TECHNICAL REPORT

TR-221
Technical Specifications for MPLS in Mobile Backhaul Networks

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1 Amendment 1	11 November 2013	13 December 2013	Balázs Varga, Ericsson	This amendment addresses issues and features that were not included in the original TR-221 and adds to the original scope.
1 Corrigendum 1	8 September 2014	23 September 2014	Yuanlong Jiang, Huawei	Corrections and clarifications to TR-221
1 Amendment 2	4 September 2017	14 September 2017	Yuanlong Jiang, Huawei Haijun Wang, China Unicom	This amendment provides new features to TR-221, including time and phase synchronization, enhancements on scalability such as support of seamless MPLS and new services such as full E-Tree service using VPLS.

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Executive Summary

With the wide deployment of LTE mobile networks and beyond, a dramatic increase of both base stations and mobile backhaul equipment poses a great challenge on the scalability of mobile backhaul networks.

TR-221 defined the use of MPLS in Mobile Backhaul access and aggregation networks. It created reference architectures for MPLS in Mobile Backhaul networks and included specifications for the various transport scenarios that are depicted in the reference architectures. TR-221 Amendment 1 addressed additional issues and features of the control, user and management planes that were not included in the original TR-221.

This amendment provides new features to TR-221, including time and phase synchronization, enhancements on scalability such as support of seamless MPLS and new services such as full E-Tree service using VPLS. This amendment is applicable to and addresses backhaul up through 3GPP Rel.11 and beyond.

1 Purpose and Scope

1.1 Purpose

This document provides new amendments to TR-221, including specifications on time and phase synchronization, enhancements on scalability such as support of multi-area LSP signaling, full E-Tree service support using VPLS and seamless MPLS. This amendment is applicable to and addresses backhaul up through 3GPP Rel.11 and beyond.

1.2 Scope

This amendment adds some functions not addressed in TR-221 or TR-221 Amd 1, including:
- Time and phase synchronization
- Multi-area LSP signaling
- Seamless MPLS
- Loop free alternates (LFA)
- Full E-Tree support using VPLS

2 References and Terminology

2.1 References

Document		Title	Source	Year
[1]	MEF6.2	*EVC Ethernet Services Definitions Phase 3*	MEF	2014
[2]	TR-221	*Technical Specification for MPLS in Mobile Backhaul Networks*	BBF	2011
[3]	TR-221 Amd.1	*Technical Specification for MPLS in Mobile Backhaul Networks, Amendment 1*	BBF	2013
[4]	RFC 3107	*Carrying Label Information in BGP-4*	IETF	2001
[5]	RFC 4206	*Label Switched Paths (LSP) Hierarchy with Generalized Multi-Protocol Label Switching (GMPLS) Traffic Engineering (TE)*	IETF	2005
[6]	RFC 5036	*LDP Specification*	IETF	2007
[7]	RFC 5150	*Label Switched Path Stitching with Generalized Multiprotocol Label Switching Traffic Engineering (GMPLS TE)*	IETF	2008
[8]	RFC 5283	*LDP Extension for Inter-Area Label Switched Paths (LSPs)*	IETF	2008
[9]	RFC 5286	*Basic Specification for IP Fast Reroute: Loop-Free Alternates*	IETF	2008
[10]	RFC 7490	*Remote Loop-Free Alternate (LFA) Fast Reroute (FRR)*	IETF	2015
[11]	RFC 7796	*Ethernet-Tree (E-Tree) Support in Virtual Private LAN Service (VPLS)*	IETF	2016
[12]	G.8271.1	*Network limits for time synchronization in packet networks*	ITU-T	2013
[13]	G.8273.2	*Timing characteristics of telecom boundary clocks and telecom time slave clocks*	ITU-T	2014
[14]	G.8275	*Architecture and requirements for packet-based time and phase distribution*	ITU-T	2013

[15]	G.8275 Amd.1	*Architecture and requirements for packet-based time and phase distribution, Amendment 1*	ITU-T	2015
[16]	G.8275.1	*Precision time protocol telecom profile for phase/time synchronization with full timing support from the network*	ITU-T	2016
[17]	G.8275.2	*Precision time protocol telecom profile for phase/time synchronization with partial timing support from the network*	ITU-T	2016
[18]	1588v2	*Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*	IEEE	2008

2.2 Definitions

Telecom Grandmaster (T-GM), see Section 5 of G.8275.1 [16].
Telecom Time Slave Clock (T-TSC), see Section 5 of G.8275.1 [16].
Telecom Boundary Clock (T-BC), see Section 5 of G.8275.1 [16].
Telecom Transparent Clock (T-TC), see Section 5 of G.8275.1 [16].

