TECHNICAL REPORT

TR-221
Technical Specifications for MPLS in Mobile Backhaul Networks

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Issue History

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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.

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Executive Summary

With the increase of bandwidth demand per mobile user combined with the decrease of the average revenue per user, mobile operators and transport providers need to evolve their mobile backhaul networks to be faster and more efficient. MPLS provides the convergence of multiple backhaul technologies into one unified technology and supports more efficient use of network resources, reducing operational costs.

TR-221 defined the use of MPLS in Mobile Backhaul access and aggregation networks and provided solutions for the transport of traffic in 2G, 3G and LTE mobile networks. It has created reference architectures for MPLS in Mobile Backhaul networks and included specifications for the various transport scenarios that are depicted in the reference architecture.

The amendment addresses additional issues and features of the control, user and management planes that were not included in the original TR-221. This document is not changing the main content of TR-221, but rather adds functions to it.

1 Purpose and Scope

1.1 Purpose

TR-221 addressed mobile backhaul and 3GPP releases up through Rel.10. This amendment is applicable to address backhaul up through 3GPP Rel.11 and beyond. For Small Cell architectures however this document addresses backhaul up to Rel.11. Additionally it deals with MPLS enhancements from IETF, and NGMN requirements.

1.2 Scope

The amendment will address issues and features that were not included in TR-221. This amendment is not intended to change the main content of TR-221, but rather add functions to the base TR.

The items in this amendment are:

- OAM – Ethernet/PW Interworking
- BGP VPWS
- HetNet (Heterogeneous Networks as an evolution based on TR-221)
- PW redundancy

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in RFC 2119 [1].

MUST	This word, or the term "REQUIRED", means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the adjective "RECOMMENDED", means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.
A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	RFC 2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2]	RFC 7023	*MPLS and Ethernet OAM Interworking*	IETF	2013
[3]	RFC 6870	*Pseudowire Preferential Forwarding*	IETF	2013

		Status Bit		
[4]	RFC 6718	*Pseudowire Redundancy*	IETF	2012
[5]	IP/MPLS Forum 22.0.0	*BGP Auto-Discovery and Signaling for VPWS-based VPN services*	BBF	2012

2.3 Definitions

The following terminology is used throughout this Technical Report.

Abis Interface between the BTS and BSC (TNL is TDM)

ATM TNL The Transport Network Layer defined in this document as the transport bearer for 3G ATM traffic.

CSG Cell Site Gateway – Node at the cell site that presents the transport network interface to the Base Station equipment. For purposes of this document this device is an MPLS capable node.

HetNet Heterogeneous Network is a combination of small and macro cells.

Iub Interface between the NB and RNC (TNL is ATM or IP)

IP TNL The Transport Network Layer defined in this document as the transport bearer for LTE and 3G IP traffic. It should also be noted that there is a possible difference between the TNL and what is transported over MPLS. For example, when carrying the ATM TNL using TDM over MPLS or when carrying IP TNL using Ethernet over MPLS.

MASG Mobile Aggregation Site Gateway - Node at the radio controller, MME or serving gateway site that presents the transport network interface to the mobile equipment. For purposes of this document this device is an MPLS capable node.

S1 interface Interface between the eNB and the MME or S-GW

TDM TNL The Transport Network Layer defined in this document as the transport bearer for 2G TDM traffic.

X2 interface Interface between two neighboring eNBs

2.4 Abbreviations

This Technical Report uses the following abbreviations:

3GPP	3rd Generation Partnership Project
BGP	Border Gateway Protocol
BS	Base Station
CE	Customer Edge
CSG	Cell Site Gateway
EN	Edge Node
HetNet	Heterogeneous Network Service
H-VPLS	Hierarchal Virtual Private LAN Service
IETF	Internet Engineering Task Force
IP	Internet Protocol
ITU-T	International Telecommunication Union - Telecom
L2VPN	Layer 2 Virtual Private Network
L3VPN	Layer 3 Virtual Private Network
LDP	Label Distribution Protocol
LER	Label Edge Router
LSP	Label Switched Path
LSR	Label Switch Router
MASG	Mobile Aggregation Site Gateway
MEF	Metro Ethernet Forum
MPLS	Multi Protocol Label Switching
MS-PW	Multi-Segment Pseudowire
OAM	Operations, Administration and Management
P	Provider
PE	Provider Edge
PW	Pseudowire
RAN	Radio Access Network
RFC	Request for Comments
RSVP-TE	Resource ReSerVation Protocol
S-PE	Switching Provider Edge Router
SS-PW	Single-Segment Pseudowire
TE	Traffic Engineering

T-LDP	Targeted Label Distribution Protocol
TLV	Type/Length/Value
TR	Technical Report
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
VPWS	Virtual Private Wire Service

3 Changes / Updates in TR-221

The topics addressed by this amendment are described in the following sections. Reference is given where and how to change or update the corresponding TR-221 text.

