MPLS Mobile Backhaul Evolution – 4G LTE and Beyond

MR-305

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Ambassador name
Broadband Forum Ambassador/Title
Company

Agenda

1. Introduction to the Broadband Forum
2. Mobile Market Overview
3. Ethernet and IP VPN Backhaul Architecture
4. Timing and Synchronization
5. Quality of Service (QoS) Requirements
6. Resiliency, Protection and Performance
7. IPv6 Considerations
8. Energy Efficiency
9. Relationship to MEF 22.1
10. Deployment Examples
11. BBF Mobile Backhaul Work Plan – 2012
12. Summary

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Insert slides from current approved Ambassador slide deck

Mobile Market Overview

Issues, trends and enablers of the transition to IP/MPLS in evolving backhaul architectures

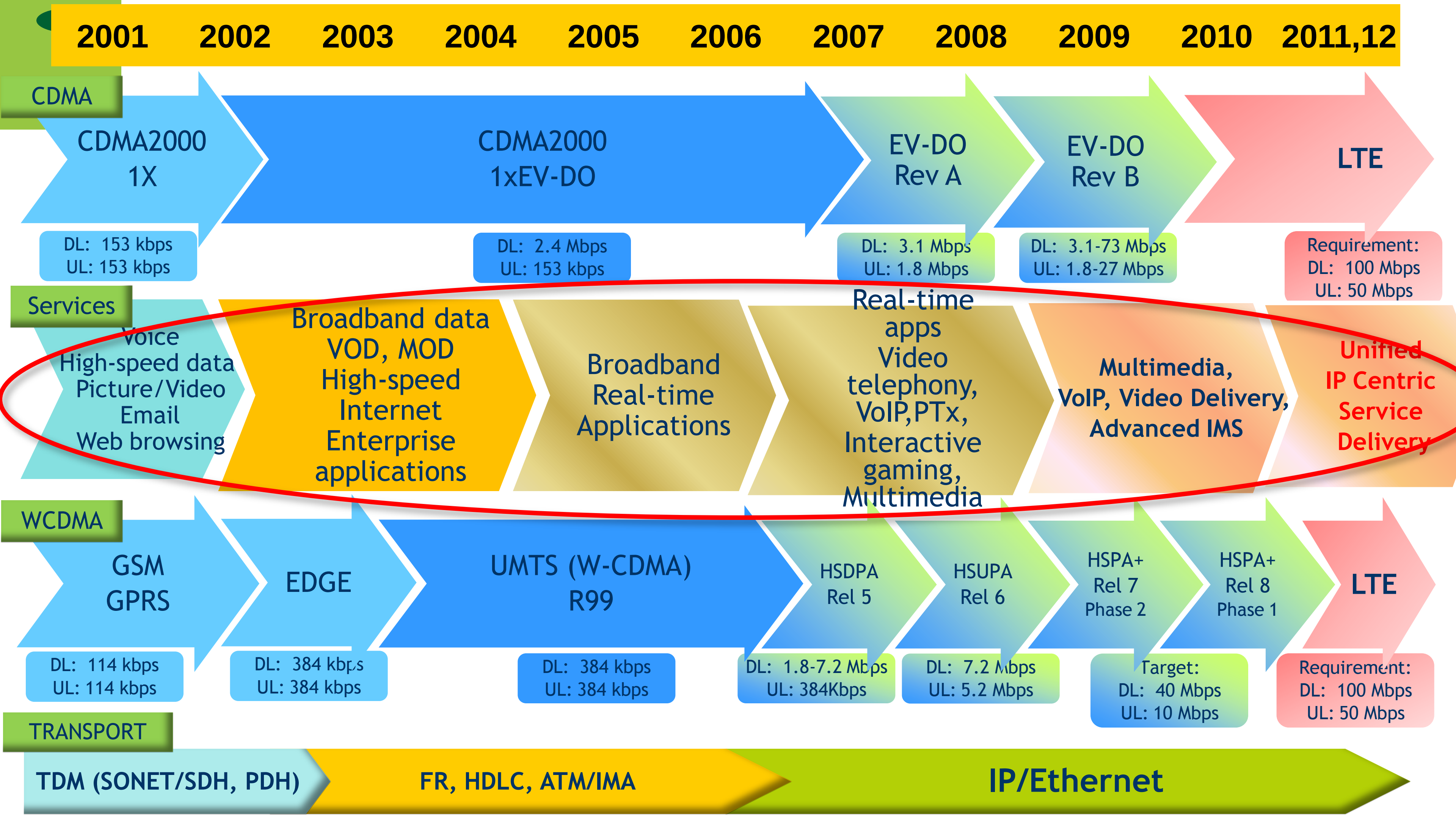
State of the Market

- Voice, text messages and data consumption drive majority of current revenue
  - Price competition
  - Reduction or flattening of growth in minutes per subscriber in markets such as North America
  - Subscribers granted ability to customize phones

→ Declining average revenue per user (ARPU)

- LTE Deployments
  - Significantly expand data capacity to enable new devices, services and applications → ARPU growth
  - Initial LTE deployments focus on data services
  - Focus on enhancing throughput and reducing cost per bit
  - Increased services for more demanding applications and smart devices

Evolution to LTE is all about Services



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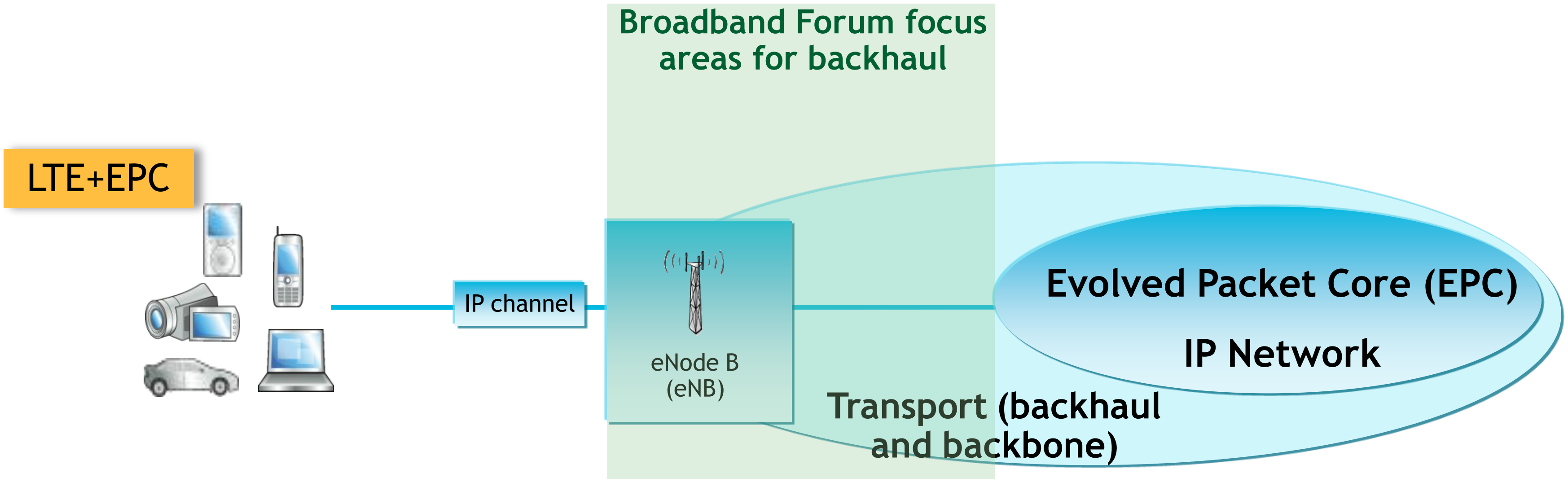
LTE: All-IP, simplified network architecture

What is EPC ?

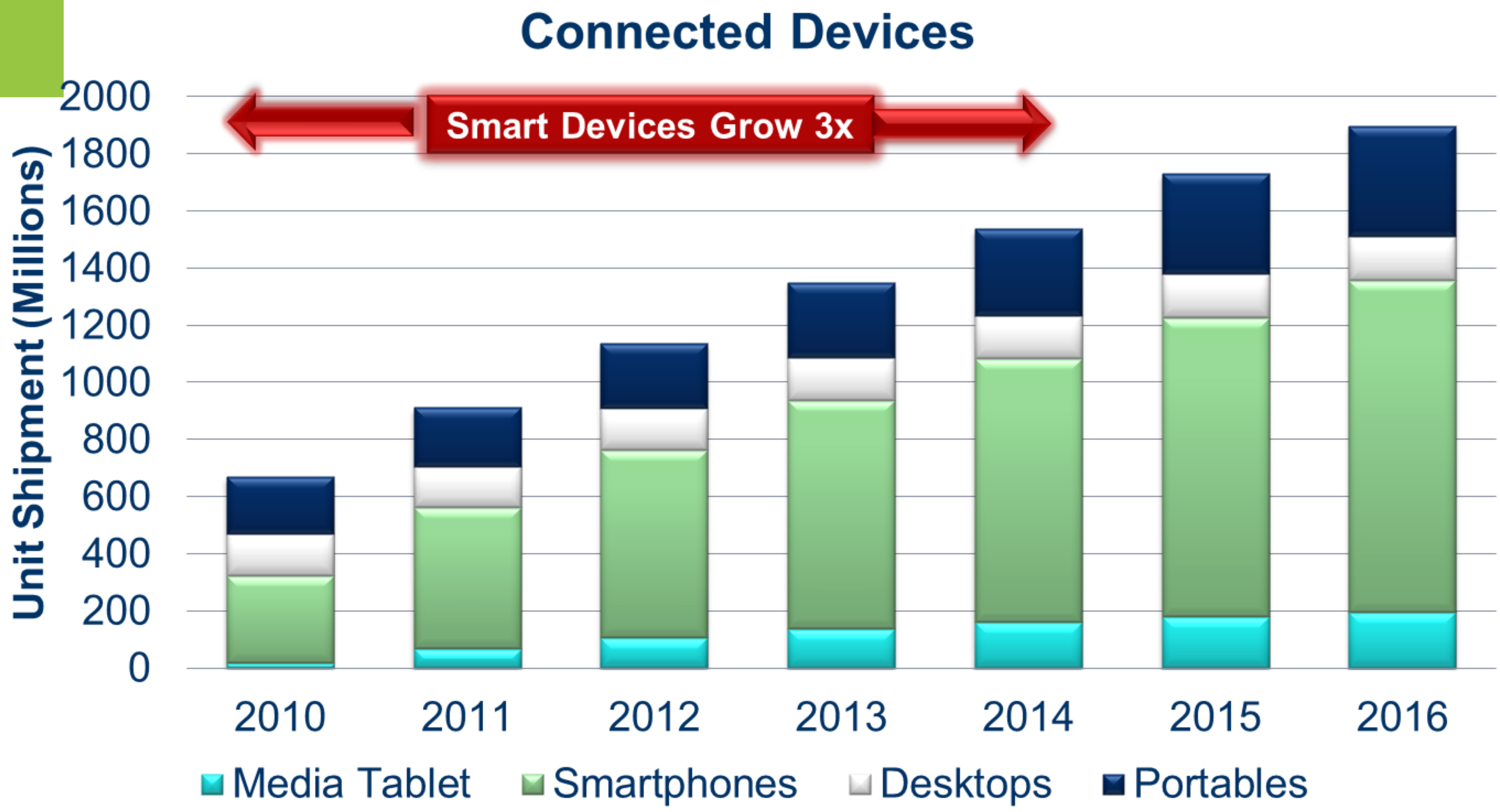
New, all-IP mobile core network introduced with LTE

- End-to-end IP
- Clear delineation of control plane and data plane
- Simplified architecture: flat-IP architecture with a single core



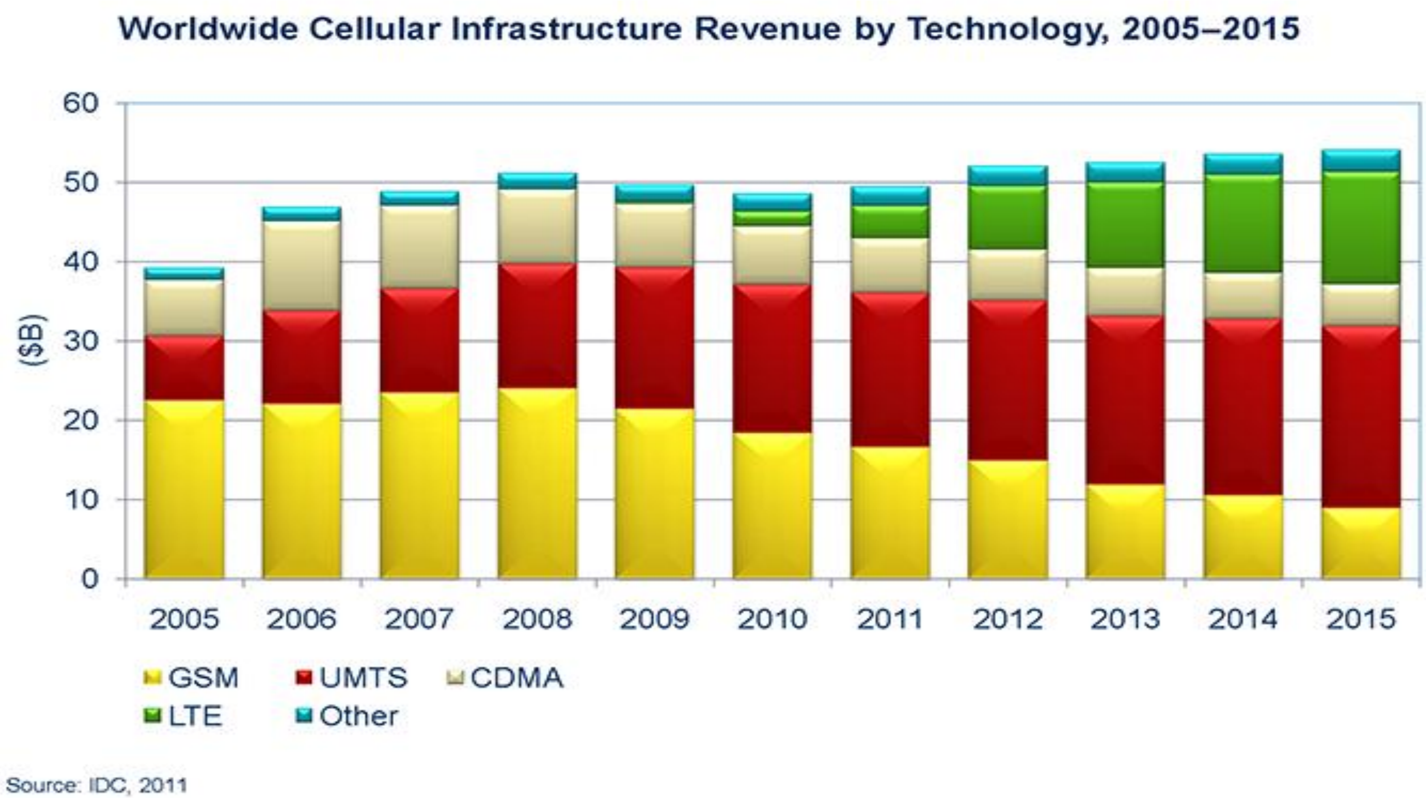
Evolved Packet Core = end-to-end IP transformation of mobile core