2.3 Abbreviations

BGP-LU	BGP Labeled Unicast
CSG	Cell Site Gateway
E-Tree	Ethernet Tree
EVC	Ethernet Virtual Connection
GNSS	Global Navigation Satellite System
LTE-TDD	Long Term Evolution - Time-Division Duplex
MASG	Mobile Aggregation Site Gateway
MEF	Metro Ethernet Forum
PE	Provider Edge
PRC	Primary Reference Clock
PRTC	Primary Reference Time Clock
T-BC	Telecom Boundary Clock
T-BC-P	Partial Support Telecom Boundary Clock
T-GM	Telecom Grandmaster
T-TC	Telecom Transparent Clock
T-TC-P	Partial Support Telecom Transparent Clock
T-TSC	Telecom Time Slave Clock
T-TSC-A	Assisted Partial Support Telecom Time Slave Clock
T-TSC-P	Partial Support Telecom Time Slave Clock
TD-SCDMA	Time Division - Synchronous Code Division Multiple Access
UNI	User Network Interface

3 Changes / Updates in TR-221

3.1 Time and phase synchronization

The following texts are to be added as a new section after Section 9 of TR-221.

3.1.1 Time and phase distribution requirements

Stringent time/phase synchronization is needed for some mobile networks, such as TD-SCDMA and LTE TDD. Though GNSS (e.g., GPS) can provide accurate timing, they may not be available to the base station in all circumstances. Service providers need a mechanism to deliver phase/time in high precision over their MPLS networks in an interoperable way.

Depending on the location of the Primary Reference Time Clock (PRTC), a Distributed PRTC method or a Packet-based method can be used.

3.1.2 Distributed PRTC based time and phase distribution

In this case, the PRTC function is located directly at the base station or the edge of the mobile network (e.g., CSG); typically a GNSS receiver is connected to the base station or the CSG. Therefore, the time synchronization reference is directly delivered from the PRTC to the base station or the CSG.

3.1.3 Packet based time and phase distribution

3.1.3.1 Time and phase distribution with full timing support from the network

It can further be classified into the following 3 cases:

- Case A: centralized PRTC co-located with Primary Reference Clock (PRC)

In case A, the PRTC is co-located with the PRC in the aggregation network (e.g., MASG), and may receive a frequency reference from the PRC (the two functions may be integrated within the same equipment). The time synchronization reference is then delivered from the PRTC via the packet master (T-GM) all along the mobile backhaul network, down to the base station, using a time protocol such as PTPv2.

- Case B: centralized PRTC not co-located with PRC

In case B, the PRTC is located in the aggregation network (MASG), but not co-located with the PRC. The PRTC may receive the frequency reference from the PRC. The time synchronization reference is then delivered from the PRTC via a packet master (T-GM) all along the mobile backhaul network, down to the base station, using a time protocol such as PTPv2.

- Case C: PRTCs in access networks

In case C, the PRTC is located in an access network; typically a GNSS receiver is added to an access device. The PRTC may receive the frequency reference from the PRC. The time synchronization reference is then delivered from the PRTC via a packet master (T-GM) all along the mobile backhaul network, down to the base station, using a time protocol such as PTPv2.

These packet based time and phase synchronization cases can be fulfilled by the mechanism and PTP profile as defined in G.8275.1. The specific architecture is described in G.8275 which allows the distribution of phase/time with full timing support from the network, and is based on the second version of PTP defined in IEEE 1588v2 [18]. That is, all of the nodes in the transmission path will provide timing support by participating in the timing protocol, and the assumption is all the intermediate nodes are Telecom Boundary Clocks (T-BC) with physical layer frequency support. The network limits are specified in G.8271.1 [12]. Note: work is ongoing concerning the inclusion of Telecom Transparent Clocks (T-TC) into the network reference chain (T-TC is being defined in G.8273.3).

The following requirements are needed to support packet based time and phase synchronization:

[R-1] Time and phase distribution architecture MUST be per G.8275 [14].
Note: The PRTC function may be incorporated within the MASG or other PE or implemented externally to it.

[R-2] A PE or P device that implements Telecom Boundary Clock (T-BC) function MUST support T-BC timing characteristics as defined in the ITU-T Recommendations G.8273.2 [13].

[R-3] A CSG or other PE that implements Telecom Time Slave Clock (T-TSC) function MUST support T-TSC timing characteristics as defined in the ITU-T Recommendations G.8273.2 [13].

