techniques applicable to TIPHON mobility services



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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Project Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON).

1 Scope

The present document focuses on basic services as defined in TR 101 306 [10].

It provides a definition of TIPHON mobility, concentrating on the roaming service, and contains an examination of the different roaming technologies, e.g. Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), Internet Protocol (IP) and recommends the adoption of a roaming technology for TIPHON mobility.

2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ITU-T Recommendation E.164 (1997): "The international public telecommunication numbering plan".

[2] ETSI TR 101 307: "Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); Requirements for service interoperability; Phase 2".

[3] ITU-T Recommendation Q.1701: "Framework for IMT-2000 networks".

[4] IETF RFC 1771: "A Border Gateway Protocol 4 (BGP-4)" - Y. Rekhter, T. Li, T.J. Watson Research Center, IBM Corp., Cisco Systems Editors - March 1995.

[5] UMTS 22.05: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); Mobile Station Application Execution Environment (MExE); Service description; Stage 1 (3G TS 22.057 version 3.0.1 Release 1999)".

[6] 3G TR 23.920: "3rd Generation Partnership Project; Technical Specification Group Services and Systems Aspects; Evolution of the GSM platform towards UMTS".

[7] GSM 02.79: "Digital cellular telecommunications system (Phase 2+); Support of Optimal Routeing (SOR); Service definition (Stage 1)".

[8] GSM 03.79: "Digital cellular telecommunications system (Phase 2+); Support of Optimal Routeing (SOR); Technical realization".

[9] ITU-T Recommendation Q.1711 (1998): "Network functional model for IMT-2000".

[10] ETSI TR 101 306 (V1.2.3): "Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); Requirements for service interoperability; Scenario 1".

[11] ETSI TR 101 308: "Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); Requirements for service interoperability; Scenario 3".

[12] ETSI ETS 300 392: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D)".

[13] ETSI ETS 300 393: "Terrestrial Trunked Radio (TETRA); Packet Data Optimized (PDO)".

[14] ETSI ETS 300 396: "Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO)".

[15] IETF RFC 2002: "IP Mobility Support - C. Perkins, IBM - October 1996".

[16] IETF RFC 2003: "IP Encapsulation within IP - C. Perkins, IBM - October 1996".

[17] IETF RFC 2004: "Minimal Encapsulation within IP - C. Perkins, IBM - October 1996".

[18] IETF RFC 1701: "Generic Routing Encapsulation (GRE) - S. Hanks, T. Li, D. Farinacci, P. Traina, Netsmiths, Ltd., Cisco Systems - October 1994".

[19] IETF RFC 2290: "Mobile-IPv4 Configuration Option for PPP IPCP - J. Solomon, S. Glass, Motorola, FTP Software - February 1998".

[20] IETF RFC 2486: "The Network Access Identifier - B. Aboba, M. Beadles, Microsoft, WorldCom Advanced Networks - January 1999".

[21] ETSI TR 101 300: "Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); Description of technical issues".

[22] ITU-T Recommendation Q.700: "Introduction to CCITT Signalling System No.7".

[23] ETSI ETS 300 008-1: "Integrated Services Digital Network (ISDN); Signalling System No.7; Message Transfer Part (MTP) to support international interconnection; Part 1: Protocol specification [ITU-T Recommendations Q.701 (1993), Q.702 (1988), Q.703 to Q.706 (1993), modified]".

[24] ETSI ETS 300 009-1: "Integrated Services Digital Network (ISDN); Signalling System No.7; Signalling Connection Control Part (SCCP) (connectionless and connection-oriented class 2) to support international interconnection; Part 1: Protocol specification [ITU-T Recommendations Q.711 to Q.714 and Q.716 (1993), modified]".

[25] ETSI ETS 300 287-1: "Integrated Services Digital Network (ISDN); Signalling System No.7; Transaction Capabilities (TC) version 2; Part 1: Protocol specification [ITU-T Recommendations Q.771 to Q.775 (1993), modified]".

[26] SR 001 687: "Global Multimedia Mobility (GMM); Seamless service offering".

[27] SR 001 677: "Seamless service offering; Giving users consistent access to application/service portfolios idenpendent of access network and core network; Companion document".

[28] ITU-T Recommendation H.323 (1999): "Packet-based multimedia communications systems".

[29] IETF RFC 2543: "SIP: Session Initiation Protocol".

[30] ETSI TS 101 337: "Telecommunications and Internet Protocol Harmonization over Networks (TIPHON); Mobility and Access to Wireless Systems; Extensions to Requirements, Architecture and Protocols".

[31] ANSI TIA/EIA-41: "Cellular Radio Telecommunications Intersystem Operations".

[32] 3G TS 23.101: "Universal Mobile Telecommunications System (UMTS); General UMTS Architecture".

3 Definitions and abbreviations

3.1 Definitions

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

access network: comprises of the functional elements that enables communication between a terminal and the core network.

base station: land-based interface point for a wireless communications system. Many wireless systems require base stations to enable remote wireless devices to communicate with a land-based transmission network.

NOTE 1: In cordless telephony, this term is used for the device that provides the transparent connectivity between the handset and the Plain Old Telephone Service (POTS).

NOTE 2: In radio telephony such as cellular or Personal Communications Service (PCS), this term is used for the system serving cell phones in a metropolitan area or a Private Integrated Services eXchange (PINX) that serves cordless phones within a building.

border router: entity that resides at the edge of the network and provides connectivity between the access network and the backbone network.

business role: see TR 101 306, V1.2.3 [10], clause 5.

care-of address: termination point of a tunnel toward a mobile node (see IETF RFC 2004 [17]).

clearinghouse: company that collects and processes roaming and billing information from a number of carriers. It then transfers the compiled data to the proper carrier for credits and billing.

core network: architectural term relating to the part of a network which is independent of the connection technology of the terminal (e.g. radio, wired).

correspondent node: network exchanging datagrams with a mobile node (see IETF RFC 2004 [17]).

Domain Name Server (DNS): distributed server hierarchy that resolves a known symbolic Internet address to its 32-bit equivalent.

fixed access: property indicating that a user's equipment is physically connected to the network.

foreign agent: router handling visiting mobile nodes (see IETF RFC 2004 [17]).

foreign network: network other than the home network that is acting as host to a mobile node (see IETF RFC 2004 [17]).

H.323 gatekeeper: gatekeeper is an H.323 entity on the network, which provides address translation, and controls access to the network for H.323 terminals, Gateways, and MCUs. The Gatekeeper may also provide other services to the terminals, Gateways, and MCUs such as bandwidth management and Gateway location.

H.323 gateway: H.323 GW is an endpoint on a network which provides for real-time, two-way communications between H.323 Terminals on an IP based network and other terminals on a switched circuit network.

home agent: router forwarding packets to mobile nodes registered in foreign networks (see IETF RFC 2004 [17]).

home environment: responsible for enabling a user to obtain services in a consistent manner, regardless of the user's location or terminal used (within the limitations of the serving network and current terminal).

home network: network that contains the users service profile.

IP application point of attachment: entity (e.g. an H.323 Gatekeeper) with which the IP application (e.g. H.323 terminal) is registered.

IP service provider: company or organization, which provides access to IP services which, could be either access to a private IP network (Intranet) or to the Internet.

Message Transfer Part (MTP): Signalling System Number 7 (SS7) protocol [23] responsible for the reliable transport of signalling messages across the SS7 network.

mobile IP: mobility for Internet hosts IETF RFC 2004 [17].

mobile node: mobile IP host or router IETF RFC 2004 [17].

mobile subscriber: person or entity that has a subscription for mobile service with a service provider. An entity may take responsibility for payment of charges incurred by one or more users.

network: generic term used by voice service providers and data service providers to refer to the infrastructure that provides for the transport of user information.

(network) operator: maintains and runs the physical infrastructure over which runs user applications. A service provider may be also be an operator and vice versa.

network point of attachment: point where one IP network is connected to another IP network. IP addresses are topologically significant and unique only within a routing realm. For example, a network point of attachment maybe a Gateway, border router, or an Internet service provider.

Public land mobile network (PLMN): telecommunications network providing services to mobile users.

roaming: use of a network other than the home network. This requires registration in the visited network.

routing: process of selecting a path through a network(s) over which information is passed. The selection is based on a knowledge of the network topology, the network addressing scheme (e.g. telephone numbers. IP addresses) and (in some cases) the network traffic levels.

NOTE 3: In connection-oriented environments, the path is selected at the time of connection establishment and it is used for passing of information for the duration of the connection.

NOTE 4: In connectionless environments, the path is selected each time there is information to forward (for example, datagrams). The forwarding entity may have knowledge of how to forward the information to its ultimate destination, or may forward the information to another entity that will perform routing based on its knowledge.

service provider: provides a subscriber with services, billing and customer care. A service provider may be also be an operator and vice versa.

serving network: network to which the subscriber is attached. This may be a home network or a visited network.

Signalling Common Transport Protocol (SCTP): protocol being developed by the IETF (see RFC 2486 [20]). This protocol is specifically designed to transport signalling protocols, which require a telecom carrier-grade Quality of Service (QoS), over IP networks. It supports traditional telephony services and the new multimedia services.

Signalling Connection and Control Part (SCCP): SS7 protocol that enhances MTP routing functionality for efficient use of the network to transport non-circuit control related information (see [24]). Interfaces to the SCCP are consistent with the OSI Network Layer.

Signalling System Number 7 (SS7): internationally standardized common channel signalling system (see [22]). [22] defines the architecture, network elements, interfaces, protocols and the management procedures for a network which transports control information between network switches and between switches and databases.

NOTE 5: There are regional differences in SS7, e.g. there is a North American Version and also a European version.

terminal: device which is capable of providing access to services to users. Note the type of terminal is defined by the context (e.g. H.323 terminal, GSM terminal, etc).

TIPHON compliant system: system that complies with the mandatory requirements identified in the TIPHON requirements documents together with compliance to the parts of the TIPHON specifications in which these requirements are embodied:

- TR 101 306 [10] (for compliance with TIPHON phase 1);
- TR 101 307 [2] (for compliance with TIPHON phase 2); and
- TR 101 308 [11] (for compliance with TIPHON phase 3.

Transaction Capabilities Application Part (TCAP): SS7 application layer protocol used for the exchange of non-circuit control related information between application processes operating in different network nodes, for example, Switch-to-Switch and Switch-to-SCP (see [25]). [25] defines the messages, formats and procedures to establish and maintain a dialogue between communicating applications processes.

tunnelling protocol: protocol that enables another protocol to be carried transparently within it.

value added service provider: provides services other than basic telecommunications service for which additional charges may be incurred.

Virtual Home Environment (VHE): concept for portability of personal service environment (a combination of services, profiles and personalization information) across network boundaries and between terminals.

visited network: network other than the home network that is acting as host to a mobile user.

wireline access: see fixed access.

