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**Integrated broadband cable telecommunication networks (CABLE);
IPv6 Transition Technology Engineering and Operational Aspects;
Part 4: MAP-E**

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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Integrated broadband cable telecommunication networks (CABLE).

The present document is part 4 of a multi-part deliverable. Full details of the entire series can be found in part 1 [26].

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Considering the depletion of IPv4 addresses, transition to IPv6 is required in order to enable continued growth of the customer base connected to cable networks and ensure service continuity for existing and new customers. High-quality connectivity to all kinds of IP-based services and networks is essential in today's business and private life.

The present document accommodates an urgent need in the industry to implement and integrate the IPv6 transition technologies as specified by ETSI TS 101 569-1 [1] into their cable networks. The choice of the technology implemented depends on factors such as the business needs, current deployed architectures and plans for cost effectively transition from IPv4 to IPv6.

Current global IPv4 address space was projected to be depleted around the middle of 2012; depletion for the operator was estimated around end 2012. As part of the resulting roll-out of IPv6 in the operator's network, specific measures had to be taken to allow a smooth transition and coexistence between IPv4 and IPv6. ETSI developed requirements to address transition from IPv4 to IPv6 specifying six transition technologies as given by ETSI TS 101 569-1 [1] that were at the time considered to be the most appropriate to assist cable operators to transition there cable networks to IPv6.

Since then the industry has acquired more experience with the technology options settling in the main for DS-Lite across the cable network market and NAT64 IPv6 transition technologies across the mobile market.

The objective of the present document is to define the operational and engineering requirements to enable engineers to implement a seamless transition of the cable networks to IPv6 with the application of the MAP-E transition technology.

The present document is the final part of a companion of ETSI standards developed in 4 phases to provide the cable sector in particular cable operators engineering and operational staff a standardized approach when integrating one of the five IPv6 transition technologies, NAT64, DS-Lite, 464XLAT, 6RD and MAP-E.

The first phase assessed the different IPv6 transition technology options being defined by industry with recommendation for the most appropriate with consideration of current network architectures, ensuring adequate scale and a cost effective transition approach from IPv4 to IPv6 as the IPv4 addresses deplete. The objective being to examine the pros and cons of the IPv6 transition technologies and recommend the most cost effective solution that would enable the cable operators to minimize the cost of upgrades to their existing network plant whilst maintain continuity of services to their present and new added customers. The details of the study are given by ETSI TR 101 569 [i.2].

In the second phase an ETSI technical specification was developed to specify technical requirements for six transition technologies that industry were considering for use by Cable Operators depending on the current state of their deployed cable network architecture, service model requirements and their IPv6 transition strategy as the IPv4 addresses depleted. These six IPv6 transition technologies are specified by ETSI TS 101 569-1 [1], covering NAT64, DSLite, 6RD, NAT44, 464XLAT and MAP-E.

In the third phase ETSI developed a series of conformance test specifications to enable the compliance verification of the five IPv6 transition technologies, NAT64, DS-Lite, 464XLAT, 6RD and MAP-E that were specified during phase 2 standardization. The conformance tests are developed against the requirements given by the ETSI TS 101 569-1 [1]. The series of conformance tests developed for each of the four transition technologies, are as given by, ETSI TS 103 238 parts 1 [2] to 3 [4] respectively for NAT64; ETSI TS 103 239 parts 1 [5] to 3 [7] respectively for MAP-E; ETSI TS 103 241 parts 1 [8] to 3 [10] respectively for DS-Lite; ETSI TS 103 242 parts 1 [11] to 3 [13] respectively for XLAT and ETSI TS 103 243 parts 1 [14] to 3 [16] respectively for 6RD.

Phase 4 is the present project phase for development of technical specifications covering the operational and engineering requirements with the present document being part 4 of a multi-part series covering the IPv6 transition technology MAP-E.

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1 Scope

The present document presents the engineering and operational requirements for the application of the IPv6 transition technology MAP-E as defined by ETSI TS 101 569-1 (IPv6 Transition Requirements) [1] implemented within an integrated broadband cable network end to end across its network domains.

The present document is part 4 of a multi-part series and presents the operational aspects of the IPv6 transition technology MAP-E across the cable network domains.

Only those elements of the network that have to be engineered to operate the IPv6 transition technology MAP-E are presented. Descriptions and interface details of network elements that do not change are already addressed by the relevant equipment cable standards and therefore this information is not included in the present document.

The conformity of the MAP-E implementation is relevant when assessing its implementation and operational requirements across the cable network to ensure the implementation is correctly engineered to conform to the requirements of the base standard ETSI TS 101 569-1 [1]. These conformance tests are not specified in the present document as they are already specified by ETSI TS 103 239 parts 1 [5] to 3 [7].

The operational aspects for the IPv6 transition technology MAP-E are considered when engineered end to end across the cable network domains:

- CPE Home Networking Domain.
- Access Network Domain.
- Core Network Domain.
- Data Centre Domain.
- DMZ Service Domain.
- Transit and Peering Domain.
- Management and Monitoring Domain.
- Security Domain.

The present document specifies the requirements to be considered when the defined IPv6 transition technology MAP-E is engineered across the cable network domains.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 101 569-1: "Integrated Broadband Cable Telecommunication Networks (CABLE); Cable Network Transition to IPv6 Part 1: IPv6 Transition Requirements".

