



# **MPLS in Mobile Backhaul Networks Framework and Requirements**

## **Technical Specification**

**IP/MPLS Forum 20.0.0**

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# 1 Introduction

## 1.1 Purpose

This document provides the framework and requirements for the use of MPLS in mobile wireless access and aggregation networks. MPLS is used to provide transport services for mobile control and user plane traffic in different topologies (e.g., centralized and flat. See section 1.3.1 for details) used to support various RAN interfaces and technologies (e.g., GSM, UMTSLTE, mobile WiMAX, HSPA+ flat).

The framework includes a reference architecture covering centralized mobile networks that is intended to be broad enough to cover the deployment cases of interest, together with use cases for MPLS in this reference architecture. The framework includes also a reference architecture covering flat mobile networks with generic MPLS use cases that can be used for mobile backhauling.

## 1.2 Overview

### 1.2.1 Motivation

Mobile wireless backhaul networks are required to support services that are delay and loss sensitive, that are used for revenue generating and mission critical applications and thus expect a high level of network availability. These networks must support the evolution from TDM-based backhaul, ATM based backhaul through to IP/MPLS-based backhaul for e.g., 3G, mobile WiMAX [WiMAX-IEEE] and LTE. The transport infrastructures available to mobile operators also vary widely, from SONET/SDH, PDH and ATM, to Ethernet.

The motivations for the use of MPLS<sup>1</sup> in mobile wireless network are thus:

- MPLS supports the transport of a wide range of layer 2 and layer 3 services, including TDM, ATM, HDLC and IP, and is thus able to support the migration from legacy (TDM and ATM) to IP based RANs. It also supports the migration to a PSN network.
- MPLS provides a range of resiliency and OAM functions that can be used to ensure the reliability of the mobile wireless backhaul.
- MPLS provides traffic engineering and QoS capabilities that enable better management of network resources in the transport network, maximizing the utilization of the network infrastructure and thus the return on investment of the network operator, while also supporting the QoS objectives of mobile wireless services.
- MPLS allows network operators to provide access/aggregation services to different sets of mobile operators using both legacy and near-term technologies over a converged network.

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<sup>1</sup> MPLS in this document refers to IP/MPLS defined by the IETF. This specification does not preclude the use of any subset of MPLS capable of meeting the requirements in this document.

- MPLS can run over a range of underlying transport infrastructures, including Sonet/SDH, PDH and Ethernet, to provide consolidated transport services to the mobile backhaul network.
- MPLS includes a control plane that can ease provisioning.
- MPLS provides a comprehensive set of protection and restoration mechanisms.

### 1.3 Scope

There is a range of technologies that may be used to transport wireless traffic in the access, aggregation, and core networks. For example, in the aggregation network the choices can include IP forwarding, ATM, Ethernet, and MPLS.

This framework specification focuses on the application of MPLS technology in these networks. The cell site gateway interfaces and access network technologies considered in this specification may be MPLS-based. At the same time, it is recognized that portions of the network based upon MPLS may interface with portions based on IP forwarding, ATM or Ethernet. However, details of the use of other technologies in the aggregation and core of the network are outside the scope of this specification.

Expected services over this transport network include: real-time voice, multimedia services, data traffic and multicast e.g., MBMS and broadcast services. As such the solution must provide the requisite Quality of service (QoS) and traffic engineering (TE) capabilities to support the reference architecture

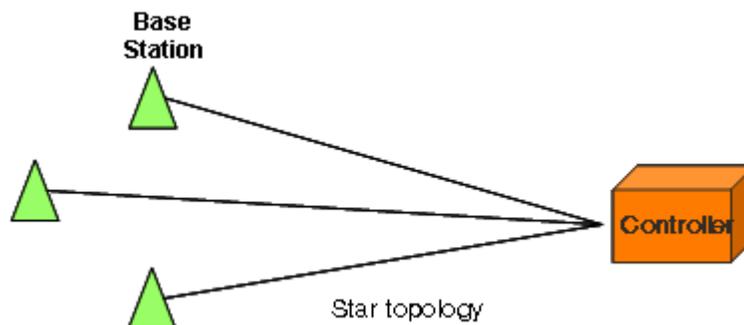
The scope of this specification includes the following:

- The use of MPLS technology to backhaul mobile wireless traffic (user plane and control plane) over access and aggregation networks. While MPLS is widely deployed in the mobile core network, the use of MPLS technology in the core network is not within the scope of this specification. The scope is to include several RAN interfaces e.g., Abis for GSM, Iub for UMTS, A15, A8, A9 for CDMA, S1/X2 for LTE, R6/R2/R8 for WiMAX over the Access/Aggregation network portion. Other RAN interfaces are not precluded, but are not explicitly considered in this document.
- 3GPP and 3GPP2 networks such as 2G, 2.5G, 3G, LTE as well as mobile WiMAX networks, including consideration for the evolution from 2G and 2.5G to 3G and LTE.
- The use of a shared network infrastructure to support at the same time centralized mobile networks (as legacy 2G/3G Release R3/R4 and new 3G Release R5/R6/R7), as well as flat mobile networks (as LTE and mobile WiMAX networks).
- Generic QoS requirements for support of mobile services.
- Requirements for supporting clock distribution to the base stations, including frequency, phase, and time synchronization.
- Resiliency requirements taking into account failover times appropriate for wireless backhaul networks.
- OAM requirements and capabilities for the MPLS network.
- RAN equipment with a range of physical interfaces (e.g., T1/E1, STM1/OC3, DSL, Fast Ethernet, Gigabit Ethernet, etc.) and technologies (PDH, SDH, ATM and ATM/IMA, PPP, Ethernet, etc.), connected through an intervening access and aggregation network.

- Support for different kinds of access transmission technologies: point-to-point access (xDSL, microwave, Fiber), point-to-multipoint access (GPON, WiMAX).
- The framework allows for a converged access/aggregation network supporting both wireline, e.g. residential and enterprise, and wireless services.
- MPLS facilities in the Access and/or Aggregation networks which may be leased from a third party.
- The following Transport Network Layers (TNLs) are within scope of this specification: TDM TNL (e.g., for 2G), HDLC TNL (may be used for CDMA), ATM TNL (e.g., for 3G R3/R4/R5) and IP TNL (e.g., for 3G R5 and beyond, LTE and WiMAX) (Note for definition of TNL please see: section 2.)
- Support for a smooth migration strategy for network operators as the IP TNL is introduced and legacy TNLs are phased out.
- Tunneling technologies such as GRE are not precluded, although specific requirements are not provided.
- Security requirements that apply to the MPLS network; however security requirements that apply to services carried over the MPLS network are not considered, and are assumed to be supported where needed through higher level mechanisms (e.g., IPSec).

### 1.3.1 RAN Topology Differences

Regardless of the RAN topologies which may be **centralized** or **flat**, the different topologies must be supported by the underlying MPLS network. As presented in Figure 1, the RAN architecture for centralized mobile networks relies on star topology enabling communication from BS to Controller and from Controller to BS.



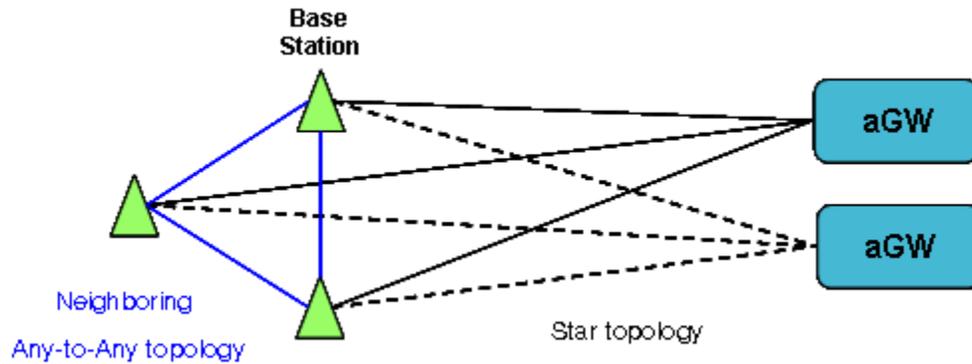
**Figure 1: RAN topology for centralized mobile networks**

As presented in Figure 2, RAN architecture for flat mobile networks relies on:

- Star topology enabling communication from BS to aGW and communication from aGW to BS.

- Neighboring any-to-any topology enabling communication between BSs.

Figure 2 depicts a neighboring any-to-any topology within a group of BSs that require connectivity between them. The flat architecture is described in detail for 3GPP LTE in 3GPP TS 36.300, and for mobile WiMAX [WiMAX-IEEE] in WiMAX Forum Network Architecture [WiMAX-Arch].



**Figure 2: RAN topology for flat mobile networks**

The “mobile backhauling term” is usually used to represent the first segment of transport network used to carry mobile traffic:

- between BS and controller for centralized mobile networks (e.g. Abis interface for GSM, Iub interface for UMTS)
- between BS and Access Gateways (aGW) (e.g. S1 interface for LTE, R6 interface for mobile WiMAX) and between BSs (e.g. X2 interface for LTE, R8 interface for WiMAX) for flat mobile networks

The mobile backhauling network typically includes Access and Aggregation networks.

Note: The association in this document between RAN interfaces and topologies is done for illustrative purposes and does not constitute hard and fast requirements. The same network can be used to support both topologies at a given time. For example, a VPLS network could be used to support LTE interfaces as well as multi-homing of BSs to RNCs in WCDMA.

## 2 Definitions

**must, shall or mandatory** — the item is an absolute requirement of this Technical Specification.

**should** — the item is desirable.

**may or optional** — the item is not compulsory, and may be followed or ignored according to the needs of the implementer.

**TNL** - Transport Network Layer as defined by 3GPP (e.g. in [TS 25.401], [TS 25.933]). It should also be noted that there is a possible difference between the TNL and what is transported over MPLS.