3.2 Abbreviations

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

3GPP	Third Generation Partnership Project
ADSL	Asymmetric Digital Subscriber Line
AMPS	Advanced Mobile Phone Service
ANSI	American National Standards Institute
BS	Base Station
BSC	Base Station Controller
GSM-BSS	Global System for Mobile communications - Base Station System
CAMEL	Customized Applications for Mobile Network Enhanced Logic
CDMA	Code Division Multiple Access
CN	Core Network
DECT	Digital Enhanced Cordless Telecommunications
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
GGSN	Serving GPRS Support Node
GII	Global Information Infrastructure
GMM	Global Multimedia Report
GMSC	Gateway Mobile Switching Center
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GSN	GPRS Support Node
HDB	Home DataBase
HLR	Home Location Register
HPLMN	Home Public Land Mobile Network
IMEI	International Mobile Station Identity
IMSI	International Mobile Subscriber Identity
IMT-2000	International Mobile Telecommunications - 2000
IMUI	International Mobile User Identity
IMUN	International Mobile User Number
IN	Intelligent Network
IP	Internet Protocol
IPCP	IP Control Protocol

ISDN	Integrated Services Digital Network
LAI	Location Area Identifier
LAN	Locale Access Network
MAP	Mobile Application Part
MD-BS	Mobile Data Base Station
MD-IS	Mobile Data Intermediate System
M-ES	Mobile End System
MIN	Mobile Identification Number
MM	Mobility Management
MS	Mobile Subscriber
MSISDN	Mobile Subscriber ISDN
MSC	Mobile Switching Center
MSRN	Mobile Station Roaming Number
MT	Mobile Terminal
MTP	Message Transfer Part
NAI	Network Access Identifier
NANP	North American Numbering Plan
NNI	Network to Network Interface
NPA	Numbering Plan Area (Area Code) used in the North America Dialling Plan
NSS	Network Sub System
PAMR	Public Access Mobile Radio
PCCH	Paging Control Channel
PDN	Public Data Network
PDP	Packet Data Protocol
PINX	Private Integrates services Network eXchange
PLMN	Public Land Mobile Network
PMR	Private Mobile Radio
POTS	Plain Old Telephony Service
PPP	Point to Point Protocol
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RADIUS	Remote Authentication Dial In User Service
RAN	Radio Access Network
RNC	Radio Network Control
RTP	Real-time Transport Protocol
SCCP	Signalling Connection and Control Part
SCN	Switched Circuit Networks
SCP	Service Control Point
SGSN	Serving GPRS Support Node
SIM	Subscriber Identification Module
SMS	Short Message Service
SS	Supplementary Service
SS7	Signalling System number 7
SwMI	Switching and Management Infrastructure
TCAP	Transaction Capabilities Application Part
TD-CDMA	Time Division Code Division Multiple Access
TDMA	Time Division Multiple Access
TE	Terminal Equipment
TEI	Terminal Equipment Identity
TETRA	Terrestrial Trunked Radio
TSI	TETRA Subscriber Identity
UDP	User Datagram Protocol
UIM	User Identity Module
UMTS	Universal Mobile Telecommunications System
UPT	Universal Personal Telecommunications
USIM	Universal Subscriber Information Module
UTRAN	UMTS Terrestrial Radio Access Network
VDB	Visitor DataBase
VHE	Virtual Home Environment
VLR	Visitor Location Register

VMSC	Visited Mobile Switching Centre
VoIP	Voice over IP
VPLMN	Visited Public Land Mobile Network
WCDMA	Wideband CDMA

4 Overview of TIPHON mobility

Mobility and roaming within TIPHON compliant systems are part of the Global Multimedia Mobility (GMM) concept (see the Global Multimedia Mobility Report [26] and [27]). A basic assumption of [26] and [27] is that, in the future, terminals should be able to be connected to several types of access network. The choice of access network will be made dynamically and will depend on a variety of factors such as the application requested by the user, the user's subscription, and the access networks available to the user. A variety of access networks can be identified and these include Universal Mobile Telecommunications System (UMTS), Digital Enhanced Cordless Telecommunications (DECT) access, satellite (Satellite-Personnel Communications System), Global System for Mobile communications - Base Station System (GSM-BSS) and fixed access. The GMM report [26] and [27] indicates that the dynamic use of multiple access networks will enable high bit-rate services to be introduced gradually according to market demand. The GMM report [26] and [27] identifies several core networks and a variety of applications, which reside outside the core network and which are normally transparent to both the access network and the core network.

The GMM network architecture (see [26] and [27]) consists of the Terminal Equipment, the Access Systems, the Core Networks and the Applications the four "Conceptual Domains", are shown by the shaded areas of figure 1.

NOTE: The term domain used in the present document differs from the term domain used in the GMM report [26] and [27], in that it also shows functions relating to the work of TIPHON.

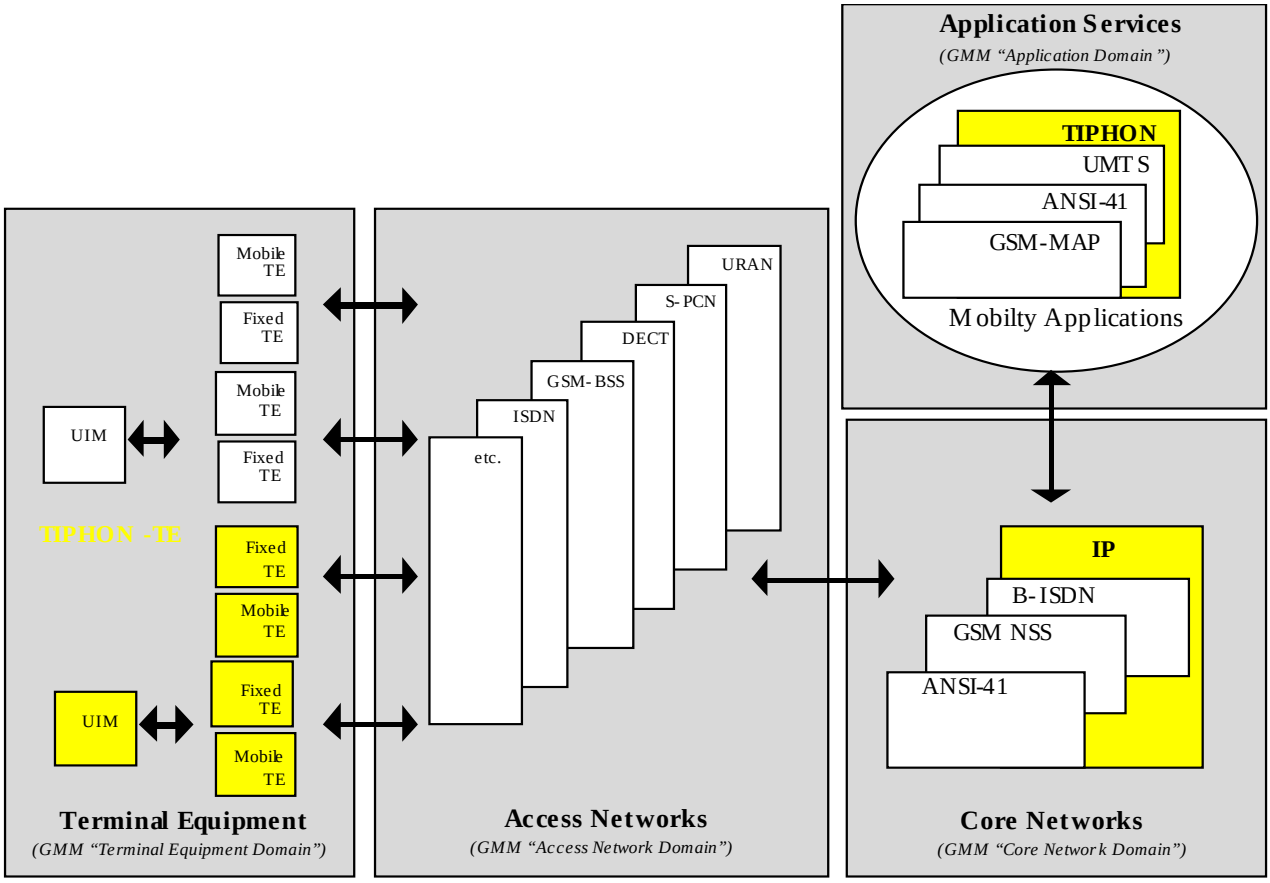


Figure 1: TIPHON Part Of The Global Multimedia Mobility

Mobility in TIPHON compliant systems comprises user mobility and service mobility in the context of the Voice over IP (VoIP) application. Figure 1 is not intended to imply that the boundary between the Switched Circuit Network (SCN) and the IP network is at the boundary between the access network and the core network.

4.1 Definition of the TIPHON mobility service

Mobility in TIPHON compliant systems is based on the assumption that the five TIPHON scenarios (see [21]) include end to end voice services when the user is mobile. Different aspects of mobility can be distinguished as follows:

- **user mobility** is the ability of a user to connect to, or use, different terminals or terminal types for the purpose of communication.
- **terminal mobility** is the ability for a terminal to change physical location, and still be able to communicate. There are two forms of terminal mobility:
  - *Discrete terminal mobility* (roaming)*:* the ability of a terminal to make discrete changes of physical location. I.e. to change location while no media streams are active; and
  - *Continuous terminal mobility* (handover)*:* the ability of a terminal to change physical location, while media streams are active. This can be seamless, no data loss during the change of physical location, or not seamless, in which case some media stream data is lost; and
- **service mobility** is the ability for a user to obtain a particular service independently of user mobility (i.e. the terminal that they are using) and terminal mobility (i.e. their change of location).

NOTE: The Virtual Home Environment (VHE) is an extension of service mobility in the sense that it relates to a service package rather than a single service.

Mobility in the context of the five TIPHON scenarios (see [21]) addresses service mobility.

Within the content of a particular service, a user might have to access, authenticate with or register with, a server in the network that provides the service. For some services this might involve only a server in the home network, or only a server in the visited network, whereas for other services interworking with servers in a visited network might also be needed.

4.2 Mobility Management using a Layered Architecture

4.2.1 Physical layer and link layer

Both access networks and core networks will have various physical layers and link layers. Diversity in access technologies will occur especially at network edges (wireless, wire-line, Public Switched Telephone Network (PSTN), Asymmetric Digital Subscriber Line (ADSL), etc.). Some of the access networks may have scarce resources, some of them may already have Quality of Service (QoS) access mechanisms (e.g. the PSTN).

The intention of a layered architecture is to hide, as much as possible, the various access technologies from the applications running on top. There are instances though where access technology related information needs to be conveyed end to end (e.g. QoS related parameters conveyed at the router level).

4.2.2 IP network layer and transport layer

One of the more important aspects of VoIP is Quality of Service. IP Quality of Service should be provided independently of the application requesting it.

The IP layer might be aware of the fact that the underlying transport mechanism is e.g. a wireless link (possibly due to header compression). IP QoS issues might also be different over a public wireless IP link compared to over a private LAN, but again, as much as possible should be hidden to applications on top of the IP layer.

4.2.3 Applications layer

The application layer itself is to some extent layered as well. Some applications may make use of underlying applications. This split within the applications layer depends on the functionality, but still, from an IP perspective, these underlying applications are all applications on top of IP.

4.2.3.1 Basic conversational voice applications and multimedia applications

Conversational voice applications provide two way speech between users. Non-conversational voice applications provide a means for a user to leave a message to be played back to the intended recipient at some later time, e.g. voice mail.

This is the application at the core of the mobility activities in TIPHON. The application can be considered as a separate layer, mainly in cases of interworking with SCNs, where the voice telephony application and voice bearer are tightly coupled and could be considered as THE application.

For an IP network, a conversational voice service should be considered as just one of the real-time applications.

In principle only the business roles (see [26] and [27]) involved in the application need to be aware of the application. In a pure IP case the business roles involved relate to the two parties involved in the call, and any service provider(s) with whom the communicating parties have a subscription. In case of roaming and Voice over IP registration in a visited network, the business role is also aware of the application. However, a core network just offering IP transport of the voice packets does not have to be aware of the application that is using the network.

4.2.3.2 Other Applications

Access to an IP network can of course be used for many applications that are not call related, e.g. mail applications, Web-browsing, content on demand.

Access to an IP network does not automatically imply that a user wishes to make or receive calls.

Another class of applications is non-call related applications that interact with or invoke underlying basic voice and/or multimedia applications (e.g. Web-portals, call centres, personal communication agents).

4.2.4 Wireless Access and VoIP

In an unbundled IP world, the application is separated from the transport. However, access registration may still be coupled to the application registration. This is not the case for certain wireless access networks such as the General Packet Radio Service (GPRS). The reason being that the initial registration is with the access (GPRS) network for the transport of the application to the IP network and a further registration is then required for the application with the IP network.

The reason a user may require wireless IP access may be to be able to read E-mail only and so the user may not want to have the ability to be called or to place calls.

Nodes between the terminal application and a telephony server in the network do not have to be aware of the telephony application. This facilitates introduction of new versions of the voice/multimedia application, or parallel operation of alternatives such as Session Initiation Protocol (SIP) [29] and ITU-T Recommendation H.323 [28].

Applications should not be tailored to one type of access so as to make optimal use of the possibilities that multimedia over IP offers. Tailoring applications to one type of access could limit the service offering, which in turn could close the architecture to new and flexible applications.

5 Roaming technologies

5.1 Global System for Mobile communications (GSM)

A GSM network can be divided into three broad parts:

- the mobile station;
- the base station subsystem; and
- the network subsystem (Mobile Switching Centre (MSC), Home location register (HLR), Visitor Location Register (VLR), Authentication Centre, and Equipment Identification Register).

The mobile station consists of a terminal and a Subscriber Identity Module (SIM) that provides a level of user mobility so that the user can have access to subscribed services regardless of the terminal used. By inserting the SIM card into another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services. The usage of SIM card is restricted to one user per card, so a user can not use two different terminals at the same time.

The mobile station is uniquely identified by the International Mobile Equipment Identity (IMEI). The SIM card contains the International Mobile Station Identity (IMSI) used to identify the subscriber to the system, a private key for authentication, and other information. The IMEI and the IMSI are independent, thereby allowing personal mobility.