3.1 OAM – Ethernet/PW Interworking

The following text replaces section 8.3.1.3.1 AC OAM in TR-221:

For interworking of the two technology domains (i.e. Ethernet and MPLS) for OAM-IWK the following requirements apply:

[R-1] The PE MUST support transparent transfer of native service OAM indications over the PW as defined in RFC 7023 [2] Section 1

[R-2] Transport related defects SHOULD be handled as follows:

- AC failure :
  - AC receive defect state entry and exit criteria – as per RFC 7023 [2] Section 5.1
  - AC transmit defect state Entry/exit criteria – as per RFC 7023 [2] Section 5.2
  - AC receive defect Consequence action – as per RFC 7023 [2] Section 6.5 and 6.6.
  - AC transmit defect Consequence action – as per RFC 7023 [2] Section 6.7 and 6.8
- PW failure :
  - PW receive defect state entry/exit criteria – as per RFC 7023 [2] Section 4.4.1
  - PW transmit defect state entry/exit criteria – as per RFC 7023 [2] Section 4.4.2
  - PW receive defect entry/exit procedure – as per RFC 7023 [2] Section 6.1 and 6.2
  - PW transmit defect entry/exit procedure – as per RFC 7023 [2] Section 6.3 and 6.4

Note: Motivation for OAM interworking in the context of Mobile Backhaul can be found in Annex-A.

3.2 VPWS with BGP Signaling and Auto-Discovery

Add the following text and new requirements in section 5.1.3/TR-221 PW Signaling after R11:

If an implementation supports IP-MPLSF 22.0.0 [5] "BGP auto-discovery and signaling for VPWS-based VPN services", which provides specification for setup of VPWS pseudowires with BGP the following requirements apply.

[R-3] PE routers SHOULD support one or more of the following encapsulation type values from IP-MPLSF 22.0.0 [5]

- For Ethernet over MPLS (RFC 4448) the Encapsulation Type is 4 or 5 as per IP-MPLSF 22.0.0 [5] Section 8.5.
- For TDM TNL (RFC 4553 or RFC 5086) the Encapsulation Type is per IP-MPLSF 22.0.0 [5] Section 8.5

3.3 HetNet (Heterogeneous Networks as an evolution based on TR-221)

The following text is to be added as a new section after Section 9. of TR-221:

Heterogeneous networks (HetNet) are about providing a seamless broadband user experience for mobile customers independent from their location (on the move, in the office or at home). HetNet implementation has to provide a seamless network evolution, adding capacity and coverage in a smooth, cost effective way. These goals can be achieved by the right mix of HetNet scenarios and their backhaul solutions.

Note: The combination of small and macro cells is referred as a "Heterogeneous Network".

3.3.1 HetNet scenarios

The main motivation for using HetNets is related to recent mobile end user experience challenges and increasing overall cell site performance, cell edge data rates and indoor data rates. In order to increase capacity & coverage the following solutions – also depicted in Figure 1. – can be used:

1. "Super-macro" – advanced antennas, spectrum aggregation
2. Macro densification
3. Small cells – Micro & Pico

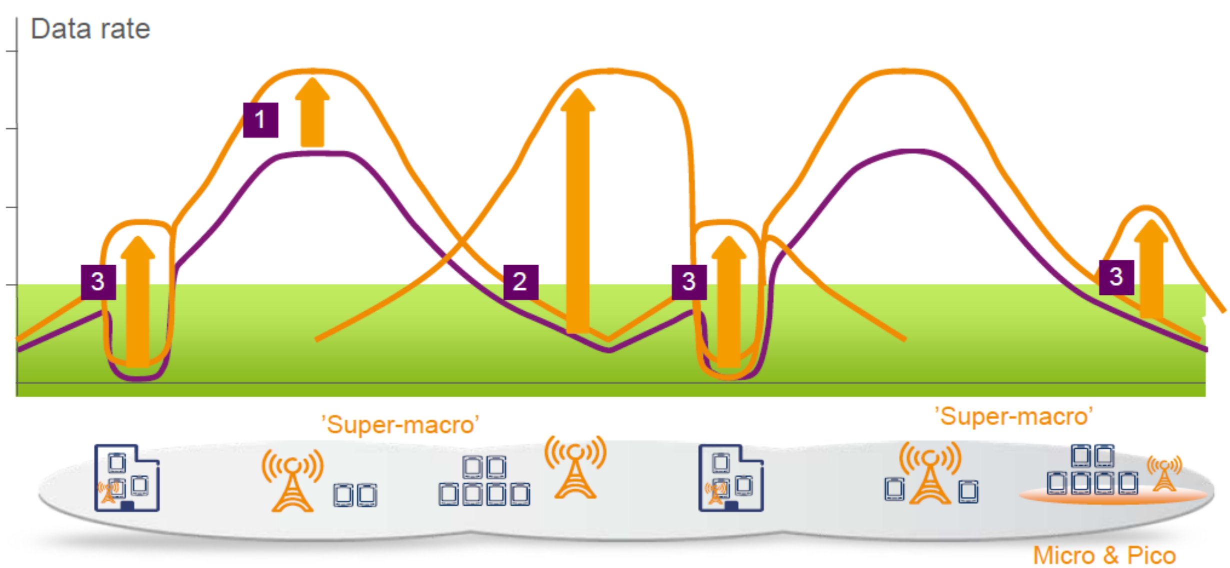

Figure 1 – Increase capacity & coverage for better mobile end user experience

3.3.2 Macro Sites in HetNet

These HetNet scenarios have different impacts on the mobile backhaul network. Improving existing macro sites and densifying macro sites impact the required capacity and the number of

PoPs of the backhaul network, but do not affect the basic architecture of it. These two methods are used by operators when possible, especially when hotspots are unknown.