[R-4] A CSG, PE or P device that implements packet based time and phase distribution MUST support G.8275.1 [16] PTP protocol profile.

3.1.3.2 Time and phase distribution with partial timing support from the network

For some mobile backhaul networks, many nodes may not have timing synchronization capabilities. ITU-T specifies synchronization architecture for a use case (case E in G.8275 Amendment 1 [15]) where intermediate nodes do not provide timing support, but timing support is provided by GNSS at the network edge, with PTP acting as a backup. This is called Assisted Partial Timing Support (APTS). The node providing support at the edge of the network is called an Assisted Partial Timing Support Clock (APTSC).

The mechanism and PTP profile for time and phase distribution with partial timing support are further defined in G.8275.2 [17]. Work is ongoing concerning the performance aspects. In particular, the network limits are being addressed in G.8271.2 and clock specification in G.8273.4. The following requirements are needed to support time and phase synchronization with partial timing support from the network:

[R-5] Time and phase distribution architecture MUST be per G.8275 case E.
Note: The PRTC function may be incorporated within the MASG or implemented externally to it.

[R-6] A MASG MUST support the T-BC-P with PTP protocol profile function as defined in G.8275.2 [17].
Note: the performance of the clock to be used with the G.8275.2 profile is under study (G.8273.4)

[R-7] A CSG or other PE MUST support T-TSC-A with PTP protocol profile function as defined in the ITU-T Recommendations G.8275.2 [17].

3.2 Multi-area LSP signaling

Section 5.1 of TR-221 supports inter-domain TE LSPs. This amendment provides support of different options of RSVP-TE LSPs and LDP LSPs. The multi-area LSP signaling requirements described in the subsections below are added to the end of Section 5.1.1 in TR-221 [2].

3.2.1 Multi-area RSVP-TE Signaling

Inter-domain TE LSPs can be supported by the following option as specified in RFC 5151:

- contiguous LSPs

Contiguous

A contiguous TE LSP is a single TE LSP that is set up across multiple domains using RSVP-TE signaling procedures described in Section 5.1.1/TR-221.

3.2.2 Multi-area LDP Signaling

RFC 5283 [8] facilitates the establishment of Label Switched Paths (LSPs) that would span multiple IGP areas in a given Autonomous System (AS).

[R-8] PE and P routers SHOULD support establishment of inter-area LSPs using LDP as per RFC 5283 [8].

3.3 Loop free alternates (LFA)

Loop-Free Alternates (LFA) provides local protection for unicast traffic in pure IP networks or MPLS networks with LDP signaling. In Section 5.3.3.3/TR-221 Resiliency Requirements, the following LFA support is added to the table.

MASG (PE router)	CSG (PE router)	P router	Requirement

MUST	MAY	MUST	[R-39a] Router supports Loop-Free Alternate (LFA) method of FRR for LDP LSP as per RFC 5286 [9], as well as support LFA FRR for the IGP on whose routes LDP depends.
SHOULD	MAY	SHOULD	[R-39b] Router supports extension to the Loop-Free Alternate (LFA) mechanism, described in RFC 5286, for providing additional backup connectivity for point-to-point links failures as per RFC 7490 [10].

3.4 Full E-Tree services using VPLS

MEF has defined a rooted-multipoint EVC based on E-Tree service type [1]. In a Rooted-Multipoint EVC, one or more of the UNIs must be designated as a Root and each of the other UNIs must be designated as a Leaf. An ingress Service Frame mapped to the EVC at a Root UNI may be delivered to one or more of the other UNIs in the EVC. An ingress Ethernet frame mapped to the EVC at a Leaf UNI must not result in an egress Ethernet frame at another Leaf UNI but may result in an egress Ethernet frame at some or all of the Root UNIs.

As defined in Section 9.3 of MEF 6.2, E-Tree service provides both P2P and P2MP connectivity between roots and leafs. Depending on the deployment scenario, efficiency may be improved using E-Tree compared with using E-LAN service, e.g., traffic between leaf sites is eliminated resulting in less traffic in the network, and less MAC address learning.

This sub-section describes how E-Tree per MEF6.2 is supported using VPLS in a PE.

Support of full E-Tree services using VPLS is OPTIONAL. When supported, the requirements in this section apply.

[R-9] A PE node MUST support transporting and processing E-Tree service frames per Section 5 of RFC 7796 [11].

[R-10] The following requirements apply for E-Tree signaling in VPLS:
- For a PE implementing LDP signaling for VPLS, E-Tree signaling per Section 6.1 of RFC 7796 [11] MUST be supported;
- For a PE implementing BGP signaling for VPLS, E-Tree signaling per Section 6.2 of RFC 7796 [11] MUST be supported.