Smart Mobile Devices: Diversity, Explosion



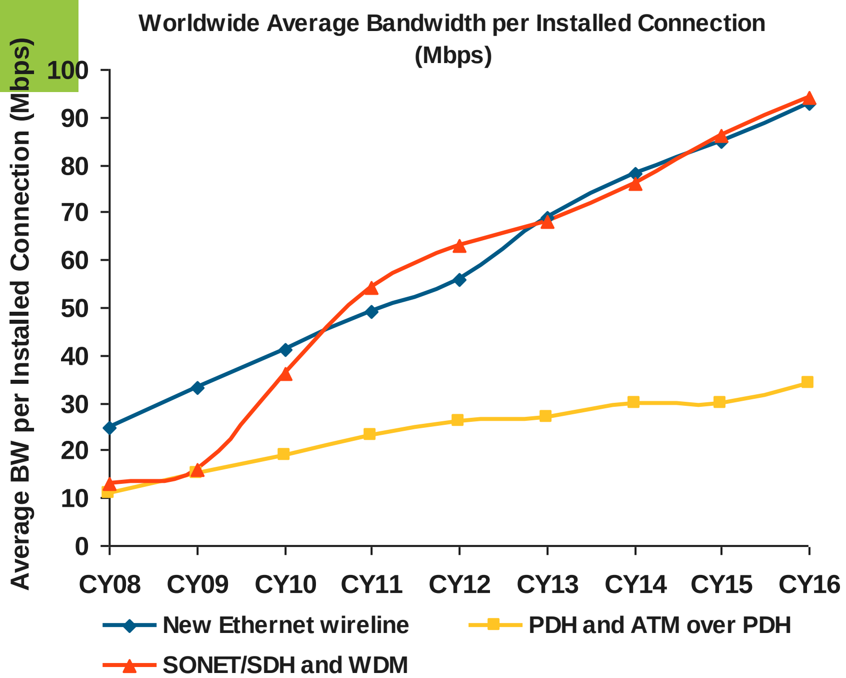
Source: IDC, 2012

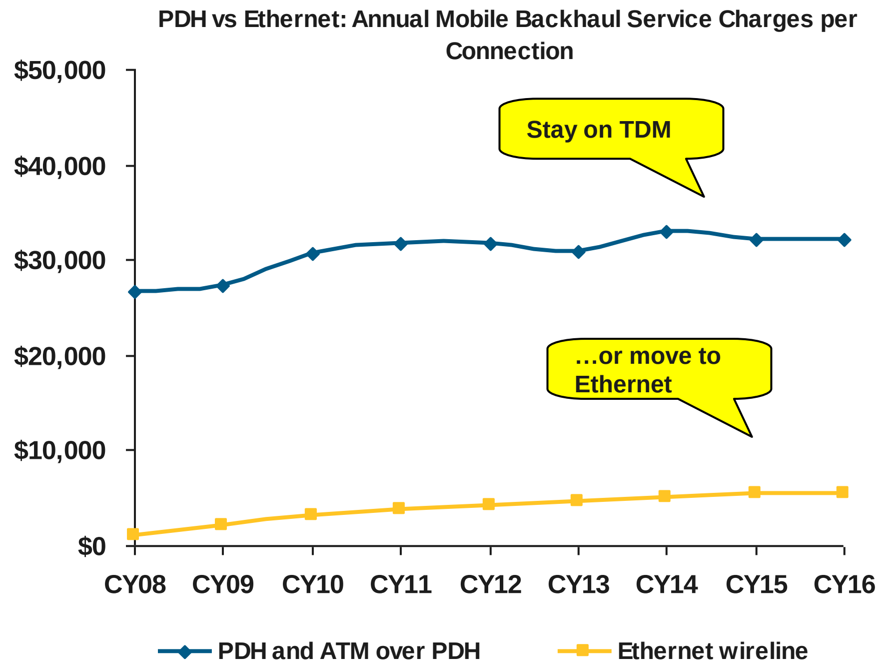
Revenue by Technology



- **Most cell sites will support multiple wireless technologies**

Traffic Growth — Ethernet to the Rescue

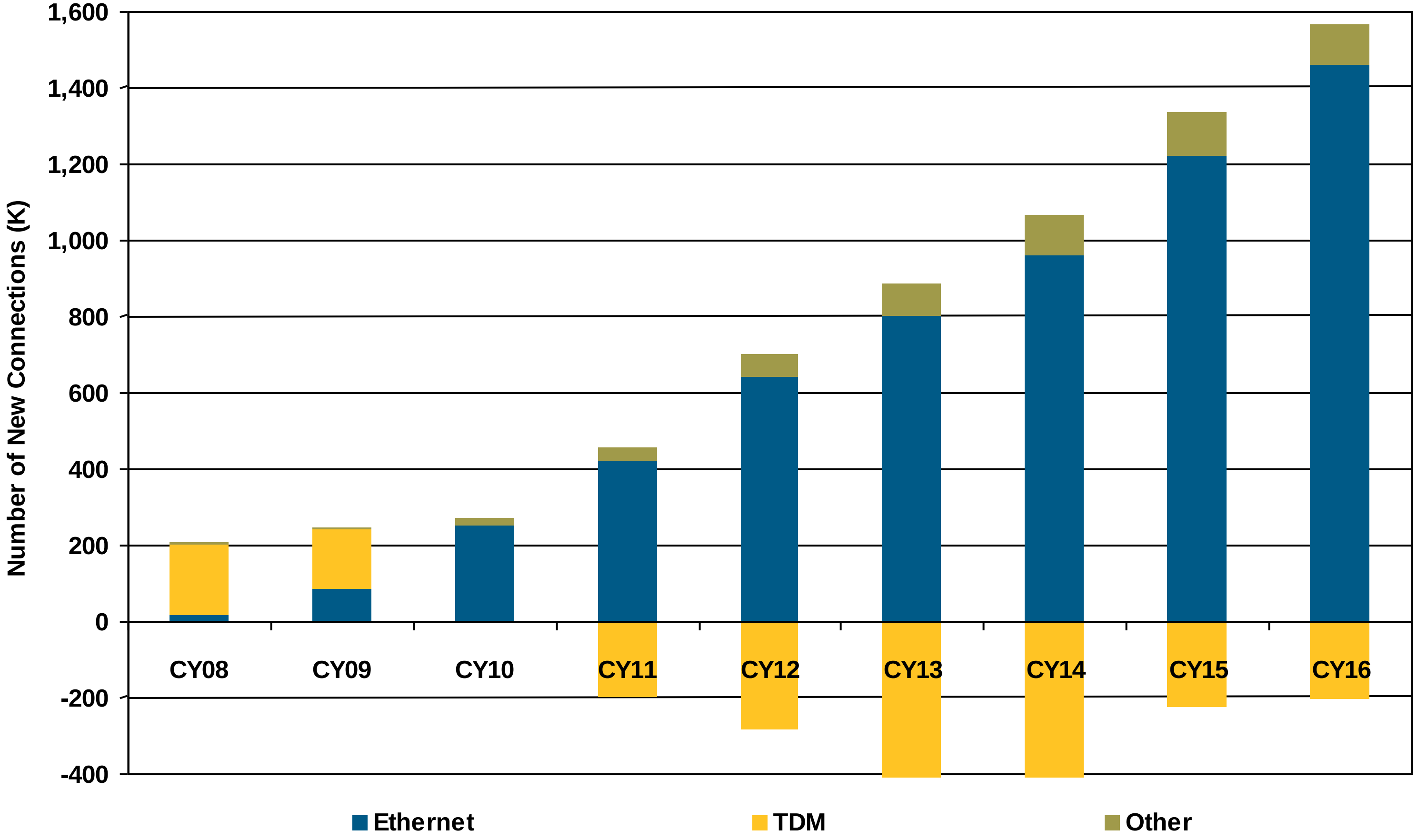




- Costs of traffic drive operators to IP/Ethernet backhaul
  - The “new Ethernet wireline” (Ethernet over fiber or copper, DSL, PON, cable) costs significantly less per bit than TDM
- Capacities and charges reflect current planning for HSPA+ and LTE

Source: Infonetics Research: *Mobile Backhaul Equipment and Services, Market Size, Share, and Forecasts,* March 2012

Virtually all New Connections are IP Ethernet



IP/Ethernet and LTE mobile backhaul are intertwined

Source: Infonetics Research: *Mobile Backhaul Equipment and Services, Market Size, Share, and Forecasts,* March 2012

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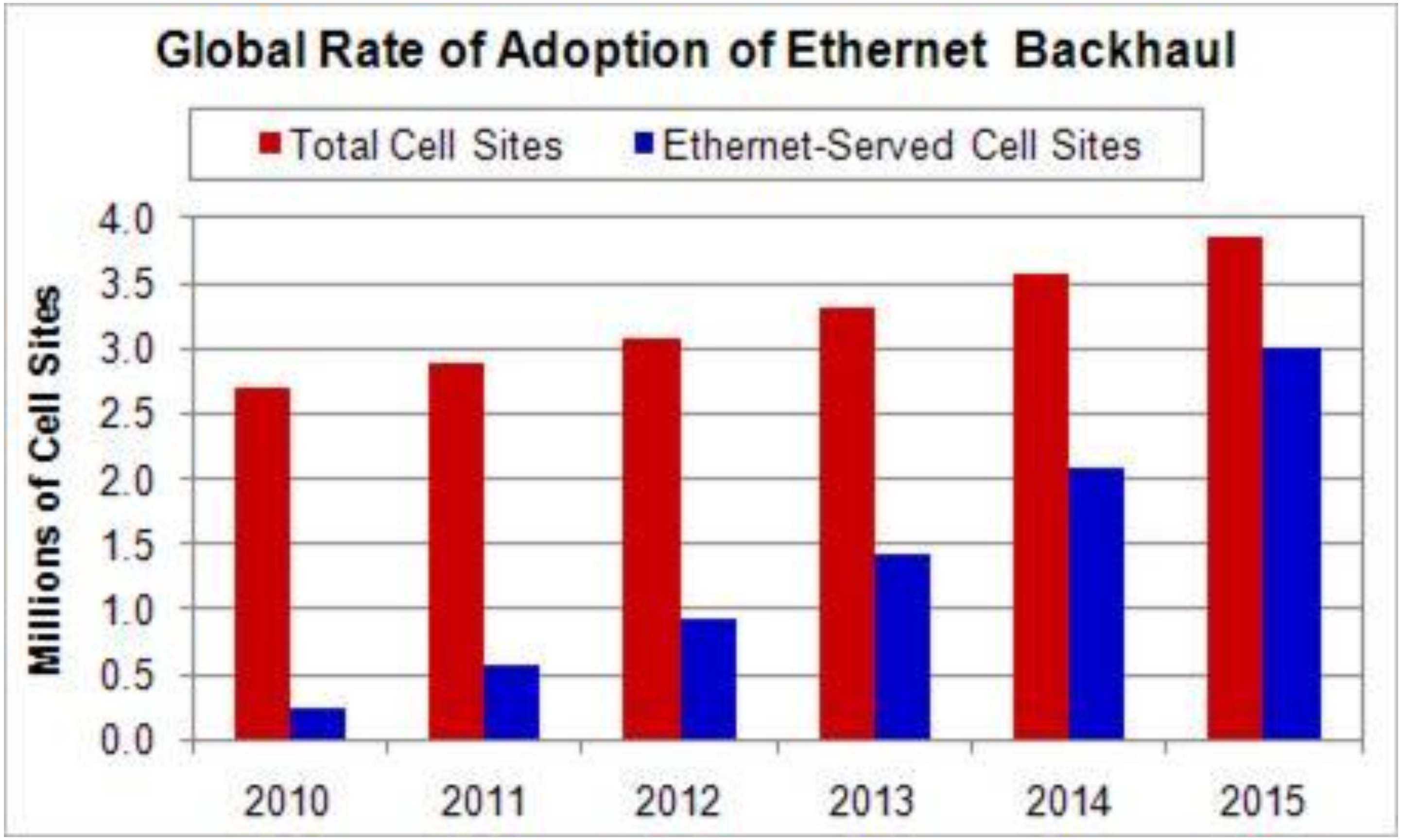
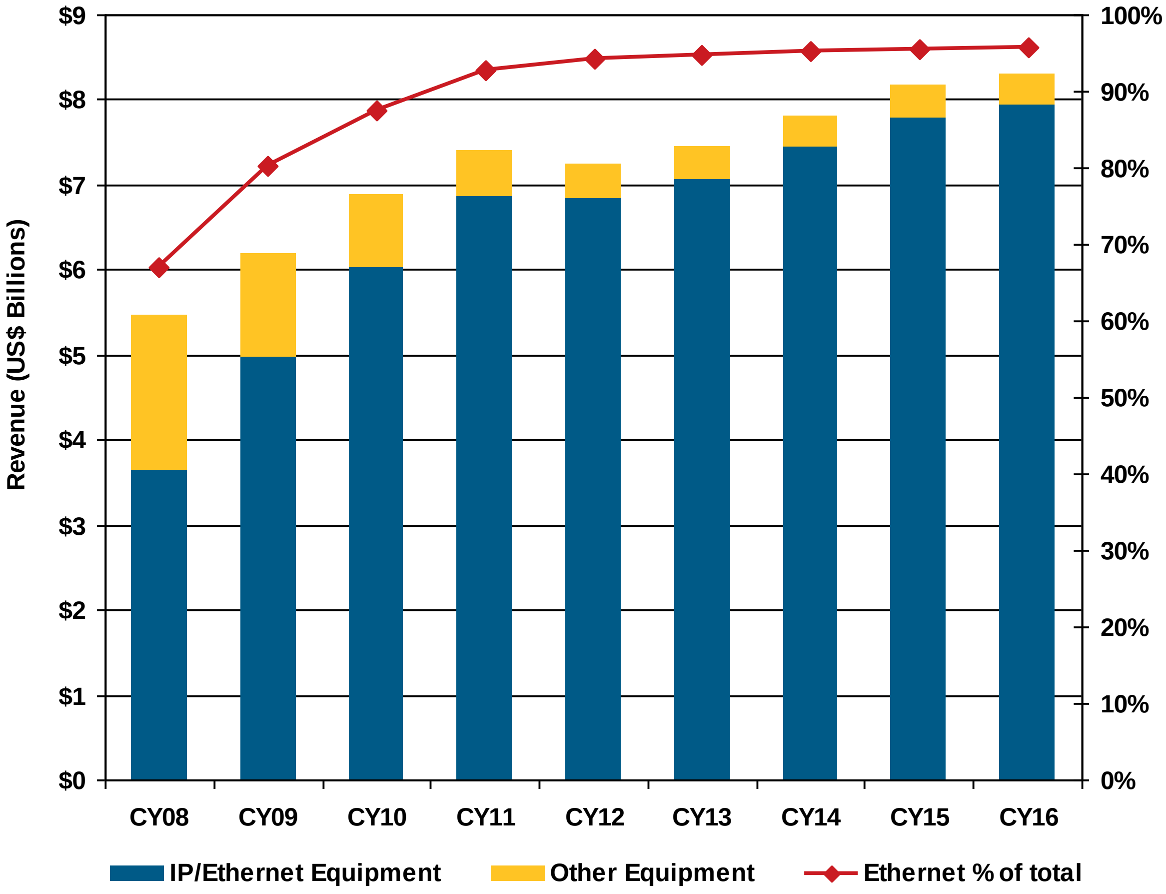
Packet Based Backhaul Adoption



Source: Heavy Reading, June 2012

IP/Ethernet is 94% of 2012 MBH Equipment Spending — Must Support LTE



- Global 2012 MBH equipment spend will be $7.3 billion
  - Surge of Ethernet MBH routers in China caused part of the 2011 bump; return to normal in 2012
- Steady growth after 2012
  - $8.3B in 2016
  - Cumulative $39B over 5 years
- This is very healthy growth, especially for a market in the billions of dollars

Source: Infonetics Research: *Mobile Backhaul Equipment and Services, Market Size, Share, and Forecasts,* March 2012

Business and Technical Drivers for Mobile Backhaul Evolution

- Mobile backhaul expense is a sizable portion of overall Mobile operator OPEX”
- 4G/LTE capacity and performance is determined by the size and performance of backhaul network
- 4G/LTE and small cells impose new requirements on backhaul network
- Solution needs to support 4G/LTE with the co-existence of 2G and 3G technologies
- Backhaul has to address network challenges: synchronization, delay, and resiliency

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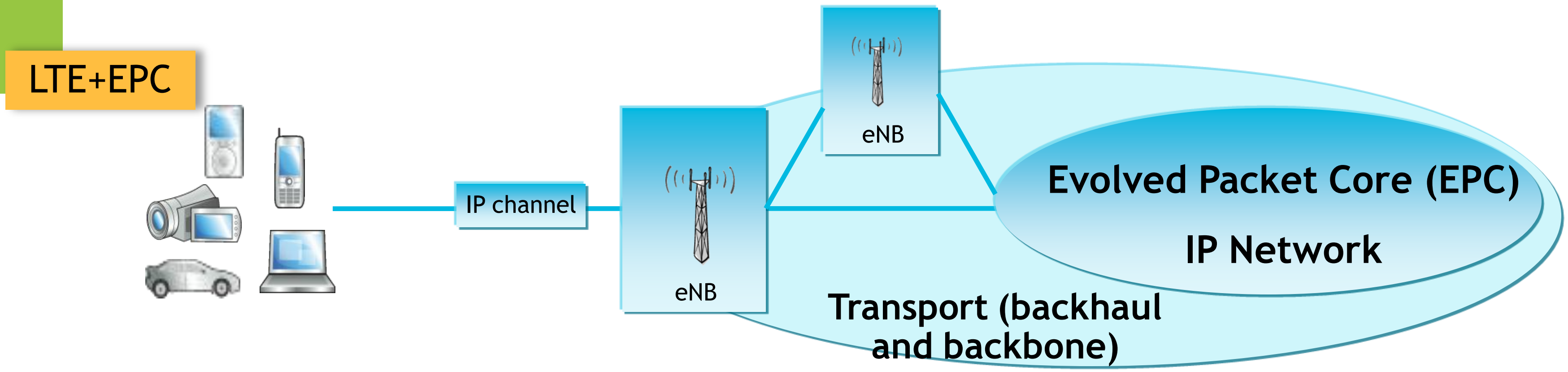
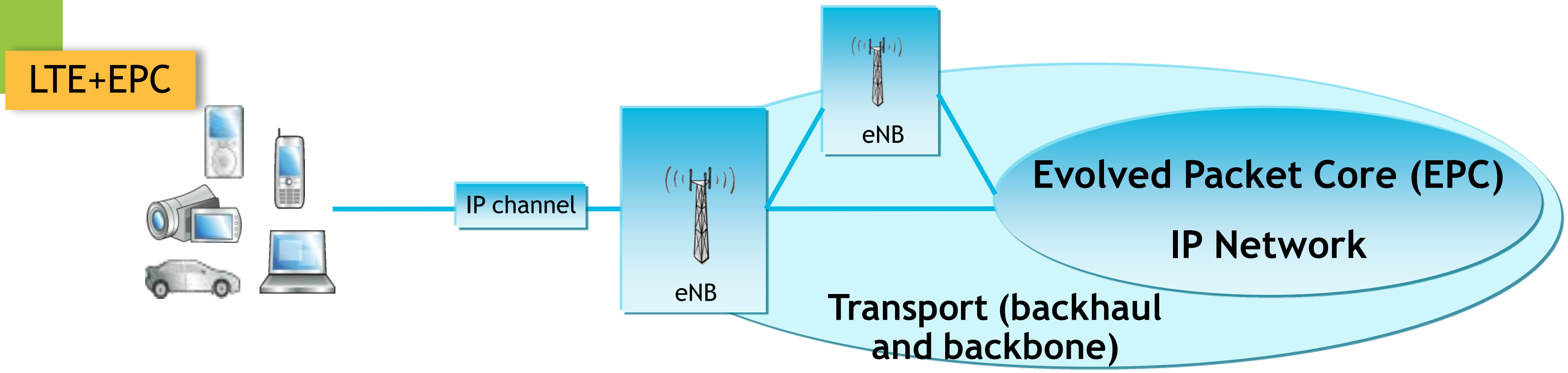
LTE Deployment Requires Evolution of Backhaul Transport



- LTE is built on an all-IP architecture – compared to 3G and previous generations of mobile technology, it has:
  - A more direct data and control path between the mobile user and the core network
  - Base stations (called eNBs) with additional functionality – including direct communication of client data and control plane traffic between eNBs
- Transport Implications
  - Favors more flexible backhaul mesh technology, such as architectures that do not need to transverse the aggregation points
  - To support transport of latency-sensitive traffic between eNBs, need a backhaul architecture that minimizes latency
  - MPLS at the aggregation points is one of the likely solutions to these challenges

LTE Deployment Requires Evolution of Backhaul Transport *(continued)*



- Flatter IP architecture requires smooth interworking between previously separate mobile backhaul and backbone transport networks
  - VPN scaling: LTE enabled eNB user plane connects directly to packet-Core
  - Scope of E2E network planning, traffic engineering, transport SLA monitoring increases (e.g. high availability, stringent E2E QoS is no longer broken up into segments with mobile NEs between each)

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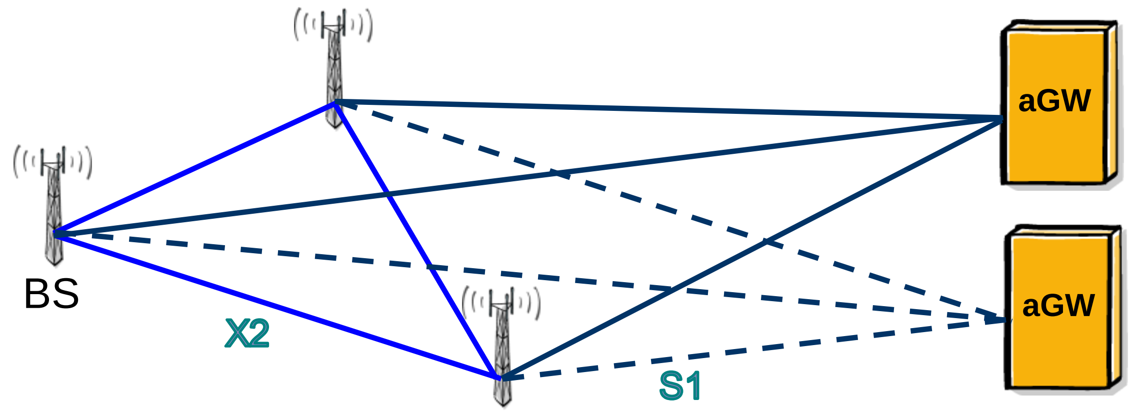
LTE RAN Connectivity



- Star topology enabling communication from BS to aGW (Access Gateway) and from aGW to BS (Base Station).
- Neighbouring any-to-any topology enabling communication among BSs (X2)

RAN - Radio Access Network

Why MPLS?