Service mobility is provided to the user through Intelligent Network (IN) services (e.g. those specified by ETSI SMG committee: Customized Applications for Mobile Network Enhanced Logic (CAMEL) and supplementary services) within the GSM systems where the end user should not see any difference in the services provided by the IN nodes irrespective of the user's location and the terminal used.

5.1.1 GSM location update

The location updating procedures, and subsequent call routing, use the MSC and two location registers: the HLR and the VLR. When a mobile station is switched on in a new location area, or it moves to a new location area or a different operator's Public Land Mobile Network (PLMN), it registers with the network to indicate its current location. In the normal case, a location update message is sent to the new MSC/VLR, which records the location area information, and then sends the location information to the subscriber's HLR. The information sent to the HLR is normally the SS7 address of the new VLR, although it may be a routing number. The reason why a routing number is not normally assigned, even though it would reduce signalling, is that there are only a limited number of routing numbers available in the new MSC/VLR and they are allocated on demand for incoming calls. If the subscriber is entitled to service, the HLR sends a subset of the subscriber information, needed for call control, to the new MSC/VLR, and, if there is a previous registration, the HLR sends a message to the previous MSC/VLR to cancel the previous registration.

For reliability reasons, GSM also has a periodic location updating procedure. If an HLR or MSC/VLR fails, and as a result all mobile stations attempt to re-register simultaneously to bring the database up to date, this would cause overloading of the network. Therefore, the database is updated only when location update events occur. The enabling of periodic updating, and the time period between periodic updates, is controlled by the operator, and is a trade-off between signalling traffic and speed of recovery. If a mobile station has not re-registered when the updating time period expires, it is deregistered.

The IMSI attach and detach mechanism is related to location updating. An IMSI detach informs the network that the mobile station is unreachable, and avoids allocating channels and sending paging messages unnecessarily. An IMSI attach is similar to a location update, and informs the network that the mobile station is reachable again. The activation of IMSI attach/detach is controlled by the operator and may be on an individual cell basis.

The location of a subscriber is uniquely identified by the Location Area Identity (LAI), which is composed of the mobile country code, the mobile network code, and the location area code. The mobile country code is a three-digit value that identifies the country where the network is located. The mobile network code identifies different (competing) networks within a country. The location area code identifies the physical area in which a mobile subscriber is located.

5.1.2 GSM Call Routing

To make a call in a GSM network, the calling party dials the called subscribers Mobile Subscriber ISDN (MSISDN) number which uses ITU-T Recommendation E.164 [1] address scheme. An incoming call is directed to the Gateway MSC (GMSC) function. The GMSC is basically a switch which is able to interrogate the called subscriber's HLR to obtain routing information, and this is achieved by the GMSC mapping the MSISDNs to the called subscriber's HLR.

5.1.2.1 Routing within a PLMN

A call terminating on a mobile station is routed through the GMSC to a Visited Mobile Switcheind Centre (VMSC) identified by the HLR, based on the location of the terminating mobile subscriber. The GMSC interrogates the HLR for the routing information of the subscriber. The HLR has the latest location area information, which it uses to request to the appropriate VLR for the temporary roaming number (Mobile Station Roaming Number (MSRN)). The VLR requests the temporary roaming number from the appropriate VMSC. The VMSC randomly selects an available temporary roaming number and this is reported to the VLR. The VLR reports the temporary roaming number to the HLR, which reports the temporary roaming number to the GMSC. Using the temporary roaming number, the call set-up is performed from the GMSC to the VMSC. The VMSC proceeds to page the subscriber in the location area. Upon page response, the call is connected (end-to-end).

5.1.2.2 Call routing for an inter-network roaming subscriber

In principle, the call establishment is identical to the scenario of "Routing in the PLMN". Inter-network roaming occurs when a subscriber is registered outside the subscriber's home network. If optimal routing is not supported , the call will be routed to the GMSC in the home network where the routing interrogation begins. The establishment of the call then takes place between the GMSC in the home network and the VMSC in the target network.

5.1.2.3 Support of Optimal Routing

Call routing in the original GSM architecture does not always follow the most direct route, particularly in the case of roaming subscribers. The call charges for non optimal routing are quite expensive and the traffic unnecessarily occupies international lines. GSM Phase 2+ intends to implement the support of optimal routing to reduce unnecessary international links. Details on the support of optimal routing can be found in GSM 02.79 [7] and GSM 03.79 [8].

5.2 US cellular system (ANSI-41)

Cellular networks conforming to ANSI TIA/EIA 41 [31] interoperate to provide nation-wide roaming services to mobile subscribers. They also interwork with the PSTN and ISDN to support calls between cellular and wire line parties. Roaming agreements between the cellular service providers in the USA and Canada form the basis for proper routing and signalling information between two networks. They also permit the ANSI-41 signalling communications specified in ANSI TIA/EIA 41 [31] between cellular networks that provides the mobility management and call processing functions. Based on these agreements, configuration tables in the network equipment contain information that enables subscribers to register and receive services from a visited system. Without roaming agreements with a visited system, the visiting mobile may obtain service through a clearinghouse network that has a roaming agreement to the roaming mobile subscriber's home network.

NOTE: To properly route a call to/from a roaming mobile, the roaming agreements require technical information (e.g. MSC Numbering Plan Area (NPA), MSC identity, SS7 Message Transfer Part (MTP)/Signalling Connection and Control Part (SCCP) point codes) shared about the cellular networks involved.

For Cellular networks conforming to ANSI TIA/EIA 41 [31] to support international roaming, numbering and international call delivery problems need to be resolved. Mobile Information Numbers (MIN) use the 10-digit subscriber directory number that follows the North American Numbering Plan (NANP). The NANP is a subset of ITU-T Recommendation E.164 [1], the international ISDN numbering plan standard. ITU-T Recommendation E.164 [1] includes a Country Code, a National Destination Code, and a Subscriber Number. Together the National Destination Code and the Subscriber Number comprise the National Significant Number. The 10-digit MIN complies with the international National Significant Number format of ITU-T Recommendation E.164 [1]. Since most of the North American mobile subscribers possess a 10-digit MIN, this causes problems when trying to register an international subscriber in North American networks. The country code of the MIN could be interpreted as part of the NPA and the wrong HLR could be queried for Mobile Subscriber service qualification. Similarly, a North American subscriber roaming internationally would have the first few digits of the MIN interpreted as a Country Code, and thus registration would also be attempted at the wrong HLR. One solution is to expand the existing MIN length to at least 12 digits to accommodate a Country Code. This would enable true seamless automatic roaming using the existing ITU-T Recommendation E.164 [1] format. However, this will require major changes throughout cellular networks conforming to ANSI TIA/EIA 41 [31] to convert all of the 10-digit MINs. Another solution that has been proposed is know as HLR double dipping. That is, when a mobile station registers with a MIN that may be ambiguous, sequential queries are made from the serving network to the two HLRs that both maintain each interpretation of the ambiguous MIN. This solution has drawbacks and causes extraneous signalling traffic. Further research is needed to resolve the numbering problem. Temporary Location Directory Number used for call delivery to a roaming mobile station in networks conforming to ANSI TIA/EIA 41 [31] also adopts a 10-digit format in ANSI-41 Rev. A and ANSI-41 Rev. B. In ANSI-41 Rev. C the Temporary Location Directory Number is explicitly stated to be a maximum of 15 digits in length. If a 10-digit Temporary Location Directory Number is used to deliver a call to a roaming mobile outside of the USA or Canada, the call may not be properly delivered due to the same numbering problem.

Networks conforming to ANSI TIA/EIA 41 [31] provide support for different wireless access technologies (e.g. Advanced Mobile Phone Service (AMPS), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Narrowband Advanced Mobile Phone Service (N-AMPS)). Unlike GSM networks, networks conforming to ANSI TIA/EIA 41 [31] are built to offer mainly terminal mobility. The entity associated with the roaming is the terminal. However, roaming is not merely the network simply monitoring of the terminal as it moves. In ANSI-41, the status of the subscriber is also tightly associated with the terminal "roaming" within the network.

Mobility Management (MM) is defined by a set of functions, enabling the network to keep track of the user's status and terminal location while the terminal/user is moving in the network. The objective of MM is to enable the network to deliver calls to the subscriber, and to authorize the subscriber for service in a given service area, also known as system.

To manage terminal/user mobility, a database record called a service profile is maintained in the network. One service profile is associated with one subscriber (and associated with one terminal). This database record contains both temporary data, such as current location and status of subscriber, as well as permanent data, such as subscribed features.

Roaming, also known as Automatic Roaming in ANSI TIA/EIA 41 [31], is a set of network functions that enable the subscriber to receive calls, and use call features while moving throughout the networks. Originating a call may not require roaming, however MM occurs as a consequence of originating a call. Roaming is transparent to the subscriber and moving between systems requires no special actions.

The detection of a subscriber/terminal in a new serving network is known as a registration event. The different types of registration events in ANSI TIA/EIA 41 [31] are largely air interface dependent, i.e. AMPS, TDMA, and CDMA all support different types of registrations. Registration may initiate other network processes such as location management, service qualification and user/terminal state management.

In ANSI TIA/EIA 41 [31], the location management may be defined as the serving system location update process and the HLR location update processes. The terminal location update process creates or modifies the subscriber's temporary record in a visited system and updates the location information in the subscriber record in the HLR. The terminal location cancellation or de-registration deletes the subscriber's temporary record in a visited system and updates the location information in the subscriber's record in the HLR.

In ANSI TIA/EIA 41 [31], service qualification authorizes roaming service capabilities for users and terminals in a serving system. The service profile is a specific set of features and service capabilities (including restrictions) that are associated with the user/terminal. The serving system uses this profile to tailor the services it provides to each individual subscriber.

In ANSI TIA/EIA 41 [31], terminal state management coordinates the call delivery Availability State of the terminal between the serving system and the HLR. A terminal in an active state is available for call delivery. When in an inactive state, the terminal is not available for call delivery, however it may be available to receive short message services.

When a call is to be routed to the terminal, the same procedure as in GSM applies, whereby an interrogation will be initiated by the gateway (if the call originates from a PSTN), or from an originating network (if the call originates from just another system conforming to ANSI TIA/EIA 41-D [31]. Upon receiving the location interrogation, the home network would request a temporary routing address (Temporary Location Directory Number) from the VLR where the terminal was last located. The request might trigger the process to locate the terminal before returning the routing address. When the HLR receives the routing address from the visited system, it will send it to the gateway or originating network to set up a call using the new routing address.

Service mobility is provided to the user through IN services (e.g. Wireless IN contained in ANSI TIA/EIA 41 [31] and supplementary services) within systems that conform to ANSI TIA/EIA 41 [31]. The end user should not see any difference in the services provided by the IN nodes irrespective of the user's location and terminal used.

In ANSI TIA/EIA 41 [31] Rev.C, the basic mobile telecommunication network functions related to automatic roaming are summarize in the following table:

Table 1: Use of ANSI-41C Operations for Basic Automatic Roaming

Use of ANSI-41C Operations for Basic Automatic Roaming	
MS service qualification	RegistrationNotification, QualificationRequest, QualificationDirective
MS location management	RegistrationNotification, MSInactive, BulkDeregistration, RegistrationCancellation, UnreliableRoamerDataDirective
MS state management	RegistrationNotification, MSInactive, BulkDeregistration, RegistrationCancellation, UnreliableRoamerDataDirective, RoutingRequest
HLR and VLR fault recovery	BulkDeregistration, UnreliableRoamerDataDirective

5.3 UMTS - Third Generation Partnership Project (3GPP)

5.3.1 UMTS PHASE-1 3GPP Release 99

The UMTS Phase1 3GPP release 1999 architecture (3G TS 23.101 [32]) consists of two network domains: the Circuit Switched Domain, centred around an MSC, and the Packet Switched Domain, centred around GPRS Support Nodes (GSN). The general architecture for 3GPP release 1999 is shown in figure 2.

NOTE: For clarity, a number of interfaces have been left off of this picture.