Note: Hotspot in this context means a geographical area with extensive usage of the provided service.

Macro sites that are part of the HetNet network do not require any changes to the TR-221 reference architecture.

3.3.3 Small Cells in HetNet

Main motivations for deploying Small Cells (Micros or Picos) are: when Macro deployments are not possible or when hotspots are well known. The impact of small cells depends significantly on the coordination between the small and macro cells:

- No coordination
  Example: uncoordinated deployment with femto cells in a macro network
- Loose coordination
  Example: Adaptive resource partitioning of pico RBSs in a macro network
- Tight coordination
  Example: Tight Coordinated scheduling (on air interface) of uplink and downlink

Note: Femto cell deployment and backhaul is outside the scope of TR-221 Amendment-1.

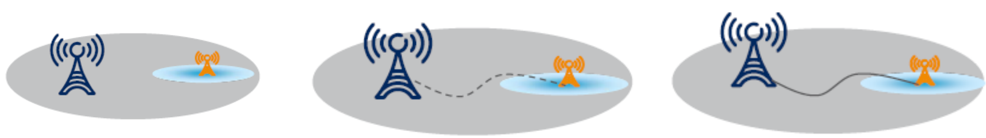

Figure 2 – Coordination (No / Loose / Tight)

Note: Names are used according to 3GPP definition: Wide Area Base Stations, (popular name macro-RBS), Medium Range Base Stations, (popular name micro-RBS), Local Area Base Stations, (popular name pico-RBS) and Home Base Stations, (popular name femto RBS).

Many of the backhaul requirements for small cells are the same as those for macro sites. Small cell base station nodes use the same logical interfaces (S1 and X2 or Iub or Iuh) as a (e)NodeB, or Home(e)NB, as defined in 3GPP TS 36.300 Release 11. Small cells do not require new connectivity topologies, other than the ones used for macro cells:

- WCDMA: Hub and Spoke communication (Iub)
- LTE: Partially meshed communication (S1 and X2)

Note: IP connectivity requirements for LTE networks are described in Appendix D of TR-221.

There are 3 main TR-221 backhaul use-cases of small cells

1. Dedicated backhaul per small cell
2. Dedicated backhaul for a group of small cells
3. Extension from existing macro base station

For the first variant CSG functionality of the small cell node is expected to be a non-MPLS node as it would significantly increase the number of MPLS nodes in the backhaul network. Scenario a, and b, of TR-221 (Figure 1.) apply.

For the second variant adding a small cell aggregation node (AgN) for backhaul may be beneficial. This AgN may be an MPLS node and can be treated as a CSG from the TR-221 reference architecture perspective. All scenarios of TR-221 (Figure 1.) apply.

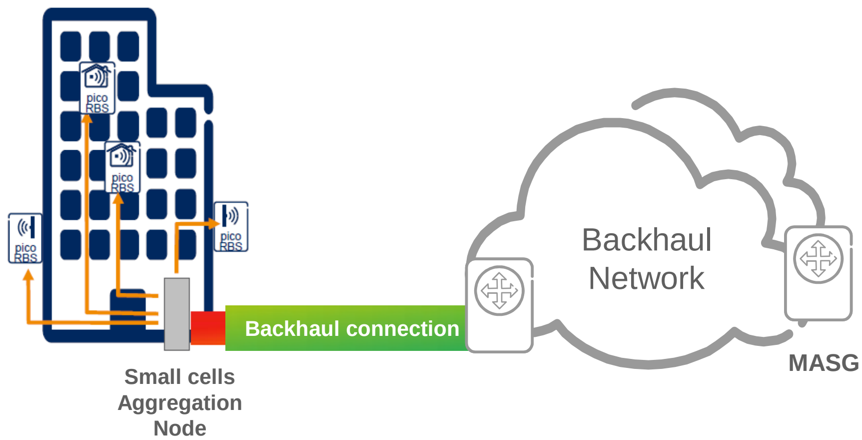

Figure 3 – Small Cell aggregation node

[R-4] If the AgN is an MPLS node it SHOULD fulfill CSG related requirements of TR-221.

For the third variant a "local access network" is expected between the macro and the small cells. For operators with existing backhaul and radio network, a quite natural choice is to connect the small cell nodes to the macro cell site. Such a local network is out-of-scope for TR-221, therefore no new requirements are discussed here. A CSG is used on the macro site for which no additional requirements apply.