- MPLS is THE unifying technology for various backhaul types
- MPLS is proven in Service Provider deployments globally – it delivers on its promises
- MPLS adds carrier-grade capabilities
  - ***Scalability*** **- millions of users/end points**
  - ***Resiliency*** **- high availability including rapid restoration**
  - ***Manageability*** **– ease of troubleshooting & provisioning**
  - ***Traffic Engineering plus QoS*** **– predictable network behavior**
  - ***Multiservice*** **– support for 2G (TDM), 3G (ATM, PPP/HDLC and IP), and LTE (IP) and co-existence with other types of traffic e.g. residential**
  - **Virtualization – VPNs to ensure separation of OAM from signaling / bearer planes, partitioning of multi-operator traffic**

Why IP/MPLS in Mobile Backhaul?

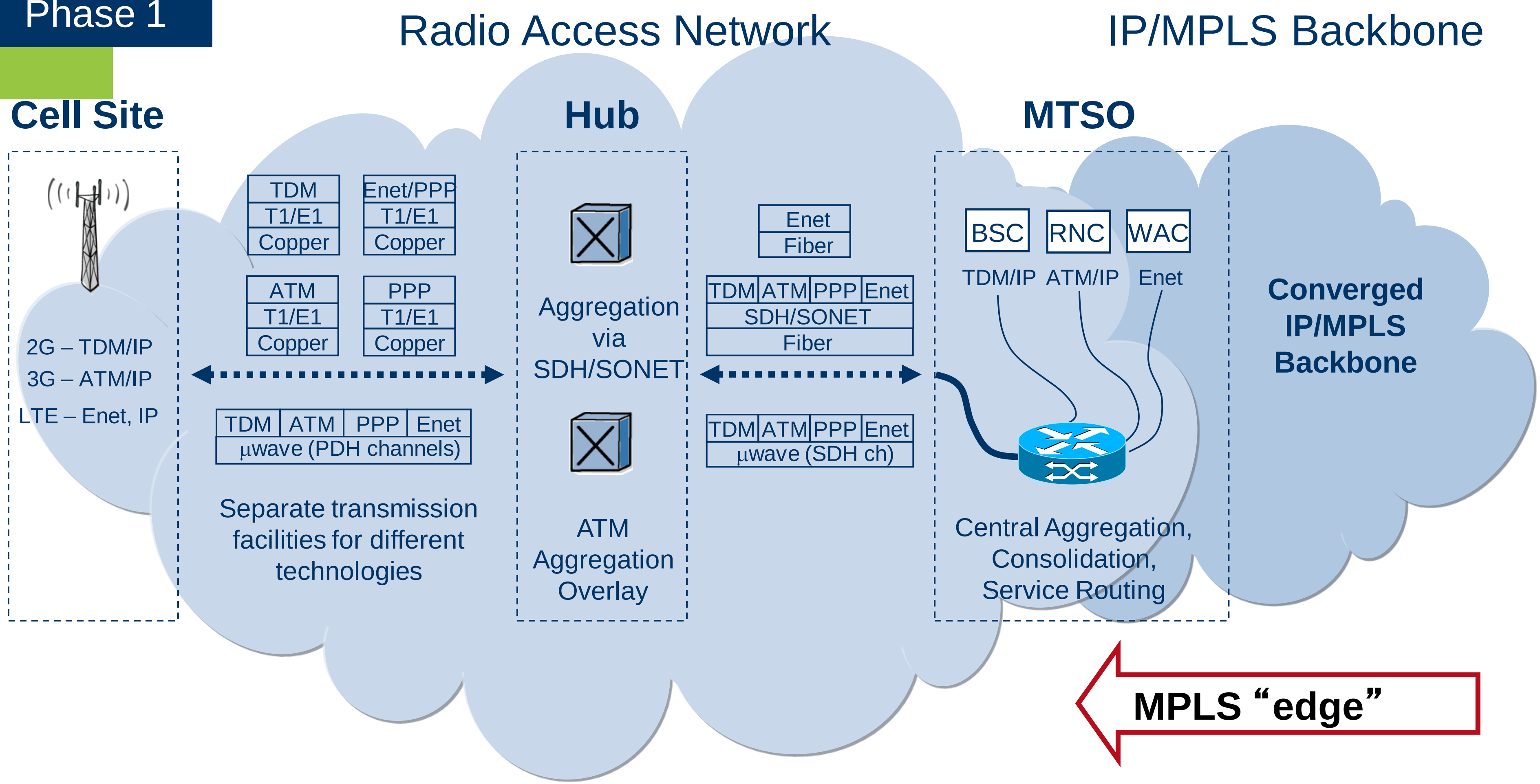
- Backhaul requires co-existence of multiple transport options
  - MPLS is a proven mechanism to support ATM, TDM, Ethernet, Frame Relay emulation (Pseudo-wires)
  - Allows legacy RAN equipment to continue to be utilized (CAPEX protection) while leveraging the advantages of new packet transport networks
- Packet Backhaul needs to support multi-media traffic
  - Voice/VoIP, Video/Multimedia, SMS, Data
  - MPLS –TE enables advanced QoS capability
  - Improved network utilization, Better ROI
- Reliability is critical
  - MPLS offers faster convergence and interoperable mechanisms for failure detection and recovery
- Backhaul is increasingly becoming a strategic asset
  - MPLS at cell site enabled carriers to offer new revenue generating services (i.e. L2/L3 VPNs)

IP/MPLS

Scalability	Resiliency	*Multi-Service*	*Manageability*	TE/QOS

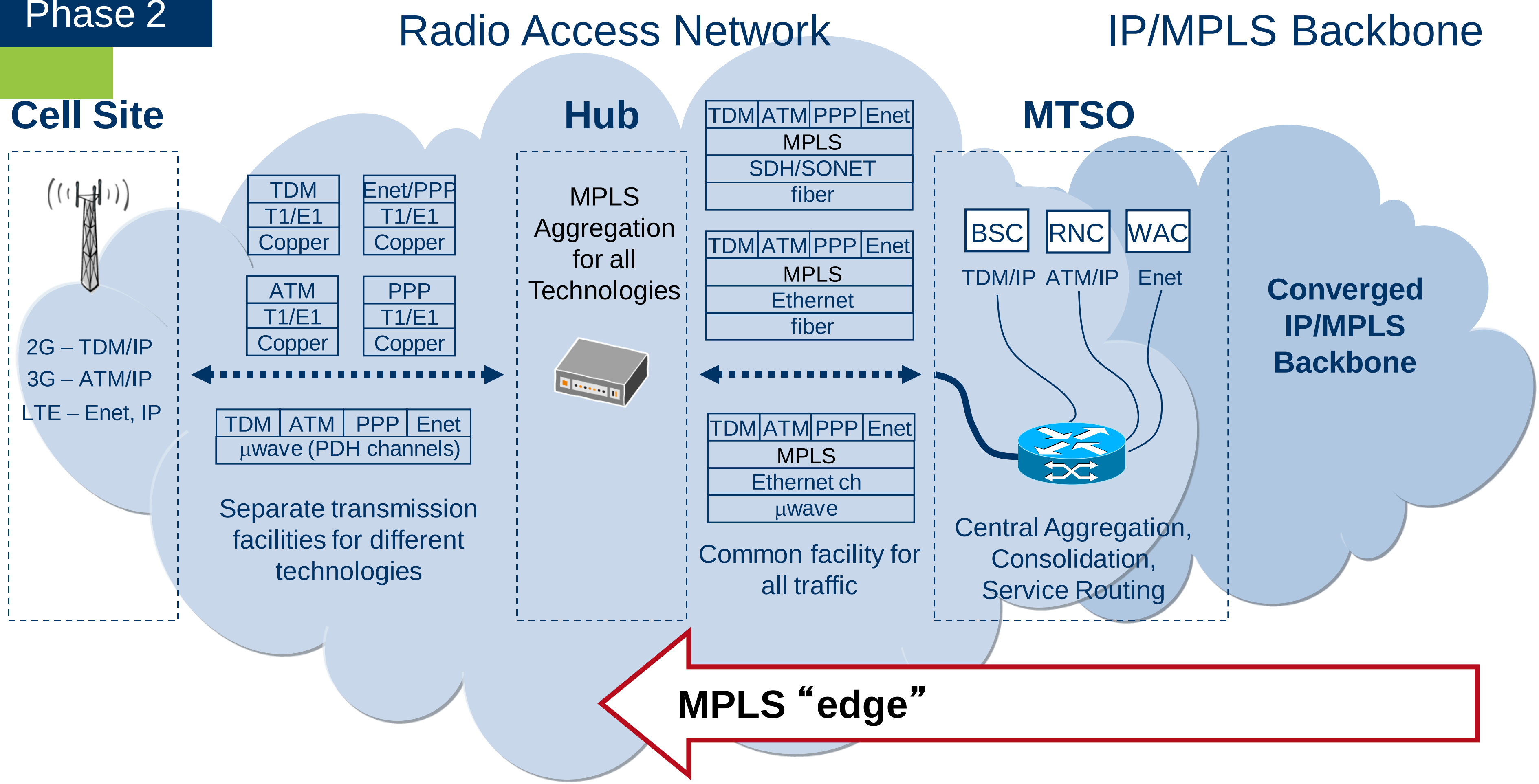
Multi-phase MPLS migration into RAN Transport

Phase 1



Multi-phase MPLS migration into RAN Transport

Phase 2



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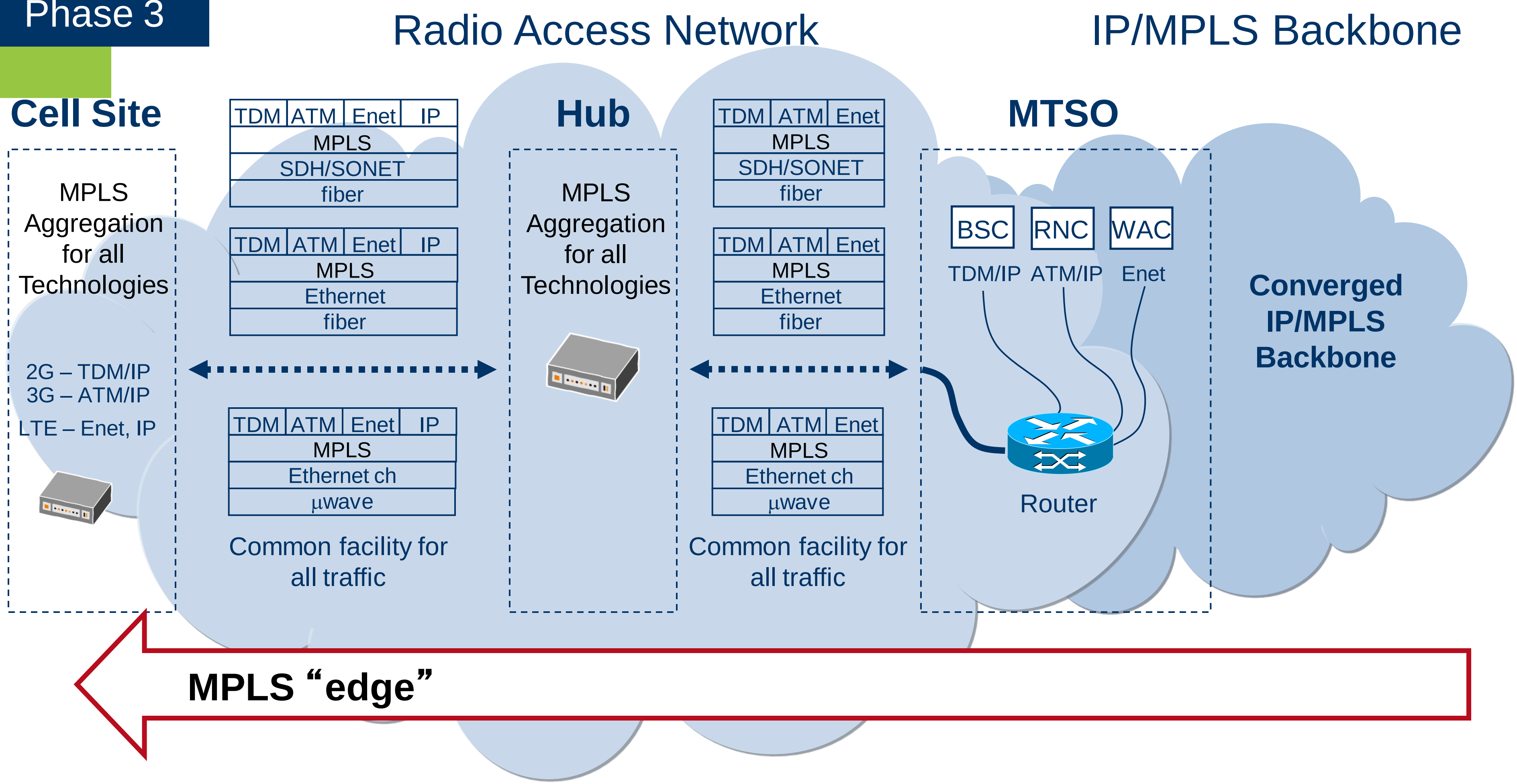
Multi-phase MPLS migration into RAN Transport

Phase 3



MPLS is agnostic to transmission techniques in Access

Mobile Backhaul Standards Landscape

- 3GPP
  - RAN definition and specification – definition of the RAN and its interfaces
- Broadband Forum
  - TR-221 – architecture of mobile backhaul transport support with MPLS
  - TR-221 Amd-1 (work in progress) – scaling and resiliency of the mobile backhaul network (for example small cell deployment)
  - WT-145 – next generation broadband network architecture to support mobile backhaul
  - Certification – certification of MPLS technologies to support mobile backhaul transport
  - Tutorials – education on MPLS in mobile backhaul transport
- MEF
  - MEF-22.1 – Metro Ethernet services and interfaces required to support mobile backhaul
  - Mobile Backhaul Whitepapers and Tutorial
- ITU-T SG 15
  - Specification for Clock Synchronization over packet network

What is MMBI?
MPLS in Mobile Backhaul (MMBI)

- MPLS in Mobile Backhaul (MMBI) is a technical initiative started in 2007 by the IP/MPLS Forum and adopted by the Broadband Forum
- The initiative currently consists of
  - Architecture and nodal requirements specifications
  - Test specifications
  - Certification programs related to mobile backhaul (e.g., TDM over MPLS)
  - Whitepapers
  - Tutorials (such as this one)
- There are currently 7 specifications
- More specifications are in progress to address mobile backhaul of LTE and beyond.

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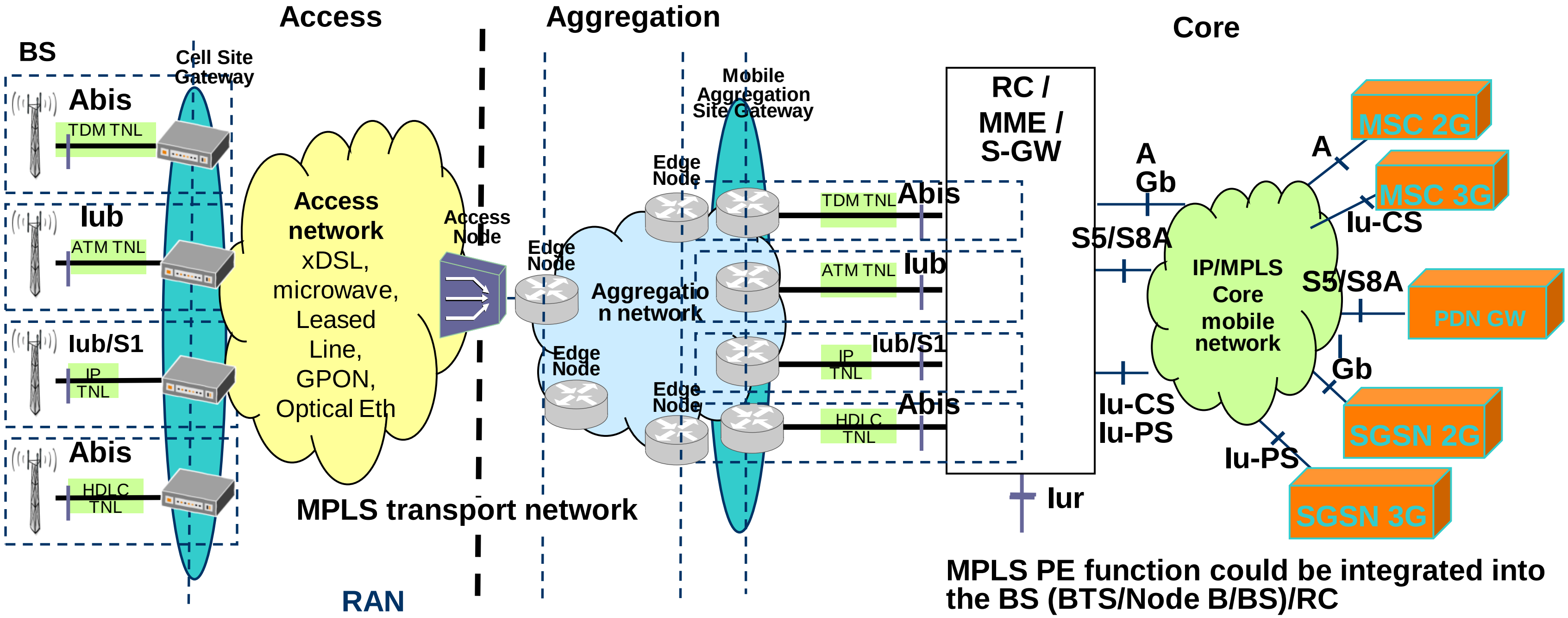
What MMBI aims to address?