[2] ETSI TS 103 238-1: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for NAT64 technology; Part 1: Protocol Implementation Conformance Statement (PICS) proforma".

[3] ETSI TS 103 238-2: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for NAT64 technology; Part 2: Test Suite Structure and Test Purposes (TSS&TP)".

[4] ETSI TS 103 238-3: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for NAT64 technology; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)".

[5] ETSI TS 103 239-1: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for MAP-E technology; Part 1: Protocol Implementation Conformance Statement (PICS) proforma".

[6] ETSI TS 103 239-2: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for MAP-E technology; Part 2: Test Suite Structure and Test Purposes (TSS&TP)".

[7] ETSI TS 103 239-3: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for MAP-E technology; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)".

[8] ETSI TS 103 241-1: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for DS-Lite technology; Part 1: Protocol Implementation Conformance Statement (PICS) proforma".

[9] ETSI TS 103 241-2: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for DS-Lite technology; Part 2: Test Suite Structure and Test Purposes (TSS&TP)".

[10] ETSI TS 103 241-3: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for DS-Lite technology; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)".

[11] ETSI TS 103 242-1: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for 464XLAT technology; Part 1: Protocol Implementation Conformance Statement (PICS) proforma".

[12] ETSI TS 103 242-2: "Integrated broadband cable telecommunication networks (CABLE) Testing; Conformance test specifications for 464XLAT technology; Part 2: Test Suite Structure and Test Purposes (TSS&TP)".

[13] ETSI TS 103 242-3: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for 464XLAT technology; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)".

[14] ETSI TS 103 243-1: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for 6rd technology; Part 1: Protocol Implementation Conformance Statement (PICS) proforma".

[15] ETSI TS 103 243-2: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for 6rd technology; Part 2: Test Suite Structure and Test Purposes (TSS&TP)".

[16] ETSI TS 103 243-3: "Integrated broadband cable telecommunication networks (CABLE); Testing; Conformance test specifications for 6rd technology; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)".

[17] IETF RFC 4459 (April 2006): "MTU and Fragmentation Issues with In-the-Network Tunneling".

[18] IETF RFC 7597: "Mapping of Address and Port with Encapsulation (MAP-E)".

[19] IETF RFC 7599: "Mapping Address and Port using Translation (MAP-T)".

[20] IETF RFC 7598: "DHCPv6 Options for Configuration of Softwire Address and Port-Mapped Clients".

[21] IETF RFC 6145 (April 2011): "IP/ICMP Translation Algorithm".

[22] IETF RFC 6052: "IPv6 Addressing of IPv6/IPv4 Translators".

[23] IETF I-D draft-murakami-softwire-4to6-translation-00: "4via6 Stateless Translation".

[24] IETF I-D draft-mdt-softwire-map-dhcp-option-02: "DHCPv6 Options for Mapping of Address and Port".

[25] IETF RFC 1918 (February 1996): "Address Allocation for Private Internets".

[26] ETSI TS 103 443-1: "Integrated broadband cable telecommunication networks (CABLE); IPv6 Transition Technology Engineering and Operational Aspects; Part 1: General".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CableLabs.

NOTE: Available at http://www.cablelabs.com/specs/.

[i.2] ETSI TR 101 569: "Access, Terminals, Transmission and Multiplexing (ATTM); Integrated Broadband Cable and Television Networks; Cable Network Transition to IPv6".

3 Definitions and abbreviations

3.1 Definitions

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

4in6: encapsulation of IPv4 packets within IPv6 packet format

NAT44: network address translation from an IPv4 address to another IPv4 address

P Router: label switching router acting as a transit router in the core network of an MPLS network

3.2 Abbreviations

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

6PE IPv6 Provider Edge
6RD IPv6 Rapid Deployment
6VPE IPv6 VPN Provider Edge
AAA Authentication, Authorization and Accounting
AMPS Amplifiers
AS Autonomous System
BFD Bidirectional Forwarding Detection
BGP Boarder Gateway Protocol

BNG	Broadband Network Gateway
BR	Boarder Routers
CDP	Cisco Discovery Protocol
CEF	Cisco Express Forwarding
CMTS	Cable Modem Termination System
CoPP	Control Plane Policing
CPE	Customer Premises Equipment
CPU	Central Processing Unit
DAD	Duplicate Address Detection
dCEF	distributed Cisco Express Forwarding
DCU	Destination Class Usage
DHCP	Dynamic Host Configuration
DMZ	Demilitarised Zone
DNS	Domain Name System
DOCSIS 3.0	Data over Cable System Interface Specification version 3.0
DR	Data Retention
DS-Lite	Dual Stack-Lite
ECMP	Equal-Cost-Multi-Path
GW	Gateway
HA	High Availability
HFC	Hybrid Fibre Coax
HSRP	Hot Standby Router Protocol
ICMP	Internet Control Message Protocol
ID	Identifier
IGP	Interior Gateway Protocol
IMIX	Internet Mix
IP	Internet Protocol
IPv4	IP version 4
IPv6	IP version 6
ISIS	Intermediate System to Intermediate System
ISSU	In-Service Software Upgrade
IXPE	Internet eXchange Provider Edge
L2	Layer 2
LDP	Label Distribution Protocol
LI	Lawful Intercept
LLDP	Link Layer Discovery Protocol
LSN	Large Scale NAT
MAP	Mapping of Address and Port
MAP-BR	Mapping of Address and Port – Border Relay
MAP-CE	Mapping of Address and Port – Customer Edge
MAP-E	Mapping of Address and Port - Encapsulation mode
MAP-T	Mapping of Address and Port using Translation
MFIB	Multicast Forwarding Information Base
MLD/L2	Multicast Listener Discovery / Layer 2
MLD/L2	Multicast Listener Discovery/ Layer 2
MP BGP	MultiProtocol Boarder Gateway Protocol
MP	MultiProtocol
MPLS	MultiProtocol Label Switching
MSS	Maximum Segment Size
MSTP	Multiple Spanning Tree Protocol
MT	Multi-Topology
MTU	Maximum Transmission Unit
NAT	Network Address Translation
NAT44	Network Address Translation IPv4 to IPv4
NAT64	Network Address Translation IPv6 to IPv4
NDP	Neighbour Discovery Protocol
NPU	Network Processing Unit
NSF/GR	Non-Stop Forwarding Graceful Restart
NTP	Network Time Protocol
NUD	Neighbour Unreachability Detection
OAM	Operation, Administration and Maintenance
PAT	Port Address Translation