Annex A: Seamless MPLS for Mobile Backhaul

[NORMATIVE]

Support of Seamless MPLS Architecture is OPTIONAL. When supported, the requirements in this section apply.

A.1 Mobile Backhaul Architecture

TR-221 network architecture supports MPLS transport in the RAN (see TR-221 sections 1.2 and 4). The location of MPLS function for the various TNL scenarios is flexible. The mobile backhaul requirements are changing due to introduction of small cells, LTE-Advanced, cloud RAN and fronthaul. The new direction creates an evolution from long-standing static mobile backhaul (private line) network to a dynamic mobile service network.

In the traditional multi-domain network, the domains are interconnected into an end-to-end service with discrete service activation points at the domain edge. When service providers add a new service, they must provision that service at the network edge, as well as at each domain edge. Seamless MPLS enables an end-to-end service and eliminates intermediate provisioning points.

A.2 Seamless MPLS

Seamless MPLS architecture can be used to extend MPLS networks to integrate access and aggregation networks into a single MPLS domain ("Seamless MPLS").

A seamless MPLS network is one in which all forwarding of packets within the network, from the time a packet enters the network until it leaves the network, are based on MPLS. Seamless MPLS introduces a systematic way of enabling MPLS end-to-end across all domains.

Seamless MPLS is not a new protocol suite but describes the architecture for deploying existing protocols. The architecture supports different services on MPLS fully integrating access, aggregation and core networks. The architecture can be used for residential services, mobile backhaul, business services and supports fast reroute, redundancy and load-balancing.

Seamless MPLS provides the deployment of service creation points anywhere in the network. Further it also allows service providers to move their services easily between different locations.

The key elements of this architecture are:

A.2.1 Separation of Service and Transport

Traditional network deployments are built with implicit coupling between the network nodes, the underlying transport technology, and the service delivery over the network. Typically, services are provisioned in multiple segments.

The separation of services and transport is one of the key elements; Seamless MPLS provides end to end service independent of transport. Therefore it removes the need for service specific configurations in network transport nodes.

With Seamless MPLS, the provisioning of services is end-to-end, it minimizes the number of provisioning points. The reason is, it only uses a single LSP across the access nodes instead of using multiple LSP segments, and the services are running on top of the LSP for transport.

A.2.2 Scalable Networks and Type of Nodes

The Seamless MPLS network supports multiple domains and hierarchy which enable scaling.

Seamless MPLS architecture supports several different types of *nodes*, each with a different function. A physical device can combine several of these functions. Conversely, a single function can require multiple physical devices for its execution. Seamless MPLS architecture specifies different node types. They are: Access Node (AN); Aggregation Node (AGN); Transport Node (TN) and Service Node (SN).

Access Node (AN)	An access node is a node which processes customer frames or packets at layer 2 or above.
Aggregation Node (AGN)	An aggregation node is a node which aggregates several ANs.
Transport Node (TN)	Transport nodes are used to connect access nodes to service nodes, and service nodes to service nodes.
Service Node (SN)	A service node is used to create service for customers and is connected to one or more TNs.

A physical device can play multiple roles (i.e., various nodes). For example, a single physical device can be an access node and can also be a service node, or a service node can double as a transport node.

A.3 Seamless MPLS Architecture

The intra-domain routing within each of the MPLS domains must use standard IGP protocols like OSPF or ISIS. Each of these domains is small enough so that there are no scaling issues.

For intra-domain MPLS LSP setup and label distribution use standard protocols like LDP and RSVP.

A.3.1 End-to-End Hierarchical LSP

Although regions add scale, they establish explicit boundaries and cut end-to-end transport into a few separate LSPs (i.e., an LSP per domain). To alleviate this problem, LSPs can be stitched between domains, extending the MPLS network over multiple domains in the MBH network. These LSPs are hierarchical end-to-end LSPs. Inside each domain, hierarchical LSPs are built on the metrics of existing control plane functionality using OSPF or IS-IS for routing, and RSVP or LDP for signaling. Meanwhile all inter-domain control plane information is shared with BGP-labeled unicast (BGP-LU). Transit routers within each domain are not required to detect or participate in BGP-LU, this increases BGP-LU scalability.

Border Nodes will usually need to take part in multiple IGP domains, for full isolation of the IGP of each domain, it can be desirable to have the IGPs of each domain run as separate instances. In that case, the maximum number of instances will be bounded by the number of domains.

