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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 1 of a multi-part deliverable covering the operational and engineering aspects of Cable Network IPv6 transition technology DS-Lite, as identified below:

Part 1: "General";

Part 2: "NAT64";

Part 3: "DS-Lite";

Part 4: "MAP-E";

Part 5: "464XLAT";

Part 6: "6RD".

Modal verbs terminology

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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 ETSI TS 101 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 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.3].

In the second phase an ETSI TS 101 569-1 [1] 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, DS-Lite, 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 [13] to 3 [15] respectively for NAT64; ETSI TS 103 239 parts 1 [16] to 3 [18] respectively for MAP-E; ETSI TS 103 241 parts 1 [19] to 3 [21] respectively for DS-Lite; ETSI TS 103 242 parts 1 [22] to 3 [24] respectively for XLAT and ETSI TS 103 243 parts 1 [25] to 3 [27] 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 1, general part of a multi-part series presenting general information relative to each of the transition technologies.

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1 Scope

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

The present document is part 1 of a multi-part series and presents a generic view of a typical end to end cable network when considering the key aspects to engineer and operate the IPv6 transition technology across its network domains.

The technical requirements addressing each network domain relative to the IPv6 transition technology in question is described in the clauses of the part specific to the IPv6 transition technology.

The operational aspects for the IPv6 transition technologies, NAT64, DS-Lite, MAP-E, 464XLAT and 6RD 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 DS-Lite 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 EN 302 878-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 1: General; DOCSIS 3.0".

[3] ETSI EN 302 878-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 2: Physical Layer; DOCSIS 3.0".

[4] ETSI EN 302 878-3: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 3: Downstream Radio Frequency Interface; DOCSIS 3.0".

[5] ETSI EN 302 878-4: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 4: MAC and Upper Layer Protocols; DOCSIS 3.0".

[6] ETSI EN 302 878-5: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 5: Security Services; DOCSIS 3.0".

[7] CableLabs CM-SP-eRouter-I17-151210: DOCSIS IPv4 and IPv6 eRouter Specification.

[8] ETSI TS 103 443-2: "Integrated broadband cable telecommunication networks (CABLE); IPv6 Transition Technology Engineering and Operational Aspects; Part 2: NAT64".

[9] ETSI TS 103 443-3: "Integrated broadband cable telecommunication networks (CABLE); IPv6 Transition Technology Engineering and Operational Aspects; Part 3: DS-Lite".

[10] ETSI TS 103 443-4: "Integrated broadband cable telecommunication networks (CABLE); IPv6 Transition Technology Engineering and Operational Aspects; Part 4: MAP-E".

[11] ETSI TS 103 443-5: "Integrated broadband cable telecommunication networks (CABLE); IPv6 Transition Technology Engineering and Operational Aspects; Part 5: 464XLAT".

[12] ETSI TS 103 443-6: "Integrated broadband cable telecommunication networks (CABLE); IPv6 Transition Technology Engineering and Operational Aspects; Part 6: 6RD".

[13] 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".

[14] 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)".

[15] 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)".

[16] 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".

[17] 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)".

[18] 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)".

[19] 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".

[20] 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)".

[21] 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)".

[22] 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".

[23] 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)".

[24] 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)".

[25] 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".

[26] 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)".

[27] 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)".

[28] IETF RFC 6145: "IP/ICMP Translation Algorithm".

[29] draft-mdt-softwire-map-dhcp-option-03: "DHCPv6 Options for Mapping of Address and Port".

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".

[i.3] IETF RFC 1918: "Address Allocation for Private Internets".

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:

6RD	IPv6 Rapid Deployment
AFTR	Address Family Transition Router
BR	Border Relay
CIDR	Classless Inter-Domain Routing
CLAT	Customer-side transLATor
CM	Cable Modem
CMTS	Cable Modem Termination System
CPE	Customer Premise Equipment
DHCP	Dynamic Host Configuration Protocol
DMZ	DeMilitarized Zone
DNS	Domain Name System
DOCSIS	Data Over Cable Service Interface Specification
DS-Lite	Dual Stack-Lite
IP	Internet Protocol
IPDR	Internet Protocol Detail Record
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
LAN	Local Area Network
MAP-E	Mapping of Address and Port - Encapsulation Mode
MAP-T	Mapping of Address and Port using Translation
MSS	Maximum Segment Size
NAT	Network Address Translation
NAT64	Network Address Translation IPv6 to IPv4
NDP	Neighbor Discovery Protocol
OSI	Open Systems Interconnection
OSS	Operational Support System
PCP	Port Control Protocol
PLAT	Provider-side transLATor
PMTUD	Path Maximum Transport Unit (MTU) Discovery
RFC	Request For Comments
SI	Softwire Initiation
T&P	Transit and Provider
UI	User Interface
WAN	Wide Area Network
XLAT	(Address) TransLATor

4 General Considerations

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

The present document and its parts do 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.