**Node B** – Terminology used in UMTS to denote the Base Transceiver Station

## 3 Acronyms

Acronym	Description
aGW	Access Gateway (MME GW, S-GW, ASN GW)
ASN GW	Access Service Network - GateWay
ATM	Asynchronous Transfer Mode
BFD	Bidirectional Forwarding Detection
BS	Base Station
BTS	Base Transceiver Station
BW	Bandwidth
CDMA	Code Division Multiple Access
CE	Customer Edge
CSG	Cell Site Gateway
ECMP	Equal Cost Multi-Path
EDGE	Enhanced Data Rates for GSM Evolution
EPC	Evolved Packet Core
FDD	Frequency Division Duplex
GPRS	General Packet Radio Service
GRE	Generic Router Encapsulation
HSPA	High Speed Packet Access
IETF	Internet Engineering Task Force
IP	Internet Protocol
ITU-T	International Telecommunication Union - Telecom
LDP	Label Distribution Protocol
LSP	Label Switched Path
LTE	Long Term Evolution

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MASG	Mobile Aggregation Site Gateway
MEF	Metro Ethernet Forum
MME	Mobility Management Entity
MPLS	Multi Protocol Label Switching
MS-PW	Multi-segment Pseudowire
OAM	Operations, Administration and Management
P	Provider
PE	Provider Edge
POS	Packet over SONET / SDH
PPP	Point to Point Protocol
PSC	Packet Switch Capable
PSN	Packet Switched Network
PW	Pseudowire
QoS	Quality of Service
RAN	Radio Access Network
RC	Radio Controller (e.g. BSC, RNC)
RFC	Request for Comments
RNC	Radio Network Controller
RSVP-TE	Resource Reservation Protocol with Traffic Engineering Extensions
S-GW	Serving – Gateway
SONET	Synchronous Optical NETwork
S-PE	Switching PE
TDD	Time Division Duplex
TDM	Time Division Multiplexing
TE	Traffic Engineering
TNL	Transport Network Layer
T-PE	Terminating PE
UMTS	Universal Mobile Telecommunications System
UNI	User-to-Network Interface
VCCV	Virtual Circuit Connectivity Verification
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
VPWS	Virtual Private Wire Service
WCDMA	Wideband Code Division Multiple Access

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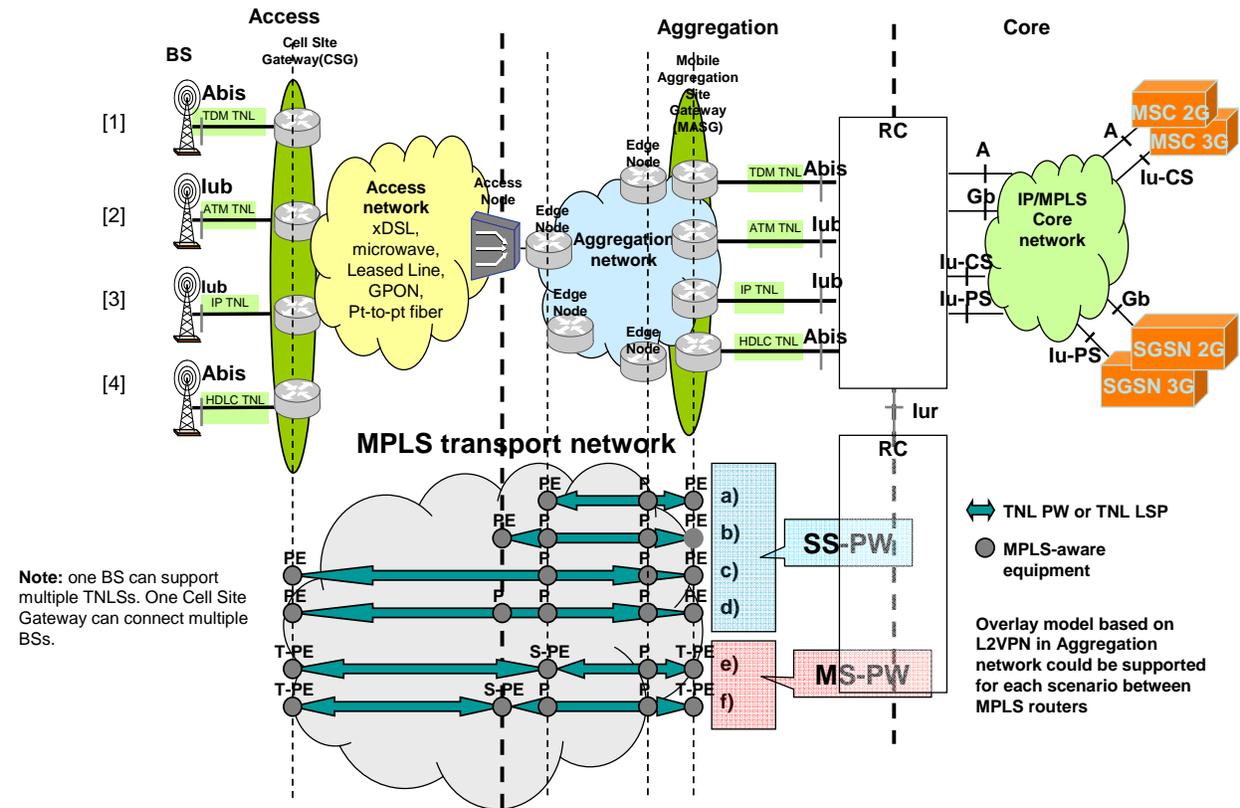
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### 5 Reference Architecture for Centralized Mobile Networks

Figure 3 provides a reference architecture applied to centralized mobile networks, depicting the Access, Aggregation and Core parts of the mobile backhaul network according to the type of TNL used over the Abis/Iub interface. This reference architecture corresponds to current and near-term mobile 3G technologies (3GPP and 3GPP2).

The RAN topology differences are discussed in section 1.3.1.



**Figure 3: Reference Architecture for centralized mobile networks with MPLS use cases for TNL transport**

This reference architecture shows various MPLS use cases that are based upon the type of the Transport network layer (TNL) carried over the MPLS network. This reference architecture gives an overview of the functional architecture without dealing with network node architecture. Four types of TNL are considered in the work item (TDM TNL, ATM TNL, HDLC TNL and IP TNL) according to the mobile network generation. TDM TNL is used for 2G/2.5G networks (GSM/GPRS, TDMA, and CDMA). HDLC TNL may be used for CDMA networks. ATM TNL is used for UMTS-R99, R4 networks, and IP TNL is

used for UMTS R5, R6, R7, CDMA 2000, 3GPP2 networks. Figure 3 presents different TNL scenarios using MPLS technology in Access/Aggregation networks to transport all these kind of TNL. A detailed listing is provided in Table 1.

**Table 1: Different RANs of Centralized Mobile Networks with Corresponding TNL**

Network	Specification	TNL
GSM/GPRS/EDGE (2G/2.5G)		TDM
UMTS	R3, R99/R4	ATM
	R99/R5, R6, R7	ATM
		IP
CDMA 1x-RTT	IS-2000	HDLC or TDM
CDMA 1x EV-DO	IS-856	IP

In the context of this work, the scenarios arising out of these TNLs are hereafter referred to as *TNL Scenarios* since they refer to the transport service provided by the MPLS network to the mobile network. Thus we have the following TNL scenarios:

1. TDM TNL
2. ATM TNL
3. IP TNL
4. HDLC TNL

For each supported TNL scenario, the MPLS transport network may extend from the RNC to various nodes in the mobile Access/Aggregation network, as indicated by cases (a) through (f). These are referred to as MPLS use cases.

Note: It should be noted that the TNLs associated with the RAN technologies above are the typical case but do not constitute absolute requirements. E.g., 2G/GSM RAN equipment can be retrofitted to work over an IP TNL.

## 5.1 TNL Scenarios for MPLS in centralized mobile networks

As mentioned above, four TNL scenarios are identified for MPLS in centralized mobile networks based upon the interface or Transport Network Layers used between BS (BTS or NodeB) and Controllers (BSC or RNC).

The interworking function (IWF) necessary to transport traffic of the emulated service over MPLS is performed in the edge node, or in the access node, or at the CSG or MASG at the edge of the MPLS network. These nodes perform the MPLS PE function.

### Case 1 – TDM TNL

Case 1 refers to a TDM layer featured in the 2G TNL: it covers base stations communicating by means of TDM bit streams (T1/E1/T3/E3/OC-3c/STM-1c). This case covers RAN equipment connected with a T1/E1 interface.

## Case 2 – ATM TNL

Case 2 refers to an ATM layer featured in the R3/R4 3G TNL: it covers RAN equipment communicating by means of ATM cells on the Iub interface. This case covers RAN equipment connected with I.432.3 E1 interfaces, or STM-1 interfaces.

## Case 3 – IP TNL

Case 3 refers to an IP layer (e.g. in the R5/R6/R7 3G): it covers RAN equipment communicating by means of IP packets. The MPLS PE function may transport the IP traffic using IPoEthoMPLS using e.g., L2VPNs or IPoMPLS using e.g., L3VPNs as a transport solution. Encapsulation of IP traffic over MPLS can be performed either in the edge node, in the access node, in the Cell Site Gateway, or in the Mobile Access Service Gateway. Note that there is no explicit Ethernet TNL defined. It is envisioned that the IP TNL uses Ethernet as its underlying layer 2 just as it could use other layer 2 protocols.

## Case 4 – HDLC TNL

Case 4 refers to an HDLC layer e.g., featuring in the CDMA 1x-RTT TNL: it covers RAN equipment communicating by means of HDLC-encoded bit streams on a TDM interface. .

## 5.2 MPLS use cases in centralized mobile networks

All encapsulation over MPLS solutions performed in the CSG require suitable adaptation mechanisms in the MASG to provide a compliant interface between base station and RC. Figure 1 depicts an MPLS-based mobile backhaul network connecting Base Stations to RCs. In the reference architecture, the location of MPLS functions for the various TNL scenarios is flexible i.e. the MPLS interworking functions required to transport mobile traffic (TNL) could be located in the Edge Node, in the Access Node, in the CSG, or in the MASG.

When the Ethernet interfaces below are connected together using Ethernet services, the interfaces may take the form of the MEF interfaces as specified in MEF MBH IA [MEF MBH], depending on the service provided and the administrative domains. For other layer 2 technologies, their respective layer 2 standardized interfaces apply.