PE routers supporting Seamless MPLS architecture should consider support of running multiple, isolated instances of ISIS.

PE routers supporting Seamless MPLS architecture should consider support of running multiple, isolated instances of OSPF.

A.3.2 Inter-Domain Routing

For scalability, the overall MPLS network is decomposed into multiple MPLS domains. The inter domain routing is used to establish control plane and forwarding plane hierarchies.

For inter domain LSP setup and label distribution requirements see section 5.1.1/TR-221 and section 3.2.

RFC 3107 [4] defines procedures for having BGP allocate labels for routes between BGP peers. By implementing RFC 3107 [4] at the Service Nodes and Border Nodes, it allows establishment of an end-to-end contiguous LSP towards remote PEs located in different IGP domains.

[R-11] PE routers supporting Seamless MPLS architecture MUST support using BGP-4 for label distribution per RFC 3107 [4].

To allow the domains to be isolated from each other from an IGP perspective, it will be required that the Border Nodes set the next hop of the labeled BGP prefixes to themselves, when progressing labeled BGP prefixes between domains.

[R-12] PE routers supporting Seamless MPLS architecture MUST support setting themselves as the next-hop of labeled BGP routes (“next-hop-self”) per RFC 3107 [4].

When the service loopback used to establish the hierarchical LSP is advertised both in labeled BGP and in the IGP/LDP, the Border Nodes will not further advertise the BGP prefix to other regions by default, as the node will prefer the service loopback prefix received by means of the

IGP and will not install the BGP route on the FIB. This situation can be resolved in two different ways:

- Using separate service loopbacks in the Service Nodes for hierarchical LSPs, not advertising them in the IGP
- Having the Border Nodes being capable of advertising labeled BGP prefixes even when they are not active in the node's FIB.

[R-13] PE routers supporting Seamless MPLS architecture SHOULD support using a second service loopback for hierarchical labeled BGP LSPs.

[R-14] PE routers supporting Seamless MPLS architecture SHOULD support advertising labeled BGP prefixes that are not active in the PE's FIB.

In order to provide fast convergence for the hierarchical LSP, it is desirable that the Service Nodes and Border Nodes support mechanisms to restore traffic after a failure in the network, such that the time it takes to restore the failure is independent of the number of BGP prefixes affected by the failure. BGP Prefix Independent Convergence (PIC) techniques provide such capabilities.

BGP Core PIC provides indirection of the IGP next-hop used to resolve a BGP peer, and together with IP/LDP LFA techniques provides fast convergence for intra-domain failures.

BGP Edge PIC provides indirection of the BGP next-hop for a prefix, and is used in Seamless MPLS scenarios in labeled BGP routes to provide fast recovery of failures affecting the ABR/ASBRs, by rapidly activating a pre-computed, alternative BGP next-hop for the affected Service Node loopbacks, advertised via labeled BGP.

Indirection mechanisms such as these should be considered for implementation.

A.3.3 Access Node

The access node functionality depends upon mode of architecture supported for Mobile backhaul. MPLS functionality in the access node should be kept to the smallest possible subset in particular for LDP.

[R-15] PE routers supporting Seamless MPLS architecture SHOULD support LDP Downstream on Demand label distribution as per RFC 5036 [6]. The default modes are:

- The default label retention mode is conservative.
- The default label distribution control mode is ordered.

Appendix A: Decoupling Services and Transport in Mobile Backhaul

[INFORMATIVE]

This Appendix provides examples of decoupling service and transport in mobile backhaul. Further it provides examples of LTE service profile and deployment scenarios.

TR-221 defines the use of MPLS in the access and aggregation network and provides solutions for the transport of traffic in various generation of mobile networks (e.g., HSPA, and LTE). This section provides some details on how seamless MPLS decoupling principle works in the MBH use case for LTE and HSPA scenarios. For this use case it is proposed to use two service profiles:

- End-to-end L3VPN deployment for LTE
- End-to-end L3VPN deployment for HSPA

Figure Ap.1 below, shows the functional roles of different network nodes for a LTE deployment scenario. In this example, the CSR in the access segment plays the role of both the access node (AN) and the service node (SN). It interconnects with the RAN and originates the L3 service. If routers in the aggregation domain function as BGP route reflectors, it serves as the RR function and as area border routers between the aggregation and access domain, corresponding to the border node (BN) function.