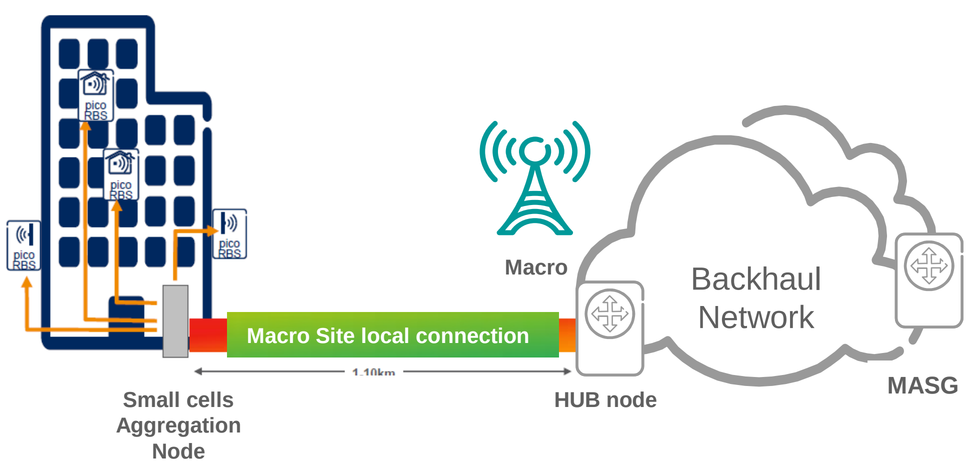

Figure 4 – Extension from existing Macro base station

Note: Performance objectives and synchronization requirements for small cells are outside the scope of this document. At the time of writing this document there is work in progress in the MEF on these two aspects of mobile backhaul for small cells.

3.4 PW Redundancy

The following text, including the 3.4.x subsections below, replaces the text of section 5.3.4 in TR-221. Section 5.3.4.1 is kept and is not changed:

This section describes PW resiliency and resiliency requirements.

[R-5] A PE SHOULD support PW protection.

In the following, a CE that is connected to a single PE via one AC is referred as a “Single-homed CE”, and a CE that is connected to more than one PE (each AC to a different PE) is referred as a “Multi-homed CE”.

Note: The CE may be a virtual entity comprised of more than one physical node.

Note: The AC that is connected to a PE might itself be protected using protection native to the AC technology (e.g. LAG for Ethernet). From the PW’s point of view this is a single AC.

3.4.1 PW redundancy scenarios

This section describes requirements to ensure resiliency for L2-VPN service (VPWS) - provided by the MPLS domain of the mobile backhaul network – using PW redundancy in the access and aggregation part of the network.

The PW is setup from the PE nodes, using LDP signaling (RFC4447) or static provisioning. For details on associated OAM see TR-221 Section 5.2.3.

Note: This section covers PW redundancy only inside the MPLS domain and does not cover complete end-to-end redundancy scenarios. Inter-domain related aspects of PW redundancy are outside the scope of this document.
Note: In the PW redundancy section, mechanisms that rely on more than one active path between the PE nodes, e.g., 1+1 protection switching, are also out of scope.

The following network scenarios are considered:

- MPLS network: provides L2 VPN service (VPWS)
    - The CSG is not part of the MPLS domain (case a, and b, as per TR-221 reference architecture)
    - The CSG is part of the MPLS domain acting as PE node (case c, d, e, and f, as per TR-221 reference architecture)
- The MASG node: has Ethernet connectivity towards RAN Control nodes

- The MASG node(s) are: redundant or non-redundant (i.e. multiple or single MASG provides connectivity for RAN Control nodes)
- The Edge Node (CSG or first PE) node(s) are: redundant or non-redundant (i.e. multiple Edge Nodes or single CSG/Edge Node provides connectivity for BS)

PW redundancy scenarios in this chapter assume usage of single-segment pseudowire (SS-PW). Similar mechanisms apply for multi-segment pseudowire (MS-PW) scenarios, where a set of redundant PWs is configured between T-PE nodes. PE/T-PE nodes indicate the preferred pseudowire to be used for forwarding via the Preferential Forwarding status bit as per RFC6870.
Note: Protection for a pseudowire segment can be provided by the packet switched network (PSN) layer, e.g. fast reroute (FRR). Interaction between the PW redundancy mechanisms and these PSN restoration functions below and/or in the MPLS layer are out-of-scope. Such PSN restoration mechanisms are assumed to react rapidly enough to avoid the triggering of PW redundancy.

From PW redundancy related requirements perspective these mobile backhaul specific network scenarios differs depending on the connection method (single-homed or multi-homed) of the CEs interconnected using PW redundancy:

- Single-homed CEs
- Single and multi-homed CEs
- Multi-homed CEs

3.4.2 PW redundancy scenario: single-homed CEs

In such scenarios two PWs are configured between two PE nodes (e.g. PW1: PE1-PE2 and PW2: PE1-PE2). As the PWs are terminated on the same PE nodes, such a scenario can provide redundancy if the PWs are "routed" differently over the MPLS network. One of the PE nodes (e.g. PE1) acts as a Master Node for selecting the active PW.