Various MPLS use cases arise based on the location of MPLS functions and the extent of MPLS in the mobile backhaul network. Cases (a) through (f) in Figure 1 depict these MPLS use cases through the Access and Aggregation networks based on Single Segment (SS) PW (cases (a) through (d)) or Multi-Segment (MS) PW (cases (e) and (f)):

- a. MPLS transport is used between the Edge Node (EN) and the MASG via a Single Segment Pseudowire (SS PW) carrying a TNL
- b. MPLS transport is used between the AN and the MASG via a Single Segment Pseudowire (SS PW) carrying a TNL.
- c. MPLS transport is used between the CSG and the MASG, with AN transparent to MPLS. A Single Segment Pseudowire (SS PW) carrying a TNL is established between CSG and MASG acting as PE devices while all MPLS nodes in the Aggregation network act as P routers.
- d. MPLS transport is used between the CSG and MASG, with an Access Node that is MPLS-aware. A Single Segment Pseudowire (SS PW) carrying a TNL is established between CSG and MASG acting as PE devices while AN and MPLS devices in the Aggregation network act as P routers.

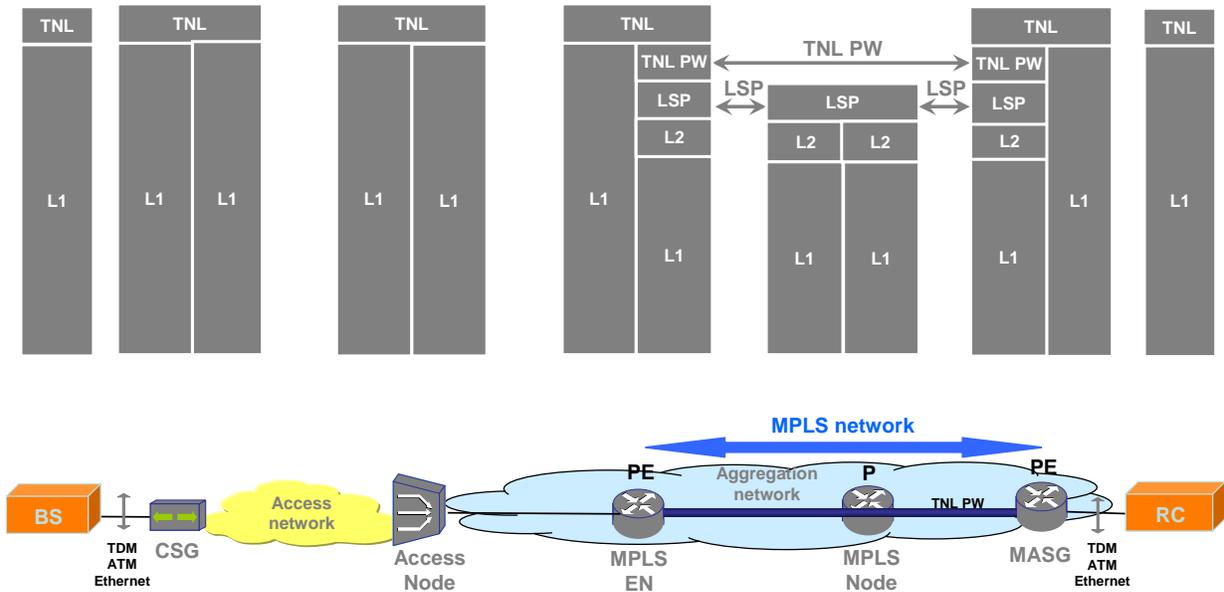
- 
- e. A Multi-Segment Pseudowire (MS PW) carrying a TNL is established between CSG and MASG acting as T-PE devices while EN acts as S-PE device.
  - f. A Multi-Segment Pseudowire (MS PW) carrying a TNL is established between CSG and MASG acting as T-PE devices while AN acts as S-PE device.

For each MPLS use case, an **overlay model** based upon L2VPN could be used between any MPLS routers. L2VPN can be based upon VPWS or VPLS in the Aggregation network, and even down to the AN. This overlay model relies on the separation of IP control planes: there is one IP control plane to support MPLS carrying TNL, and another IP control plane used for the Aggregation network which is completely independent from the previous one. It is important to note that in this overlay model TNL is carried over PWoEth at CSG/MASG and the Ethernet layer is carried over L2VPN in the Aggregation network (including AN optionally). This overlay model could be chosen by operators to tackle operational or equipment constraints.

Note that in scenarios (e) and (f), the PW segments in the access network are built between equipment that are directly connected (i.e. there is no intervening MPLS-aware equipment). These PW segments are between the CSG and EN (scenario e) or between the CSG and AN (scenario f). These PW segments may be carried over a physical layer with constrained bandwidth, such as a leased line or microwave circuit. To support efficient transport for these bandwidth-constrained PW segments, an implicit null PSN tunnel label may optionally be used in these scenarios where the PE nodes are connected at layer 2 or below without any intervening IP/MPLS devices.

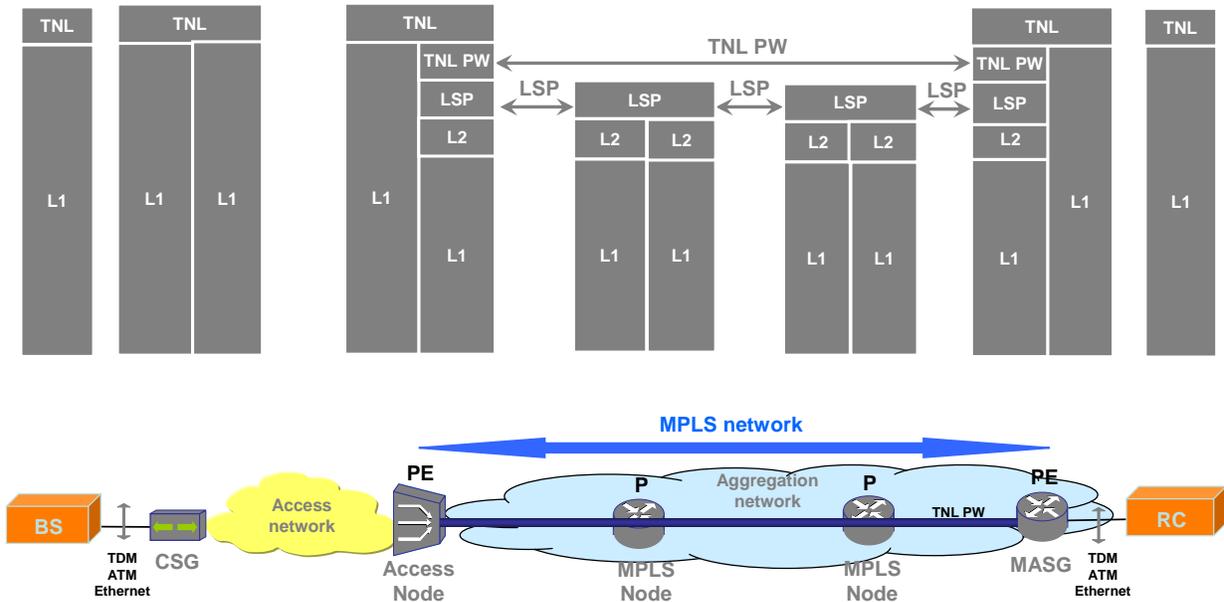
### 5.2.1 TNL encapsulation

This section describes the protocol stacks used by Access/Aggregation network nodes to transport TNL for each MPLS deployment scenario described in section 5.1. Note: For the figures below, in the case of the IP TNL, the IP TNL runs over a layer 2 protocol and in turn over layer 1.



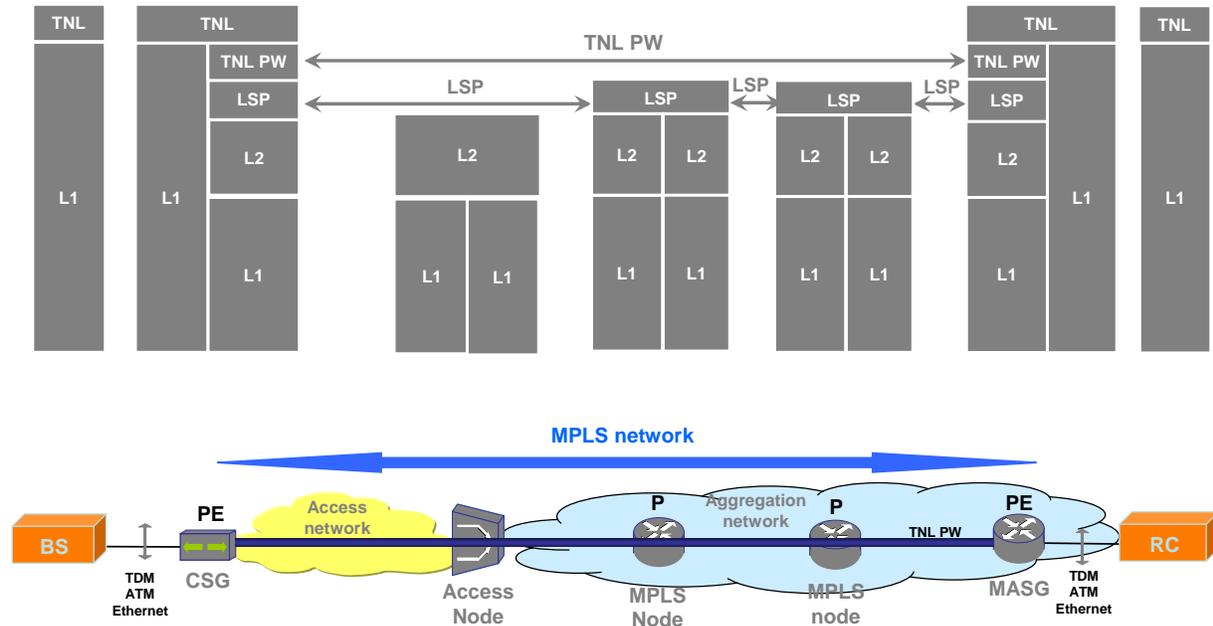
**Figure 4: Protocol stacks used for TNL transport in MPLS use case (a)**

In Figure 4, MPLS extends across the aggregation network. The PSN tunnel is switched at the P routers.