Some access and aggregation routers can have a pure transport node (TN) role as label-switching routers (LSRs). Aggregation routers have a border node (BN) function because they act as autonomous system (AS) boundary routers (ASBRs) or area border routers (ABRs) between the aggregation domain and the core domain, peering with the PE service router. In the core network, the remote service edge router acts as the service node (SN), connecting the evolved packet core (EPC) elements to the core network. A hierarchical end-to-end LSP established using BGP-LU provides connectivity between service nodes in the access and service nodes in the core network without any mid touch points between domains at transport or services layers.

Note that the ABRs/ASBRs must set themselves as the next-hop of the labeled BGP routes when propagating them between domains, and allocate their own downstream label for the route. They may optionally act as in-path Route Reflectors (RR) for the IPv4 labeled unicast BGP address family, reducing the amount of BGP peering sessions required inside a given region.

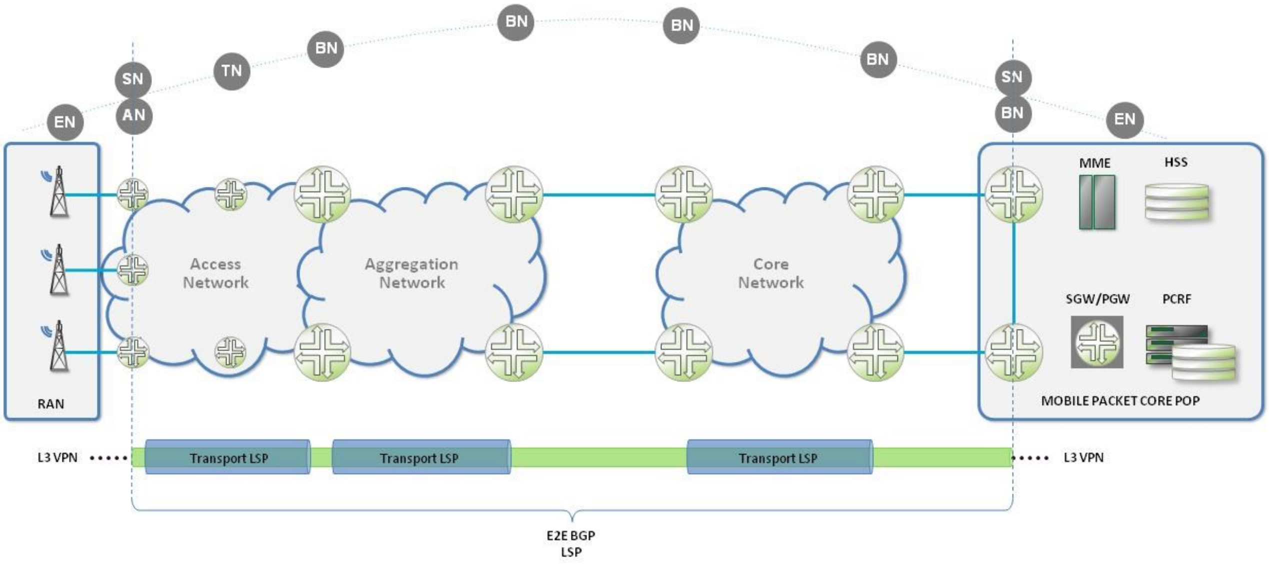

Figure Ap.1 Seamless MPLS functions in a 4G LTE backhaul network - end-to-end L3VPN

The example in Figure Ap.2 uses the same network topology as in the LTE example, but it serves now to backhaul HSPA traffic from NodeB to RNC. A Layer 3 connectivity is also used between mobile network domains in this example. In the access domain, the CSR has an access node (AN) function, together with an service node (SN) function. Because the HSPA radio network controller (RNC) is located closer to the mobile RAN, the service node function moves from the remote edge to the aggregation router shown near the RNC in the figure below. All the changes to the service plane happen independently from the transport plane, so that the transport plane is agnostic to changes in the service functions.