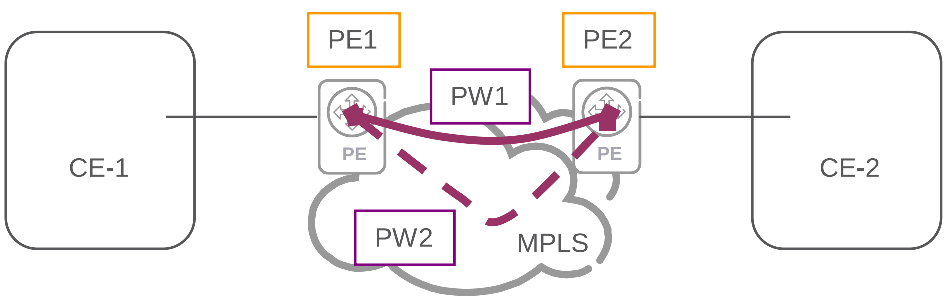

Figure 5 – 2 Single-homed CEs connected with PW redundancy

[R-6] The PE SHOULD support PW redundancy and signaling procedures in Master/Slave Mode as per RFC 6870 [3].

3.4.3 PW redundancy scenario: single and multi-homed CEs

Such a scenario protects the emulated service against a failure of one of the PEs (PE2 or PE3) or ACs terminated on the multi-homed MASGs. The two PWs are configured between the PE nodes (e.g. PW1: PE1-PE2 and PW2: PE1-PE3). The PE node on the single sided end of the connection which terminates both PWs (PE1) acts as a Master Node for selecting the active PW.

PW redundancy determines which PW to make active based on its preference and the forwarding state of the ACs so that only one path is available between CE-1 to CE-2. The PE connected to active PW on multi-homing side will act as “forwarder” to/from CE.2. The other PE on the multi-homed side will block the AC for forwarding and receiving.

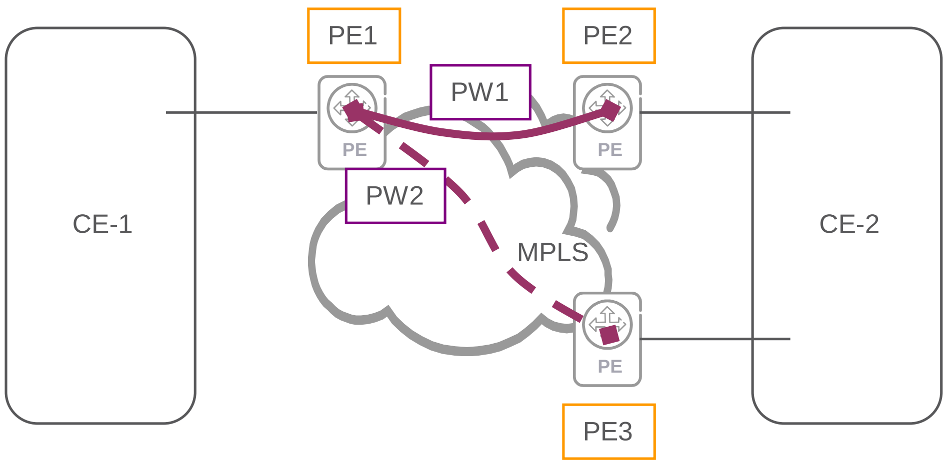

Figure 6 – Single and multi-homed CEs interconnected with PW redundancy

Based on AC status signaling the Master node is able to select which PW to use for forwarding traffic. Depending on the technology used in the MPLS domain AC signaling methods differs. In case of LDP RFC4447 applies and in case of static PW RFC6478 applies.

For the PE nodes the same requirement as [R-6] applies.

3.4.4 PW redundancy scenario: Multi-homed CEs

In such scenarios 2 x 2 PE nodes are used to provide connectivity to the MPLS domain. A partial mesh of PWs is configured between the PE nodes (e.g. PW1: PE1-PE3, PW2: PE1-PE4, PW3: PE2-PE3 and PW4: PE2-PE4).

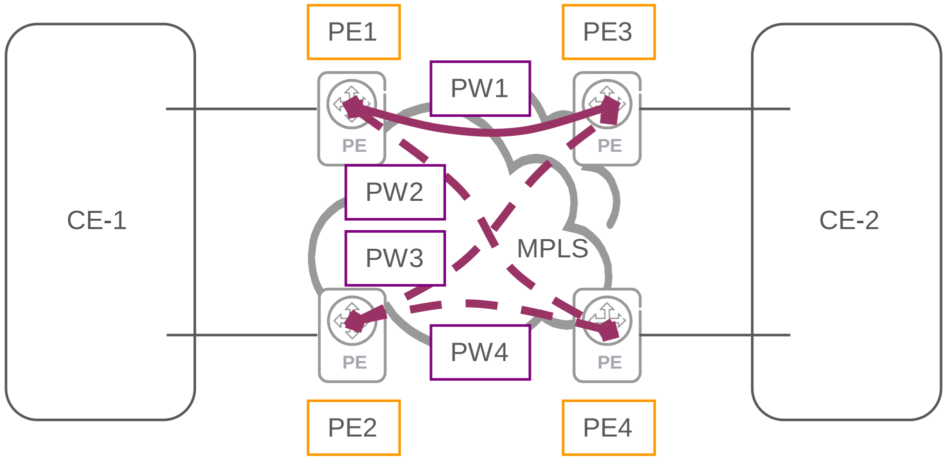

Figure 7 – Multi-homed CEs interconnected with PW redundancy

This scenario is similar to the “VPLS Bridge Module Model” described in RFC 6870 [3] Section 3.2.6.