PE	Provider Edge
PIM	Protocol Independent Multicasting
PMTUD	Path Maximum Transport Unit (MTU) Discovery
PPTP	Point-to-Point Tunnelling Protocol
PS-BGP	Pretty Secure Boarder Gateway Protocol
QoS	Quality of Service
QPPB	QoS Policy Propagation via Boarder Gateway Protocol
RADIUS	Remote Authentication Dial-In User Service
RG	Residential Gateway
RSTP	Rapid Spanning Tree Protocol
SCU	Source Class Usage
SEND	Secure Neighbour Discovery
SNMP	Simple Network Management Protocol
SP	Service Provider
SSH	Secure SHell
SSO	Stateful Switchover
SVI	Switched Virtual Interface
SYSLOG	Syslog Protocol
TACACS	Terminal Access Controller Access Control System
TCP	Transmission Control Protocol
TOS	Type Of Service
VLAN	Virtual LAN
VPLS	Virtual Protocol Local Area Network Service
VPN	Virtual Private Network
VRRP	Virtual Router Redundancy Protocol
XML	eXtensible Markup Language

4 General Considerations

4.1 Background

The present document is part of a series of ETSI technical specifications specifying requirements to engineer and operate the MAP-E transition technology end to end across a cable operator's network. Its implementation would ensure the network provider can continue to provide business continuity throughout the depletion of publicly routable IPv4 addresses and the subsequent rollout and migration to IPv6 in the operator's network.

To aid this transition some sectors of industry are currently evaluating MAP-E as their chosen technology to mitigate the gap and lack of integration and compatibility between IPv4 and IPv6.

4.2 General Overview

An objective of deploying the IPv6 transition technology is to provide a seamless experience to IPv4 users accessing IPv4 network services through new IPv6 only networks and to enable current and new content to be delivered seamlessly to the IPv4 users by deploying MAP-E.

It should be noted that Cable broadband access networks may vary in build and design with characteristics that may be vendor equipment specific. Consequently there may be aspects to the engineering and operation of the IPv6 transition technology MAP-E that are dependent on the network build and vendor specific equipment deployed.

The present document does not offer information that may be vendor and network build specific since such information may be confidential to the network operator and/or based on proprietary data.

The present document assumes the reader is familiar with the cable network architecture requirements since the description of the various elements within a cable network across its domains are already defined by ETSI standards and standards developed by CableLabs [i.1]. The present document details only the changes to the network aspects when operating the transition technology MAP-E.

The present document uses MAP-E technology to provide a seamless Internet experience to users accessing IPv4 Internet services from an IPv4 client across the service providers IPv6 network.

The network elements required to implement the IPv6 transition technology MAP-E across the cable network domains is as illustrated by figure 1.

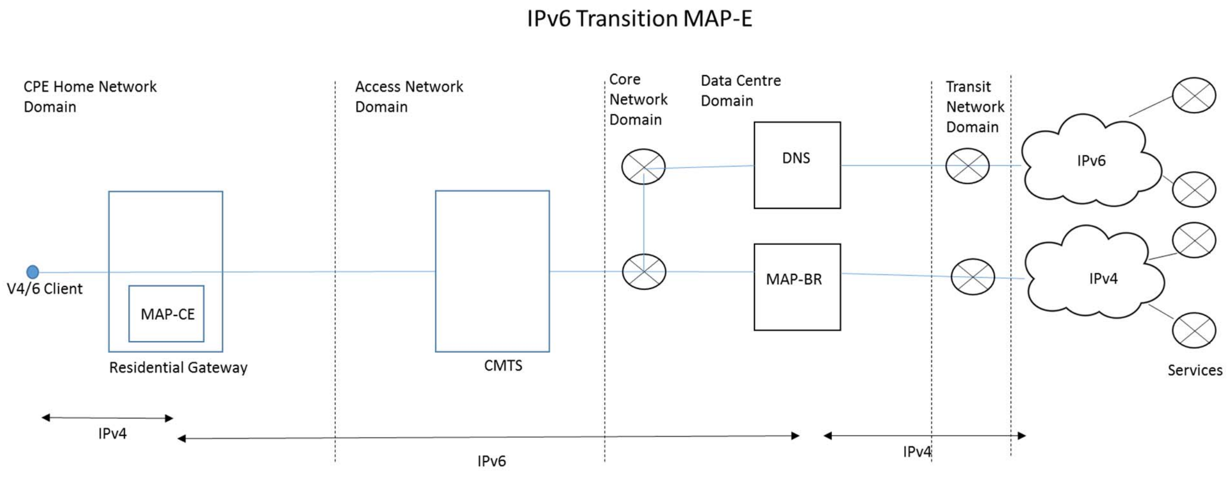

Figure 1: Illustration of network elements to support IPv6 transition technology MAP-E across Cable Network Domains

The specific aspects are given in the subsequent clauses for each network domain.