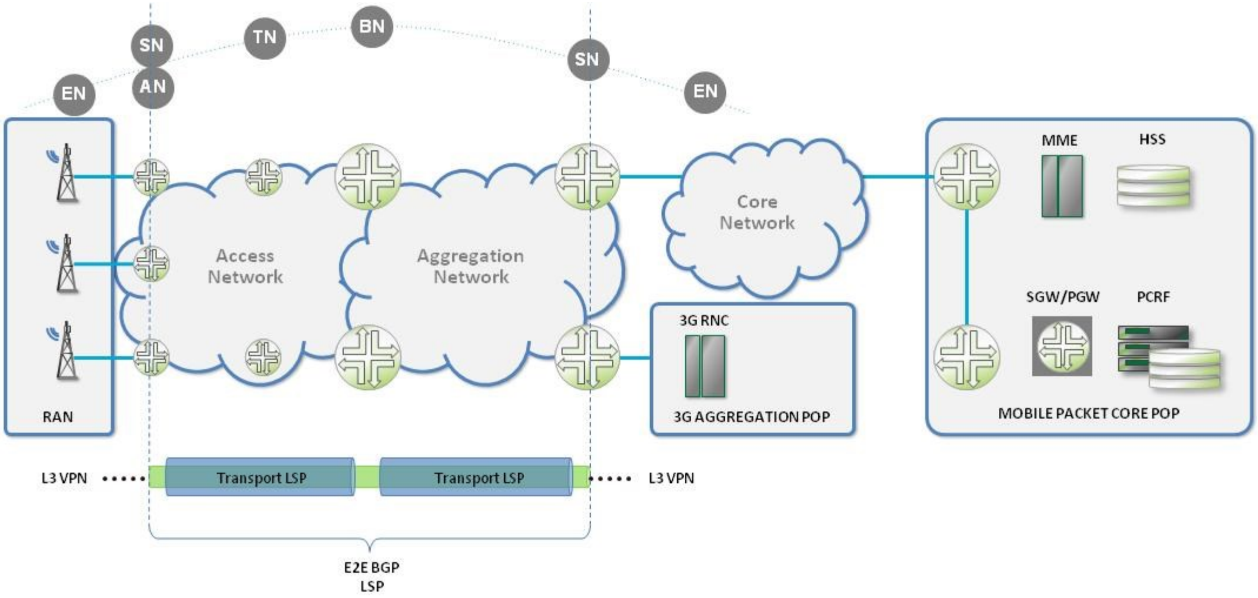

Figure Ap.2 Seamless MPLS Functions in an HSPA Backhaul Network

Ap.1 LTE Service Profile and Deployment Scenarios

The LTE mobile network uses an IPv4 infrastructure to interconnect its entities. Providing IPv4 over Ethernet connectivity is the main objective of the MBH network.

The following interfaces are defined within the LTE mobile infrastructure: S1-U; S1-MME; X2 (Signaling and User plane); eNodeB management and timing.

To provide connectivity between mobile network elements over an MBH network for these interfaces, the following deployment scenarios can be used:

- End-to-end L3VPN
- L2VPN to L3VPN termination
- L2VPN to VPLS termination (Hierarchical VPLS)

The following sections provide example of L3VPN with MPLS PW in access domain. Both service layer deployment and underlying transport infrastructure are provided.

Ap.1.1 L3VPN with MPLS PW in Access

Deploying Layer 3 VPN enables this deployment scenario with pseudowire in the Access.

Figure Ap.3 illustrates the recommended service architecture for a 4G LTE service profile. Each eNodeB is connected on individual physical Ethernet UNI of the MBH cell site router (CSR). At the UNI, a VLAN-tagged logical interface for 4G LTE eNodeBs represents the service. Separate logical Layer 2 interfaces are used at physical UNI of the CSR per mobile network interface (S1-MME, S1-U, X2). VLAN tagging is implemented at the UNI to separate traffic between logical interfaces. To connect an eNodeB to an access node or an EPC to a PE router, operators can use an arbitrary unique VLAN number within the 1 through 4094 range. The VLAN number has a local meaning within the port of each service node, so operators do not need to synchronize the VLAN number across the MBH network.

To extend Layer 3 service delivery from the service node, an MPLS pseudowire - LDP signaled pseudowire or BGP signaled Layer 2 VPN - is originated at each logical interface of the access node. The key design for this deployment scenario is that the access pseudowires are terminated directly into the Layer 3 VPN service instances without any intermittent breakout into Layer1, Layer 2, or VLAN connections.