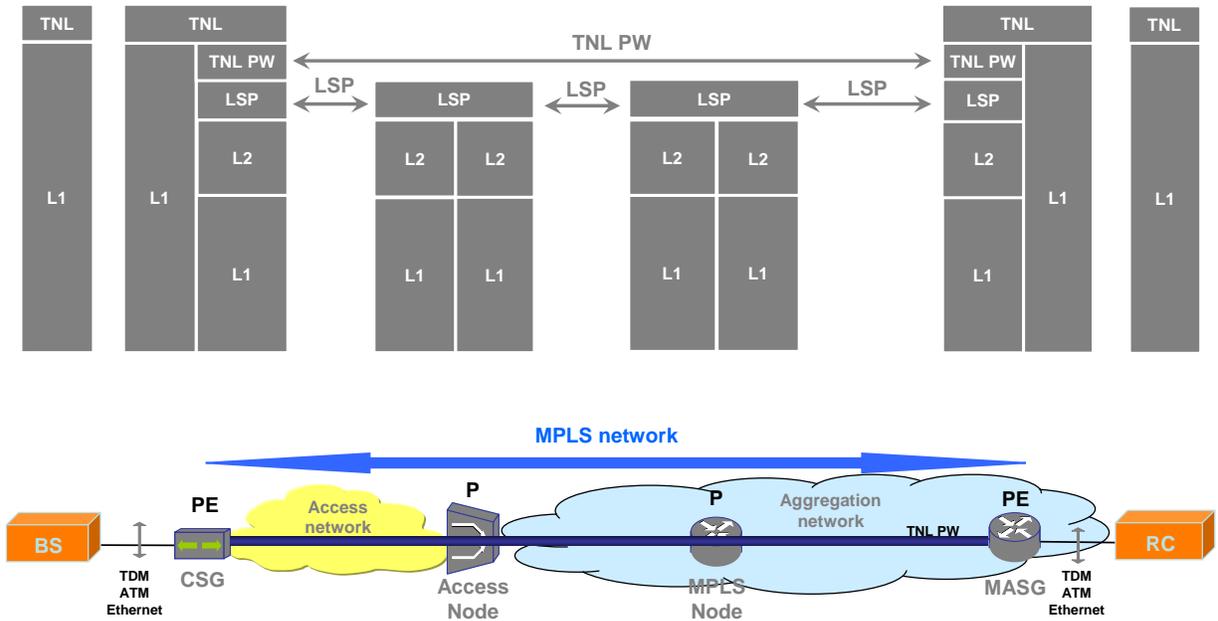
**Figure 5: Protocol stacks used for TNL transport in MPLS use case (b)**

In Figure 5, MPLS extends across the aggregation network, and further downstream to the PE device at the edge of the access network. The PSN tunnel is switched at the P routers.



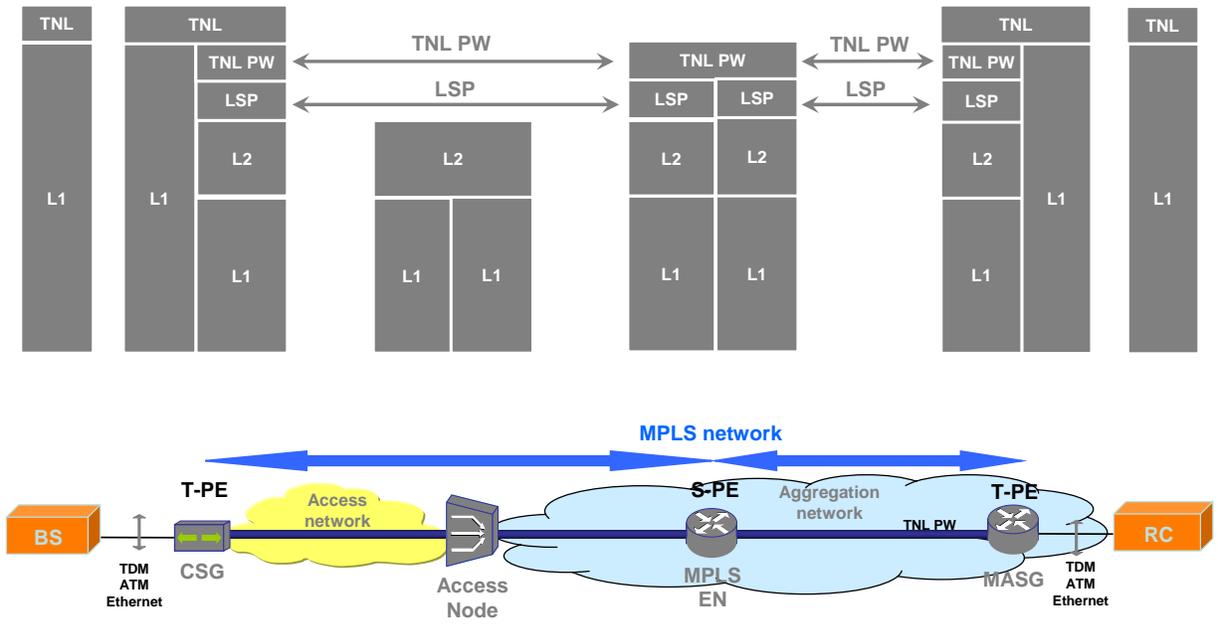
**Figure 6: Protocol stacks used for TNL transport in MPLS use case (c)**

In Figure 6, MPLS extends across the aggregation and access networks. The Access Node is not MPLS-aware. The PSN tunnel is switched at the P routers.



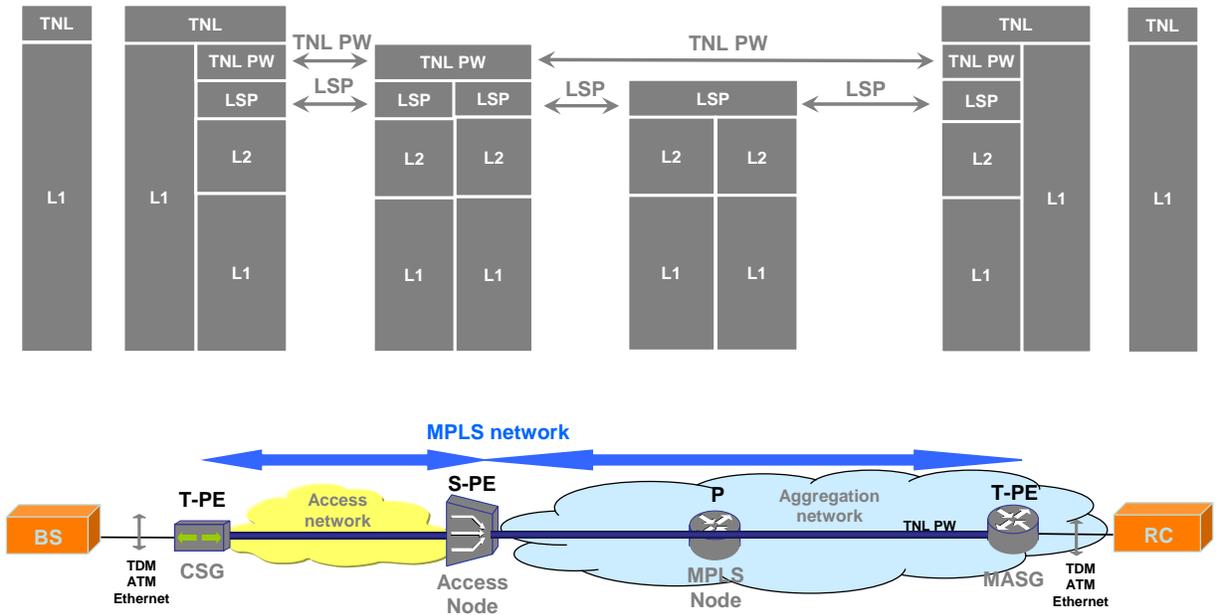
**Figure 7: Protocol stacks used for TNL transport in MPLS use case (d)**

In Figure 7, MPLS extends across the aggregation and access networks. The Access Node is MPLS-aware, acting as a P router. The PSN tunnel is switched at the P routers.



**Figure 8: Protocol stacks used for TNL transport in MPLS use case (e)**

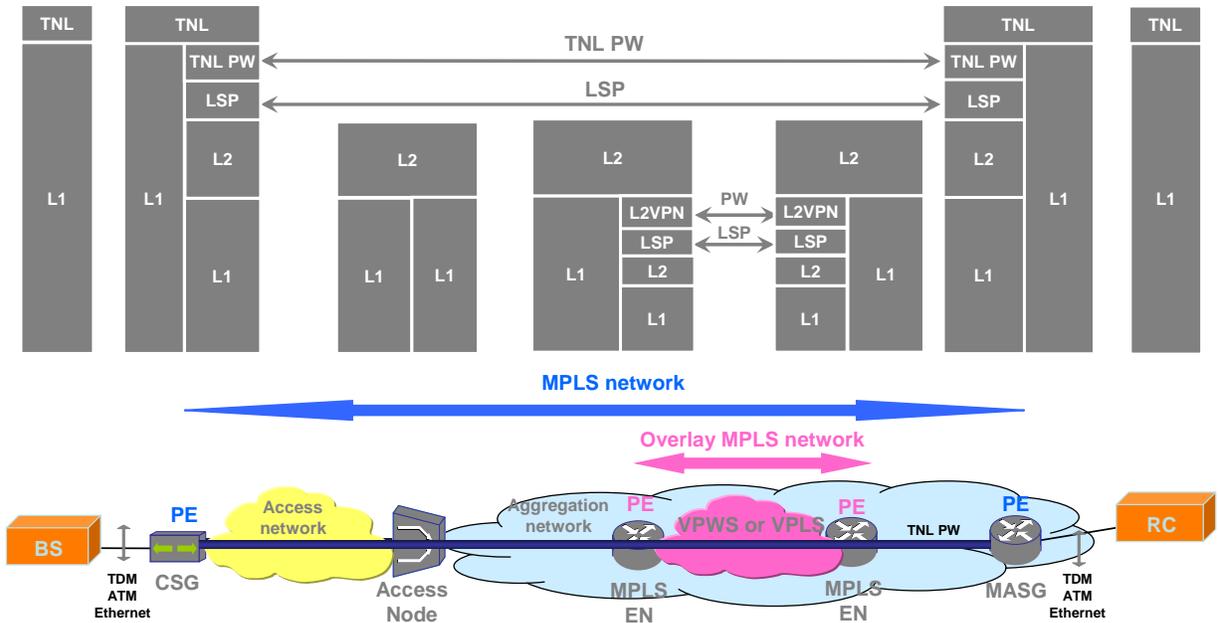
In Figure 8, MPLS extends across the aggregation and access networks. The Access Node is not MPLS-aware. The MS-PW segments are switched at the S-PE device.