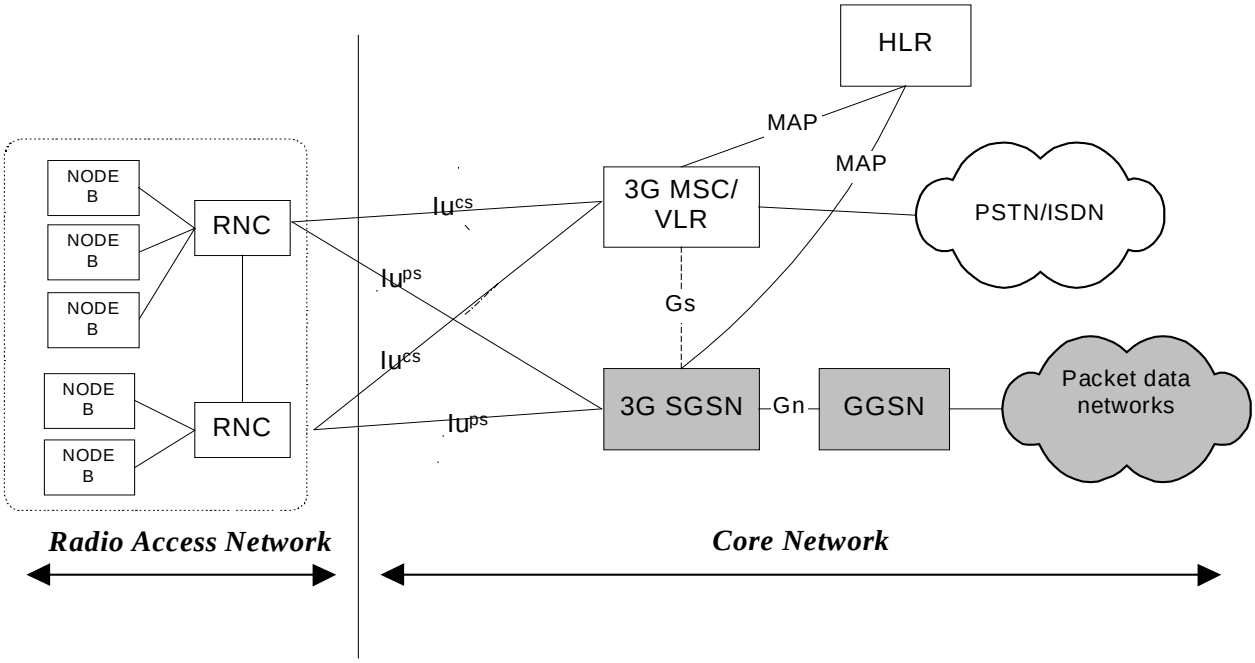


Figure 2: UMTS Phase1 3GPP'99

The Packet-Switched Domain in the Core Network has 2 main interfaces that involve the use of IP: Iu^{PS}, between the Radio Network Control (RNC) and the 3rd Generation Serving Gateway Support Node (SGSN), and Gn, between the 3rd Generation SGSN and the GPRS Gateway Support Node (GGSN). The feasibility of Mobile IP as a means to provide connectivity between fixed and mobile access networks connected to an IP network, are among the issues studied by the 3GPP S WG2 Mobile-IP ad-hoc group.

A network conforming to UMTS 22.05 [5] is a network operated by a single network operator and consists of:

- UMTS Terrestrial Radio Access Network (UTRAN) access networks;
- Wideband CDMA (WCDMA); and/or
- Time Division CDMA (TD-CDMA); and
- GSM BSS access networks; and
- a UMTS core network (defined as an evolved GSM network infrastructure (GSM Network SubSystem (NSS) and GPRS backbone) or any new UMTS core network infrastructures, integrating circuit and packet switched traffic).

The scope of UMTS requires parallel existence with the pre-UMTS technologies such as, GSM, DECT etc.. The UMTS objectives relevant to the present document are:

- to provide a single integrated system in which the user can access services in an easy to use and uniform manner in all environments;
- to provide support of roaming users by enabling users to access services provided by their home environment in the same way even when roaming; and
- to be IMT2000 (ITU-T Recommendation Q.1711 [9]) compliant in regards to terminal mobility (roaming).

The distribution of functionality between the home environment and serving network for an UMTS system are as follows:

- the home environment takes care of user authentication, Universal Subscriber Information Module (USIM) issues, billing and User Profile/VHE management; and
- the serving network handles the access and transport.

The following responsibilities can be provided by either the home or the serving network or both:

- service control;
- QoS negotiation;
- mobility management including roaming and automatic establishment of roaming agreements.

The interfaces have to be able to support inter-system roaming between systems conforming to different standards, provide unified mobility management from the user's perspective and support 3rd Generation features such as VHE.

UMTS requires that a system is able to provide User, Terminal, and Service mobility to the end user. Each USIM will be unique and associated with only one home environment. However, a user can have multiple user profiles which can be activated on a per access basis and simultaneous access by the same user using different profiles will also be possible. For an originating access, a user will choose the profile required. For terminating accesses, the profile selected will be based on the user address indicated by the caller (e.g. International Mobile User Number (IMUN) which will be a diallable number allocated to a UMTS user).

In respect to personal mobility, UMTS systems rely on the user having a valid USIM, which can be inserted in any compatible 3rdGeneration terminal, whereas, terminal mobility is achieved through the ability of interacting with the access network. The proposed UMTS system is in line with the GSM development of roaming platform for international roaming.

The registration and roaming process requires the serving network to be able to contact the given Home Environment and thus maintain some form of process of determining the Home environment. The serving network provides access to the user and through the roaming broker, is able to interwork with any home environment needed. Any user who wants to use the services of a particular network would register with the network and the network would either directly or indirectly interwork with the home environment. As the serving network will need to know how to route the registration message, several methods such as global title translation table or Internet Domain Name Server (DNS) address request etc. can be used.

There *is* no standardization required to facilitate automatic establishment of roaming relationships because these can be implemented with current standards and procedures. This conclusion is based on the fact that three issues have to be resolved for automatic roaming fulfilment:

1) a contractual relationship;
2) a signalling network to support authentication, incoming call handling, etc.;
3) an accounting and settlement procedure.

These components have been addressed within the International roaming platform in GSM. The two types of mobility requirements defined by UMTS are described hereafter.

5.3.1.1 UMTS Call-Unrelated Mobility

REGISTRATION FUNCTIONS:

- Location Registration - Terminal notifies the network of making first access to the system and provides it with location information and capabilities and services.
- Registration of Additional Subscribers - Terminals that allow multiple subscribers can use this process to notify the network of additional subscriber on a specific terminal and its requested services.

REGISTRATION REQUIREMENTS:

- Subscriber controlled access - Registration should support the possibility of explicit or predefined actions from the mobile subscriber to choose the desired service.
- Access restrictions - The limitation of service selection shall be possible according to subscription and authorization.
- Subscriber information - A mobile subscriber must be informed about the availability and restrictions of services in the service environment. This information should be available before registration is made.

- Multiple subscribers - Some types of UMTS terminals should provide services to more than one subscriber simultaneously.

- Provision of home services - The subscriber shall be able to register in a serving network for services provided by his home environment. The serving network shall provide the services with the same "touch and feel" regardless of serving network (virtual home environment).

ATTACH/DETACH:

This process will inform the network of the subscriber being reachable or not. Any signal from a detach subscriber will change status to attach. In the same manner, when the status of a subscriber is unknown to the network for a pre-defined period, the status is changed to detach.

5.3.1.2 UMTS Call-related Mobility

REQUIREMENTS FOR CALL HANDLING:

- Route Optimization - Route chosen from originating to terminating party should be independent of the location of the home mobility provider. But for heterogeneous environments that are evolving, new mechanisms may be required in order to recognize an UMTS subscriber.

- Transparency - A user should be unaware of mobility aspects such as location updating and handover.

VIRTUAL HOME ENVIRONMENT:

Virtual Home Environment (VHE) is defined as a system concept for personalized service portability across network boundaries and between terminals.

The key requirements of the VHE are to provide a user with:

- personalized services;

- personalized User Interface (within the capabilities of terminals);

- consistent set of services from the user's perspective irrespective of access e.g. (fixed, mobile, cordless etc.);

- global service availability when roaming.

Roles and components involved in realization of VHE are:

- Home Environment;

- one or more unique Identifiers;

- one User;

- one or more terminals (simultaneous activation of terminal providing the same service is not allowed);

- one or more Serving Network Operator;

- one Subscription;

- possibly one or more Value added service providers.

The requirements for each component are being specified as part of UMTS ongoing work.

The Home Environment is responsible for providing services to the user in a consistent manner. The user may have a number of user profiles which enable her to manage communications according to different situations or needs. A combination of services, profiles and personalization information forms the user's personal service environment or VHE. The Home Environment provides services to the user in a managed way, possibly by collaborating with HE-VASPs, but this is transparent to the user.

5.3.2 UMTS Packet-Switched Domain Architecture

The Packet-Switched Domain in the Core Network has 2 main interfaces that involve the use of IP: Iu^{PS}, between the RNC and the 3G SGSN, and the Gn, between the 3G SGSN and GGSN. The feasibility of Mobile IP as a means to provide connectivity between fixed and mobile access networks, connected to an IP network, are among the issues currently studied by the 3GPP S WG2 Mobile-IP ad-hoc group.

5.3.2.1 The Iu^{PS} Interface

The Iu^{PS} interface comprises of two separate planes, a control plane and a user plane.

5.3.2.2 The Iu^{PS} interface control plane

For transport of RANAP messages over Iu^{PS} an SCCP protocol shall be used. The SCCP protocol shall fully comply with ITU-T white book. RANAP protocol shall be designed to use this service according to the ITU-T standard. The Iu^{PS} shall be designed so that RANAP is not impacted by alternatives for SCCP message transport on layers below SCCP. The UMTS standard shall allow operators to chose one out of two standardized protocol suites for transport of SCCP messages.

- Broadband SS7 stack comprising MTP3b on top of SAAL-NNI.
- IETF/Sigtran SCTP protocol suite for MTP3 users with adaptation to SCCP. The protocol suite shall fully comply with the IETF standards developed by the Sigtran working group. No UMTS specific adaptations shall be standardized below the SCCP protocol.

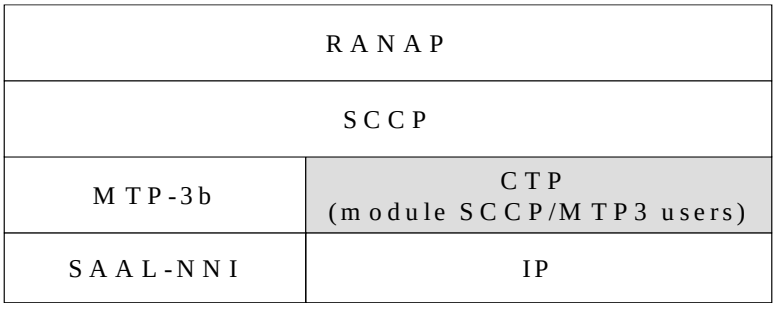


Figure 3: RANAP Protocol stack options

5.3.3 Using GPRS Gn Interface within UMTS

User data is transported from the RNC, across the Iu^{PS}, via the3G-SGSN, across the Gn, to the GGSN. A tunnelling protocol is used on top of a common layer 2. This tunnelling protocol corresponds to an evolution of the user plane part of GTP (GPRS Tunnelling Protocol) used in GPRS and carried within UDP/IP.

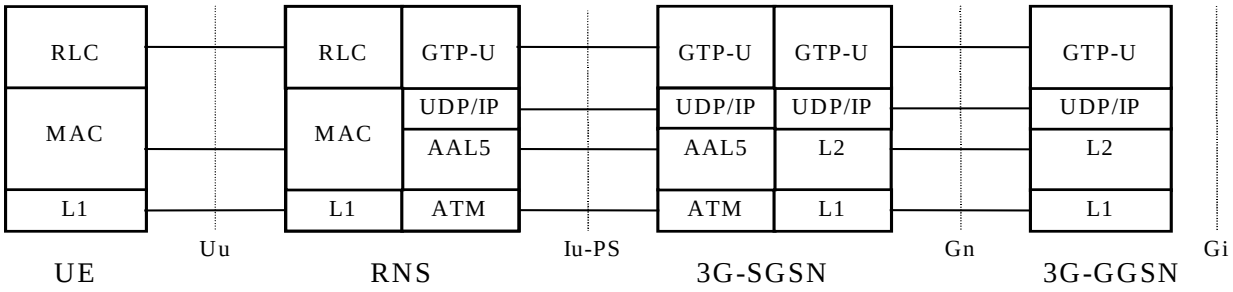
The user data plane in the UMTS core network PS Domain is made up of two tunnels:

- a first IP/UDP/GTP tunnel between an RNC and a 3G SGSN on Iu^{PS};
- a second IP/UDP/GTP tunnel between a 3G SGSN and a GGSN on Gn.

This architecture:

- Provides hierarchical mobility;
- Allows an RNC to be directly connected on the IP domain backbone;
- Ensures that all traffic is routed through 3G-SGSN: this supports the operation of functions such as charging and Lawful Interception;
- Allows easy insertion of different underlying transport protocols (or new protocol versions) on Gn and Iu if needed in the future.