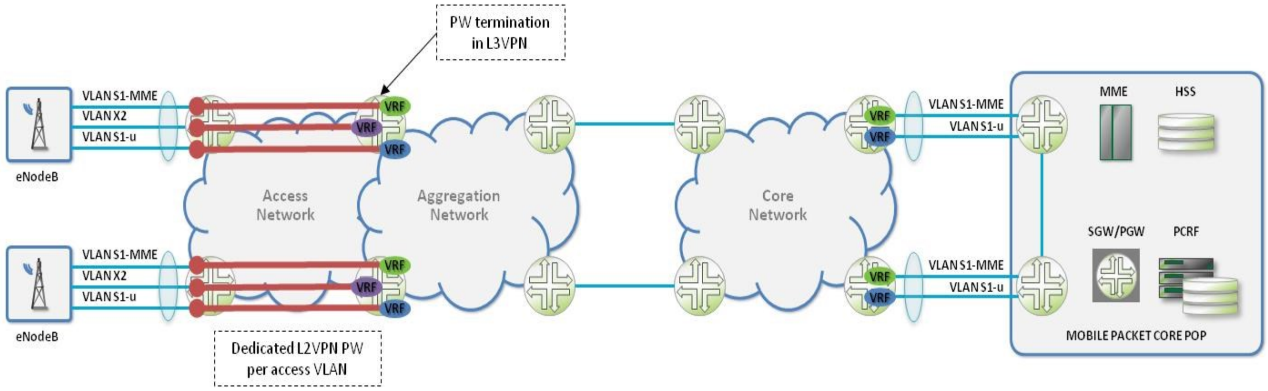

Figure Ap.3: 4G LTE Service Profile with Layer 3 VPN and PW in Access

Ap.1.2 Transport Infrastructure

Figure Ap.4 provides the full protocol stack for the MPLS transport and service portions of the solution. The full protocol stack and actions taken with MPLS labels when a CSR forwards an MPLS packet that travels across the network to a PE router (CSR-to-PE router).

In Figure Ap.4, the CSR must push a minimum of two labels - a Layer 2 VPN service label (PW) and a transport label (such as using RSVP-TE) for the intraregional LSP. The service label defines the endpoints across the access domain. Aggregation routers in Figure Ap.4 would apply a pop action to the Layer 2 VPN service label, push the new Layer 3 VPN service label, and send the packet end-to-end through the inter-domain LSP signaled with BGP-LU. Finally, the Layer 3 VPN service label is popped by the remote PE router, and the native IP packet is forwarded to the 4G EPC.

The RSVP or LDP signaled transport label defines packet forwarding within the IGP routing region. Service routers and domain boundary routers push or pop the RSVP or LDP transport label. Transport nodes swap the RSVP or LDP transport label.

The BGP-LU label provides reachability between routing regions, domains, and autonomous systems. It is pushed or popped at the service node and swapped at the ABR/ASBR nodes.

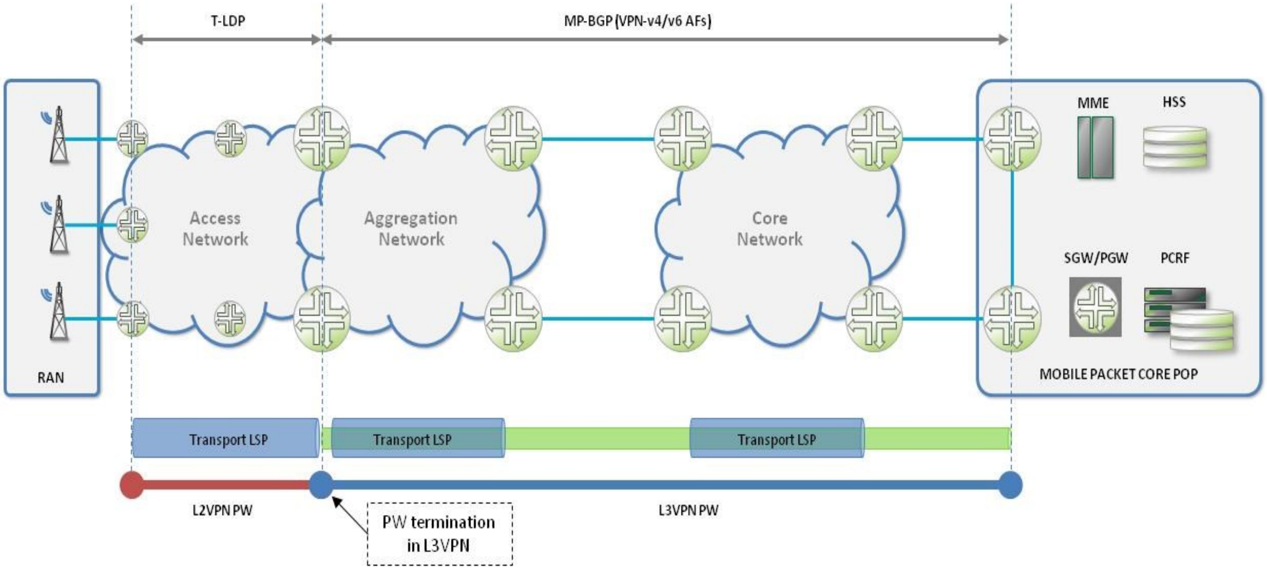

Figure Ap.4: Transport Infrastructure - Layer 3 VPN with PW in Access

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