**Figure 9: Protocol stacks used for TNL transport in MPLS use case (f)**

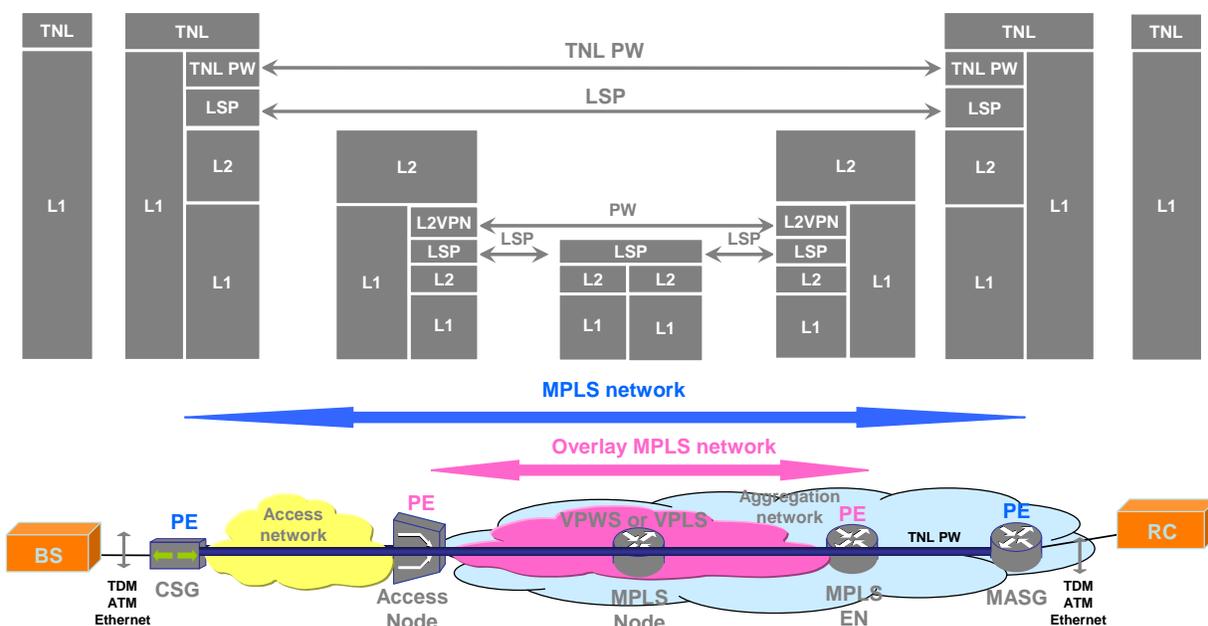
In Figure 9, MPLS extends across the aggregation and access networks. The Access Node is MPLS-aware, acting as an S-PE device. The MS-PW segments are switched at the S-PE device.

Note: in the case of scenarios (e) and (f) (figures 8 and 9 respectively), an implicit null LSP label may optionally be used for the MS-PW segment between directly-connected equipment across the access network, i.e. for the segment between the CSG and IP/MPLS Router (Edge Node) in scenario e, or for the segment between the CSG and Access Node in scenario f.



**Figure 10: Protocol stacks used for TNL transport in MPLS use case (c) with overlay model in Aggregation Network**

Figure 10 illustrates the encapsulation stacks for the overlay model applied to MPLS use case (c) with L2VPN used in the Aggregation network. In this scenario, MPLS extends across the aggregation and access networks. The Access Node is not MPLS-aware. VPWS or VPLS is used in the aggregation network to transport the Ethernet layer carrying the TNL.



**Figure 11: Protocol stacks used for TNL transport in MPLS use case (c) with overlay model to Access Node**

Figure 11 illustrates the encapsulation stacks for the overlay model applied to MPLS use case (c) with L2VPN used in the Aggregation network down to the AN. In this scenario, MPLS extends across the aggregation and access networks. The Access Node is MPLS-aware, acting as a PE device. VPWS or VPLS is used across the AN and aggregation network to transport the Ethernet layer carrying the TNL.

## 6 Reference Architecture for Flat Mobile Networks

IP TNL is the unique TNL that is utilized in flat mobile networks. The reference architecture presented here applies to flat mobile networks (LTE, mobile WiMAX, HSPA+ flat, and UMB). There are 2 different solutions based upon MPLS that could be used to transport IP TNL in the Access/Aggregation/Core networks: L2VPN MPLS and L3VPN MPLS solutions. MPLS use cases have to support connectivity requirements related to flat mobile networks depicted in 1.2.2, i.e. on one hand connectivity between BS and aGW, and on the other hand connectivity between BSs.

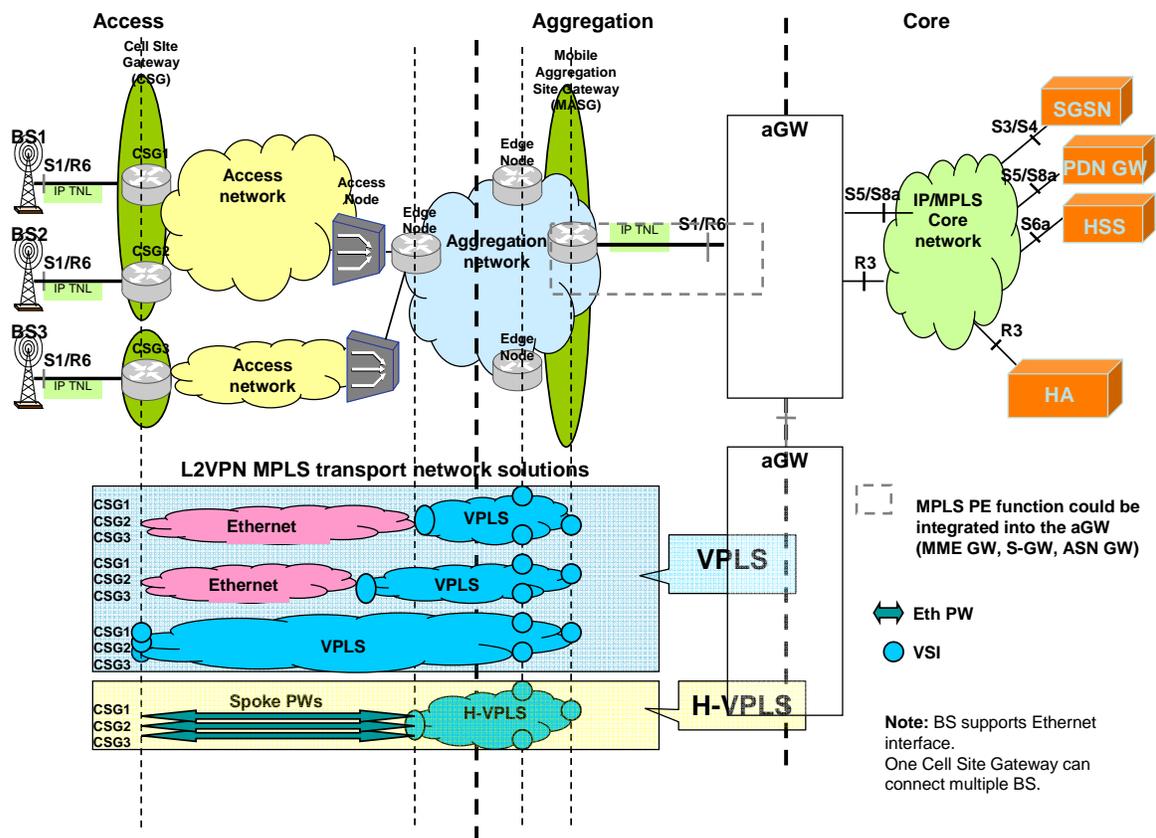
The RAN topology differences are discussed in section 1.3.1.

When the Ethernet interfaces below are connected together using Ethernet services, the interfaces may take the form of the MEF interfaces as specified in MEF MBH IA [MEF MBH], depending on the service

provided and the administrative domains. For other layer 2 technologies, their respective layer 2 standardized interfaces apply.

### 6.1 L2VPN MPLS use cases

Figure 12 provides the reference architecture for flat mobile networks using L2VPN MPLS [RFC4762 or RFC4761], depicting the Access, Aggregation and Core parts of the mobile backhaul network to transport IP TNL over the interface between BS and aGW on one hand, and over the interface between BSs on the other hand. It is important to note that the same L2VPN MPLS transport solution has to be used to backhaul both the BS-aGW interface and the BS-BS interface in order to have a homogeneous and efficient solution.



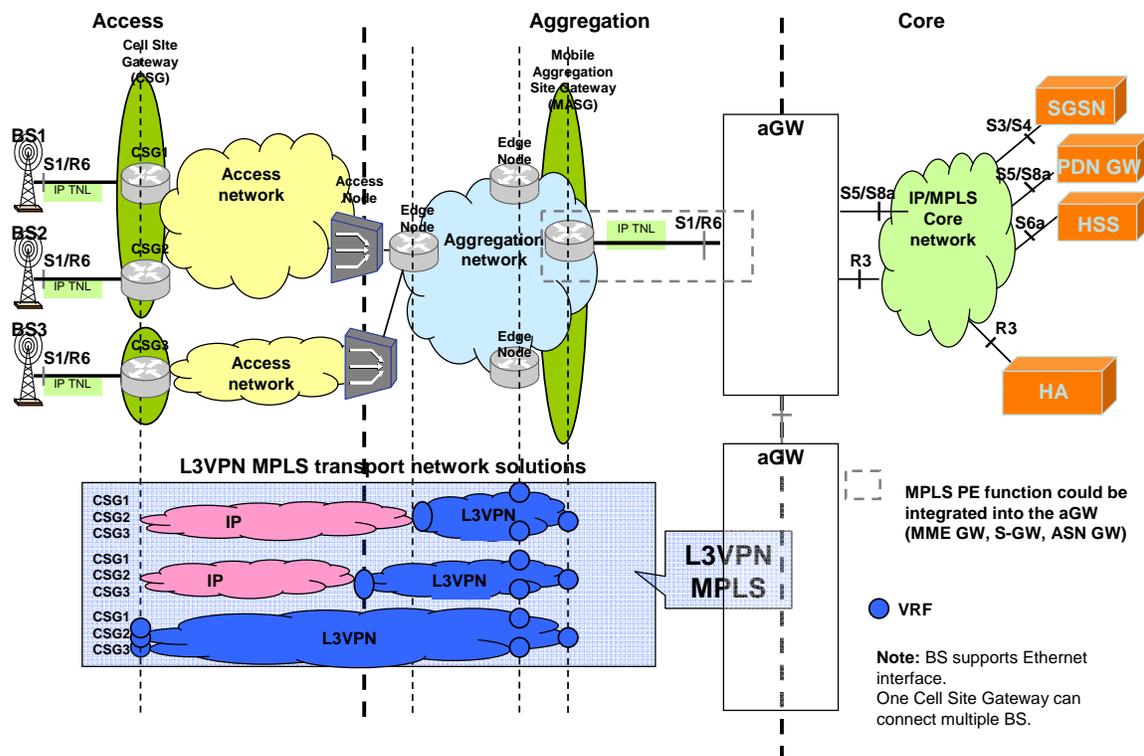
**Figure 12: Reference Architecture for Flat Mobile Networks with L2VPN MPLS Transport in the Access (optional)/Aggregation/Core networks**