Note: A dual-homing control protocol is out-of-scope in RCF6870, but it is needed for the selection of the single active PW. Such a scenario is left for further study.

The following appendixes are to be added after Appendix F in TR-221:

Appendix A: Use cases for MPLS and Ethernet OAM Interworking

Transport networks may be built from network segments using different technologies and forwarding paradigm. OAM tools and protocols are technology dependent therefore the handover between the Ethernet and MPLS network segments require OAM related interworking functionality (OAM-IWK). That OAM-IWK can ensure that OAM functions can provide end to end information. This section focus on Ethernet and MPLS OAM interworking for emulated Ethernet service and propagation of connectivity status information over the handover points.

Use-cases of OAM-IWK in Mobile Backhaul networks have the following characteristics:

- The MPLS network: provides L2 VPN service (VPWS)
- The MASG node: has Ethernet connectivity towards RAN Control nodes
- The MASG node(s) are: redundant or non-redundant (i.e. multiple or single MASG provides connectivity for RAN Control nodes)
- The Edge Node (CSG or first PE) node(s) are: redundant or non-redundant (i.e. multiple Edge Node or single CSG/Edge Node provides connectivity for BS)

Motivations for using OAM-IWK can be the following use-cases:

1. Connectivity check in the mobile backhaul network for operation and maintenance purposes
2. Multi-homing: Forwarding Path Selection based on connectivity check results

A.1 Use-case-1

Implementing the OAM-IWK function allows for the operators to make end-to-end connectivity check in their mobile backhaul network (e.g. between CSG and MASG). This information can be used for various O&M purposes (e.g. SLA verification, troubleshooting, etc.).

A.2 Use-case-2

In a multi-homing scenarios, when the MASG and/or Edge Node are redundant the reach-ability information provided by the OAM-IWK can be used for selecting the forwarding path (i.e. PW) over the MPLS domain. When ACs are Ethernet based, then mapping between OAM status information of the MPLS and Ethernet domains has to be performed in order to ensure that OAM works end-to-end.

For transport over the MPLS domain MASG and Edge Nodes can involve the information provided by the OAM-IWK about end-to-end (e.g. between CSG and MASG) reach-ability.

Use-case-2 scenarios:

A. CSG is a PE node: usage of OAM-IWK provided information depends on network setup. Using MPLS OAM can be sufficient to signal the ACs' statuses between CSG and MASG to influence PW selection.

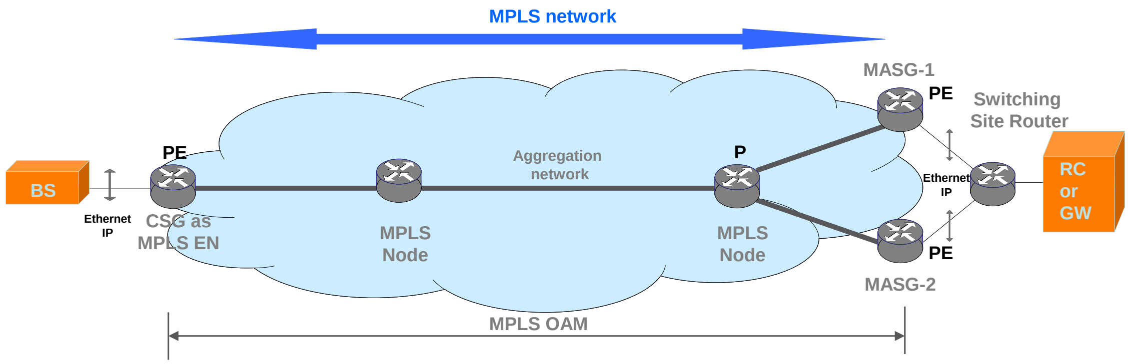

Figure 8 – OAM-IWK used during Multi-homing (CSG is a PE node)

For signaling AC status RFC 6478 (Pseudowire Status for Static Pseudowires) is applicable for static pseudowires and RFC 4447 (Pseudowire Setup and Maintenance Using the Label Distribution Protocol (LDP)) may be applicable in case of dynamic control plane.

B. CSG is not PE node: CSG is connected to the MPLS network via a L2 segment. Therefore the information provided by the OAM-IWK function can be essential to select an appropriate PW over the MPLS domain to avoid connectivity problems (e.g. black-holing, etc.).