- Faster mobile broadband deployment
  - HSPA/HSPA+/LTE/LTE-A
- Supporting 4G/LTE-Advanced features
- Enhanced experience for mobile users with new data services and application, along with voice
  - Location based service, VoIP, gaming, etc
- Future-proof investments
- Improve mobile operator's bottom line and simplify operations
  - Converging technology specific backhaul networks to single multi-service packet infrastructure
  - Based on proven benefits of IP/MPLS while leveraging cost-benefits of Ethernet

MMBI Reference Architecture

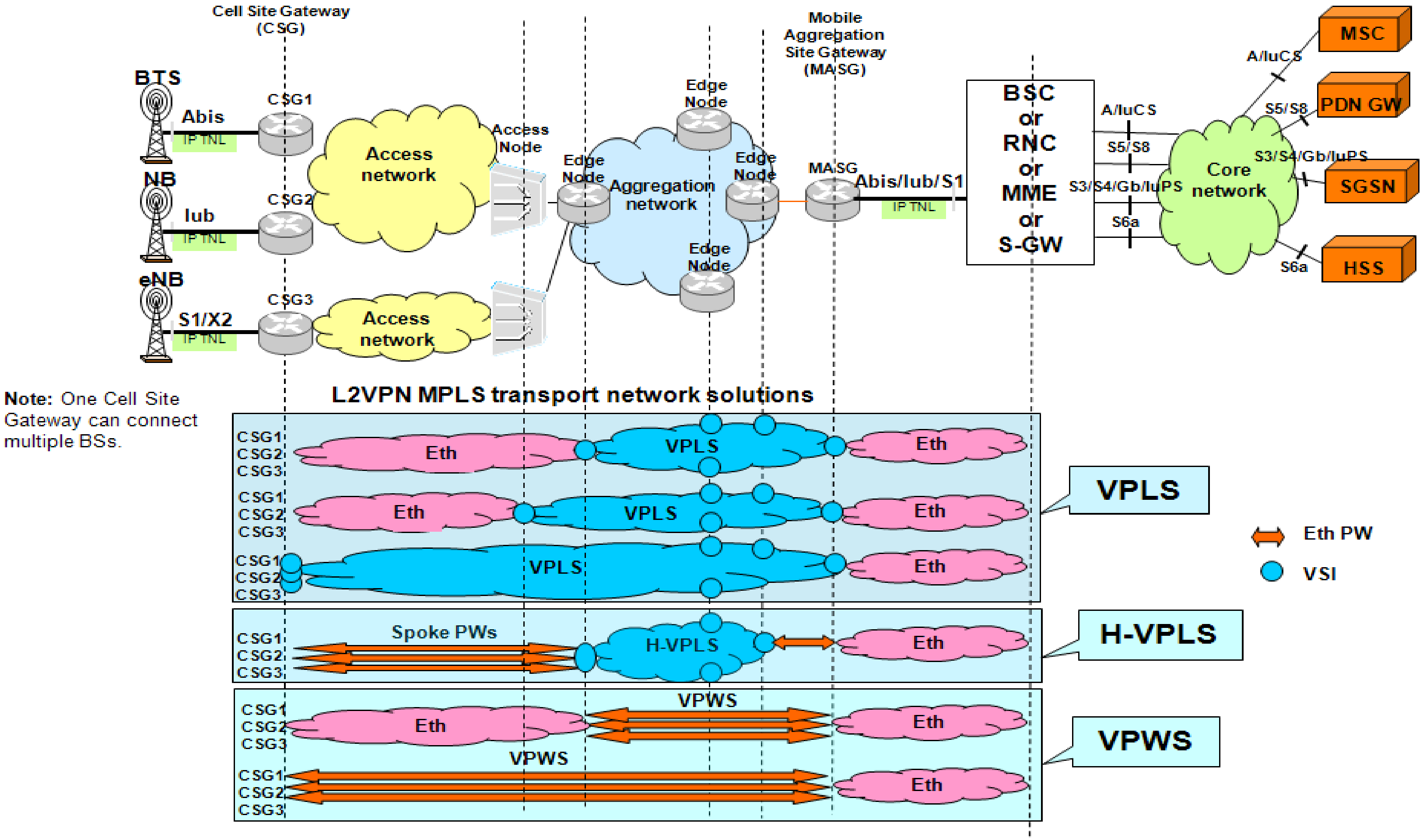


MPLS PE function could be integrated into the BS (BTS/Node B/BS)/RC

Terminology	WCDMA/ UMTS	CDMA 2000/1x	LTE
Base Station	Node-B	BTS	eNB
Base Station Controller	RNC	BSC	-
Circuit Edge devices	MSC	MSC	-
Packet Edge devices	SGSN, GGSN	PDSN	S-GW / MME

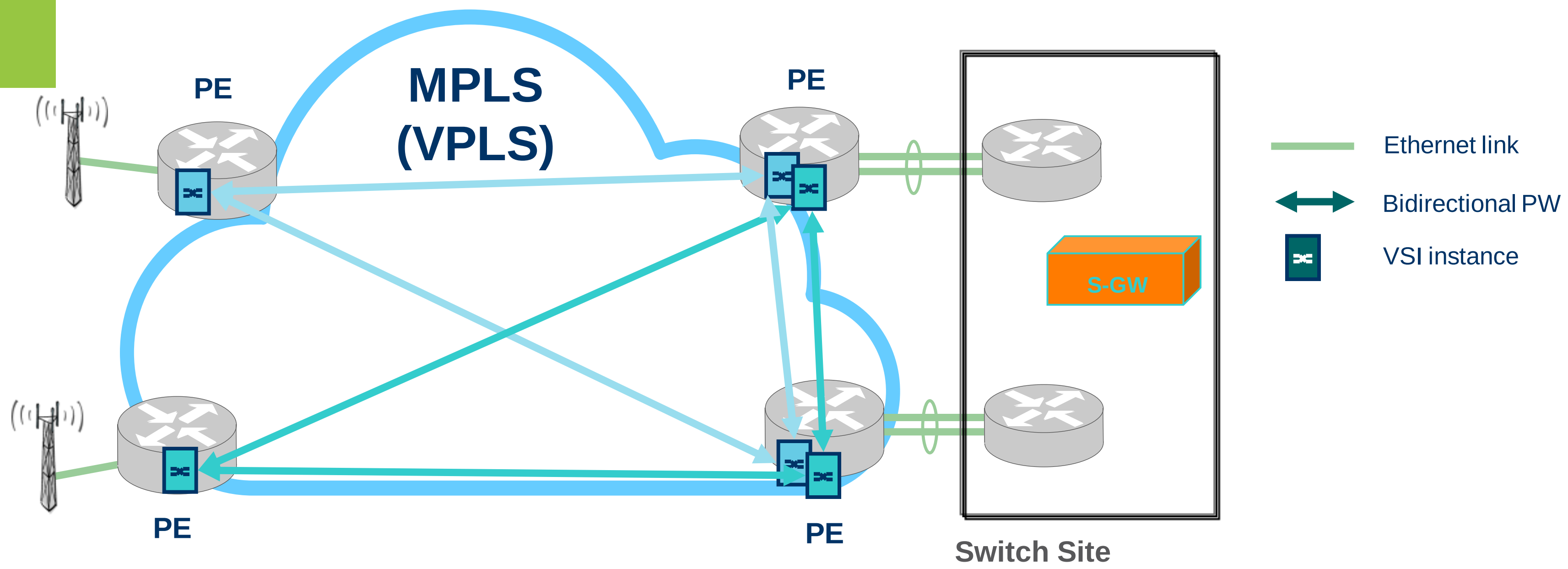
Ethernet and IP VPN Backhaul Architecture

IP TNL with L2VPN (Transport Network Layer)



VPLS - Virtual Private LAN Service
H-VPLS - Hierarchical Virtual Private LAN Service
VPWS - Virtual Private Wire Service

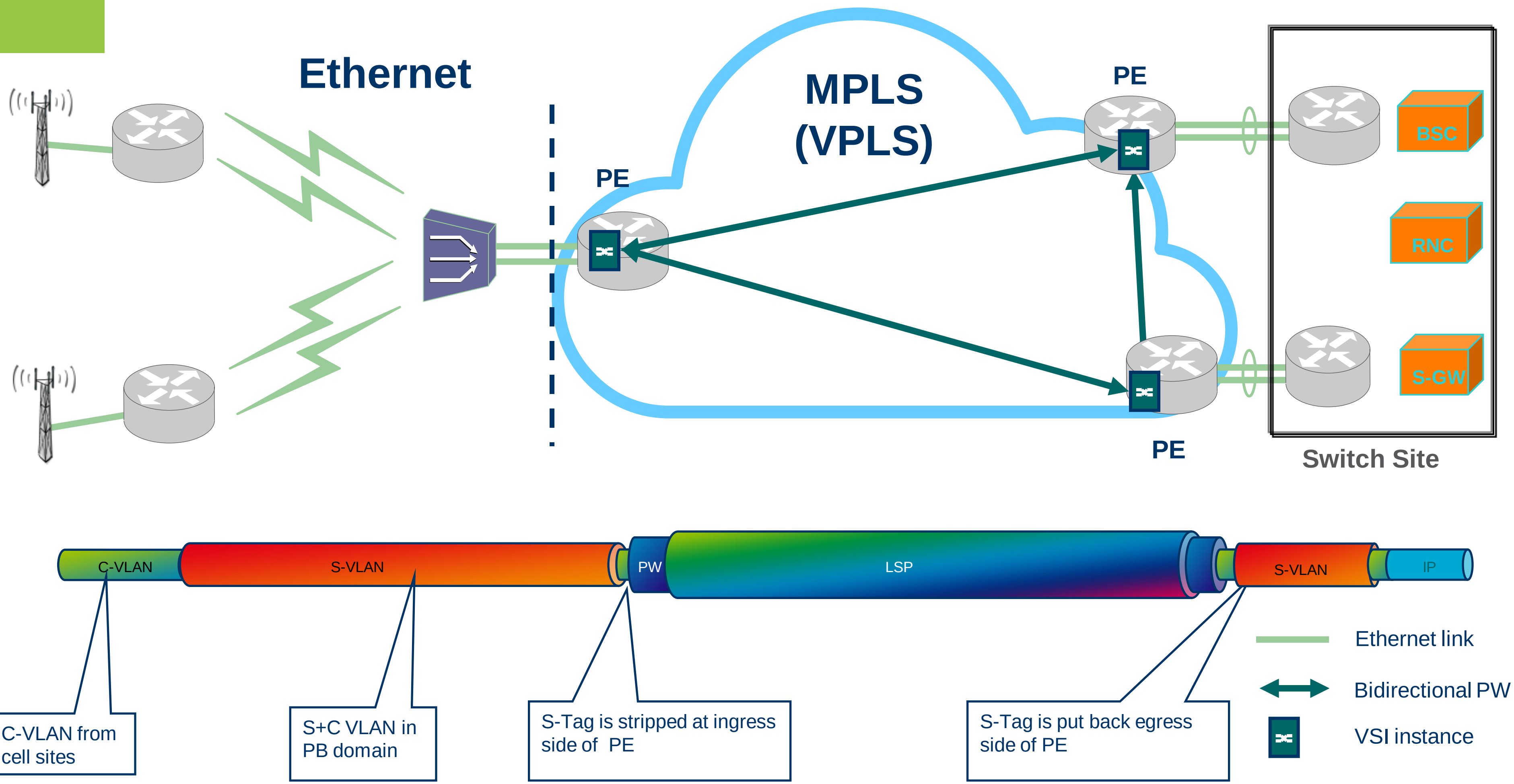
VPLS (Access & Aggregation)



Virtual Switching Instance (VSI) per Cell Site:

- Network is made up of many VPLS instances (3 nodes in each)
- LSP-based protection is mandatory (from all flavours of MPLS)
- Protection against a node failure at the switch site (PE or Router)
- VRRP runs between the switch site routers

VPLS and Ethernet



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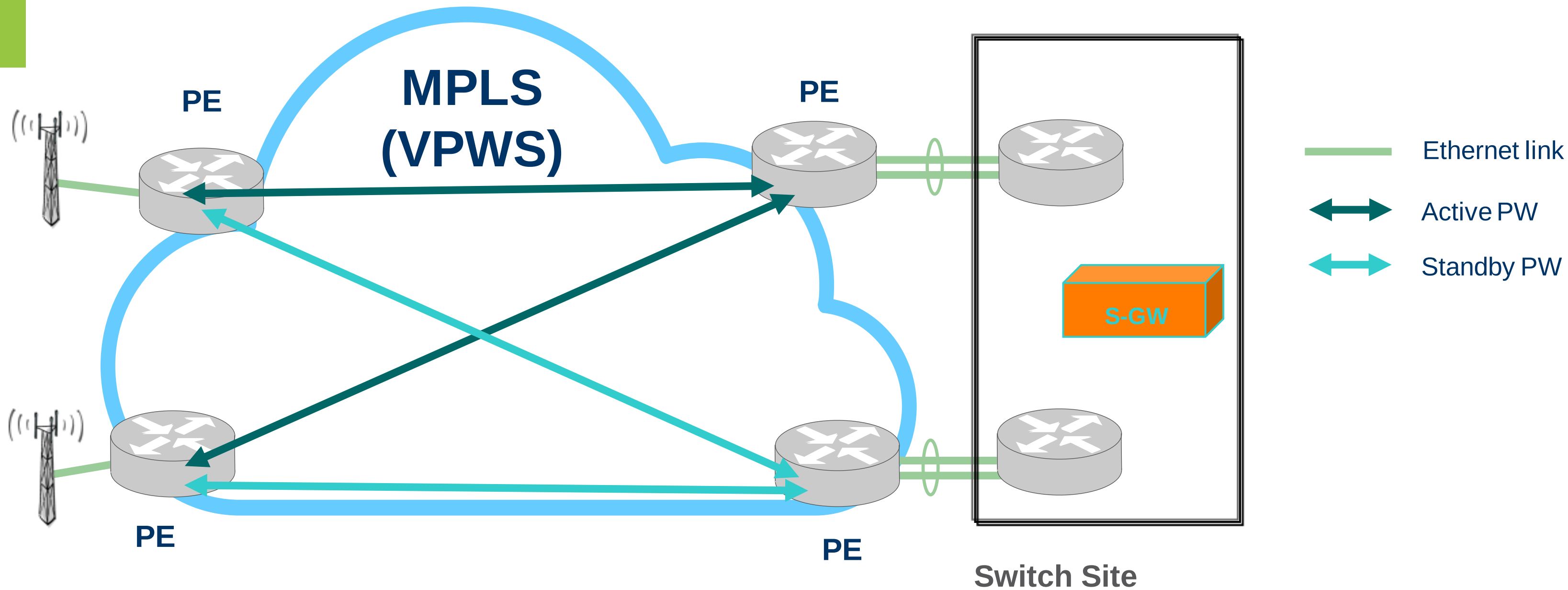
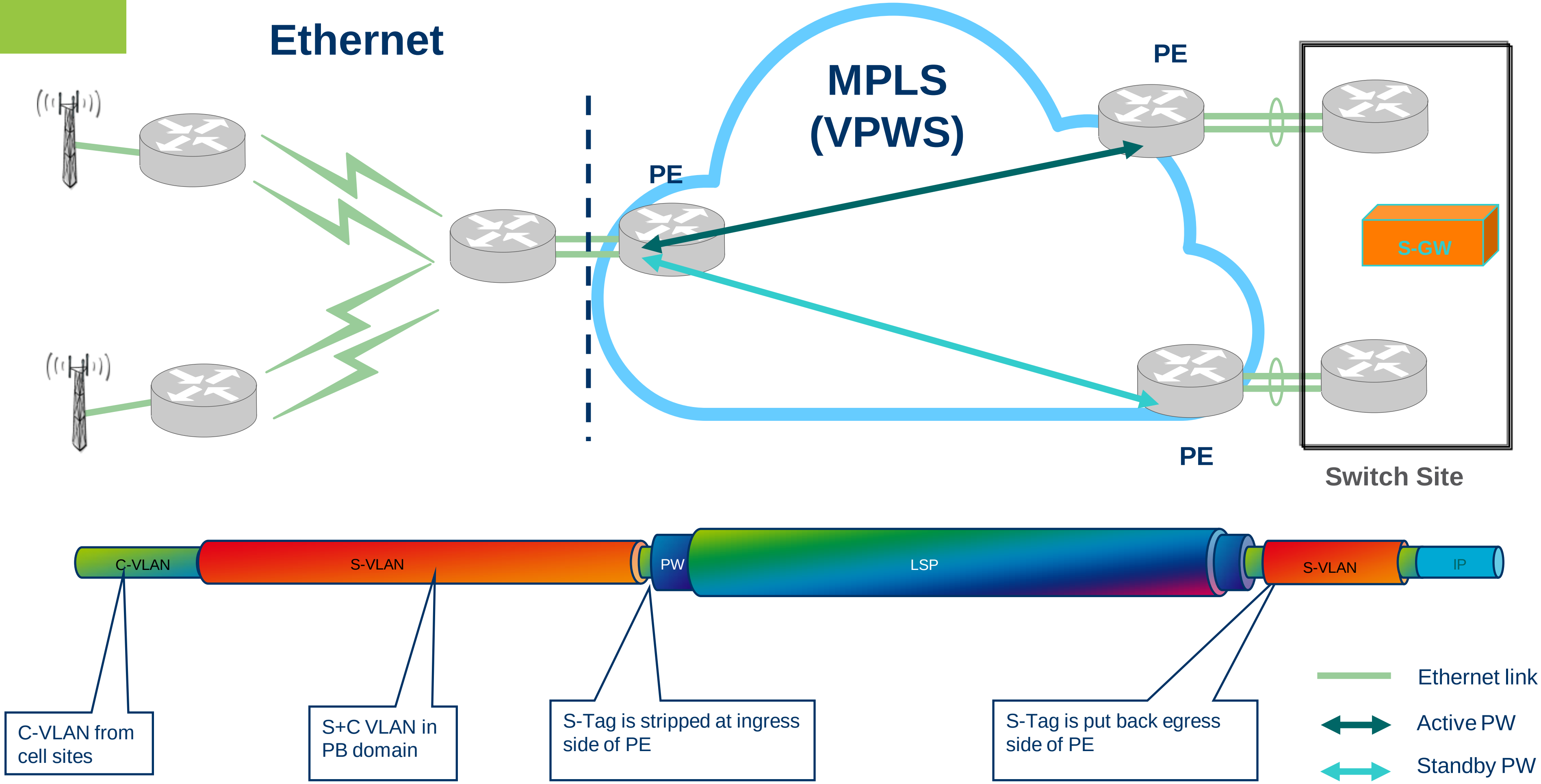
VPWS (Access & Aggregation)