### 6.2 L3VPN MPLS use cases

Figure 13 provides the reference architecture for flat mobile networks using L3VPN MPLS, depicting the Access, Aggregation and Core parts of the mobile backhaul network to transport IP TNL over the

interface between BS and aGW on one hand and over the interface between BSs on the other hand. It is important to note that the same L3VPN MPLS transport solution [RFC4364] has to be used to backhaul both the BS-aGW interface and the BS-BS interface in order to have a homogeneous and efficient solution.

The connectivity between the CSG and the L3VPN in the access network can be provided by a native layer 2 technology or emulated using e.g., VPWS or VPLS.



**Figure 13: Reference Architecture for Flat Mobile Networks with L3VPN MPLS Transport in the Access (optional)/Aggregation/Core networks.**

### 6.3 IP TNL Scenario

As mentioned before, only the IP TNL is used in flat mobile networks (e.g., LTE, HSPA+ flat, mobile WiMAX, UMB) on the mobile interfaces between BS and aGW, and on the mobile interfaces between BSs for control plane and user plane (e.g. S1/X2 for LTE, R6/R8/R2 for WiMAX).

This scenario covers RAN equipment communicating by means of IP packets. The MPLS PE function may transport the IP traffic using IPoEthoMPLS using e.g., L2VPNs or IPoMPLS using e.g., L3VPNs as a transport solution. Note that there is no explicit Ethernet TNL defined. It is envisioned that the IP TNL uses Ethernet as its underlying layer 2 just as it could use other layer 2 protocols.

**Table 2: Different RANs of Flat Mobile Networks using IP TNL**

<b>Network</b>	<b>Specification</b>	<b>TNL</b>
HSPA+ flat	3GPP R7	IP
LTE	3GPP R8	
Mobile WiMAX	Mobile WiMAX architecture R1.2	
UMB	3GPP2 C.S0084	

For inter BS-aGW connectivity, the encapsulation of IP or Ethernet traffic over MPLS can be performed on the Aggregation side in the MASG or aGW, and on the BS side in the Edge node, Access node, or Cell Site Gateway.

For inter-BS connectivity, encapsulation of IP or Ethernet traffic over MPLS can be performed in the Edge node, in the Access node, or in the Cell Site Gateway.

## 7 Generic Requirements for MPLS Backhaul Transport Network

A complete list of requirements for MPLS networks for mobile backhaul is outside the scope of this document. Detailed functional requirements and specifications are work in progress in the IP/MPLS Forum at the time of publication. However, there are a number of general requirements that the MPLS network should meet in order to support mobile backhaul services. These are specified in the following sub-sections. In addition, where MPLS-based services span multiple operator domains, requirements specified in [MPLS-ICI] may apply. This section covers the specifications for MPLS transport networks that are common to all mobile application and deployment scenarios discussed in the sections below. It includes assumptions regarding underlying PSN that provides the MPLS service.

As per the PWE3 network model in RFC 3985 [RFC3985], a PSN tunnel is established to provide a data path for the pseudo-wire (PW). Native data units arrive at the attachment circuit, are encapsulated in a PW-PDU, and are carried across the underlying network via the PSN tunnel. The following assumptions are made regarding the underlying MPLS-based transport network.

1. The underlying transport network is a MPLS-capable IP-based packet switched network (MPLS PSN).
2. The MPLS/IP PSN network is capable of supporting QoS/TE features. The detailed requirements are formally specified in the sections corresponding to each individual TNL scenario.
3. The PE nodes shall support pseudowire signaling and encapsulation capability. The detailed requirements are formally specified in the sections corresponding to each individual TNL scenario.
4. The underlying PSN tunnel can be manually provisioned or signaled using RSVP-TE [RFC 3209], or LDP [RFC 5036].
5. The underlying PSN tunnel may optionally support OAM capabilities as defined by LSP Ping [RFC 4379], [BFD-MPLS].

This section describes the encapsulation, signaling, OAM, QoS and resiliency requirements for pseudowires that may be common to some of the TNL scenarios. The individual TNL sections can refer to the specifications here. In the case of IP TNL, these common requirements may not be valid and the corresponding section describes the details. This section also lists specific requirements of the outer PSN tunnel if applicable.

### 7.1 Encapsulation requirements

This section specifies general requirements for encapsulation of TNL packets between the ingress and the egress PEs.

An MPLS-based RAN must comply with RFC 3031 [RFC3031] and RFC 3032 [RFC3032] for the MPLS tunnel, and RFC 3985 [RFC3985] for pseudowire emulation. If MS-PWs are supported, PEs must comply with the requirements in [MS-PW-Req].

For the ATM TNL, PEs must support the N-to-1 mode of RFC 4717 [RFC4717], where N=1 is mandatory and N>1 is optional. The usage of N>1 is work in progress in the IP/MPLS Forum at the time of publication. This capability allows the encapsulation of several VCs or VPs on one PW based on the ATM class of service, which minimizes the number of PWs. PEs may also support the N-to-1 mode of

RFC 4717 with a mapping of a complete ATM port to each PW, as specified in RFC 4816 [RFC4816]. All other encapsulations are optional.

For the TDM TNL, the choice of pseudowire encapsulation depends upon whether structure-aware or structure-agnostic encapsulation is desired. Structure-aware encapsulation enables awareness of the underlying TDM stream structure by the PE to enable better statistical multiplexing of the TDM traffic across the MPLS network. If structure-agnostic encapsulation is required, the PE must use encapsulations specified in RFC 4553 [RFC4553]. If structure-aware encapsulation is required, the PE must use encapsulations specified in RFC 5086 [RFC5086] and optionally RFC 5087 [RFC5087].

For the HDLC TNL, CDMA networks typically encapsulate IP PDUs over MLPPP or PPP over a T1 BS interface. For an MPLS-based RAN, MLPPP or PPP is typically terminated at the CSG, or may be backhauled using encapsulations specified in RFC 4618 [RFC 4618] to the RC, especially in cases where the traffic that is carried over PPP is not an IP PDU. Where it is terminated at the CSG, IP PDUs are extracted and backhauled to the RC using an Ethernet PW [RFC 4448], VPLS [RFC 4762], or IP Layer 2 transport [RFC 4447]. The advantage of using Ethernet for IP layer 3 transport is that a common PW type can be deployed for HDLC and for other LTE and mobile WiMax services. For the IP TNL, base stations will typically support Ethernet interfaces. The PE may therefore support the Ethernet PW encapsulation, as per RFC 4448 for either VPWS or VPLS, or may use an MPLS Layer 3 VPN [RFC 4364]. The PE may optionally support the IP layer 2 transport PW [RFC 4447].

## 7.2 MPLS Network Signaling Requirements for PWs and LSPs

Static provisioning or dynamic signaling may be used for MPLS TE and non-TE LSPs and PWs.

The following requirements apply to dynamically signaled PWs:

- PEs must support pseudowire setup and maintenance as per IETF RFC 4447 [RFC 4447].
- For MS-PW use cases, PEs must support [MS-PW-Req] for MPLS PWs.

The following requirements apply to dynamically signaled PSN tunnel LSPs:

- For MPLS tunnels where traffic engineering is not used, PEs and P routers should support LDP signaling [RFC 5036]. Use of RSVP-TE signaling [RFC3209] without signaling the traffic parameters or setting the bandwidth to zero, etc. is optional.

## 7.3 MPLS Network Signaling Requirements for VPLS and L3VPNs

- VPLS PEs must follow RFC 4761 or RFC 4762.
- L3VPN PEs must follow RFC 4364.

## 7.4 OAM

In a consolidated MPLS-based RAN, OAM must be supported at the native service (e.g. ATM or Ethernet) layer, the MPLS layer, and at the pseudowire layer. This specification provides requirements for the MPLS layer and pseudowire OAM.

In general, if a defect occurs (such as loss of connectivity, misconnection, looping, or lost or mis-inserted packets), it is necessary to detect it, diagnose it, localize it, notify the appropriate entities, and take corrective actions appropriate to the type of defect. MPLS and pseudowire OAM should operate in-band

in order to detect defects on the LSP or PW, whether or not a dynamic control plane is used. In addition, it should be possible to propagate defect notifications from attachment circuits (e.g. the native circuit between the BS and CSG) across the MPLS network.

For the MPLS LSP, PEs and P routers should support LSP Ping [RFC4379] and may support BFD [BFD-Base] for the detection of defects. For the pseudowire, PEs should support VCCV-Ping as per RFC 5085 [RFC5085]. For defect notification, PEs should support the mapping of attachment circuit OAM messages to the pseudowire. Note: These mechanisms were IETF work in progress at the time of publication of this specification.

For MS-PW deployment scenarios, T-PEs and S-PEs should support multi-segment pseudowire status signaling and multi-segment VCCV. Note: These mechanisms were IETF work in progress at the time of publication of this specification.

## 7.5 Traffic Engineering and QoS Requirements

Traffic Engineering and QoS enable the QoS requirements of the mobile services to be achieved, while avoiding the need to over-provision the MPLS network.

The MPLS network must provide DiffServ support for MPLS LSPs, as per RFC 3270 [RFC3270]. Support of DiffServ allows distinction of several traffic classes. Note that a mapping between the classes on the TNL interface and the classes on the transport network must be supported.