It should be noted that there are no changes to be engineered when considering the transit and peering domain since the transit 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. The DMZ and its services is expected to be dual stack supporting both IPv4 and IPv6 packets irrespective of the IPv6 transition technology and therefore no specific additional requirements are needed to be defined.

Information is specified for a cable network based on the following network build to provide a baseline against which other variations of cable network builds may be assessed when operating the IPv6 transition technology.

Network Build:

- CPE Home Network Domain: DOCSIS 3.0 Residential Gateway [7].
- Access Network Domain: DOCSIS 3.0 CMTS, [2], [3], [4], [5] and [6].
- Core Network Domain: IP Routing and Forwarding Equipment e.g. edge router, core aggregation routers.
- Data Centre Domain: DHCP, MAILWEB, Service Routers, DNS.
- DMZ Service Domain: within data centre domain, firewall.
- Transit and Peering Domain: T&P Routers.
- Management and Monitoring Domain: OSS Equipment for provision requirements.
- Security Domain: firewalls, IPDR Logging equipment.

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 1.

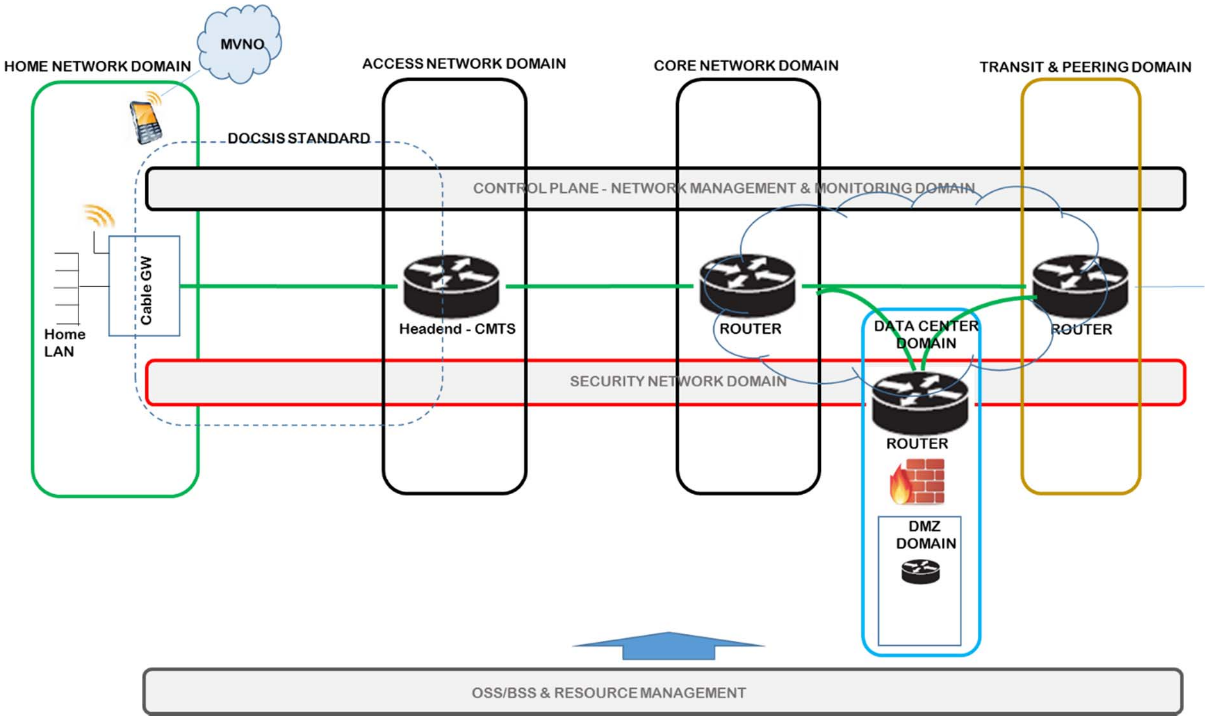

Figure 1: Illustration of the Cable Broadband Network Domains

The operation and engineering of each of the IPv6 technologies as specified by ETSI TS 101 569-1 [1] across the cable network domains are given in the respective part 2 [8], part 3 [9], part 4 [10], part 5 [11] and part 6 [12].