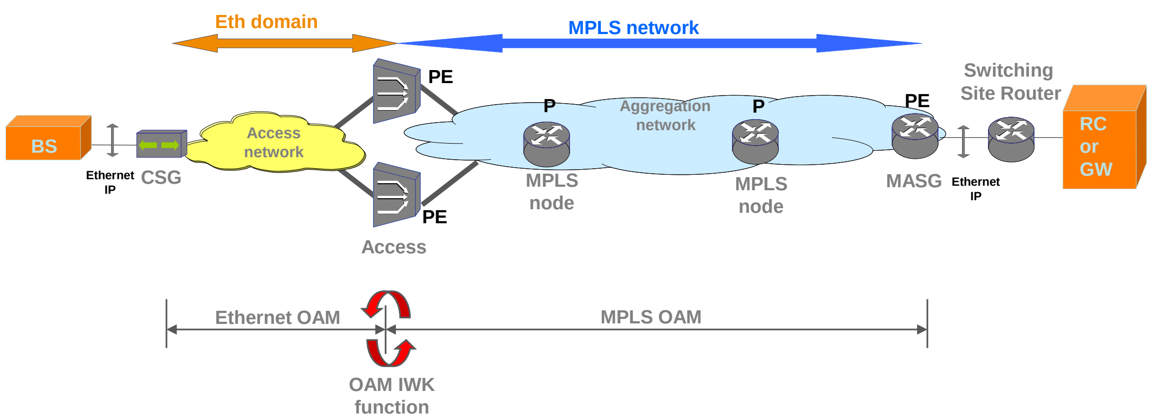

Figure 9 – OAM-IWK used during Multi-homing (CSG is NOT a PE node)

In this use-case scenario the functions defined in Section 5 and Section 6 of RFC 7023 [2] are applicable.

Appendix B: PW redundancy use-cases

The cases explained show PW redundancy in a fully MPLS and a partially MPLS case (i.e. TR 221 reference architecture cases C and A).

B.1 Single technology (MPLS) based MBH network (CSG acts as PE node)

Considering a single technology mobile backhaul network the non-redundant CSG acts as a PE node. In this case redundancy can be provided only for scenarios with redundant MASG nodes.

In such a VPWS based architecture PWs are set-up using the active/standby PW concept, which ensures that only a single active forwarding path exists between the CSG and the MASG nodes. The CSG acts as a Master Node. The status of Attachment Circuit (AC) links must be tracked in order to control PW switch-over in possible failure scenarios.

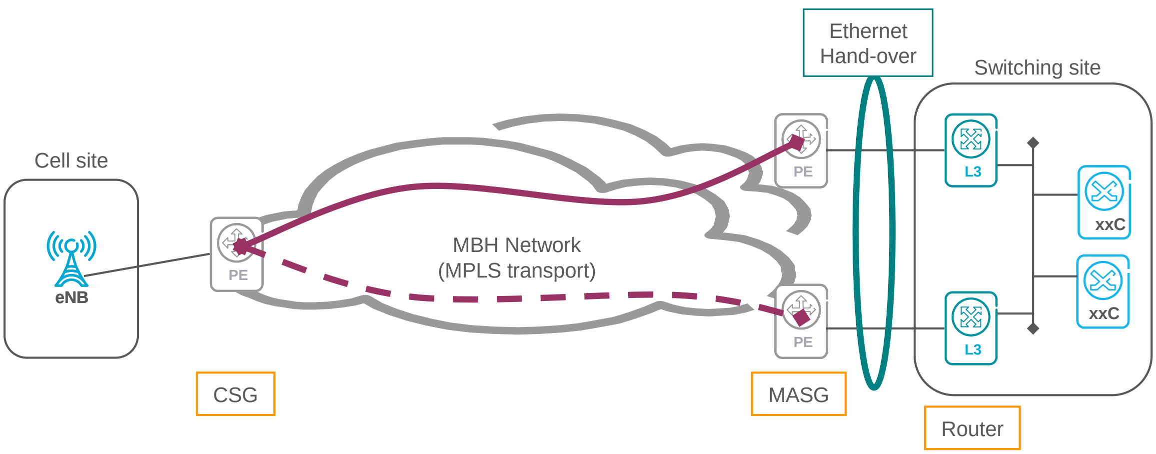

Figure 10 – OAM Single technology based MBH network (CSG acting as PE node)

B.2 Multi technology based domain (CSG is not a PE node)

This section focuses on the network scenario, where the mobile backhaul network is built based on two domains:

- L2 domain: provides native Layer-2 connectivity between CSG and the Edge Nodes.
- MPLS domain: interconnects the L2 domain(s) and the Switching Site by using redundant PWs inside the domain.

Non-redundant Edge Node + Redundant MASG

For single Edge Node scenarios the same considerations apply as described in the single technology based mobile backhaul network section above. The Edge Node acts as Master Node.

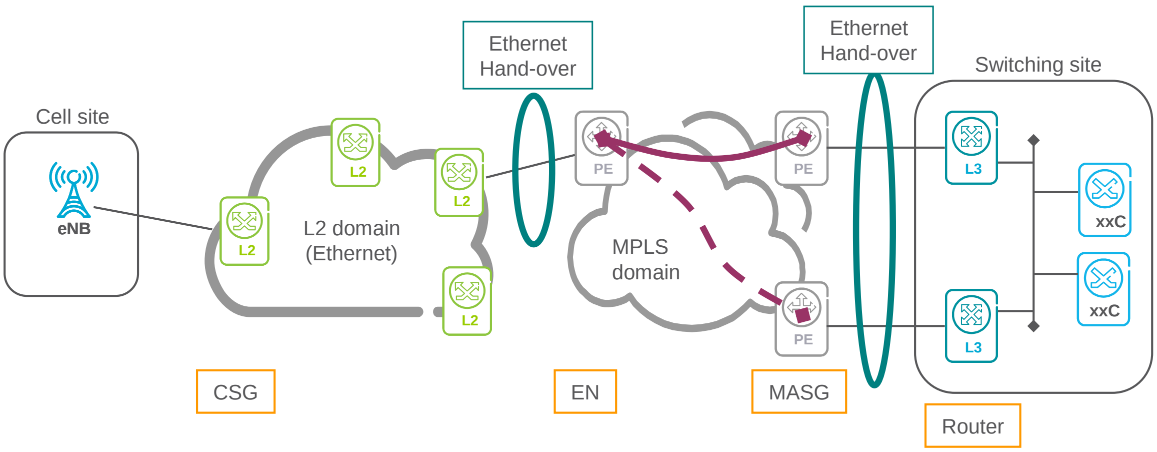

Figure 11 – Multi technology based MBH network (non-redundant Edge Node)