## 7.6 Protection

Protection capabilities should be provided for LSPs and PWs in the mobile backhaul network. These must operate rapidly enough so that the SLA of the mobile backhaul service is not contravened.

For all statically-configured LSPs, failure detection of the LSPs can be accomplished by detecting the loss of the physical layer signal, layer 1 OAM, layer 2 OAM, or by utilizing IP Bidirectional Forwarding Detection (IP-BFD) [IP-BFD]. Failure notification for LSP segment protection switching can be based on Layer 1 or Layer 2 OAM, or by utilizing IP-BFD. Further protection requirements for statically-provisioned LSPs and PWs are for further study.

The following requirements apply to dynamically-signaled LSPs and pseudowires.

For the protection of LSPs signaled by RSVP-TE, PEs and P routers should support MPLS fast reroute [RFC 4090].

MASGs or CSGs can be dual-homed into the MPLS network to provide protection for the attachment circuits and for the PEs. Furthermore, active/standby pseudowire protection can be used to protect MS-PWs against failures of the S-PE. Note: These mechanisms were IETF work in progress at the time of publication of this specification. See 7.9 for more information.

## 7.7 CSG and MASG Configuration

In order to simplify provisioning, manual configuration on the CSG should be minimized. Configuration for parameters such as e.g., binding of PW to the AC, system IP address, etc. should be accomplished automatically.

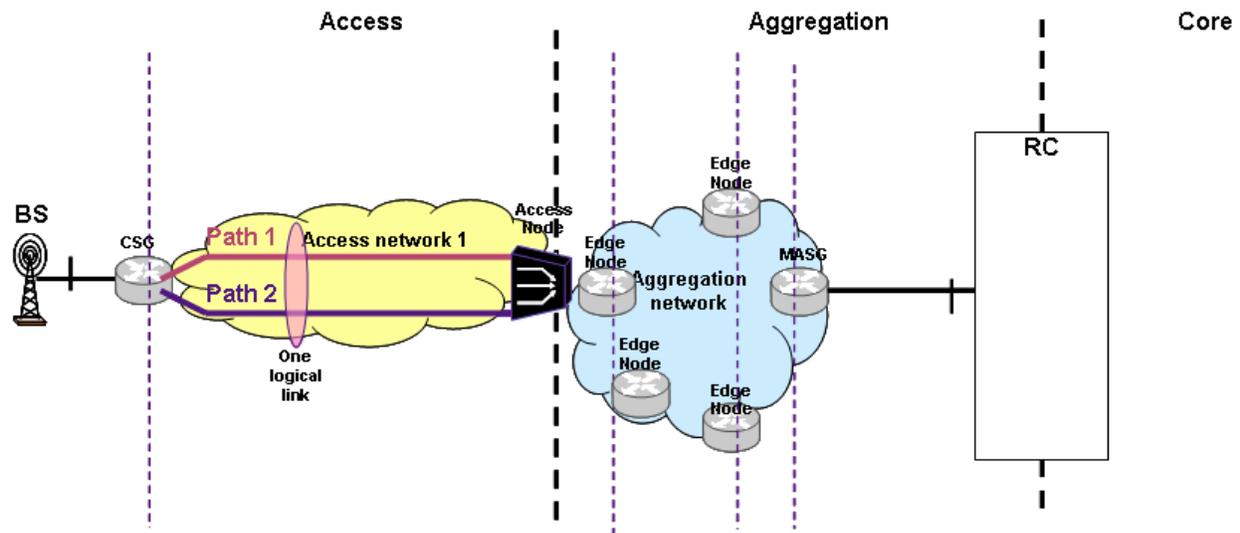
## 7.8 Multicast Requirements

- If multicast optimization in the RAN is needed, MPLS provides the following:
- Multicast support in L3VPNs
- Pt-Mpt LSPs
- VPLS (with multicast routing protocol support)

## 7.9 Multi-Path Optimization

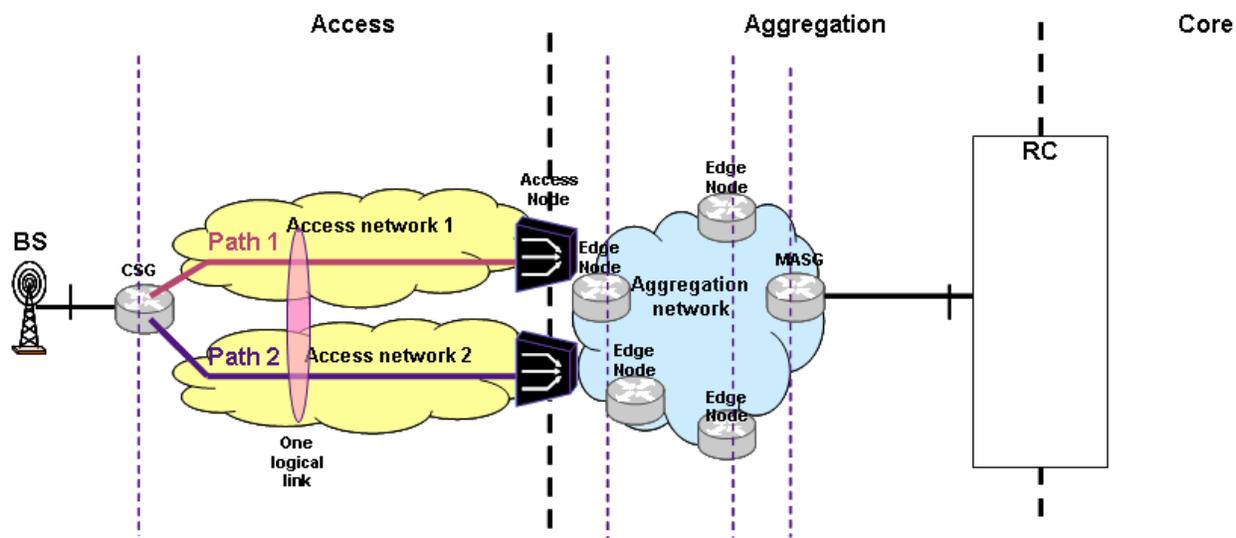
Load balancing of mobile backhaul traffic on LSPs and PWs over similar and different interfaces is for further study. At time of this writing, the only method of satisfying the scenarios below is to use IP load balancing.

Multi-path in the Access network should be supported for bandwidth optimization when the CSG is connected through multiple interfaces to the Access network (e.g. one SHDSL interface and one ADSL2+ interface) or when it is connected to 2 different Access networks (e.g. one ADSL2+ interface and one MW interface). As an example, the figure 14 below shows path 1 and path 2 as distinct physical links in DSL network (e.g. path 1 is based on ADSL2+ link and path 2 is based on SHDSL link). Multi-path optimization aims at considering these two different physical paths as only one single logical link for bandwidth optimization purposes.



**Figure 14: Multi-path Optimization with Two Paths in the Same Access Network (e.g. DSL Network)**

As another example, the figure 15 below shows path 1 and path 2 as distinct physical links belonging to two different Access networks (e.g. path 1 is based on ADSL2+ link and path 2 is based on MW link). Multi-path optimization aims at considering these two different physical paths as only one single logical link for bandwidth optimization purposes.



**Figure 15: Multi-path Optimization with Two Paths Belonging to Two Different Access Networks (e.g. DSL Network and Microwave Network)**

Multi-path optimization enables the traffic to be forwarded on path 1 or path 2 for load-balancing or path protection issues according to the bandwidth available on the two different paths. Solutions supporting multi-path optimization have to be proposed when the first mile is not MPLS-based (e.g. scenarios a and b) and when it is MPLS-based (scenarios c, d, e, f).

When the traffic is IP and is routed over the network, it is possible to achieve the capabilities above using ECMP load balancing.

## 7.10 Security Requirements

Consideration should be given for the security of the MPLS network, as per the PWE3 requirements [RFC 3916] for the SS-PW use cases, and as per [MPLS-PW-Reqs] for the MS-PW use cases. For MPLS VPNs, consideration should be given to the security requirements in [RFC 3809] and [RFC 4111]. For L3VPN use cases, the requirements in [RFC 4364] should be considered, and for L2VPN use cases, the requirements in [RFC 4761] or [RFC 4762], as appropriate, should be considered.

## 7.11 Network Synchronization

The synchronization requirements, as they unfold in all cellular standards can be divided into two main aspects:

1. Frequency accuracy requirements on the radio interface (e.g. in order to support handover function).
2. Time/phase synchronization requirements (e.g., for TDD systems).

Network synchronization is a generic concept that depicts a way of distributing common time and frequency references to all the nodes of a network, to align their respective time and frequency scales. It plays a particularly important role in wireless technologies requiring frequency synchronization, such as GSM, UMTS, and LTE. Other wireless technologies, such as CDMA and WiMAX, also need to be distributed accurate time and phase to the Radio Base Stations in order to properly generate the signals on the radio interface.

Details on the requirements for the various mobile technologies network synchronization as well as the Clock Distribution Scenarios over mobile transport networks are provided in Appendix I and Appendix II respectively.

Several methodologies have been defined for the purpose of distributing frequency and/or time/phase<sup>2</sup> synchronization to the end nodes over a packet network (see ITU-T G.8261 [G.8261]).

For each synchronization solution the appropriate requirements of the mobile network (given in 3.1.2) as well as the following aspects, should be taken into consideration:

- Clock distribution recovery signaling
- QoS
- Resiliency
- Topology (point to point or point to multi-point), etc

Depending on the synchronization solution and aspects above, the MPLS backhaul network may or may not be requested to provide specific support and fulfill specific synchronization requirements.

Note: Multiple distribution methods outlined below can be used on the same network simultaneously.

## 7.11.1 Clock Distribution over MPLS Based Mobile Backhaul Networks

### 7.11.1.1 Frequency distribution

There are three prevalent scenarios of frequency distribution in mobile networks using MPLS transport.