When engineering IPv6 transition technology IPv6 needs to be implemented on all of the network elements.

The engineered network elements to enable MAP-E in each cable network domain is integrated with existing network elements and shall be validated by network integration testing. The conformance of the implementation for MAP-E would need to be verified before operation as given by ETSI TS 103 239 parts 1 [5] to 3 [7].

5 Gap Analysis

5.1 Consideration

The engineering and operational requirements applying ETSI TS 101 569-1 [1] need to be specified with the following design objective to define the logical and physical parameters to allow for customers to access the public IP Internet across an IPv6 network using MAP-E.

5.2 Overview

Mapping Address and Port (MAP) refers to two similar technologies.

MAP is an approach that uses stateless address sharing at the service provider Border Router (BR) and stateful address sharing at the CPE; while transporting packets over IPv6:

- Leveraging distributed statefulness.
- Leveraging IPv6 route aggregation.
- Provides a mapping between IPv6 addresses and IPv4 addresses.

MAP-Encapsulation (MAP-E), defined in draft-ietf-softwire-map IETF RFC 7597 [18]:

- An approach that uses IPv4-in-IPv6 encapsulation to transport IPv4 packets over IPv6 and a mechanism for mapping.
- between IPv6 address and IPv4 addresses and transport layer ports.
- Standards track document ETSI TS 101 569-1 [1] and IETF RFC 7597 [18].

MAP-E provides a mechanism for operators to provide IPv4 services in an IPv6-only network, without requiring translation state to be kept in the service provider environment.

By distributing the NAT functionality to the CPE, the processing requirement is distributed across many devices:

- CPU and memory distribution efficiency.

No state to be managed in the SP core which makes failover between BRs much easier.

While address mapping architecture makes the IPv4-IPv6 identity simpler, the Service Providers can only identify shared IPv4 to subscriber mapping if they are provided with the source port used by the subscriber:

If the source port is not provided the mapping cannot be made as with other technologies.

This may require some operators to deploy detailed flow logging.

CPE support is currently limited with MAP-E.

Dynamic port block extension is currently not possible with MAP-E.

Port exhaustion may become a challenge.

Fragmentation and reassembly presents performance and challenges if the subscriber link cannot support the IPv6 overhead with full IPv4 packet sizes.

MAP-Translation (MAP-T), defined in draft-ietf-softwire-map-t, IETF RFC 7599 [19]:

- an approach that uses translation between IPv4 and IPv6 address families to support IPv4 over an IPv6 network; and
- a mechanism for mapping between IPv6 address and IPv4 addresses and transport layer ports;
- experimental track document.

The MAP-T solution presents an operator with the prospect of a full transition of a domain to IPv6-only in a manner that:

- Retains the ability for IPv4 end-hosts to communicate across the IPv6 domain with other IPv4 hosts while also permitting both individual IPv4 address assignment and address sharing.
- Allows communication between IPv4-only end hosts, as well as any IPv6-enabled end hosts, to native IPv6-only servers in the domain that are using an IPv4-mapped IPv6 address.
- Does not require the operation of a stateful IPv4 overlay network, nor the introduction of nonnative-IPv6 network device or server functionality.
- Allows the use of IPv6 native network operations, including the ability to classify IP traffic, as well as to perform IP traffic routing optimization policies such as routing optimization, based on peering policies for Internet IPv4 destinations outside of the domain.
- Extends stateless IPv4-IPv6 translation with algorithmic address and port mapping.

6 Domain Functionality

6.1 End to End Network Domains

In order to operate the IPv6 transition technology it has to be engineered and verified end to end across the cable broadband network addressing each of the domains as illustrated in figure 2.