Redundant Edge Node + Non-redundant MASG

The set-up of PWs in the MPLS networks depends on the network scenario. If only a single MASG is present than Master/Slave Mode can provide the required PW redundancy function, where the MASG acts as Master Node.

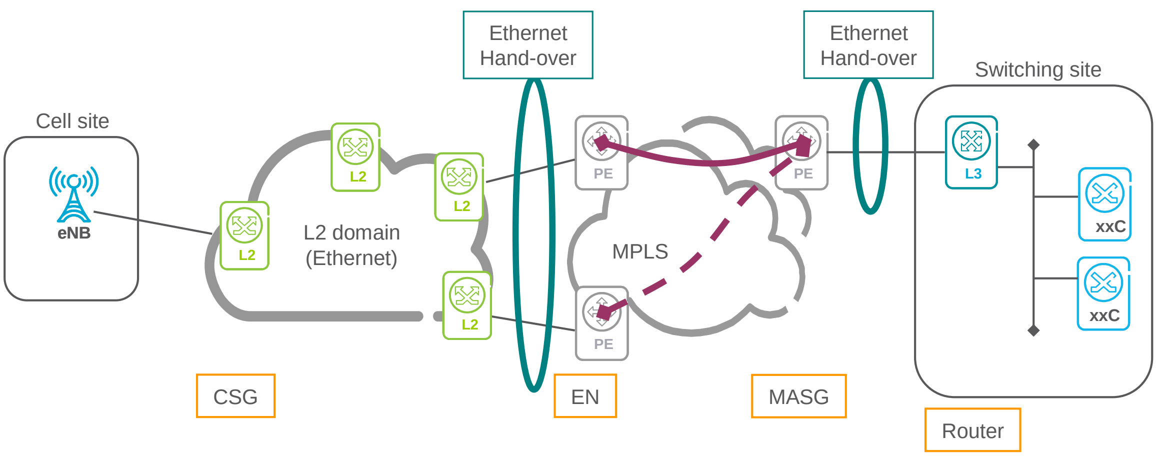

Figure 12 – Multi technology based MBH network (redundant Edge Node)

Redundant Edge Node + Redundant MASG

If both the Edge Nodes and the MASGs are redundant then transport redundancy can be provided by the PW redundancy concept. The MPLS domain provides interconnection of the L2 domains and the Switching Site using a single active PW. Partial mesh of PWs means, that four PWs are used with endpoints at an Edge node and an MASG node (see figure-13).

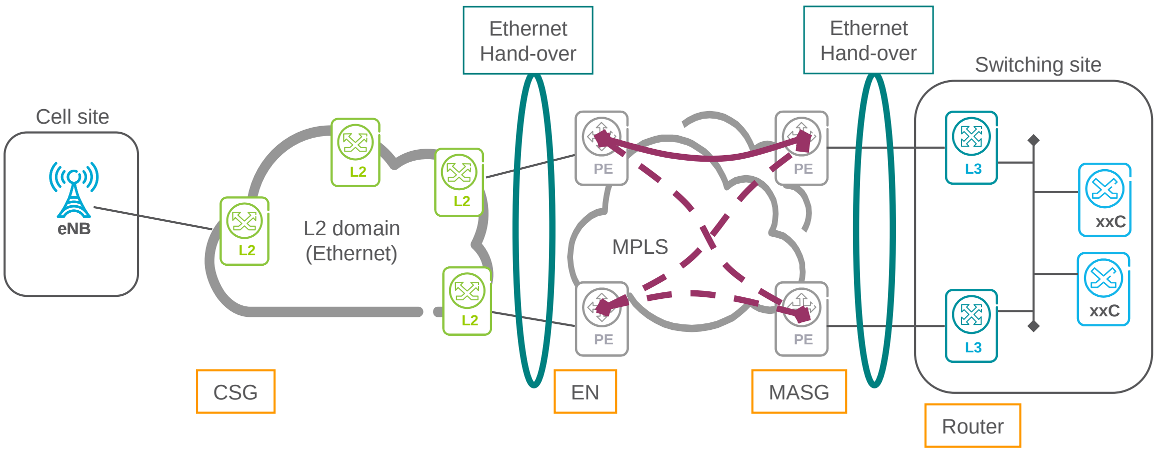

Figure 13 – Multi technology based MBH network (Redundant Edge Node + Redundant MASG)

Selection of the active PW is based on Independent mode with primary/secondary concept.

End of Broadband Forum Technical Report TR-221