5 IPv6 Transition Technologies Overview

Cable network operators are having to adopt IPv6 as the IPv4 addresses become depleted in all registries in order to maintain continuity of services. However, cable operators have extensive investment in the build of their cable networks and consequently need to consider the integration of IPv6 in a pragmatic way within an end-to-end network. Technologies that were developed in order to work around the limitations of the available IPv4 address pool such as NAT and CIDR provided stopgaps towards the depletion of IPv4 addresses and, thus, slowed the process of transitioning to a more advanced protocol. The industry across all sectors had not managed to move collectively towards adoption of IPv6, consequently the market had to consider transitional functionality and network migration since not all equipment and services deployed in current networks are IPv6 capable. The evolution in the development of IPv6 has failed to consider interoperability with IPv4 as a key requirement. With hindsight, had this been a consideration during the development of IPv6 then the industry would have been equipped with the means to integrate the IPv6 solution alongside the existing IPv4 deployed network architecture. For example, it may have been possible to use a /96 address range to embed the full IPv4 range in the IPv6 addressing structure. However, since no consideration had been given to interoperability it meant the industry was offered two protocols, IPv4 and IPv6, that are not interoperable with each other.

The current situation within industry is for cable network operators having to manage their network topologies using both IPv4 and IPv6 since IPv6 had not been designed to be backward compatible with IPv4. The choice for the industry was to either develop two network topologies, i.e. to have end-to-end architectures of both IPv4 and IPv6 or develop suitable transition technologies that would transition the network towards IPv6 considering IPv4 equipment architectures. The former was clearly uneconomical and therefore the industry developed IPv6 transition technologies that favoured different levels of legacy network builds based on the most economic approach to evolve legacy investments whilst maintaining continuity of services.

The five IPv6 transition technologies that the industry have adopted are being engineered and operated within the operators cable networks. These are explained in more detail in parts 2 to 6 of this multi-part series as given below:

- Part 2: NAT64; Cable IPv6 transition technology engineering and operational aspects; General Aspects [8].
- Part 3: DS-Lite; Cable IPv6 transition technology engineering and operational aspects; General Aspects [9].
- Part 4: MAP-E; Cable IPv6 transition technology engineering and operational aspects; General Aspects [10].
- Part 5: 464XLAT; Cable IPv6 transition technology engineering and operational aspects; General Aspects [11].
- Part 6: 6RD; Cable IPv6 transition technology engineering and operational aspects; General Aspects [12].

Each of the above IPv6 transition technologies are being operated within a cable operator's end-to-end network where existing equipment may not be IPv6 capable, by engineering the transition technologies to allow for a smooth economic entry into IPv6.

New equipment with requirements specific to the chosen IPv6 transition technology has to be engineered across the cable operator's network domains to support V6 and legacy V4 customers access both legacy V4 and V6 servers transparently. The impact is a significant change in the operator's basic network infrastructure of the Internet.

The change in the IP address structure impacts the whole networking stack in transit and end nodes (Layers 2 and 3 but not Layer 1 in the OSI layer model). IPv6 does not just disturb the Layer 3 functionality, new protocols such as NDP also change Layer 2 functions to a certain degree with multicast being used instead of broadcast while link-local neighbour tables and destination cache replace the ARP/RARP function. All intelligent protocols that are located within Layers 2 and 3 as well as some protocols associated with Layer 4 has to change to accept the new structure and role IPv6 plays within the stack.

Some systems and applications may not have an upgrade path to IPv6 and, thus, will remain IPv4 clients until they are taken out of service, while others may be expensive or impractical to upgrade in a timely manner. These factors have to be considered when engineering the network towards an IPv6 migration path with the selected transition technology. The transitions technologies selected has to be subject to a thorough technical analysis focusing on their suitability for deployment in a cable network environment, their impact on cable network equipment and the operational impact to maintain continuity and QoS for both current and new services.

To assist cable network operators decision on which of the five IPv6 transition technologies to integrate end-to-end within their legacy network, table 1 provides a brief analysis of each and requirements to engineer the technology for it to operate end-to-end across the cable network domains is specified in more detail by the relevant multi-parts series of technical specifications.