The protocol stack is shown in figure 4:



NOTE: Protocol layers above RLC and GTP-U are for further study.

Figure 4: GPRS Gn Interface within UMTS

5.3.4 Use of Mobile IP within UMTS

"Presently, the work of the Mobile IP ad hoc group is defined by two work items (WI) in 3GPP TSG SA WG2, namely, "Combined GSM and Mobile IP mobility handling in UMTS IP CN" and "GPRS Mobile IP interworking". The WI "Combined GSM and Mobile IP mobility handling in UMTS IP CN" is a feasibility study of using Mobile IP for mobility management within the CN. The WI "GPRS Mobile IP interworking" is to identify how to offer Mobile IP to end-users for R99.

The following three steps for achieving GPRS evolution towards Mobile IP are foreseen (3G TR 23.920 [6]):

- Step (Stage) 1 represents a minimum configuration for an operator, who wishes to offer the mobile IP service. The current GPRS structure is kept and handles the mobility within the PLMN, while MIP allows user to roam between other systems, such as LAN's, and UMTS without loosing an ongoing session, e.g. TCP. This step is corresponds to the WI "GPRS Mobile IP interworking".

- Step (Stage) 2: The SGSN and GGSN can be co-located without any alterations of the interfaces. However, to obtain more efficient routing, the MS could change GGSN/FA, i.e. PDP context and care-of address after an inter SGSN handover if it is not transferring data. MS's which are transferring data during the inter SGSN handover could perform the streamlining after the data transfer is completed, using the old GGSN as anchor during the completion of the data transfer.

- Step (Stage) 3 is to let MIP handle also handover during ongoing data transfer. The Gn interface is here only needed for handling roaming customers without support for MIP".

The ad-hoc group will present its work in an ETR, which will serve as the basis for the changes needed to support the steps described above.

5.3.5 UMTS Open Service Architecture

The UMTS Open Service Architecture defines so-called Service Capability Servers, which provide open interfaces for services/applications (API's to be defined in IDL) towards GSM/UMTS bearers and service mechanisms. Examples of server components are Call Control, Location/Positioning, PLMN Information & Notifications. Each of these server components offers its services via defined open interfaces, and implements these by using GSM/UMTS protocols (e.g. MAP, CAP, WAP). The service mechanisms for UMTS phase 1 are Mobile Execution Environment (MeXE), SIM Application Tool kit (SAT) and CAMEL.

5.4 IMT 2000

IMT-2000 is an ITU-T draft recommendation (ITU-T Recommendations, Q.1701 [3] and ITU-T Recommendation Q.1711 [9]) to provide telecommunication services to mobile and fixed users via a wireless link, covering a wide range of user sectors (e.g. public, private, business, residential, local loop, etc.), radio technologies and coverage (cellular, satellite, cordless, etc.) and accommodating a wide range of user equipment. Intentionally, IMT-2000 systems shall support global roaming and the Virtual Home Environment (VHE) concept, i.e. the user will be provided with a comprehensive set of services and features which have the same look and feel whether they are used in the home or visited network. However, there are no detail implementation or information flows yet to assess how IMT-2000 systems perform automatic global roaming. Some guidelines and functional models to support global roaming are described in ITU-T Recommendation Q.1701 [3] and ITU-T Recommendation Q.1711 [9]. The Network Capabilities Roaming section in the proposed Capability Set 1 for IMT-2000 is outlined to support:

- interoperability and roaming among IMT-2000 family of systems using a single subscription;
- ability to supplement mobility management with IN-type service logic;
- ability to supplement authentication control with IN-type service logic. This capability does not include generation of authentication parameters.

Mobility and global roaming:

- Location Management, including automatic update;
- User Registration, Update and Cancellation;
- Service Monitoring Registration, Update, Activation, Deactivation and Cancellation;
- User Profile Database management and control;
- Security and Authentication Database management and control.

Concept and requirements for mobility and roaming.

An IMT-2000 System can be described by a set of functional subsystems which perform actions and interact among themselves to support IMT-2000 wireless users. An IMT-2000 System consists of the following functional subsystems: User Identity Module (UIM), Mobile Terminal (MT), Radio Access Network (RAN) and Core Network (CN).

IMT2000 is characterized by its concept of family and family members used to realize a global service offering among IMT-2000 systems. The UIM, MT, RAN, and CN functional subsystems may be specific to each Family Member along with the associated internal processes, internal interactions, and internal communication between functional entities. Support for IMT-2000 capabilities and interfaces will facilitate roaming between family members.

5.4.1 IMT 2000 Global roaming

An essential service requirement of IMT-2000 is that IMT-2000 users should be able to use their equipment and subscriptions in different family member networks, and to establish calls and connections between networks of different operators. To support this service requirement, interconnection between different IMT-2000 family member networks is required. An IMT-2000 network should therefore be able to interwork with a wide range of existing and future partner networks and services such as other mobile networks, Internet, ISDN, B-ISDN, PSTN, UPT, PDN, GII, etc.

IMT2000 specifies that the network to network interface (NNI) be supported between the following networks:

a) **Home network** is the IMT-2000 network which is related by subscription to the IMT-2000 User. It permanently holds location and service profile information related to the IMT-2000 User.

b) **Supporting network** is the network which provides support for a variety of services including but not limited to service logic programs and service related data for IN supplementary services provided to IMT-2000 Users.

c) **Visited (Serving) network** is the IMT-2000 network where an active IMT-2000 User is being served.

d) **Interrogating network** is the network from which a routing data retrieval request is sent to the Home network of the called IMT-2000 User.

e) **Destination network** is the network to which an outgoing call from an IMT-2000 User is destined.

f) **Previously visited network** is the network where an IMT-2000 user has been served before entering the Visited/(Serving) network.

Between IMT-2000 networks, user profile data and location (routing) data is separated from normal call control. This supports the mobility aspect. For this, the following operations of transfer and retrieval of user data and location data would have to be supported by the visited, home, previously visited networks.

Location registration/updating, transfer or retrieval of trigger/ service profile data, Retrieval of location and user data, Updating of user data, Location and user data cancellation and Call routing/terminating which could be performed with or without the MSRN number as specified in GSM.

5.4.2 IMT-2000 Virtual Home Environment

The VHE is a capability whereby a User is offered the same service experience in a visited network as in his Home system. This would allow users to enjoy Internet style flexibility and operators to differentiate services. The degree to which the VHE matches the actual home environment may be subject to, for example, the degree of co-operation between the visited network and home or supporting networks their relative technical capabilities and the compatibility of the user terminal.

The specifications for VHE exist at the requirements level. VHE requires that:

1) the user profile data belongs to user; it can be stored in USIM and/or home database;

2) this profile data can control/run software in mobile station or terminal, serving network or home network (e.g. IN server);

3) this software may already exist or may need to be created and/or delivered to appropriate location;

4) software code and/or data may be needed at more than one node for a given service.

Two possible scenarios for VHE are: the Direct-home command and the relay service control. These scenarios are described in ITU-T Recommendation Q.1711 [9]. The service may be executed, based on the program and data in one or more of those entities. The control data could be transported across interfaces such as IP, GPRS, X.25, SMS, SS7.

5.5 Universal Personal Telecommunication (UPT)

UPT is a personal mobility telecommunications service wherein a subscriber/user can register at a terminal on any connected network and be provided with UPT service at that terminal location.

UPT enables access to telecommunication services while allowing personal mobility. It enables each UPT user to participate in a User-defined set of subscribed services and to initiate and receive calls on the basis of a personal, network-transparent UPT Number across multiple networks at any terminal, fixed or mobile, irrespective of geographic location, limited only by terminal and network capabilities and restrictions imposed by the network operator. Basically, the fixed association between terminal and user identification is removed. Consequently, the identification of UPT Users is treated separately from the addressing of terminals and network access points.

When a UPT user is invoking the service on a particular access, his service profile must apply there and replace the features attached to the subscription of the owner of the terminal. This requirement applies to any action of the UPT user as outgoing call, incoming call, registration or service profile management.

The handling of a UPT call implies that the involved exchanges have the knowledge of the UPT characteristics of this call. UPT architecture is derived from the standard architecture by assembling the IN architecture for the originating, terminating and home networks. UPT is provided by a set of procedures that are classified into three different categories. The categories related to mobility and roaming is:

1) **Personal mobility procedures**

   Personal mobility procedures are UPT procedures relating to the personal mobility of the UPT user and require access, identification and authentication procedures to be carried out with or before these procedures. Personal mobility procedures are registration procedures used to specify where to receive or make calls and do not include the actual receiving or making of calls.

2) **UPT call handling procedures**

   UPT call handling procedures are procedures relating to the actual receiving and making of calls and may require access, identification and authentication procedures to be carried out with or before these procedures.

3) **UPT service profile management procedures**

   UPT service profile management procedures allow the UPT user to manage accessible data in their own personal service profile, and require access, identification and authentication procedures to be carried out before or as part of these procedures.

5.6 Cellular Digital Packet (CDPD)

Cellular Digital Packet Data or CDPD uses existing cellular network infrastructure and frequency channels, enabling digital AMPS (D-AMPS) and AMPS wireless network operators to offer packet data services for wireless Internet and corporate database access applications. The following list represents the functional components within a CDPD network:

- **M-ES**: the Mobile End System to gain access to CDPD network;
- **MDBS:** the Mobile Data Base Station providing radio link;
- **DIS**: the Mobile Data Intermediate System providing mobility management, registration and forward and redirect data to M-Ess;
- **S**: the Intermediate System that routes data between different components;
- **ES:** the Fixed End System representing traditional external data application and value added network service application systems.

CDPD system provides an extension to the existing AMPS and data communications system allowing users to use traditional voice services from the wireless system and at the same time get access to the data applications outside and within the CDPD network (such as SMS delivery, Web browsing). CDPD system does not make use of or connect to the traditional MSCs of the ANSI-41 system. As such, the system has its own set of mobility management and roaming operations independent of the ANSI system.

CDPD mobility management is based on same principles as mobile IP. The MD-IS is the central element in the process. A MD-IS is logically separated into a home MD-IS and a serving MD-IS. There is often several serving MD-ISs in a network, all connected to a home MD-IS. A serving MD-IS manages one serving area. The MD-BSs that provides coverage in this area is connected to the serving MD-IS, which has a database containing information about all subscribers currently visiting the area.

A home MD-IS contains a subscription database for its geographical area. Each subscriber is registered in the home MD-IS associated with his home area. The IP address of a subscriber points to his home MD-IS. The database keeps information on which serving area a subscriber is currently visiting.

Mobility management in a CDPD network involves maintaining location information database and routing of Network Protocol Data Units (NPDU) based on this information. This information is managed and constrained within the MD-ISs so that routing and relaying is transparent to all other external and internal systems from the CDPD network point of view.

Mobility is supported in both Data link layer and Network layer. MD-ES is logically member of a fixed home area that provides mobility-independent routing destination area for ISs and ESs that are not mobile aware. CDPD mobility provides rerouting and forwarding messages from home to the current location of the M-ES. Cell selection procedure allows the M-ES to discover, select and maintain the most optimal channel available in the serving system.

Location updating procedure between the M-ES and serving MD-IS results in authenticating and updating the Location directory in the home MD-IS and updating the Registration directory in the serving MD-IS. Redirection and forwarding delivers messages that are destined for M-ESs that are located in a serving MD-IS area by the process of home MD-IS redirecting the messages by forwarding them to the serving MD-IS. Serving MD-IS completes the delivery by routing the message to the M-ES in its current location.

The M-ES must be switched on before an end-user can send any data. The M-ES switch-on action sends a message to the serving MD-IS, identifying the user and his home MD-IS. User access rights and authentication processes are performed at the home MD-IS. The IP packets are assembled in the serving MD-IS using the link layer frames received from the MDBS. From the serving MD-IS the IP packets are routed to their destinations.

An incoming IP packet is routed to the home MD-IS of the receiver. After finding out in which serving area the subscriber is currently located, the IP packet is tunnelled to the corresponding serving MD-IS. This MD-IS checks in which channel stream the subscriber is active and forwards the packet to the mobile data base station responsible for that channel stream.

CDPD has support for sleep mode (inactive). Packets are stored in the serving MD-IS in case a mobile end system is sleeping. If the system (except for sleep mode) is out of contact with mobile end systems, packets are only stored for the time it takes to perform the predetermined number of retransmissions. Then they are discarded.

5.7 General Packet Radio Service (GPRS)

General Packet Radio Service (GPRS) provides end-to-end packet data access for the subscriber within GSM systems and towards the PDNs without using circuit switched mode.