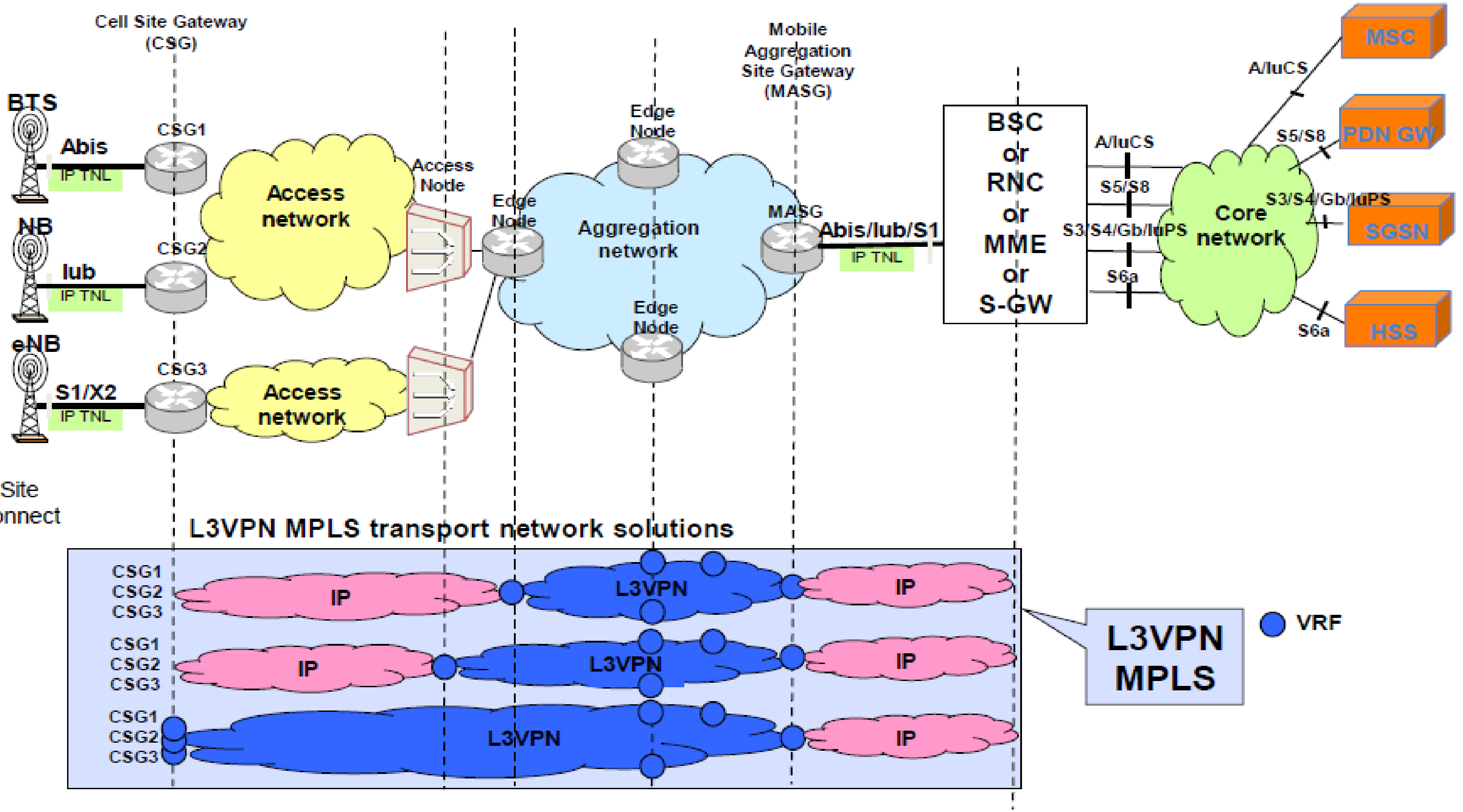
PW Redundancy group per Cell Site:

- Network is made up of many VPWS instances
- LSP-based protection is mandatory (from all flavours of MPLS)
- Protection against a node failure at the switch site (PE or Router)
- PW Redundancy runs in Independent mode from each Cell Site

VPWS and Ethernet

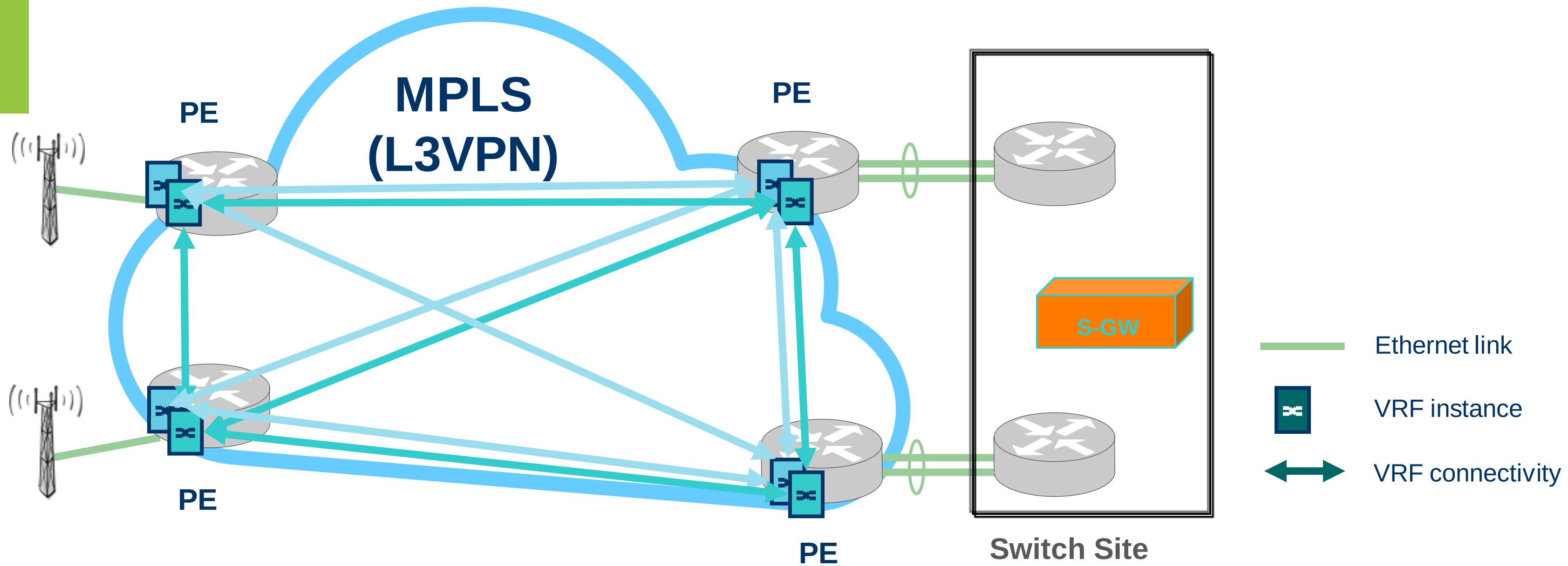


IP TNL with L3VPN (Transport Network Layer)



Note: One Cell Site Gateway can connect multiple BSs.

L3VPN (Access & Aggregation)



Multiple VPN Routing and Forwarding (VRF) instances:

- One VRF for RAN management traffic (security)
- One VRF for all other RAN traffic (CDMA, 2G, 3G, LTE)
- Single IP address space for the RAN ➔ no further VRFs necessary
- Single or Multiple Autonomous System (AS) options for scalability

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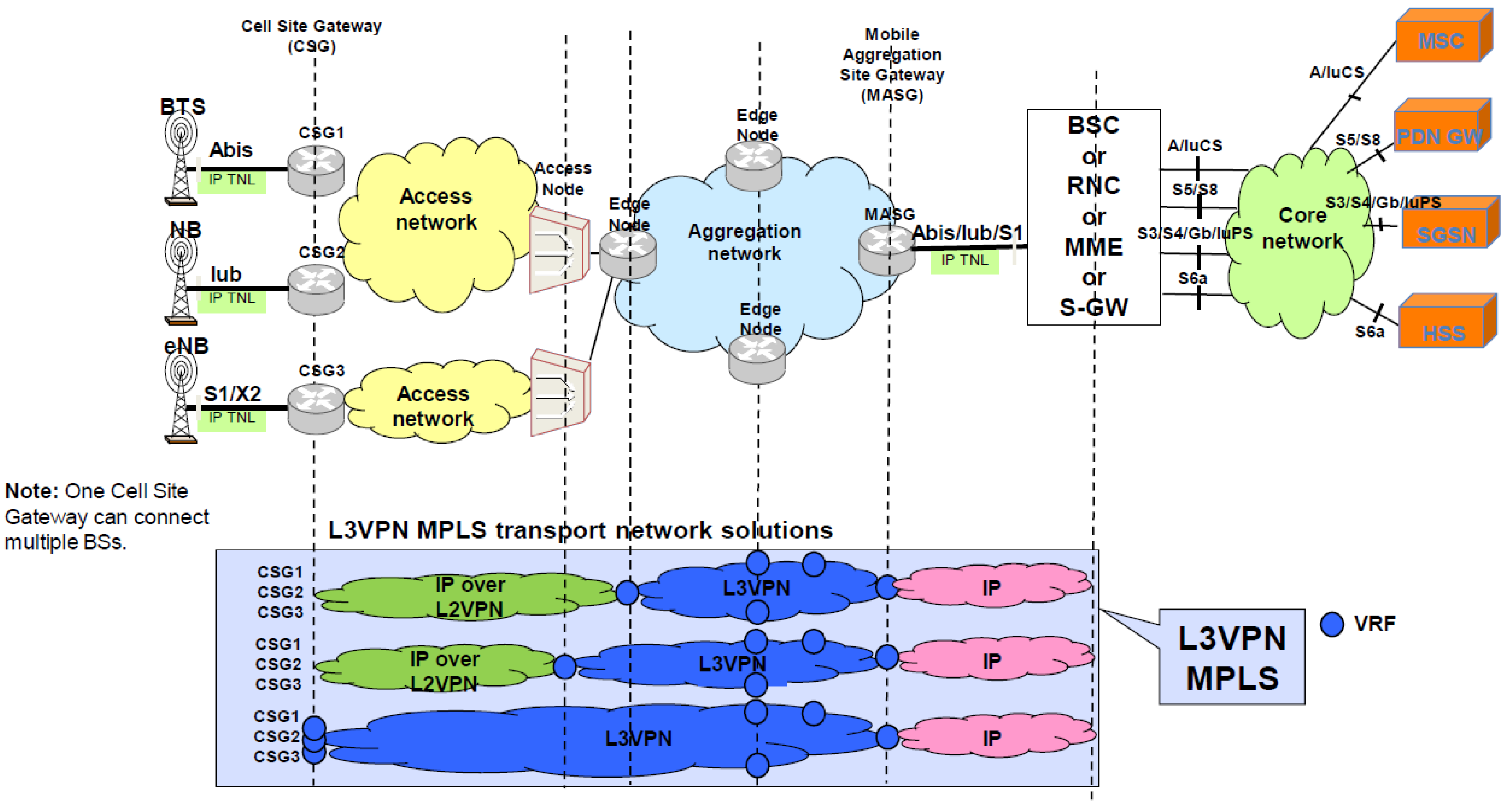
IP TNL Using L2 & L3 (Transport Network Layer)



Note: One Cell Site Gateway can connect multiple BSs.

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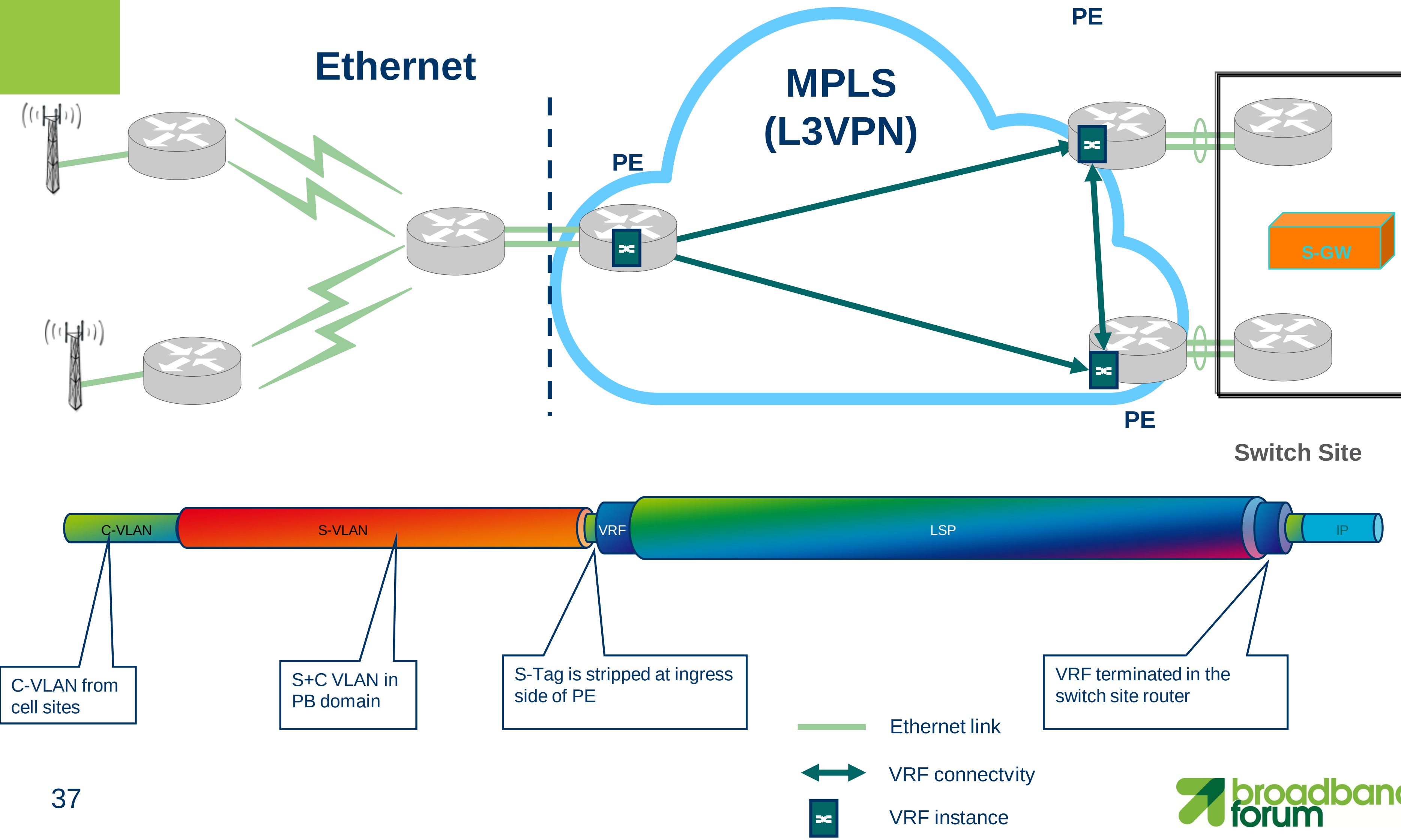
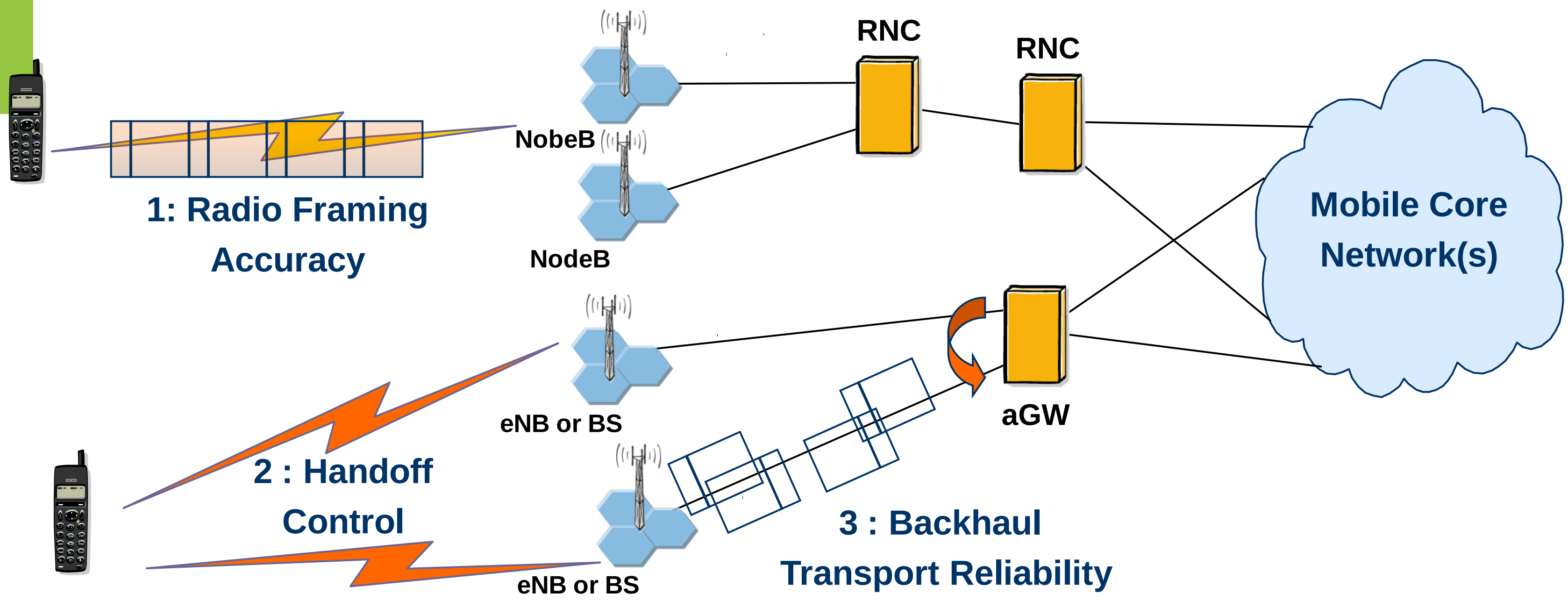
L3VPN and Ethernet



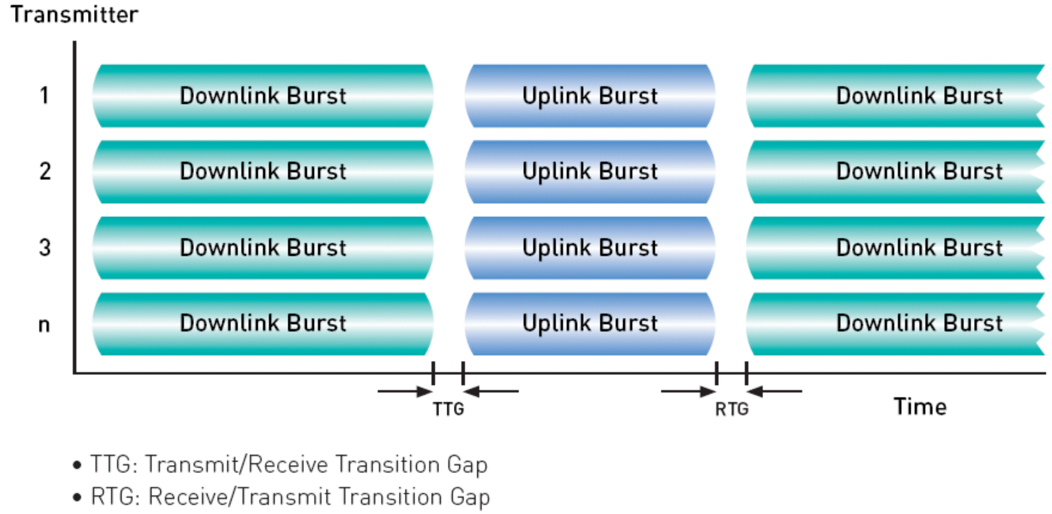
Timing and Synchronization

The Need for Synchronization in Mobile Networks



- Synchronization is vital across many elements in the mobile network
- In the Radio Access Network (RAN), the need is focused in three principal areas

Radio Framing Accuracy



- In Time Division Duplexing (TDD), the base station clocks must be time synchronized to ensure no overlap of their transmissions within the TDD frames
  - Ensuring synchronization allows for tighter accuracies and reduced guard-bands to ensure high bandwidth utilization
- In Frequency Division Duplexing (FDD) the centre frequencies must be accurate for receivers to lock