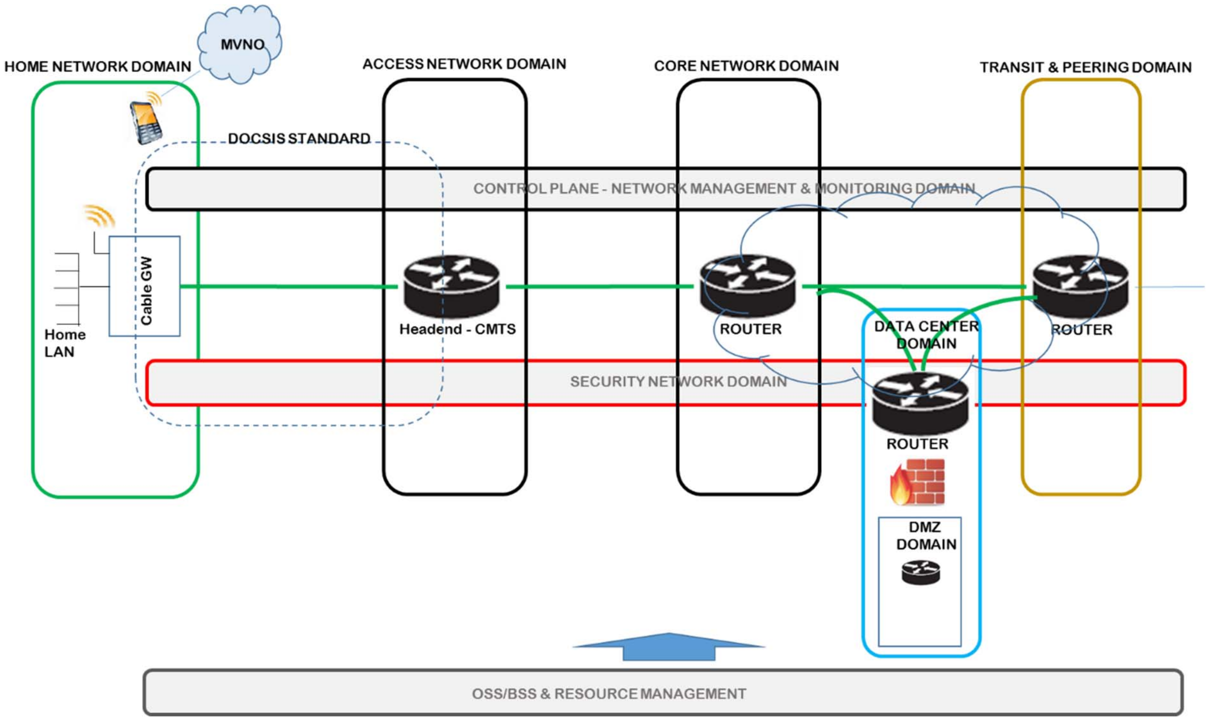

Figure 2: Illustration of the Cable Broadband Network Domains

6.2 CPE Home Network Domain

MAP-E enables a customer's device that is V4 to be supported across the Cable network when communicating to a V4 service.

Functionality to be engineered in the cable network:

- The cable residential gateway device shall have the MAP-CE function as specified by IETF RFC 7597 [18].
- IPv4 packet size is 1 500 bytes. When the 40 bytes is added for the MAP-E encapsulation, the packet size increases to 1 540 which exceeds the DOCSIS 3.0 IP MTU size of 1 500.
- A solution would be to reduce the data field from 1 460 bytes to 1 420 bytes using MSS clamping as detailed within IETF RFC 4459 [17].
- However, as not all service providers will be able to increase their MTU, the MAP-CE elements will be required to fragment the IPv6 packet before transmission which is reassembled at the MAP-BR.
- To reduce the impact on CPU processing it is recommended to implement MSS clamping.
- The DOCSIS management between the Cable Modem and CMTS may be IPv4 or IPv6.

Operation:

A V4 client sends an IP Packet to the RG which uses the MAP-CE functionality to map the IPv4 address and port details into an IPv6 header and forward the IPv6 packet to the MAP-BR.

Refer to clause 6.4 for the functions required from the core network with the addition of the MAP-BR network device.

6.3 Access Network Domain

Functionality to be engineered in the cable network:

- The cable headend CMTS shall be capable of IPv6 connectivity for customer traffic.
- The DOCSIS management between the Cable Modem and CMTS may be IPv4 or IPv6.

NOTE: There are no additional requirements on the HFC distribution network i.e. AMPS, taps, etc.

6.4 Core Network Domain

Functionality to be engineered in the cable network:

- The core network routers shall support IPv6 routing and forwarding capabilities.
- The MAP-BR shall be implemented as specified by IETF RFC 7597 [18].

Operation:

A v6 client communicating with v6 service has direct end to end connectivity and does not utilize the MAP-CE or MAP-BR resources, however a v4 client communicating with a v4 service will utilize the functions of the MAP-BR such that the received V4 packets IPv4 address and port details are mapped and encapsulated at the residential gateway using the MAP-CE functionality adding an IPv6 header and forwarded to the MAP-BR which then de-encapsulates the packet by removing the IPv6 header to reveal the IPv4 packet and forwards it to the v4 server.

The communication between the MAP-BR and V4 server for the session will be using v4 packets, whereas the communication between the v4 client and MAP-BR is encapsulated in IPv6 in accordance with IETF RFC 7597 [18] so this enables the V4 client to communicate to a V4 service. Since the state of the session is not maintained by the MAP-BR the V4 server may reply to any of the configured MAP-BR devices.

6.5 Data Centre Domain

Functionality to be engineered in the cable network:

There are no changes to the network DNS functionality required. The DNS shall be IPv6 capable.

The DHCP server is inherently IPv6 only and shall include DHCP option for MAP-E as specified in IETF RFC 7598 [20].

6.6 DMZ Service Domain

Functionality to be engineered in the cable network:

- There are no specific operational requirements for the DMZ however it is strongly recommended that all services within the DMZ are IPv6 capable either by dual stack configuration or the use of V6/V4 load balancing.
- V6/V4 load balancers allow V6 access to existing v4 services such as a web server avoiding the need to engineer v6 only content on these servers.
- To minimize the impact on the MAP-BR from having to perform encapsulations on the received IPv4 packets for the network providers own services then all services within the DMZ shall be IPv6 capable.