Table 1: General Analysis of IPv6 Transition Technologies

Technology	Summary Analysis
NAT64	NAT64 is a transition technology using IPv6 in the home network. The main caveats being: 1) Applications who do not use DNS will not work across the network. 2) It requires the complete home network to be IPv6 enabled and it does not support IPv4 only devices in the home network. 3) It requires an IPv6 native transport from CPE to the NAT64 device. 4) Extensive ALGs are required due to the fact that the NAT64 device translates IPv6 to IPv4 and vice versa. 5) It requires PCP to prevent service deprecation on subscribers who previously had IPv4 public addresses and provided Internet access to their home. 6) Deployment requires NAT64 to be carrier-grade in terms of its performance and features. NAT64 is not widely adopted as a transition technology so far given the above complications mainly mentioned in items 1 and 2.
DS-Lite	DS-Lite is an almost non-service deprecating technology with a few caveats: 1) It requires a new CPE to be delivered to the customer location supporting the features required for SI. 2) It requires an IPv6 native transport from CPE to AFTR. 3) Deployment requires DS-Lite to be carrier-grade in terms of performance and features. 4) It requires PCP to prevent service deprecation on subscribers who previously had IPv4 public addresses and provided Internet access to their home. DS-Lite is a commonly supported in devices connected to Cable Networks due to the functionality potentially built in. DS-Lite does not require to further assign IPv4 private addresses in the network and uses a common form of NAT for IPv4 which is a proven technology.
6RD	6rd is a dual stack transition technology providing with some caveats. The mains caveats being: 1) The CM needs to support 6rd and a 6rd border relay needs to be added to the network 2) Since the IPv6 address is provided from a IPv4 address, while IPv4 exhaustion is happening, the IPv6 address is subject to NAT with its implications and a second transition to native IPv6 support will be required, which adds costs. 3) It requires PCP to prevent service deprecation on subscribers who run services from their home. 4) Deployment requires to be carrier grade feature wise on the 6rd border relay. 6rd is mainly used when the access network cannot transition to IPv6, but given a second transition is required to native IPv6 the technology is not widely adopted.

Technology	Summary Analysis
464XLAT	This technology allows customers to access services natively over IPv6 and through translation over IPv4 and is thus a last resort technology. IPv4 connectivity to IPv4 hosts over home routers (CPEs) and access networks that are provisioned with only IPv6 addresses. Dual-Stack connectivity for hosts connected to IPv6-only access networks. Less need to maintain IPv4 or dual-stack access networks. A lightweight solution for providing IPv4 connectivity over IPv6 only access. Single NAT - i.e. no need to have multiple layers of NATs. Multiplexing public IPv4 addresses for large number of customers across a limited number of IPs using port translation. Port forwarding capability on a PLAT using technologies such as: Web-UI, NAT-PMP, UPnP, A+P It does not require DNS64 as described in IETF RFC 6147 since an IPv4 host may simply send IPv4 packets, including packets to an IPv4 DNS server, which will be translated on the CLAT to IPv6 and back to IPv4 on the PLAT.
MAP-E	MAP-E is a viable technology in its basis but lacks vendor support and a full feature set, plus standardization is lacking at present and incomplete. **BR** Native IPv6 WAN support. Dual-stack IPv4/IPv6 LAN support. IPv4 to IPv6 header translation in accordance with IETF RFC 6145 [28]. NAPT-44 to translate private RFC 1918 addresses [i.4] to public IPv4 address and port range Provision of IPv6 prefix via DHCPv6. DHCPv6 MAP-T options as defined in draft-mdt-softwire-map-dhcp-option-03 [29]. IPv6 to IPv4 header translation. Port forwarding mapping for NAT translation. Support for UPnP NAT Traversal. MSS Clamping for TCP/IPv4 connection negotiation. PMTUD support for both IPv4 and IPv6 support. Fragmentation/reassembly of IPv6 packets. **CPE** IPv6 prefix assigned for IPv6/IPv4 translation (customer-side). IPv4 address for forwarding to/from IPv4 Internet. IPv4 to IPv6 header translation in accordance with IETF RFC 6145 [28]. IPv6 to IPv4 header translation. MSS Clamping for TCP/IPv4 connection negotiation. PMTUD support for both IPv4 and IPv6 support. Fragmentation/reassembly of IPv6 packets.

Annex A (informative): Bibliography

draft-ietf-softwire-dual-stack-Lite-11: "Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion".

History

Document history		
V1.1.1	August 2016	Publication