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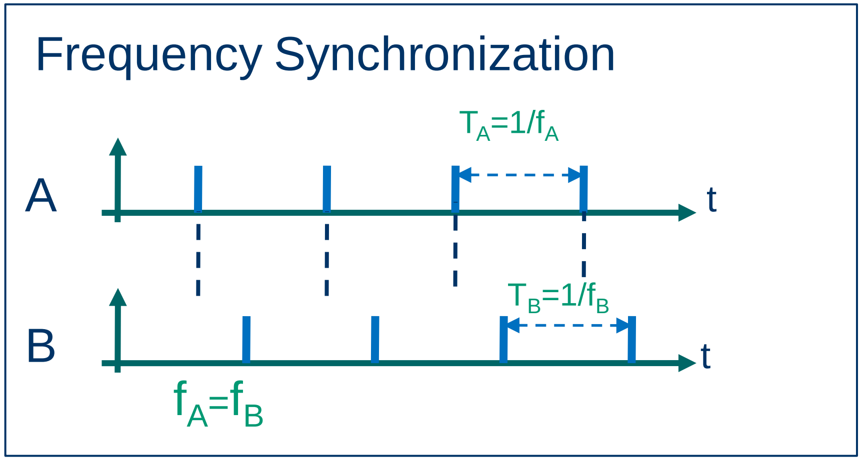
Radio Framing Accuracy

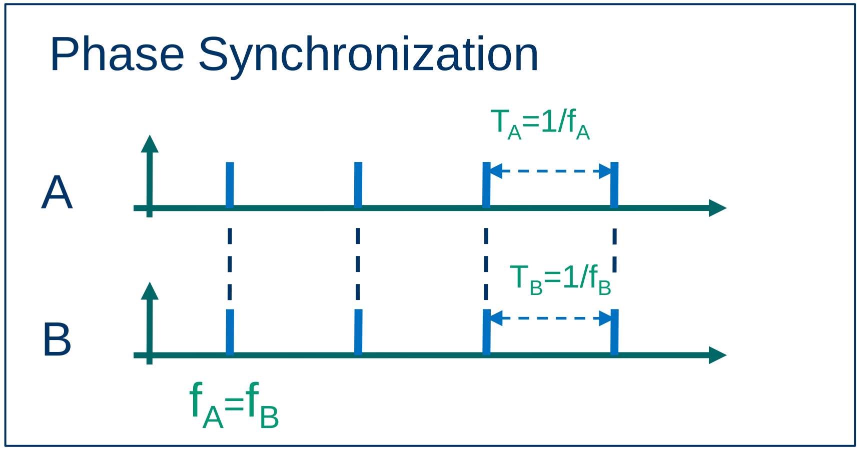
Radio Frequency Accuracy

- LTE TDD/FDD: 50 ppb
- LTE – A TDD/FDD: 50 ppb

Radio Phase/ToD Accuracy

- LTE TDD: +/-1.5 µs
- LTE-A with eICIC/CoMP: +/-1.5 - 5 µs



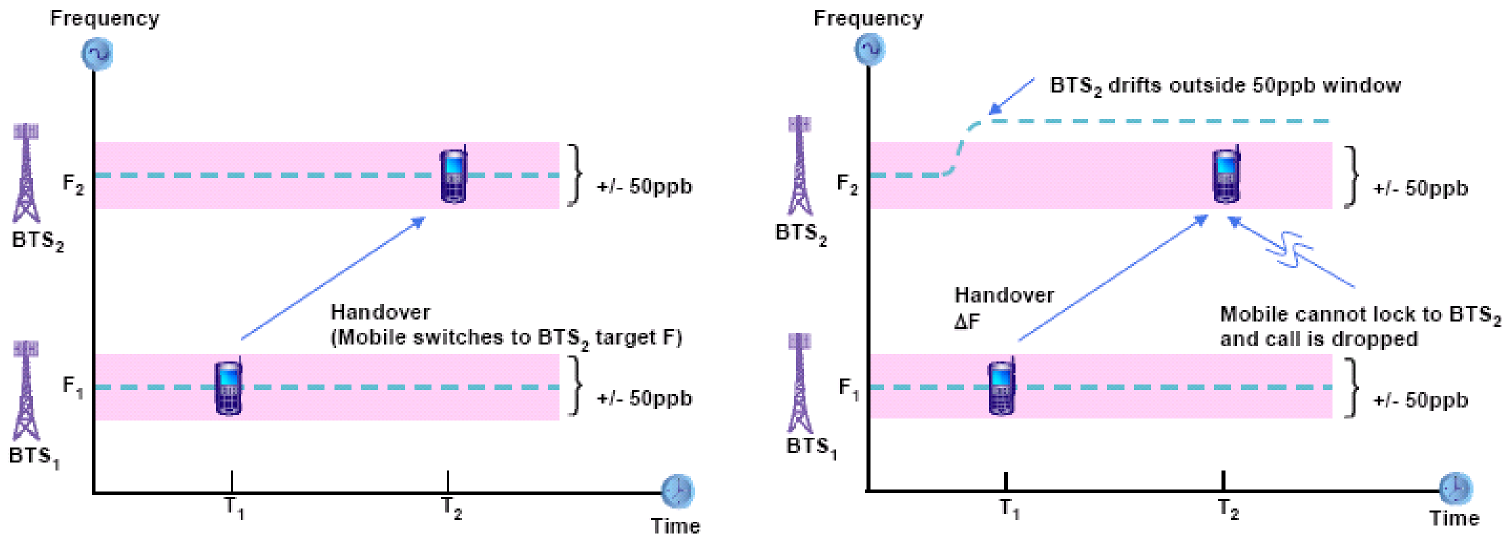


ToD – Time of Day

eICIC - Enhanced inter-cell interference coordination

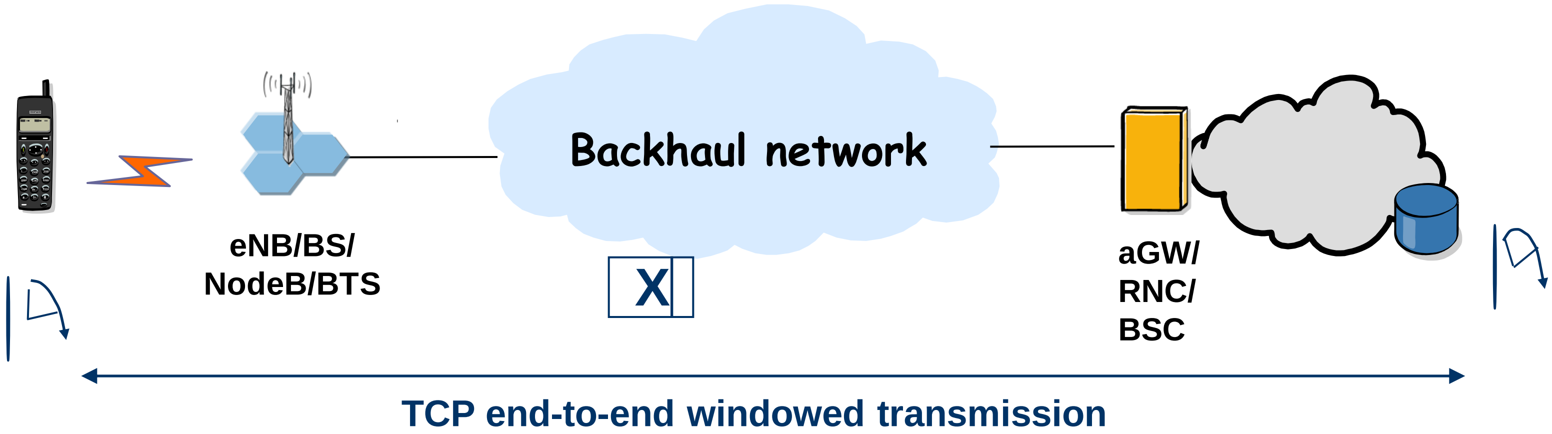
CoMP - Coordinated multiple point

Handoff Control For Reliable Mobility Performance



- Synchronization is vital to ensure service continuity (i.e. successful handoff)
- Studies have shown significant reduction in call drops when good synchronization is in place; enhanced QoE

Backhaul Transport Reliability



- Wander and Jitter in the Backhaul and Aggregation Network can cause underflows and overflows
- Slips in the PDH framing will cause bit errors leading to packet rejections
- Packet rejections lead to retransmissions and major perceptible slow down in TCP windowed sessions

Timing Distribution Methods

- External Timing Source
  - GPS
- Physical layer clock
  - Using synchronous TDM interfaces, e.g. PDH/SDH
  - Using synchronous Ethernet as per G.8261/G.8262, and G.8264 for ESMC/SSM
- Physical Timing distribution over packet network
  - IEEE 1588-2008 / ITU G.8265
  - NTP
  - Adaptive Clock Recovery
  - Differential Clock
- Multiple methods might be deployed in a network

Note: Both GPS and IEEE1588-2008 support frequency and phase, there is ITU-T work in progress on the telecom profiles for phase/Time of Day support

Quality of Service Requirements

Quality of Service (QoS) capabilities of MPLS mobile backhaul networks

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Quality of Service Requirements

- Supports QoS and service level agreements
- Uses IETF DiffServ Architecture (RFC 2475)
- Supports at least 4 CoS and associated service metrics (e.g., delay, delay variation, packet loss).
- Supports Connection Admission Control to guarantee sufficient bandwidth is available to support new connections conforming to all SLAs.
- SLAs are enforced using functions such as policing/shaping, marking and hierarchical scheduling.
- Supports the pipe model of RFC 3270. Supports both E-LSPs and L-LSPs.
- Supports mapping between the QoS of the TNL and TC bits of the LSP labels.

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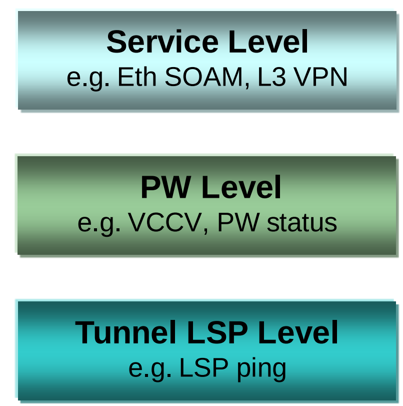
Resiliency, Protection and Performance

Operations, Administration and Management (OAM) and Resiliency

OAM Requirements

- OAM needed for reactive & proactive network maintenance
  - Quick detection and localization of a defect
  - Proactive connectivity verification and performance monitoring
- OAM tools have a cost and revenue impact to carriers
  - Reduce troubleshooting time and therefore reduce OPEX
  - Enable delivery of high-margin premium services which require a short restoration time
- Top level requirements
  - Provide/co-ordinate OAM at relevant levels in IP/MPLS network
  - Proactive and reactive mechanisms, independent at all levels

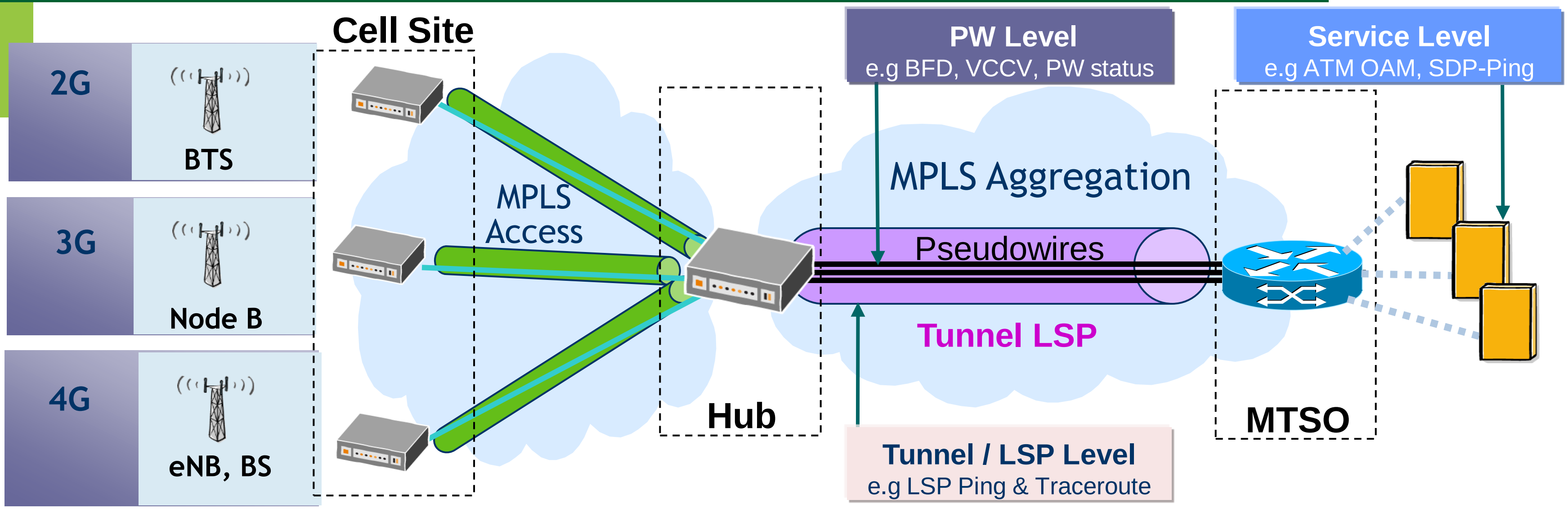


SOAM – Service OAN
VCCV - Virtual Circuit Connectivity Verification

Service and Transport OAM

- Service and Transport OAM rely on the same set of protocols
- Service OAM is a service-oriented mechanism that operate and manages end-to-end service
  - IP/MPLS VPN service OAM and PM
    - IP and VRF ping and trace route
    - BFD
    - PM based on RFC 6374
  - Ethernet Service OAM and PM
    - 802.1ag Connectivity Fault Management (CFM)
    - ITU-T Y.1731 PM for Ethernet services
- Transport OAM is a network-oriented mechanism and manages the network infrastruture.
  - IP/MPLS VPN service OAM and PM (Performance Monitoring)
    - BFD (Bidirectional Forwarding Detection)
    - LSP ping and traceroute
    - PW – VCCV and Status

Service-Aware OAM Toolkit



Quickly isolate and troubleshoot faults to reduce MTTR

Tool set for reactive & proactive network operation and maintenance

- Defect detection, proactive connectivity verification, and performance monitoring
- Provide/co-ordinate OAM at relevant levels in IP/MPLS network
  - Services Level: Eth SOAM, ATM OAM, IP/MPLS VPN Service OAM
  - Tunnel LSP Level: LSP ping and LSP Traceroute
  - Pseudowire Level: PW Status, VCCV-BFD, VCCV-Ping, mapping to Ethernet, TDM, ATM notifications
- MPLS has been extended to provide additional capabilities for performance monitoring, path segment monitoring and alarm suppression

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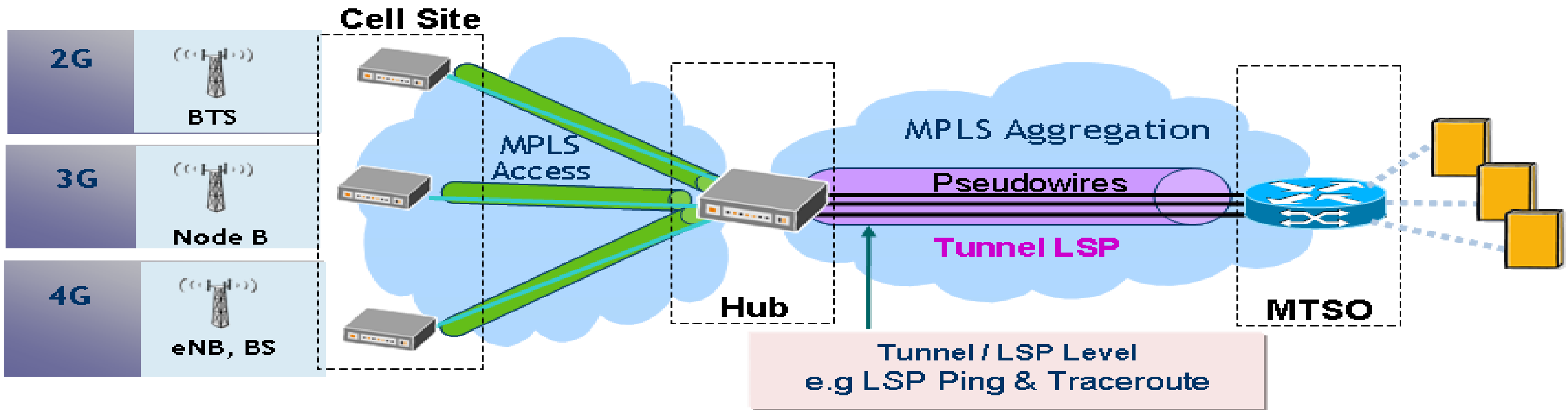
LSP Ping

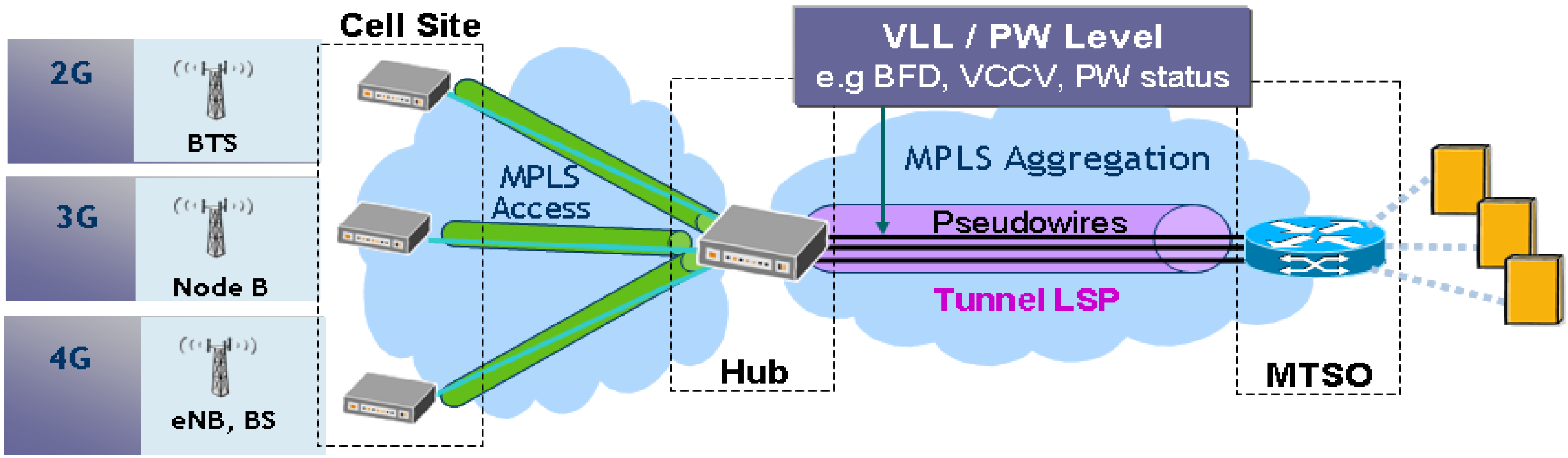


- LSP Ping is MPLS specific variation of traditional ICMP (Internet Control Message Protocol) ping/traceroute ad hoc tool
  - Ping is simple e2e loopback
  - Traceroute uses TTL (Time to Live) to incrementally verify path
- Ping paradigm useful for craftsperson initiated testing
  - TELNET/CLI