6.7 Transit and Peering Service Domain

Functionality to be engineered in the cable network:

There are no changes to be engineered when considering the transit and peering domain since the transmit and peering links are dual stack and support both IPv6 and IPv4 packets simultaneously and therefore no specific additional requirements are needed to be defined for this domain.

6.8 Management and Monitoring Domain

Functionality to be engineered in the cable network:

- DOCSIS management between the CMTS and Cable Modem may remain deployed either using IPv4 or IPv6 addresses.
- There is the additional functionality to monitor and manage the Cable Modem MAP-CE functionality. Similarly to manage and monitor the MAP-BR in order to provide sufficient capacity to scale with the traffic throughput.
- The V4 address pool on the DHCP server shall need to be managed based on the number of customers and the address sharing ratio between the V6 and V4 ports e.g 16 customers sharing 1 IPv4 address as detailed in IETF RFC 7598 [20].

6.9 Security Domain

Functionality to be engineered in the cable network:

- The cable modem packet classifiers shall be updated to support IPv6 filtering.
- The continuity of the security of the end to end service shall be maintained when operating MAP-E, however the operational implications from MAP-E shall be minimized as specified in IETF RFC 7597 [18] section 10, and IETF RFC 7598 [20], section 9.
- The logging of IPv4 addresses for LI and DR purposes shall additionally contain the IP port and the customers IPv6 address.

7 Topologies

This clause explains the potential MAP-E domain topologies. At the time of writing, two topologies are possible, the integrated topology and the hairpin topology; however, depending on future hardware and software developments, additional topologies may be introduced.

Use of the integrated topology would provide the most flexibility, as in the hairpin topology the use of an IGP is required and will not allow to connect the LSN BR anywhere on the core to any PE without running BGP in the core.

To support the hairpin topology P-routers may need to be converted into PE-routers or extra PE-router devices may need to be deployed for one to distribute the LSN BR's as required.

In the integrated topology the LSN BR would function as a full MPLS 6PE router.

In the hairpin topology the LSN BR functions as L3 router, hair-pinning connections through an external 6PE router. This topology would only be used when application of the integrated topology is not possible.

Mapping of Address and Port (E) leverages the natural aggregation ability of addresses and ports to allow IPv4 addresses to be translated or encapsulated in IPv6, without requiring a stateful translator on the CORE network. This provides an IPv6 transition mechanism that allows cable operators to share scarce IPv4 address resources, while deploying an IPv6-only provider network. Two versions of MAP exist today-MAP-T and MAP-E -which use translation and encapsulation respectively. MAP-T has largely been disqualified and not developed while MAP-E along with XLAT is a technology that the cable operator market considers has potential for future deployments. The key benefit of MAP is its stateless implementation on the PE router, which allows it to scale proportionally to the number of aggregated prefixes and traffic volume instead of by the number of end user connections or states.

8 Technical Considerations

8.1 General

The requirements of the MAP-E implementation are based on enabling seamless MAP connections without degradation in service, access, functionality or speed. It is currently not considered as a fully deployable solution for carrier grade networks but as experiences in its implementation evolve the support for this technology by industry is maturing.

Two network components are involved in the end-to-end MAP-E approach; the LSN BR and the CPE.

MAP leverages an IPv6-address-to-IPv4-address mapping, as well as port mapping algorithms that use specific bits in the IPv6 address space to represent both IPv4 addresses and L4 ports. In MAP-T, the original L3 and L4 information is available to regular IPv6 data plane devices via the IPv6 header. In comparison, MAP-E encapsulates the entire original IPv4 datagram with an IPv6 header with the IPv6 source and destination corresponding to the tunnel endpoints, so that no IPv4 header information is directly exposed to the IPv6 data plane.

NAT44 is a component of the MAP solution, but the NAT44 in MAP differs from traditional NAT44 or NAT444 deployments in that instead of assigning a public IPv4 address range to each CPE for translation (in the case of NAT), or a single public IPv4 address for translation (in the case of PAT) to each CPE, it extends the granularity beyond a single public IPv4 address, by being able to assign a port range to each of the CPEs sharing the same IPv4 public address. This unique address and port range combination is then translated into the IPv6 address space when transitioning into the IPv6 domain using the MAP CPE. The MAP algorithm still retains the ability to assign the full IPv4 address or an IPv4 prefix to the MAP CPE.

In this way, there are stateless mappings between the IPv4 and IPv6 address without requiring a large stateful translator in the network.

8.2 LSN and CPE Requirements

The LSN device is placed in the edge of the network (IXPE) as the IPv4 gateway to perform de-capsulation on the egress from a 4in6 packet to a pure IPv4 packet. Requirement considerations for LSN are:

- Hardware Topology
- Logical Topology
- Software/Hardware Features
- Scalability
- Resilience and Redundancy
- IP Allocation & DHCP specific features (v4 and v6)
- Forwarding/Convergence Performance
- Monitoring, Management, Reporting & Access
- DR Specifics

8.3 CPE

The CPE is a device in customer's home to encapsulate the traffic on egress from a pure IPv4 packet to a 4in6 packet. Requirement considerations for MAP-E CPE are:

- Hardware Topology
- Logical Topology
- Software/Hardware Features

- Scalability
- Stability
- IP Allocation/DHCP (v4 and v6)
- Forwarding performance

9 MAP-E Feature Requirements

The MAP-E features are as summarized in table 1 detailing for each function the requirement as required or optional with a brief description of each of the named functions.