5.7.1 GSM/GPRS

The GSM/GPRS network infrastructure is obtained from the existing GSM infrastructure by adding two new network elements, the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN).

GPRS defines the concept of Routing Area (RA), defined as a set of radio cells where an idle MS doesn't need to update its location with the network. One or more cells form a RA, which is a subset of the cell in one GSM Location Area (LA).

5.7.1.1 GPRS Mobility Elements: SGSN, GGSN, VLR and HLR

An SGSN (Serving GPRS Supporting Node) provides mobility management, register functions such as subscription information (e.g. the IMSI and temporary identities) and location information (e.g. the cell or the RA where the MS is registered, the VLR number of the associated VLR, the GGSN address of the GGSN corresponding to an active PDP context, zero or more PDP addresses).

The SGSN is connected to the BSC and is the service access point to the GPRS network for the GPRS MS. An SGSN can support several RAs and can support one or several BSCs. Each routing area is served by one and only one SGSN. The GSM MSC/VLR area (Location Area) and the SGSN area need not have any relationship.

GGSN (Gateway GPRS Supporting Node) is the access point from the IP network into the GPRS system. The GGSN stores subscription information (IMSI and zero or more PDP addresses) and routing information (SGSN address needed to deliver packets towards the MS registered in the SGSN) for each subscriber that has at least one Packet Data Protocol (PDP) context active with the GGSN. At the GGSN level, user mobility is tracked with a precision of SGSN.

The VLR (Visited Location Register) that supports both GSM and GPRS needs to provide, in addition to the circuit switched GSM functionality, GPRS function such as storing the identity of the SGSN where the mobile is registered. VLR doesn't provide any register/location management function for the GPRS part of the GSM/GPRS network.

HLR (Home Location Register) provides register function for the permanent subscription information and stores the identity of the SGSN where the mobile is registered. GSM HLR is enhanced with GPRS subscriber information.

The following identifiers are defined in GPRS:

user: IMSI (International Mobile Subscriber Number): it is the same subscriber identifier adopted in GSM.

terminal: IMEI (International Mobile Equipment Identity): it is the same terminal identifier adopted in GSM.

application: no specific application level identifiers are defined in GPRS. An MS can be assigned one or more logical names (like IP addresses or context identifiers), but the association between the subscriber and the logical name is outside the scope of the GPRS specification.

location-identifiers: CellID identifies the cell where the MS is camping. CellID is meaningful only when the MS is actively involved in a connection.

RAI (Routing Area Identifier) identifies the RA where the MS is attached to the GPRS network. RAI is used by the MS to determine that a RA update is needed and to indicate to the network its location.

temporary-identity: P-TMSI (Packet Temporary Mobile Subscriber Identity): a GPRS IMSI is allocated a temporary P-TMSI when the MS attaches to the network, and a new P-TMSI can be reallocated when the MS changes RA.

5.7.1.2 GPRS Registration and Context Activation Procedures

For a MS to access GPRS services, the MS needs first to make its presence known to the network by performing a *GPRS Attach* to the SGSN. The *Attach* procedure includes updating the location information in the HLR (if the MS is registering with a new SGSN), transferring information between the old SGSN where the MS was previously attached and the new SGSN, and cancellation of the MS data from the old SGSN (and old VLR if MS was attached also for circuit switched services with the GSM network).

In order to transmit or receive data, an MS needs to activate *PDP contexts*. Activation of PDP context makes the MS known to the GGSN corresponding to the PDP context, and allows packet data transfer to/from the corresponding user. A PDP context contains mapping and routing information for transferring Packet Data Units (PDU) for that particular PDP address between MS and GGSN and vice versa. For each PDP context, the MS is provided with either a static PDP address (includes ETSI X.121 or IETF IPv4 or IPv6 address among other data) assigned at subscription time or a dynamic address, allocated at the PDP context activation by the GGSN of either the HPLMN or VPLMN operator. Dynamic addresses allow only MS-initiated data transfers.

Mobile-terminated point-to-point communications ("calls") are delivered to the MS in the following way:

- packets are delivered to the GGSN corresponding to the PDP address;
- GGSN verifies if the address (e.g. IP address) is active. If it is, the GGSN retrieves the PDP context corresponding the PDP address and the SGSN address of the SGSN where the MS is registered;
- GGSN forwards the data to the SGSN serving the MS using the *GPRS Tunnelling Protocol* (GTP), i.e. encapsulating and tunnelling the received packets to the SGSN with an appropriate Tunnel Identifier (TID) built from the PDP context information;
- SGSN received and decapsulates the packets and, from TID, retrieves the information regarding the MS;
- SGSN delivers the packets to the MS.

If the GGSN determines that the PDP address is inactive, the data is discarded.

For mobile-terminated point-to-point communications, if packets are received by the GGSN before a PDP context has been established by the MS, the GGSN may initiate (when allowed) a network requested PDP context activation procedure (valid for static address only).

At GPRS detach, all PDP contexts are implicitly deactivated for the MS. Network (HLR and SGSN) or MS can request an explicit detach. Detach can occur implicitly due to time expiration during the period when there has been no activity by the MS. VLR is notified of the detach procedure so that SGSN association or IMSI related detach information can be managed.

For roaming subscribers that have a PDP address allocated from the HPLMN, a forwarding route between the HPLMN and the VPLMN is created for communication to and from the MS. Protocols such as BGP (IETF RFC 1771 [4]) and other routing protocols can be used between the BGs (Border Gateway) based on bilateral agreements between operators.

5.7.1.3 GPRS Mobility Management

GPRS provides indication of reachability both to the MS and to the network. MS knows its location both in terms of cell and RA, whereas in the network the MS location is tracked at two levels, depending on the present mobility management state of the Mobile Station (MS). When the MS is in STANDBY, i.e. the MS is attached to the GPRS network for mobility management but is not involved in any active connection, the location is tracked at the Routing Area level. When the user is READY, i.e. it is involved in active connection, the location is tracked at the cell level (i.e. the cell where the MS is camping at present).

Mobility between SGSN and GGSN is supported through the adoption of the GPRS Tunnelling Protocol (GTP). GTP allows also transfer of subscriber information and user data between SGSNs when the MS is changing SGSN.

In order to maintain its location updated with the network, the MS performs mobility management procedures when it has entered a new cell or a new RA, and periodically depending on network settings (periodic RA updates). A cell update (re-selection) takes place when the MS enters a new cell inside the current RA and the MS is in READY state. If the RA has changed, a RA update is executed instead of a cell update. RA update takes place also when the MS in STANBY state detects that it has entered a new RA, or when the periodic RA update timer has expired.

RA update may involve a change of SGSN (inter-SGSN RA update): in this case, the procedure triggers the SGSN to initiate a RA update procedure involving:

- the old SGSN, to transfer the PDP context information regarding the active PDP contexts and to setup a forwarding path for data still in transit from the GGSN to the old SGSN;
- the GGSN corresponding to each active PDP context, to update the GTP tunnels;
- the HLR, in order to store the new SGSN information and to remove the old SGSN and information from it.

For transport of real-time services (e.g. voice) over GPRS, a critical element is the RA update. It has to be verified if such procedure can be fast enough to allow MS mobility without disruption in the service. In fact, in GPRS the concept of handover is implemented in terms of cell re-selection and RA update.

5.7.1.4 GPRS Analysis and Comments

GPRS mobility management protocols are stable. Improvements are being made to adapt GPRS protocol to 3G systems (e.g. UMTS).

GPRS does not allow QoS re-negotiation during mobility. QoS is negotiated at PDP context activation, but nor renegotiated at cell update/RA update. If QoS has to be modified, SGSN can modify it after Cell Update/RA Update has taken place.

The concept of Codec re-negotiation does not apply to GPRS.

GPRS does not support security re-negotiation during mobility. The MS can anyway be re-authenticated during the RA update, however.

GPRS does not support routing optimization when using a PDP context from HPLMN. As an example, a forwarding route between the HPLMN (Home PLMN) and the VPLMN (Visited PLMN) is created for communication to and from the MS for roaming subscribers that have a static IP PDP addresses allocated from the HPLMN. Protocols such as BGP (IETF RFC 1771 [4]) and other routing protocols can be used between the *Border Gateways* based on bilateral agreements between operators.

GPRS supports service portability between GPRS network, since when the MS roams to a VPLMN the MS service profile is downloaded to the SGSN in the VPLMN where the user is registering.

Table 2: GPRS mobility

Criteria		GPRS
Identities recognized	User	IMSI
	Terminal	IMEI
	Application	PDP Address
	Location identity	RAI, CellID
Stability of protocols		Stable
Critical protocol elements		MS, SGSN, GGSN, HLR (VLR)
Handover capability		Yes
Mobility elements involved in handover phase		MS, SGSN (VLR)
Mechanism to reach the terminal		
Reachability status flags		
Resource (re-) negotiation capability	QoS	
	Codec	
	Security	
	Other	
Routing optimization		
Service portability		

5.8 ANSI (IS-136)/GPRS

GPRS architecture has been adapted to work with ANSI-41 system. New additional specifications have been defined in order to interwork GPRS with ANSI-41, but no modifications have been made that may impact GSM GPRS specifications.

From the point of view of GPRS mobility management, no differences with GSM GPRS have been introduced, and the same comments reported in the previous subclause are still valid. The following differences are made within the core network functions relevant to mobility management and roaming.

(Note that additional changes have been made towards the air interface, other interfaces such as Gs´ and mobile terminals have changed specifications too.)

SGSN is also responsible for tunnelling the ANSI-41 related control messages for authentication, location updates, registration etc. SGSN routes packets within the service area it is defined to serve.

Both **ANSI-41 HLR/AC and** GPRS part of **GSM HLR** is needed in order to support GPRS in ANSI-41 system. The HLR/AC for ANSI-41 requires modifications to handle the GPRS related system access by the MS.

The **Serving ANSI-41 MSC/VLR** serves existing circuit switched based information as defined within ANSI-41.

The **Gateway ANSI-41 MSC/VLR** integrates circuit switched and packet functions within GPRS-136 network by providing circuit switched call routing, redirections, supplementary service interactions and paging and registration handling towards ANSI-41 HLR/AC and provides MIN to IMSI mapping**.** Provides VLR functions when the serving node is a GPRS SGSN by enabling gateway functions to/from GPRS networks.

The **Message Centre (MC)** is able to receive and accept requests to deliver teleservice messages over the GPRS-136 network and ANSI-41 (136) network.

The mobility management for GPRS (as defined in the GSM GPRS SGSN function) and for IS-136 system is kept separately, meaning there is an additional GSM HLR required. An IS-136 registration is handled within ANSI-41 HLR whereas GSM HLR handles GPRS registration. Call delivery from circuit switched network is always handled by the ANSI-41 HLR towards the MSC/VLR.

Serving ANSI-41 MSC/VLR sends the necessary page request towards the SGSN for call delivery when the MS is camped on PCCH (GPRS attach has been performed).

5.9 Mobility and roaming in datacom networks

5.9.1 Mobile IPv4

Mobile IPv4 - referred to as Mobile IP - allows terminals to roam freely to other networks while still maintaining the same IP address IETF RFC 2004 [17]. Mobile IP consists of three components: *mobile node*, *home agent* and a *foreign agent*, latter two being basically routers with some special functionality. A home agent allows mobile nodes to roam to other networks. A foreign agent allows mobile nodes from other networks to visit to the network. A host exchanging messages with a mobile node is called *correspondent node*. It may be an ordinary stationary Internet host, or an another mobile node.

Mobile IP allows mobile nodes to effectively utilize two IP addresses, one for identification (*home address*) and one for routing (*care-of address*). There are two types of care-of addresses in Mobile IP: co-located and foreign agent care-of address. The co-located care-of address represents an address temporarily assigned to the mobile node itself from a PPP or DHCP server. The foreign agent care-of address is the address of the foreign agent with which the mobile node is registered. The mobile node will indicate its preference for a foreign or co-located care-of address in the Mobile IP registration procedures. As using a co-located care-of address wastes scarce resource, namely an IPv4 address, foreign care-of address is assumed for the rest of this subclause.

The mobile node uses *agent discovery protocol* to locate a foreign agent that is willing to provide mobility support to the mobile node. The foreign and home agents periodically multicasts/broadcasts *agent advertisement* messages, and a mobile node can ask for an agent advertisement message by sending an *agent solicitation* message. The mobile host can discover the foreign agent identity and the care-of address upon receiving an advertisement message. Once a foreign agent is discovered, the mobile node registers its care-of address along with the registration lifetime to the home agent via foreign agent. The home agent processes the registration by updating its routing table; creates or modifies its mobility binding, associating the mobile host's home address with its current care-of address for the specified registration lifetime.