LSP Ping is augmented with a number of TLVs (Type Length Value)

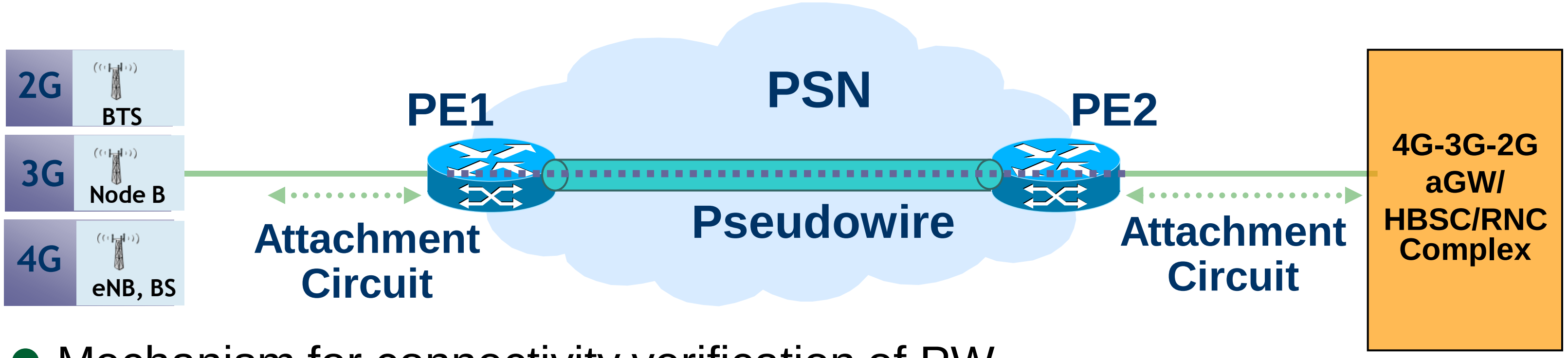
- processed by the receiver to extend functionality
- As LSP is unidirectional, and Ping is bi-directional, LSP Ping is augmented with options for distinguishing real problems from return path problems

Bidirectional Forwarding Detection (BFD)



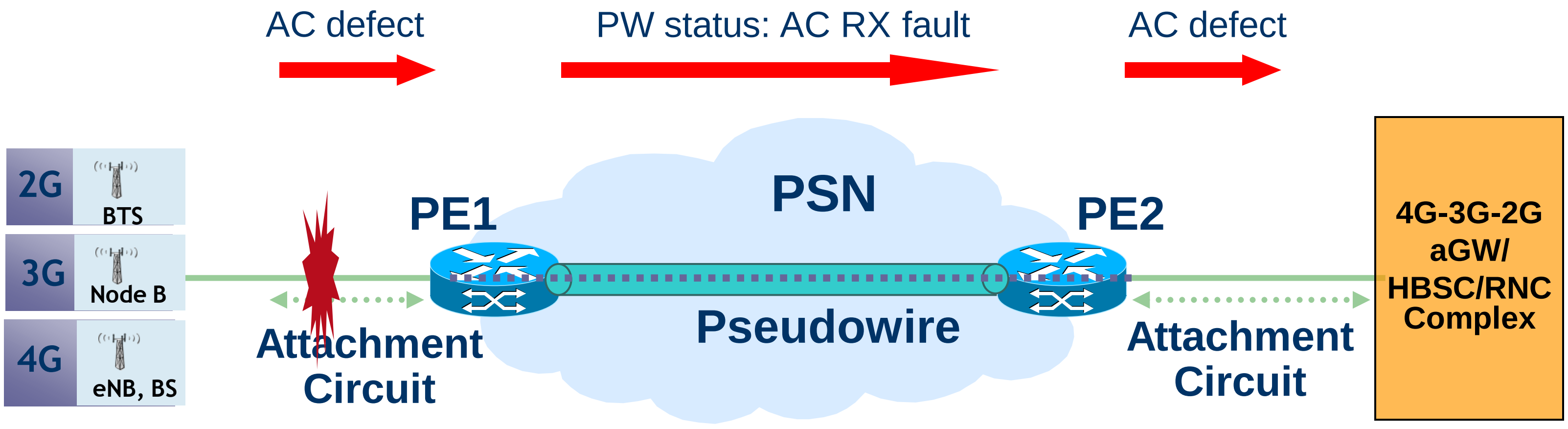
- Simple, fixed-field, hello protocol
  - Easily implemented in hardware
  - Very useful as a fault-detection mechanism
- Nodes transmit BFD packets periodically over respective directions of a path
- If a node stops receiving BFD packets some component of the bidirectional path is assumed to have failed
- Applicable to tunnel end-points

Virtual Circuit Connection Verification (VCCV)



- Mechanism for connectivity verification of PW
- Multiple PSN tunnel types
  - MPLS, GRE,…
- Motivation
  - One tunnel can serve many pseudo-wires
  - MPLS LSP ping is sufficient to monitor the PSN tunnel (PE-PE connectivity), but not PWs inside of tunnel
- Features
  - Works over MPLS or IP networks
  - In-band CV via control word flag or out-of-band option by inserting router alert label between tunnel and PW labels
  - Works with BFD, and/or LSP ping

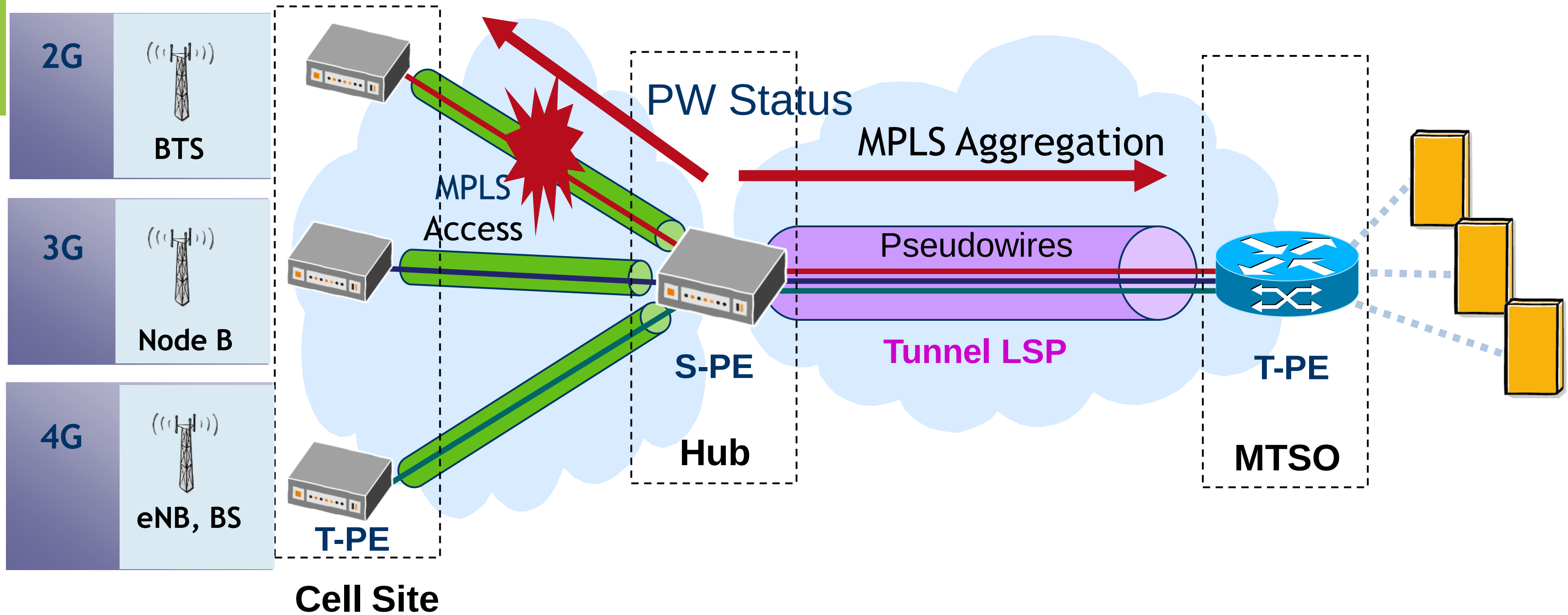
PW Status Signaling



PWs have OAM capabilities to signal defect notifications:

- Defect status mapped between AC and PW in the PE
- PW status signaling propagates defect notifications along PW
  - Extension to T-LDP signaling

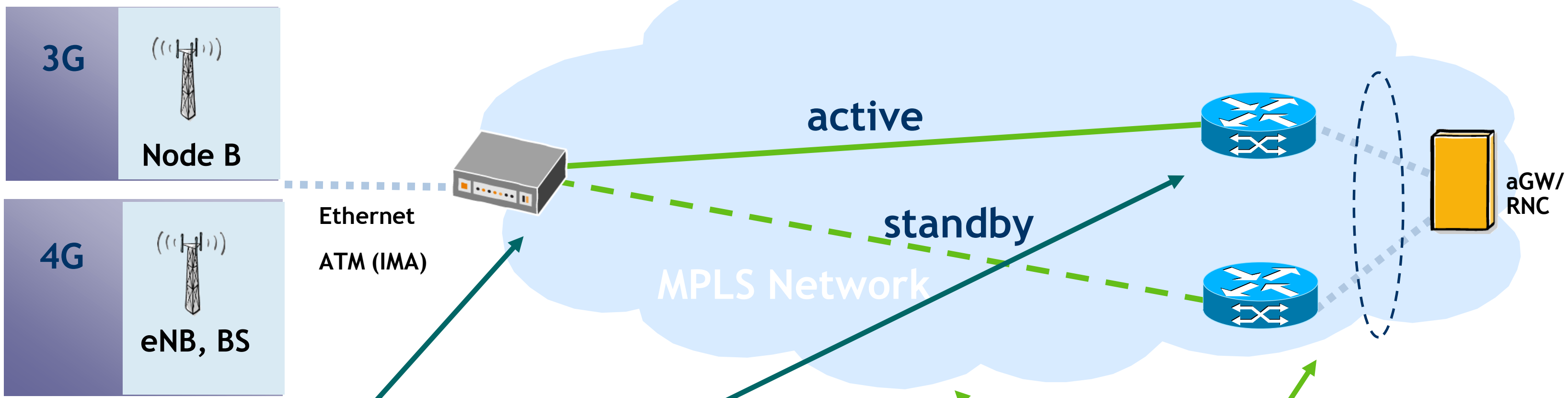
PW Status Signaling: Multi-segment PWs



- PW status signalling also works for MS-PWs
- S-PEs:
  - Transparently pass remote defect notifications
  - Generate notifications of local defects

MPLS Network Reliability

Both node level and network level recovery are required



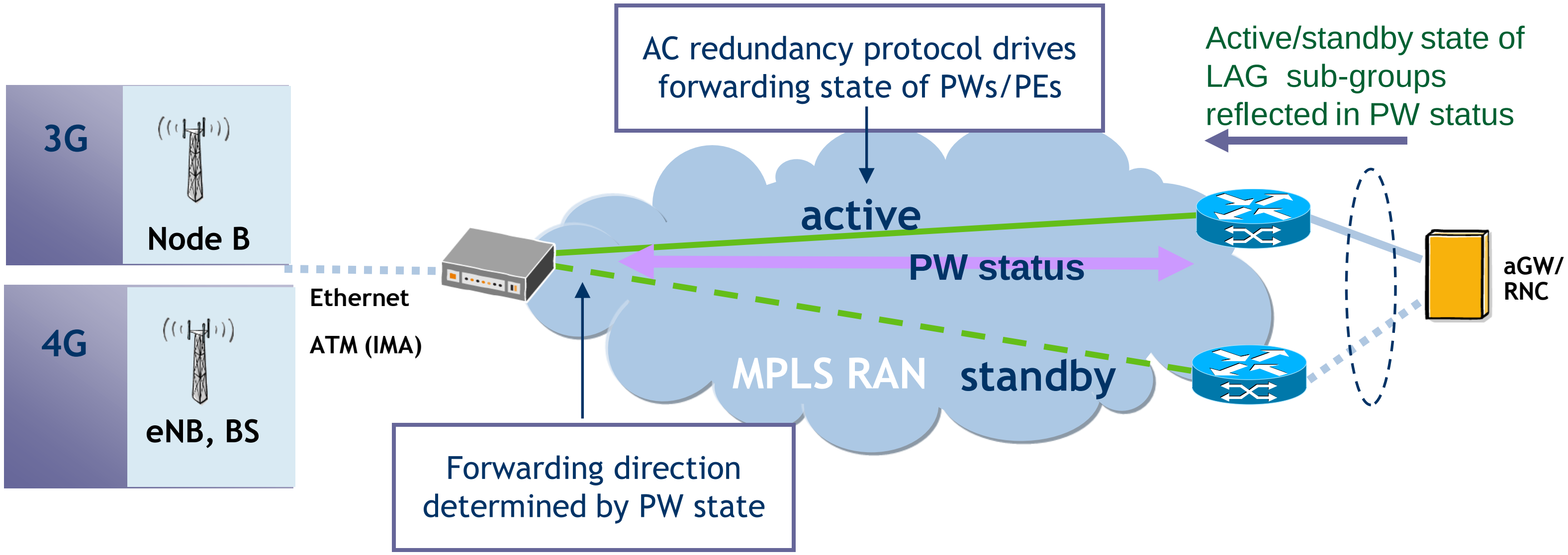
Node Level Recovery

- Non-stop routing for ALL protocols (LDP, OSPF, IS-IS, BGP, multicast, PIM-SM)
- Non-Stop Service for ALL services (VPLS, VLL, IP-VPN, IES (Internet-Enhanced Service), multicast)

Network Level Recovery

- Dual-homing w/o RSTP
- MPLS FRR (Fast Reroute)
- MPLS Standby Secondary
- Sub 50 ms restoration
- End-to-end path protection
- MPLS extensions to include additional approaches

Network Level Redundancy for PWs



Protects against PE and AC failures

- **PE configured with multiple pseudowires per service with multiple end-points**
- **Local precedence indicates primary PW for forwarding if multiple PWs are operationally UP**
- **PW status exchanged end-to-end to notify PEs of operational state of both PWs & ports / attachment circuits (PW Status Notification).**

RFC-5718 PW Redundancy & draft-ietf-pwe3-redundancy-bit

MPLS Service Restoration Capabilities

- **Supports speedy detection and location of failure**
- **LSP protection**
  - End-to-end LSP protection and segment protection
  - Link and Node protection with RSVP-TE FRR
  - Loop-free alternate (LFA) adds fast reroute capability to IS-IS, OSPF and LDP. It is a local repair.
  - Combining FRR and LFA provide deterministic service restoration
  - Fast BFD
  - Support graceful restart of protocols
- **PW protection**
  - BFD-VCCV triggered restoration
  - Redundant PW

IPv6 Considerations

IPv6 Considerations

- Mobile backhaul network architectures use:
  - Layer 2 network (native, emulated or both)
  - Layer 3 network (routed IP or IP VPN)
  - Combination of both
- Layer 2 – agnostic to IPv6
  - IPv6 is carried transparently as payload to the mobile backhaul network
  - QoS from IPv6 should be mapped onto MPLS and layer 2 QoS mechanisms
- Layer 3 – must be v6 aware
  - IPVPN for v6 ("6VPE") can be used to support a IPVPN that routes IPv6 traffic.
    - VPE is needed for VPN separation
  - Not used today as most v6 is encapsulated in layers over IPv4

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Energy Efficiency

Energy Efficiency

- Motivation:
  - Increasing energy cost and regulatory initiatives
  - Increasing network infrastructure and data hungry applications
- Energy Efficient Mobile Backhaul: A Holistic Approach
  - Energy Efficient Network Planning (BBF Architecture)
    - Converged transport over MPLS architecture - Network Virtualization
      - Introduce fewer "boxes", unifies 2G/UMTS/HSDPA/LTE
      - Encourages sharing
  - Nodal Requirements
    - Energy Efficient Network Equipment
    - Network Based Energy Conservation
  - Energy Saving Management
- Main Contributions:
  - RAN Technology Independent
  - Align RAN and Core Network Energy
  - Holistic Approach