Table 1: Summary of MAP-E Features Requirements

Functional Name	Requirement	Description
MAP-E	Required	Main MAP-E, mapping of address & port - encapsulation version, IETF RFC 7597 [18].
MAP-T	Optional	Main MAP-T, mapping of address & port - translation version, IETF RFC 7599 [19].
MAP-T IETF RFC 6145 [21]	Optional	Compliance with IETF RFC 6145 [21] "IP/ICMP Translation Algorithm".
Compliance with IETF RFC 6052 [22]	Required	Compliance with "IPv6 Addressing of IPv4/IPv6 Translators.
Compliance with IETF RFC 7598 [20] and [23]	Required	Port and address mapping derivative.
Shared Resource	Required	Single BR GW address. The BR IPv6 address should be able to be shared amongst different NPU's in the BR. A hashing mechanism should be in place to hash all upstream packets based on the source IPv6 address.
BR Addressing & Virtual Interfaces	Required	BR shall be able to assign a single virtual interface with up to 8 Map-E GW addresses for any given BR instance on the node.
Anycast	Required	Anycast MAP-E gateway prefixes are a requirement to allow simplicity of deployment for a single prefix across multiple BRs.
BR Address withdrawal	Required	The BR should have at least four points of BR GW address withdrawal occurrence. The list includes: - loss of IPv6 route out, - loss of all BGP/IGP sessions, - loss of forwarding, - loss of NPU capacity Any of the failures should be detectable based on configurable timers with 15 seconds being the default setting.
Basic mapping rule	Required	Compliance IETF RFC 7597 [18], IETF RFC 7599 [19] and IETF draft-murakami-softwire-4to6-translation-00 [23].
Forwarding mapping rule	Required	Forwarding rules
Tunnel MTU sizing	Required	The MTU physical and protocol requirements for MAP-E tunnels, compliance per IETF RFC 7597 [18]
Fragmentation	Required	The IPv4 and IPv6 fragmentation requirements for MAP-E.
Re-ordering & Buffering out-of-sync packets	Required	The requirement to hold/wait on all ordered packets for each flow to forward.
Customer CPE ID	Required	IPv4 Private and IPv6 address.
Support for 1:1 redundant NPU card	Required	The NPU shall not only be able to do full-cone deployment but also 1:1 mapping per NPU.
Configuration of the size of consecutive blocks and sharing ratio	Required	MAP-E requires fixed blocks to be configured on the CPE, this shall be configurable through the boot file.
IPv6 ACLs	Required	IPv6 ACLs before the MAP-E processing on the BR.

Functional Name	Requirement	Description
IPv4 ACLs	Required	The ability for ACLs to be applied before the de-capsulation of the IPv6 packet.
UDP-Lite	Required	UDP-lite should be supported.
TOS rewrite when translating IPv6 to IPv4 and from IPv4 to IPv6	Required	Marking & Remarking should be supported for all tunnelled traffic.
TCP MSS definition	Required	MSS clamping to enable MSS value on all packets ingress and egress.
24 MAP-E instances per BR	Required	The ability to stack transition instances on top of one another.
40 m Translations (per npu) - black assignment	Required	The requirement to translate sessions within the technology at a certain speed denoted by the sessions themselves. These are all session types not only Primary.
Minimum 50 Gbps bi-directional throughput per npu with IMIX traffic	Required	Per half slot throughput requirement.
1 M+ primary connections per second setup rate	Required	Primary sessions, port block assignments, per NPU.
500 k users per NPU	Required	The BR has far less requirement for processing but it should be able to handle a minimum of 500 000 users per chassis or NPU.
Latency	Required	Latency is between 40 and 200 micro seconds (μs).
6 npu Cards per chassis	Required	If the BR requires specific NPU service processing units for MAP-E function then 6 NPUs per node should be the minimum requirement.
IRB/SVI support	Required	Integrated Routing and Bridging/Virtual Interfaces (L3 interface for Bridge Domain).
Broadband Network Gateway (BNG) support	Optional	32 k BNG sessions and up to 256 k NAT users at the same time.

10 Network Node Requirements

10.1 Network node Hardware Feature/Topology

MAP-E uses an IPv4/IPv6 address and port mapping technique to associate an IPv4 address with an IPv6 address. This allows the automatic creation of tunnels between the Border Relay and the CPE Router. The format of the IPv6 address is the same as for MAP-T. In order to perform the mapping, MAP-E allows the provisioning of an IPv4 address and port range to the CPE Router.

Provisioning of the CPE Router requires the following attributes:

- IPv6 prefix.

NOTE: The IPv6 prefix is not dedicated for use with MAP-E and can be part of the customer-assigned IPv6 prefix used for native IPv6 traffic.

- Embedded address bits - these indicate the public IPv4 address and port range.
- MAP-E Border Relay IPv6 prefix.
- DHCPv6 options defined in [24].

The Border Relay has to be configured with a public IPv4 address and the IPv6 prefix for translation in addition to its own IPv6 prefix.

For each outbound packet, the CPE Router is required to perform NAT44 translation from the private IPv4 address IETF RFC 1918 [25] to the address provided by the Service provider and a port within the range specified. Once translated to a public IPv4 address, the CPE Router creates the mapped IPv6 packet header in accordance with the stateless IPv4/IPv6 translation mechanism defined in IETF RFC 6145 [21] and using the MAP header mapping rules. The translated packet is sent across the IPv6 network to the MAP-E Border Relay.