The mobile node identification is currently based on its home address. The Mobile IP working group is working on more generic solution, where a NAI is used for identification purposes. Using NAI is necessary for the home agent to dynamically assign an address to the mobile node, or to use private IP addresses for mobile nodes.

When the datagrams sent by a correspondent node arrive to the home network, the home agent redirects them to the care-of address by using an encapsulation method, also known as tunnelling IETF RFC 1701 [18]. It uses the care-of address as the destination address in the new IP header. The new packets are then tunnelled from the home agent to the care-of address indicated in the new IP header, bypassing the usual effect of IP routing. The foreign agent where the tunnel terminates decapsulates the received packet and sends the original packet from the correspondent node to the mobile node.

In the reverse direction, a mobile node usually sends its packets through a router on the foreign network and assumes that routing is independent of source address. Reverse tunnelling could be used to allow a mobile node's care-of address to shuttle packets towards the home agent using a symmetric topologically correct reverse tunnel. The tunnel starts from the mobile node's care-of address and terminates at the home agent.

An extension providing optimized routing (see Internet Draft mobileip-optim) using routing bindings similar to Mobile IPv6 is still work in progress (July 1999).

Table 3: Mobile IP (V4) mobility

Criteria		Mobile IP (v4)
Identities recognized	User	NAI, Home IP Address
	Terminal	MAC Address
	Application	
	Location identity	Care-of address
Stability of protocols		Proposed Internet standard, extensions in Internet drafts
Critical protocol elements		Mobile node, home agent, foreign agent
Handover capability		
Mobility elements involved in handover phase		
Mechanism to reach the terminal		Sending datagram
Reachability status flags		ICMP messages may be sent if node is not reachable
Resource (re-) negotiation capability	QoS	RSVP
	Codec	Not applicable
	Security	IP Sec
	Other	
Routing optimization		Optional, requires support from correspondent node
Service portability		Not applicable

5.9.2 Mobile IPv6

IPv6 packets addressed to a mobile node's home address are transparently routed to its care-of address. The protocol enables IPv6 nodes to cache the binding of a mobile node's home address with its care-of address and to then send any packets destined for the mobile node directly to it at this care-of address. IPv6 mobile nodes would have additional capabilities such as support of tunnelling protocol and neighbour discovery.

A mobile node typically acquires its care-of address through stateless or stateful (such as DHCPv6, Dynamic Host Configuration Protocol for IPv6) address auto configuration, according to the method of IPv6 neighbour discovery. While away from home, the mobile node registers one of its bindings with a router on its home link, requesting this router to function as the "home agent" for the mobile node. This binding registration is done by the mobile node sending a packet with a "BindingUpdate" destination option to the home agent. The home agent then replies by returning a packet containing a "Binding Acknowledgement" option to the mobile node. The mobile node's home agent thereafter uses proxy neighbour discovery to intercept any IPv6 packets addressed to the mobile node's home address on the home link and tunnels each intercepted packet to the mobile node's primary care-of address. To tunnel each intercepted packet, the home agent encapsulates the packet using IPv6 encapsulation, with the outer IPv6 header addressed to the mobile node's care-of address.

When sending a packet to an IPv6 destination, a correspondent node checks its cached bindings for an entry for the packet's destination address. If an entry exists, the host would use IPv6 routing header instead of IPv6 encapsulation to route the packet to the mobile node by way of the care-of address indicated in this binding. Consequently, the home agent is not involved with the packet transmission to the mobile node and optimal routing from the correspondent node to the mobile node is achieved.

If the sending node does not have a cached binding for the destination address, the node sends the packet normally which is then intercepted and tunnelled by the mobile node's home agent to the mobile node.

When a mobile node receives a packet tunnelled to it from its home agent, the mobile node assumes that the original sending correspondent node has no binding cache entry for the mobile node, otherwise the correspondent node would otherwise have sent the packet directly to the mobile node using routing header. The mobile node thus returns a binding update to the correspondent node, allowing it to cache the mobile node's binding for routing future packets.

A correspondent node with a binding cache entry for a mobile node may refresh this binding if it is actively communicating with the mobile node (e.g. it has an open TCP connection), for example if the binding's lifetime is near expiration, by sending a binding request to the mobile node. When a mobile node receives a binding request, it replies with a binding update.

Table 4: Mobile IP (V6) mobility

Criteria		Mobile IPv6
Identities recognized	User	NAI, Home IP Address
	Terminal	MAC Address
	Application	
	Location identity	Care-of address
Stability of protocols		Internet draft
Critical protocol elements		Mobile node, home agent, correspondent node
Handover capability		Yes
Mobility elements involved in handover phase		Mobile node, correspondent node
Mechanism to reach the terminal		Sending datagram
Reachability status flags		ICMP messages may be sent if node is not reachable
Resource (re-) negotiation capability	QoS	RSVP
	Codec	Not applicable
	Security	IP Sec
	Other	
Routing optimization		Yes
Service portability		Not applicable

5.9.3 Network Access Identifier

The *Network Access Identifier* (NAI) is the user ID submitted by the client during PPP authentication (or authentication on any other link frame protocol which has authentication packets which carry login prompt information such as username and password). A roaming user dials into a local network access server (NAS) using PPP, authenticates via link control protocol, identifying itself using the Network Access Identifier. The purpose of the NAI is to identify the user as well as to assist in the routing of authentication request by providing the user's home authentication server through the NAI.

When using Mobile IPv4 over PPP, the NAI is used as the user (or mobile node) identification instead of the IP address of the mobile node. As described in the Mobile IPv4 section, the mobile node may request its preference of the type of care-of address. The request could be handled via options provided in IPCP configure request if PPP is used between the mobile node and NAS. In this context, the request is negotiated with the NAS. If the NAS, possibly acting as foreign agent, grants the mobile node access to the Internet, it would send agent advertisement messages on the PPP link towards the mobile node.

The Network Access Identifier is of the form **username@realm**, where the username portion can contain any printable ASCII characters, and the optional realm portion corresponds to a domain name (conforming to the best current practice). The realm portion is used to locate user's home network.

Table 5: Analysis of NAI

Criteria		RoamOPS NAI
Identities recognized	User	NAI
	Terminal	None
	Application	None
	Location identity	Assigned IP address
Stability of protocols		Internet-draft
Critical protocol elements		NAS, AAA server
Handover capability		Not applicable
Mobility elements involved in handover phase		Not applicable
Mechanism to reach the terminal		None
Reachability status flags		None defined
Resource (re-) negotiation capability	QoS	RSVP
	Codec	Not applicable
	Security	CHAP, IP Sec
	Other	
Routing optimization		Not applicable
Service portability		Partial (service parameters are transferred from home AAA server to NAS)

5.9.4 Session Initiation Protocol

Recently, within IETF, new protocols have been drafted that provide personal mobility. One such protocol is known as Session Initiation Protocol (SIP).

SIP is an application protocol that can establish and control multimedia sessions or calls. The protocol draft indicates that personal mobility provided by SIP is based on the use of a unique personal identity.

SIP could offer users some freedom of access from different locations using different hosts. SIP has the capability of locating registered users by providing a location service through a SIP redirect or proxy server to obtain information about a callee's possible location(s).

Users register to a registrar server by sending REGISTER requests. A registrar is typically co-located with a proxy or redirect server and may offer location services. The REGISTER request allows a client to let a proxy or redirect server know at which address(es) it can be reached.

In order to set-up a session to a registered user using SIP, an INVITE method is sent from the calling host to a SIP server which could either be a proxy or redirect server. The SIP server may request the location of the called user from the location server. Once the location of the called user is returned, meaning called user@host, where the host indicates the domain and host name where the user had last been located, the SIP server, if proxy, initiates another INVITE to that new address. The SIP proxy server waits for the result, and when successful, it would expect to receive a 200OK that will then be sent to the calling user.

The calling host would send an acknowledgement to the 200OK back to the SIP server, which will forward it to the called user's host to indicate that the end-to-end session has successfully been initiated.

If the SIP server includes the registrar functionality, it may not need to query the location server for the location of the called user if the called user had previously registered within the same SIP server.

There are other different mechanisms that are available within SIP to locate a user. A mechanism such as multi-hop "searches" for a user is supported where, when a call request is made to a particular address, a SIP server is contacted at that address. As this SIP server may not be the machine where the callee is currently residing at, the server can proxy the request to one or more additional servers. These servers may in turn proxy the request to multiple servers in parallel.

Just like (current) ITU-T Recommendation H.323 [28], SIP does not address terminal mobility. It does not address wireless aspects either.

5.10 H.323 Mobility

Like cellular phone services, mobile Internet telephony demands seamlessly roaming while conversation is in progress. Under the current Version of H.323 service scope, however, host mobility is forbidden, resulting from the underlying IP mechanism that implicitly assumes that a host is fixed. Moreover, Voice over IP service is a real-time connection-oriented service over packet-switched IP-based networks.

Through proper call setup signalling with the H.323 Gatekeeper, the address of the target endpoint (i.e. callee or called party) can be resolved before call establishment, enabling the service redirection to be completely handled in the application layer. Thus, it realizes mobile IP telephony services with IP. This approach enables mobility support without the need for additional new entities and with minimal modifications to the H.323 standard, allowing such mobile IP telephony service to be a valued-added feature in the existing H.323-compliant Internet telephony systems.

5.11 Public Access Mobile Radio (PAMR) and Private Mobile Radio (PMR)

ITU has included in its Report IETF RFC 2003 [16] on 'spectrum efficient digital mobile systems for dispatch traffic', using digital modulation and trunking technologies: TETRA ETS 300 392 [12] and ETS 300 393 [13] and ETS 300 396 [14], APCO25, IDRA, DIMRS, TETRAPOL, IETF RFC 2002 [15], EDACS, FHMA. These Voice and Data digital systems are dedicated to Private Mobile Radio (PMR) where the user owns the network and Public Access Mobile Radio (PAMR) where an operator shares the network between several users, typically Large business, Utilities, Transportation, Public Safety and Emergency forces. Network size is scalable from one cell, through country, continent, to global, and from a few tens of subscribers to many millions of subscribers.

Typically PMR/PAMR operates as narrow band (low bandwidth) using RF carrier spacing of 25 kHz and 12,5 kHz with 1 to 6 traffic channels per RF carrier. Carrier (resource) management is achieved through the use of trunking methods.

5.11.1 Specificities of PAMR and PMR wireless digital networks

The specificities of wireless digital networks that have evolved for Private Mobile Radio (PMR) and for Public Access Mobile Radio (PAMR) include:

- rapid call establishment (tens of milliseconds);
- group call (point-to-multipoint);
- broadcast call;
- open channel (all informed nets);
- out of network point-to-point and point-to-multipoint (direct-mode);
- range extension by gateways and repeaters;
- data and speech optimized;
- secure; and
- scaleable.

PMR/PAMR systems where specified at the radio interface offer a number of access technologies representative examples of which are the TDMA based TETRA ETS 300 392 [12] and ETS 300 393 [13], and the FDMA based TETRAPOL, IETF RFC 2002 [15] systems. The different radio access technologies allow common infrastructures to optimize local area coverage where in general TDMA systems favour high user densities and small cells with FDMA systems finding favour in lager cells with lower user densities.

The basic services of Individual and Group calls, Broadcast calls, Emergency calls, Open channel are, in common with ISDN, extensible by supplementary services that include: call forwarding (conditional and unconditional); secondary call authorization; ambience and discreet listening; dynamic address assignment.

5.11.1.1 Mobility services in PMR/PAMR

Generic mobility in PMR/PAMR is resident in layer 3 of the protocols and is linked to the primary subscription identity. Alternative subscriber identities are bound to this mobile identity and will include group identities, alias identities, and mapping of equipment identities to mobile identities.

Handover (i.e. transfer of call handling from cell to cell) is provided by co-operation of the call handling protocol handlers (at layer 3) with the MM protocol handlers. In most cases handover is not restricted when moving between cells of different networks.

5.11.1.2.1 TETRA

TETRA offers session oriented mobility.

A TETRA session begins with registration of location that registers the network address of the terminal to the network and allows all subscribed services for that network address to be delivered to the terminal. As a terminal moves the lower layers of the protocol continually monitor the link performance and update the registration as the mobile terminal moves between serving base stations and cells. When the serving cell changes between networks mobility information is exchanged such that calls in progress can be restored.

Essentially TETRA applications are unaware of the actions of the mobility management protocol (as for any OSI application).

5.11.1.2.2 GSM Phase 2+ Advanced Speech Call Items (ASCI)

GSM ASCI offers a subset of PAMR services (Group call, priority, Specific supplementary services).