- **Scenario I:** Frequency distribution that is external to the MPLS network. One case is where the master PRC clock is directly provided to all CEs (e.g., using GPS) in a manner completely external to the network. Another case is frequency distribution by a synchronous physical layer, e.g. Synchronous Ethernet or SONET/SDH.
- **Scenario II:** End-to-end frequency distribution where the elements that participate in the frequency distribution and recovery are the RAN equipment (e.g., RNC, Node-Bs or BSC), MASG and the CSG. The other network elements in the IP/MPLS network transparently transport the synchronization information with appropriate QoS. However the PDV introduced by the packet network may have an important impact on the performance of the synchronization delivered in this way unless the oscillator implemented in the clock recovery device is sufficiently stable.

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<sup>2</sup> In the remainder of this Network Synchronization section, the term “time” is used to refer to the term “time/phase” as used in ITU-T G.8261.

For example, the MASG derives the clock from a site and sends frequency distribution dedicated frames across the MPLS network. The CSGs receive the frames, recover the original clock and distribute the clock to the BTSs/NodeBs over the legacy interface (e.g., TDM). As an alternative the CSG clock recovery function might be embedded into the base-station and there is no TDM interface.

Frequency distribution relies on two different packet-based methods:

- Time-stamping methods (e.g. IEEE 1588v2, NTP)
  - Circuit emulation PW methods (e.g. used for data and synchronization, or dedicated to synchronization)
- **Scenario III:** Stand-alone clock distribution device. Similar to scenario II but uses a stand-alone clock distributor (e.g. IEEE 1588v2 grandmaster), located somewhere in the network, to distribute clock over the MPLS transport network.

Note: Hybrid scenarios where a few of the above approaches are combined together are also possible.

### 7.11.1.2 Time distribution

There are three possible scenarios of time distribution (when needed) in mobile networks using MPLS transport.

- **Scenario I:** Using external synchronization distribution means (e.g., GPS).
- **Scenario II:** End-to-end time distribution. The elements that participate in the time distribution and recovery are the RAN equipment (e.g., RNC, Node-Bs or BSC.), MASG and the CSG. The other network elements in the IP/MPLS network transparently transport the synchronization information with appropriate QoS. However the PDV introduced by the packet network as well as the asymmetry in the network are fundamental characteristics impacting the performance of the time synchronization delivered.

For example, the MASG derives the time from a site and sends time distribution dedicated frames (which might be the same frames used for frequency distribution) across the MPLS network. The CSGs receive the frame, recover the original time and distributes it to the BTSs/NodeBs. An alternative is that the CSG clock recovery function might be embedded into the base-station

- **Scenario III:** Stand-alone time distribution device. Similar to scenario II but uses a stand-alone time distributor (e.g., IEEE 1588v2 grandmaster), located somewhere in the network, to distribute time over the MPLS transport network. These use packet based methods that require the allocation of special functions in the transport network in order to reduce the impacts from PDV and increase the quality of the time delivered (e.g., IEEE 1588v2 transparent clocks).

## Appendix I – Network Synchronization for Specific Mobile Technologies

### INFORMATIVE

This section describes the synchronization requirements of the following mobile network: GSM, WCDMA (FDD, TDD), cdmaOne (TDD), CDMA2000 (TDD) and WiMAX (FDD, TDD) as well as the Clock Distribution Scenarios over mobile transport networks. See also [G.8261] Appendix IV for more details.

#### I.1 Synchronization related definitions

- **Frequency synchronization:** A generic concept that depicts the way of distributing a common frequency to all elements in a network.
- **Time synchronization:** A generic concept that depicts the way of distributing a common time to all elements in a network.

#### I.2 Synchronization requirements in cellular backhaul networks

The synchronization requirements, as they unfold in all cellular standards can be divided into:

- The **successful transport of data**, for example, from the Base Station Controller (RNC in UMTS and BSC in GSM) to the base-station (Node-Bs in UMTS and BTSs in GSM).
- **Frequency accuracy** requirements in order to ensure sufficient frequency accuracy and stability for the radio interface to enable good handoff performance.
- Inter base-stations **time accuracy** requirements in some mobile networks (e.g., 3GPP TDD networks) in order to minimize inter-cell interferences.

##### I.2.1 GSM

See [G.8261] section IV.2.2.1.

##### I.2.2 UMTS

See [G.8261] sections IV.2.2.2 and IV.2.2.3.

##### I.2.3 IS-95 and CDMA-2000

See [G.8261] section IV.2.2.4.

##### I.2.4 T-SCDMA

See [G.8261] section IV.2.2.5.

##### I.2.5 Mobile Wimax

Mobile Wimax as defined in [WiMAX-MSP].

Frequency requirements:

- The RF timing signal shall be traceable to a PRC with accuracy better than +/-0.02 ppm.

Time requirements:

- There are no time requirements for WiMAX FDD
- For WiMAX TDD: +/- 1usec with respect to UTC

### **I.3 Synchronization distribution strategies**

#### **I.3.1 External synchronization distribution**

External synchronization is synchronization that is provided from a source that is external to the transport network. Such synchronization does not require any specific allocation of resources from the transport network (e.g., a dedicated 2.048 Mbit/s interface that is not part of the transport network).

#### **I.3.2 Transport network synchronization distribution**

Transport network synchronization is synchronization distribution that requires specific allocation of resources from the transport network (e.g., An IEEE 1588v2 timing flow within the transport network).

### **I.4 Legacy RAN clock distribution scenarios**

#### **I.4.1 Frequency distribution**

Two dominant scenarios of frequency distribution in the legacy RAN backhaul can be identified.

- **Scenario I:** Transport network frequency distribution, where the PRC master clock is directly provided to, for example, the BSC/RNC and is distributed to the cell site across the RAN using the transport network (e.g. TDM network). The radio base-station derives its RF clock from the incoming traffic link (i.e. Network Synchronization). This scenario is typical for the GSM and UMTS technologies.
- **Scenario II:** External frequency distribution, where the master PRC clock is directly provided to all RAN CEs (e.g., using GPS, BITS) in a complete external to the RAN manner. This scenario is typical for the CDMA2000 and mobile WiMax technologies. This scenario is out of the scope of this document.

#### **I.4.2 Time distribution**

Time distribution, in legacy RAN backhaul, is always distributed using external synchronization distribution means.

## Appendix II – UMTS Clock Synchronization

### INFORMATIVE

The 3GPP UMTS Terrestrial Radio Access Network (UTRAN) synchronization requirements as they unfold in ETSI TS 124 402 and ETSI TS 125 411 are divided into 4 level of synchronization:

- (i) Network synchronization
- (ii) Node synchronization
- (iii) Transport channel synchronization
- (iv) Radio interface synchronization

#### (i) Network Synchronization:

The network synchronization plane relates to the distribution of synchronization references to the UTRAN Nodes and the stability of the clocks in the UTRAN (and performance requirements on the UTRAN internal interfaces). The requirements regarding this plane of synchronization give only general recommendations regarding the Sync network architecture and clocks. Nevertheless, one main issue is the possibility to provide a synchronization reference with the proper frequency accuracy at the Node B in order to properly generate signals on the radio interface (better than 0.05 ppm for wide area or 0.1 ppm in case of local area).

A general recommendation is to supply a (PRC) traceable synchronization reference according to G.811. This basically means that the synchronization signal on the UTRAN should all be traceable to a PRC reference. It is also advised that the clocks to be implemented in UTRAN Nodes shall be chosen with a characteristic that depends on the L1 adopted. In other words, if the L1 is synchronous (e.g. TDM/SDH/SONET) then the clocks could be taken out of the already existing SDH/SONET clocks portfolio. On the other hand, if the L1 is asynchronous (e.g. ETH), then different timing distribution methods must be considered (for example, packet based methods using adaptive clock recovery).

#### (ii) Node Synchronization:

Node synchronization is related to the estimation and compensation of timing differences among UTRAN nodes. FDD and TDD modes have different requirements on the accuracy of the timing (time) difference estimation and on the necessity to compensate for these differences.

Two types of node synchronization exist: "RNC-Node-B" and "Inter Node B". Their usage and requirements differ between FDD and TDD modes. "RNC-Node B" node synchronization allows to get knowledge of the timing (time) differences between RNC and its Node Bs. The use here is mainly for determining good DL and UL offset values for transport channel synchronization between the RNC and its Node Bs. Knowledge of the timing (time) relationship between these nodes is based on a measurement procedure called RNC-Node B Node Synchronization Procedure that is carried out by mechanisms internal to the UMTS.

"Inter Node B" node synchronization is especially important in the TDD mode in order to compensate the timing (time) differences among neighboring Node Bs in order to achieve a common timing reference. The purpose of having a common timing reference is to allow Inter-cell Synchronization, which is used, within neighboring cells to minimize cross-interferences. Two optional ways for attaining this Inter-cell synchronization exists: using an external timing (time) reference (GPS is currently the only viable source for that) or by synchronization of the Node Bs via the air interface (3.84 Mcps TDD and 1.28 Mcps TDD)

The external timing (time) reference source is by far the most popular one. Each Node B is equipped with one input and one output external synchronization ports. Hence, they might be connected in a daisy chain configuration, so that a single external reference is enough and all remaining Node Bs can be

synchronized according to it (e.g. in case of an indoor operation). The external reference synchronization signals need to incorporate both accurate frequency and time.

Under all circumstances, the relative phase difference of the synchronization signals at the input port of any Node B in the synchronized area shall not exceed 2.5 usec. This requirement translates to an equivalent maximum phase difference compared to UTC requirement of less than 1.25 usec (half the 2.5 usec budget).

**(iii) Transport Channel Synchronization:**

The Transport Channel (or L2) synchronization provides a L2 common frame numbering between UTRAN and UE (frame synchronization between the L2 entities). It defines synchronization of the frame transport between RNC and Node B, considering radio interface timing. DL TBS (Transport Block Set) transmission is adjusted to fit receiver by adjusting the DL TBS timing in the upper node. UL TBS transmission is adjusted by moving the UL reception window timing internally in the upper node.

**(iv) Radio Interface Synchronization:**

The Radio Interface synchronization relates to the timing of the radio frame transmission (either in DL [FDD] or in both directions [TDD]). FDD and TDD have different mechanisms to determine the exact timing of the radio frame transmission and also different requirements on the accuracy of the timing.

In FDD Radio Interface synchronization is necessary to assure that the UE receives radio frames synchronously from different cells, in order to minimize UE buffers.

In TDD Radio Interface synchronization refers to the following two aspects:

Inter-cell Synchronization that is used to synchronize radio frames within neighboring cells in order to minimize cells cross-interferences, to allow frame

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