The Border Relay is responsible for translating the received packet back to IPv4, recovering the original IPv4 addresses from the IPv6 header using the MAP header mapping and translation technique defined in IETF RFC 6145 [21]. Finally, the packet is forwarded to its destination.

Inbound IPv4 packets are received by a Border Relay. The Border Relay translates the IPv4 header into IPv6 using the same translation technique and MAP header mapping to produce the IPv6 packet. The IPv6 packet, in turn, is forwarded to the CPE Router. The CPE Router uses once more the same translation mechanism to retrieve the IPv4 header and performs regular NAT44 to pass the packet on to the destination. Where an IPv6 server is located between the CPE Router and Border Router, it remains accessible.

As the packet size varies between IPv4 and IPv6, MTU size and fragmentation are handled by the IP/ICMP translation. The use of IPv4 PMTUD will result in ICMP 'packet too big' messages. TCP MSS Clamping is additionally required to ensure the overall IPv4 packet size does not exceed the IPv6 path MTU.

The MAP-E Border Relay is responsible for fragmentation and reassembly of any IPv4 packet received prior to the encapsulation to IPv6.

Data retention and lawful intercept systems will be required to capture the mapped IP address and port range for each customer.

10.2 Integrated topology requirements

List of features required for both IPv4 and IPv6/L2 and L3 for an integrated topology solution:

- MP BGP (as well 6PE and 6VPE)
- BGP Community/32 bit AS
- MPLS LDP (potentially only v4 native at present but the requirement for v6 native MPLS may become an absolute)
- ECMP
- QoS (v4/v6) - classification, priority queuing, etc.
- QPPB/SCU/DCU
- SNMP (transport over v4 and v6) v1/v2/v3
- ACLs/Prefix Listing (both v4/v6)
- TACACS/RADIUS (v4/v6)
- Syslog (event reporting for v4 & v6 as well as transporting over both protocols)
- CoPP (v4/v6)
- Netflowv9 (potentially previous versions will be required depending on the state of the NA4 implementation of Netflow)
- XML (v4 & v6 reporting and transport)
- Mac Accounting
- 802.1q
- Ether-channel

- Ether OAM
- NSF/GR (v4/v6)
- Policy Based Routing (v4/v6)
- ISIS (Potentially MT for ISIS as well if the MPLS IPv6 LDP allows for dual stacking) (v4/v6)
- Static Routing (v4/v6)
- OSPFv2/v3
- CDP/LLDP (v4/v6)
- VRRP/HSRP (v4/v6)
- VLAN Mapping/Double Tagging
- L3 Multicasting/MFIB (v4/v6)
- IPv6 Forwarding
- IPv4 Forwarding
- Ethernet technologies
- Hardware forwarding functionality, instead of software, across all priority flows (v4/v6)
- Virtual Interfaces (v4/v6)
- AAA (v4/v6)
- BFD (v4/v6)
- MLD/L2 Multicast
- Full NDP (ICMPv6, DAD, NUD, etc.)
- PIM/IGMPv2/v3
- CEF/dCEF
- Anycast
- Route Reflection (v4/v6)
- Standard v4 VPN
- ISSU/SSO
- NTP (v4/v6)
- SEND
- IP-Sec
- DNS (v4/v6 server & client))
- DHCP relay (v4/v6)
- MSTP/RSTP
- L2/L3 Load Balancing (v4/v6)
- VPLS (v4/v6)
- L2 Bridging

- NAT64
- MAP-E
- NAT Cache Writing
- SSH/Telnet (v4/v6)
- Authentication across most protocols such as SNMPv3/BGP/LDP/ISIS/, etc.
- PS-BGP

10.3 Hairpin topology requirements

List of features required for both IPv4 and IPv6/L2 and L3 for a "hairpin topology" solution:

- SNMP (transport over v4 and v6) v1/v2/v3
- ACLs/Prefix Listing (both v4/v6)
- TACACS/RADIUS (v4/v6)
- Syslog (event reporting for v4 & v6 as well as transporting over both protocols)
- CoPP (v4/v6)
- Netflowv9 (potentially previous versions will be required depending on the state of the NA4 implementation of Netflow)
- XML (v4 & v6 reporting and transport)
- 802.1q
- Ether-channel
- Ether OAM
- Static Routing (v4/v6)
- CDP/LLDP (v4/v6)
- VRRP/HSRP (v4/v6)
- IPv6 Forwarding
- IPv4 Forwarding
- Ethernet technologies
- Hardware forwarding functionality, instead of software, across all priority flows (v4/v6)
- Virtual Interfaces (v4/v6)
- Full NDP (ICMPv6, DAD, NUD, etc.)
- CEF/dCEF
- Anycast
- ISSU
- NTP (v4/v6)
- SEND

- BFD
- IP-Sec
- DNS (v4/v6 server & client)
- MSTP/RSTP
- L2/L3 Load Balancing (v4/v6)
- NAT64
- MAP-E
- NAT Cache Writing
- SSH/Telnet (v4/v6)
- Authentication across most protocols such as SNMPv3/BGP/LDP/ISIS/, etc.
- PS-BGP
- ECMP

Annex A (informative): Bibliography

IETF RFC 2983 (October 2000): "Differentiated Services and Tunnels".

History

Document history		
V1.1.1	August 2016	Publication