5.11.1.2.3 Inter technology SIM roaming

An alternative to mobility by MM protocols is mobility of service between technology domains by SIM roaming. This is being explored in SMG9 and in EPT.7 and by TETRAPOL.

6 Analysis of roaming technologies

These tables identifies the common elements used in the roaming technologies discussed in the present document to provide mobility.

Table 6: Mobility mechanism part-1

Mobility mechanism evaluation table (part I)								
Mobility mechanism	Identities recognized				Stability of protocols	Critical protocol elements (note 1) (and potential for recuperation)	Handover capability (note 2)	Mobility elements involved in handover phase
	USER	TERMINAL	APPLICATION	Location identity (note 3)				
GSM (5.1)	IMSI	IMEI	MS ISDN	LAI, CellID	Stable	MS, BSC, MSC, VLR, HLR	Yes	MS, MSC, VLR
UMTS/3GPP r99 (5.3)	IMUI	IMEI	MS ISDN, PDP	RAI, LAI, CellId	progressing	MS, 3G-MSC/VLR, RNC, HLR, 3G-SGSN, 3G-GGSN	Yes	MS, RNC, 3G-MSC/VLR, 3G-SGSN
GPRS (5.7)	IMSI	IMEI	PDP	RAI, CellID	Stable	MS, SGSN, GGSN, VLR, HLR	Yes (note 4)	MS, SGSN, VLR
ANSI-41 (5.2)	MIN	MSN	MIN	CellID	Stable	MS, BSC, MSC, VLR, HLR	Yes	MS, MSC, VLR
SIP (5.9.4)	u@d							
Mobile IPv4 (5.9.1)	IP Addr, NAI (note 5)	IP Addr	Port	COA	Prop. std	Mobile node, home agent, foreign agent	Limited	MN, HA, FA
Mobile IPv6 (5.9.2)	IPv6 Addr, NAI (note 6)	IPv6 Addr	Port, flow label	COA	I-D	Mobile node, home agent, correspondent node	Yes	MN, HA, CH
RoamOps/NAI (5.9.3)	NAI	None	None	None	I-D	NAS, AAA servers	No	N/A
PAMR /TETRA (5.11)	(I)TSI	TEI		LAI Cell Id	Stable	MS, BS, SwMI, VDB, HDB	Yes	MS, BS, HDB,VDB

NOTE 1: E.g. protocol time out restrictions/limitations or delay sensitivities.
NOTE 2: Handover capability as in handover of mobile set between base stations.
NOTE 3: E.g. GSM area identifier.
NOTE 4: I.e. cell re-selection and RA update.
NOTE 5: NAI is required when RFC 2290 PPP/IPCP Mobility Extensions are used.
NOTE 6: NAI is required when RFC 2290 PPP/IPCP Mobility Extensions are used.

Table 7: Mobility mechanism part-2

Mobility mechanism evaluation table (part II)									
Mobility mechanism	**Mechanism to reach the terminal**	**Reachability Status flags (note 1)**	**Resource (re-)negotiation capability**				**Routing optimization**	**Service Portability (note 2)**	**Special considerations/ Notes**
			QoS	**CODEC**	**SECURITY**	**OTHER**			
GSM (5.1)			Yes	Yes	Yes		Optional	Using CAMEL	
UMTS/3GPP r99 (5.3)	MSRN, GTPiD	Unattached, attached, active PDP cntxt	Yes	Yes	Yes		Optional	VHE/OSA	
GPRS (5.7)		Unattached, attached, active PDP cntxt	PDP Act.	N/A	RA Upd.		Yes (if using context of VPLMN)	Yes	
ANSI-41 (5.2)									
SIP (5.9.4)									
Mobile IPv4 (5.9.1)		ICMP messages	RSVP	N/A	IP Sec		Optional (note 3)	N/A	
Mobile IPv6 (5.9.2)		ICMPv6 messages		N/A	IP Sec		Yes	N/A	
RoamOps/NAI (5.9.3)		N/A	RSVP	N/A	IP Sec		N/A	Partial	
PAMR /TETRA (5.11)			Yes	No	Yes		Infrastructure dependent		
NOTE 1: E.g. terminal known, terminal located, terminal off. NOTE 2: I.e. capability for user profile exchange in the protocol. NOTE 3: Requires support from correspondent node (see Internet Draft mobileip-optim).									

The analysed roaming protocols can be divided into three main categories:

1) Protocols providing only transport-level connectivity (e.g. Mobile IP, GPRS);

2) Protocols providing both transport- and application-level connectivity (e.g. GSM);

3) Protocols providing only application-level connectivity (e.g. SIP).

Division of the roaming and mobility management operations into application-specific and transport-specific operations:

- **Paging**, i.e. peer-initiated attachment at transport level;
- **Attachment** at transport level and at application level;
- **Registration/location update** at transport level and at application level;
- **Roaming number/address query** at application level;
- **Routing optimization** at transport level and at application level.

Roaming requires a **home function**, which stores the up-to-date information required to reach the roaming subscriber. Most of the above roaming technologies have also a separate **visited function**. The cases without a visited function assume transport-level connectivity provided by means outside their scope. Although the separate visited function may have only a few duties at the application level, having an application-level visited function has clear benefits, especially when implementing location-aware services and when distributing the implementation of the various services between home and visited operator networks.

Identifying the roaming entities is done in various ways. However, it is clear that the terminal needs to be identified at transport layer. The subscriber, or rather the subscription identity may be separate from the terminal identity at the transport level. At the application level, the telephone application itself needs to be identified in order to route calls to it. An application-level user roaming identification is also needed. This user roaming identification may be separate from the actual user name used by other users.

The list of possible identifications include at least the following items:

- **Terminal identifier** (transport address, hardware identifier);
- **Subscription identifier** at transport level;
- **Application identifiers** (the access points/transport addresses of the application at transport level);
- **User roaming identifier** (subscription identifier at application level, which may or may not be different from subscription identifier at transport level);
- **User identifier** (user name at application level).

7 Recommended roaming technology

The following recommendations and guideline for the TIPHON roaming/mobility specification have been collected.

The scope of the TIPHON roaming/mobility specification is roaming at the TIPHON application plane.

If wireless or wireline access network supports roaming/mobility at IP or lower layers, e.g. Mobile IP or GPRS the TIPHON roaming/mobility may or may not take advantage of the transport plane roaming/mobility. However, the modifications to the transport plane or any access networks, if desired, are out of the scope of the TIPHON roaming/mobility.

The TIPHON roaming/mobility solution should based on the model where application mobility management is handled by the core network elements, i.e. between Service Control and User Control functional elements. The model implies a User Control element on the service layer with registration/mobility management information flows are included into the TIPHON architecture at application plane (see figure below). The model should also require as few modifications as possible to the User-to-Network Interface, i.e. H.323 or other existing call control protocols.

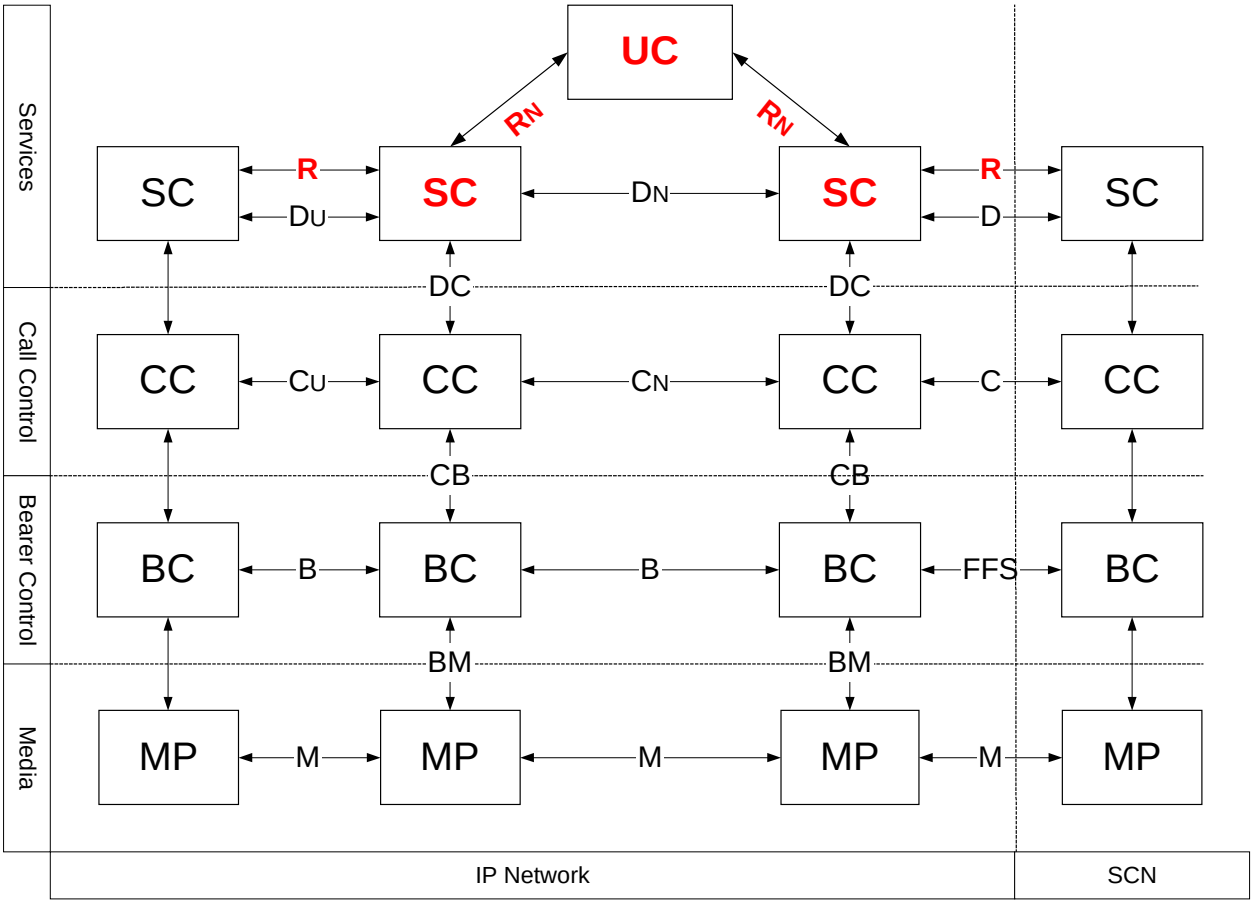


Figure 6: The (note) User Control functional element and the registration/roaming information flows adapted to the TIPHON scenarios 1 and 2

NOTE: Similar figures for other scenarios are to be included in TS 101 337 [30].

Information flows to and from the User Control Element shall be mapped to separate reference points from other service-specific signalling. Required procedures for mobility management protocol shall be specified as a part of the TIPHON roaming/mobility recommendation. These procedures shall cover common aspects of roaming technologies listed in the analysis section (clause 6) of the present document.

For smooth interoperability with other mobility networks it is recommended that the TIPHON mobility management protocol follows basic principles of the MAP protocol. However, in order to enable widespread utilization within the Internet the mobility management protocol should not depend on any SS7 protocol layers nor SS7 addressing.

The TIPHON roaming/mobility specification shall allow user roaming between TIPHON and existing mobile networks, e.g. GSM SIM roaming and ANSI-41, and between TIPHON and 3G networks.

More detailed requirements, roaming scenarios, etc., will be specified in TS 101 337 [30].

The Recommended roaming technology:

- should support wireline or wireless IP terminals e.g. an H.323 terminal;
- should be based on the TIPHON system in an totally IP-based network;
- should support roaming of legacy mobile terminals; and
- should re-use all or most of the TIPHON protocols and IP infrastructure.

The Recommended roaming technology should support the following scenarios:

A. Changing Network Point of Attachment:

   1) Intra-zone, Inter-zone, and Inter-domain roaming;

   2) Handover (MT only) resulting in a changing IP address.

B. Changing IP Application Point of Attachment:

   3) Intra-zone, Inter-zone, and Inter-domain roaming;

   4) Handover (MT only) resulting in a changing IP address.

C. Interworking:

   5) Network interworking: connections between TIPHON and legacy mobile networks (e.g. GSM, ANSI 41, UMTS,...) and connections between TIPHON and PSTN or other networks;

   6) Tandeming minimization;

   7) Minimizing transcoding events within media streams;

   8) Terminal interworking: use of legacy mobile terminals (e.g. GSM handset, H.324 terminal, H.320 terminal, etc.) to communicate with TIPHON, including mapping of user identifications between TIPHON and legacy mobile networks.

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