Relationship to MEF 22.1 Mobile Backhaul IA

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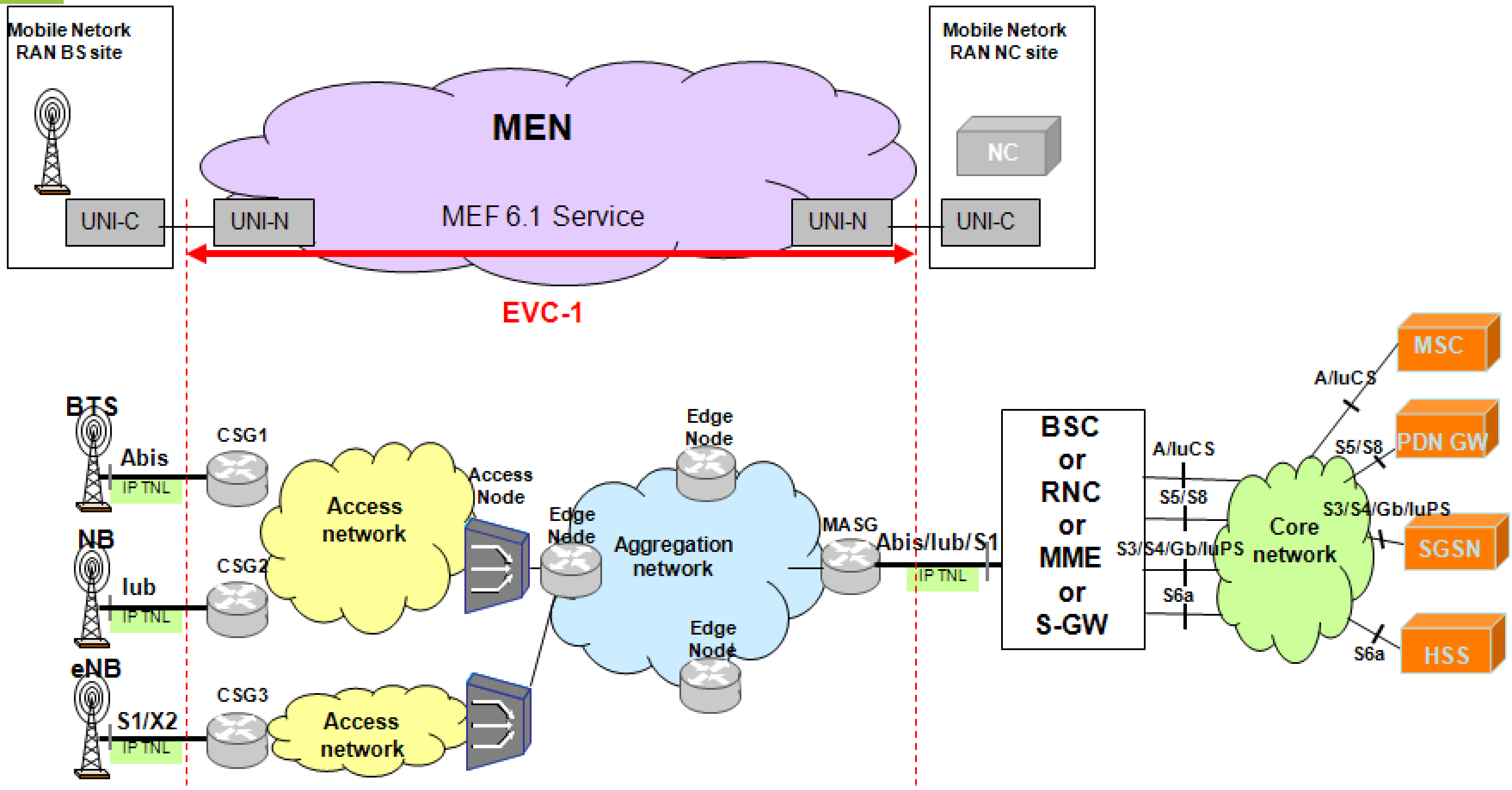
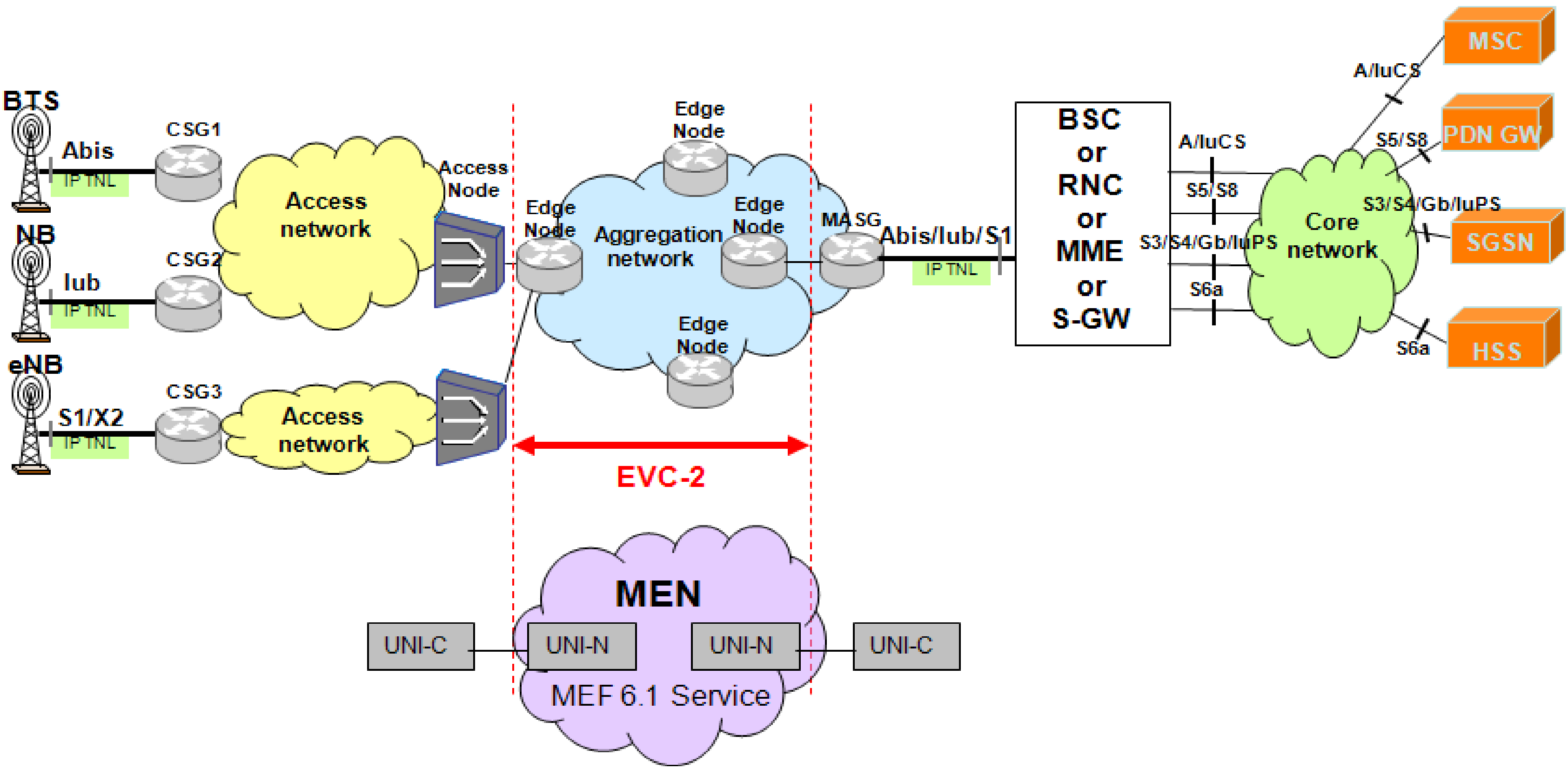
MPLS provides MEF service



MPLS uses MEF service



Notes:

- Ethernet CES GIWF (MEF 3, 8) not mentioned since transparent to MPLS
- The MEF cloud can be at the aggregation network, the access network, or both

CSG - Cell Site Gateway
GIWF – Generic Interworking Function
TNL – Transport Network Layer

Deployment Examples

Other Factors for Choice of Deployment

- Network size (small and large)
- Support legacy 2G/3G services and flexible any-to-any connectivity for LTE. The mobile network evolving to an all-IP network.
- Scaling MPLS to support large number of Cell Site Gateways.
- The architecture model can support large geographies and support hierarchical LSPs.
- Optimized for advanced 4G requirements like IPSec and authentication, eNodeB X2 interface communication
- Operators may choice deployment scenario based on organization, skill and service.

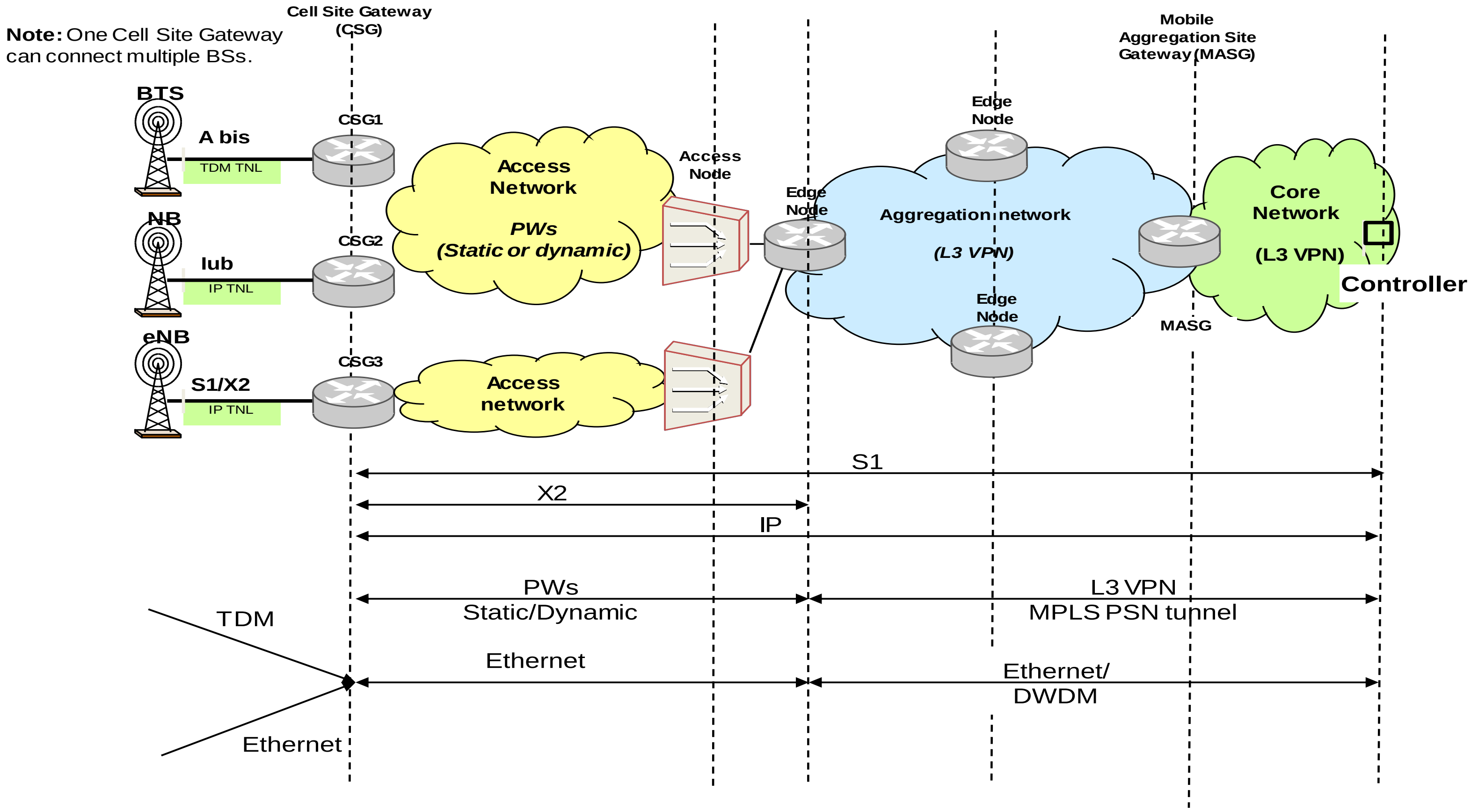
Security Considerations

- IPsec not mandatory but likely to be used
  - IPsec tunnels between eNB and Security Gateway function (control only or both)
  - Some care needed to evaluate the architecture
  - SeGW (Security Gateway) position and Distribution of credentials of Network Elements
- Match the security architecture with the transport architecture (logical connectivity, traffic steering)
- Trade-off between performance and security
- Security considerations depend on “trusted” analysis of Operator
- See White Paper by the NGMN Alliance - Security in LTE backhauling http://www.ngmn.org/uploads/media/NGMN_Whitepaper_Backhaul_Security.pdf

Backhaul Deployment Scenarios

- NGMN Alliance white paper on LTE backhaul provides:
  - Reference architecture and frame work
  - LTE backhaul deployment scenarios and applicability
- BBF TR-221 support all proposed NGMN deployment scenarios
- Examples are based on the L2 and L3 protocols forecast
  - Supports both TDM and IP TNLs in the access.
  - LTE is evolving to an all-IP network.
  - Limited use of VPLS
- Example of scenarios
  - Example 1: Access - PWs (Static or dynamic) + L3 VPN in Aggregation
    Point-to-point MPLS Pseudowires in Access. Layer 3 VPNs in Aggregation network.
  - Example 2: MPLS PWs in both Access & Aggregation
    PWs (Static or dynamic) in Access network and PWs (dynamic) in Aggregation network.
  - Example 3: L3 VPNs in access and aggregation networks

LTE Deployment Example –
VPWS in Access + L3 VPN in Aggregation



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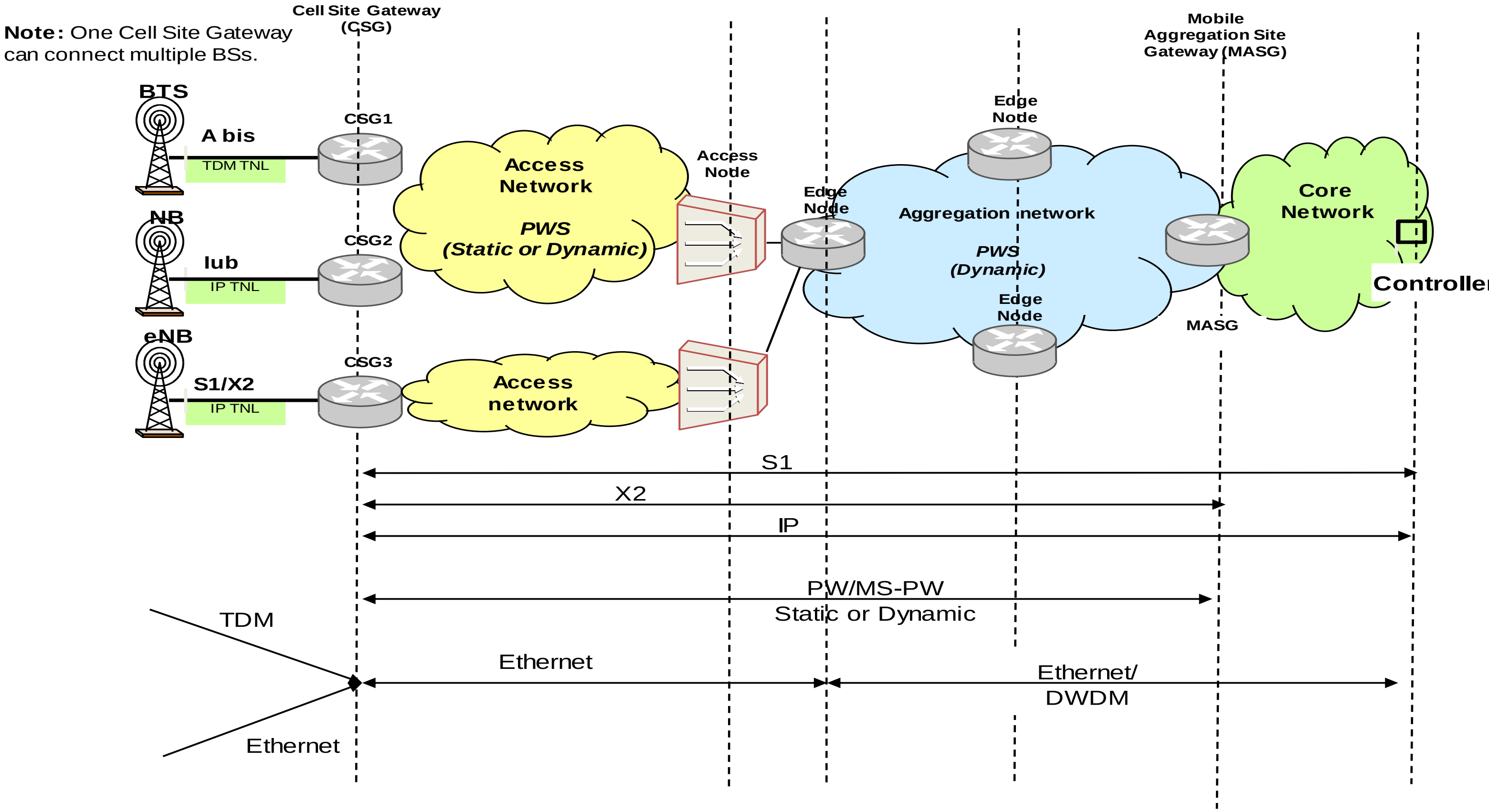
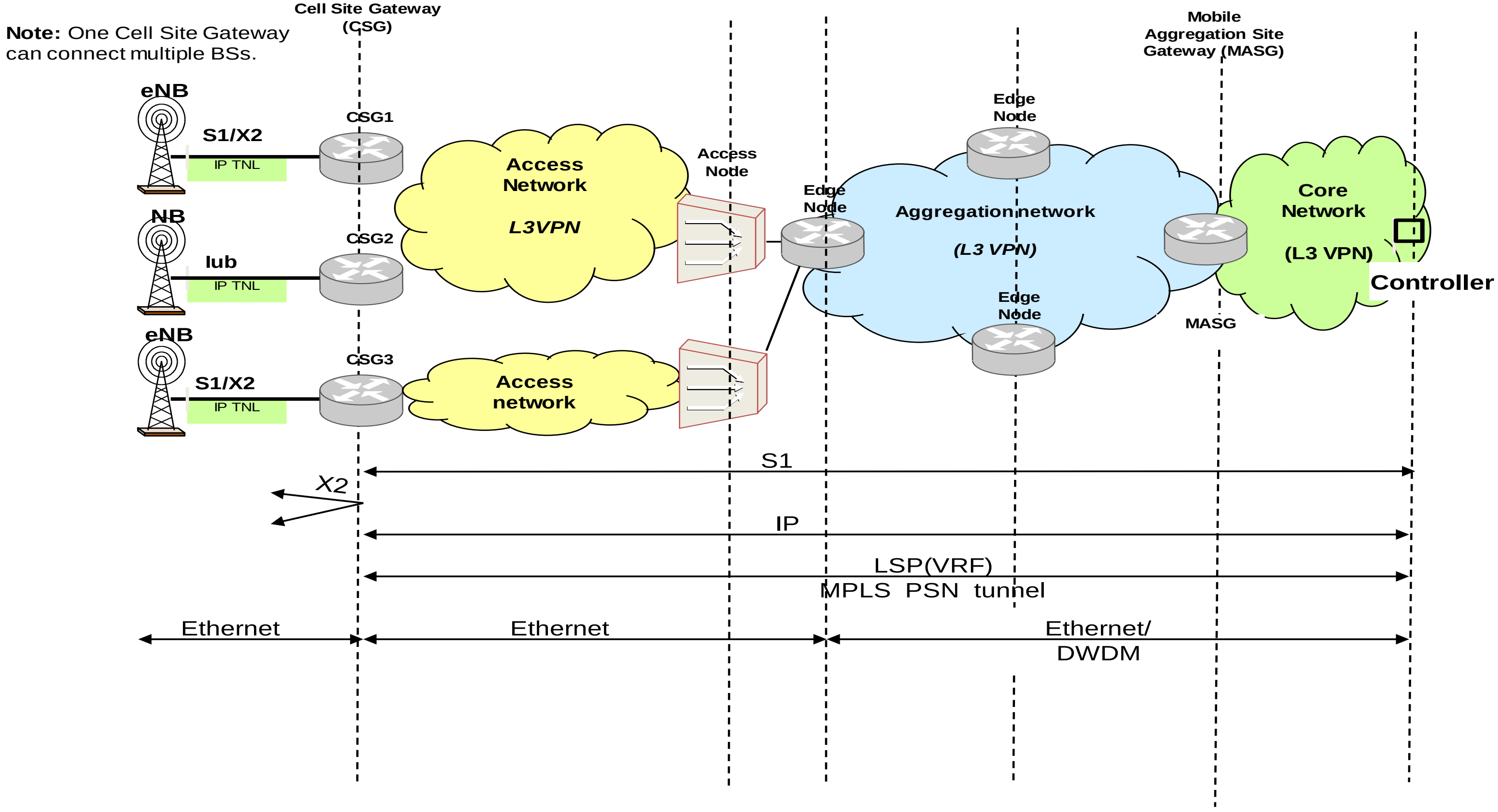
LTE Deployment Example – PW in both Access & Aggregation



LTE Deployment Example – L3 VPN in both Access & Aggregation



BBF Mobile Backhaul Work Plan – 2012

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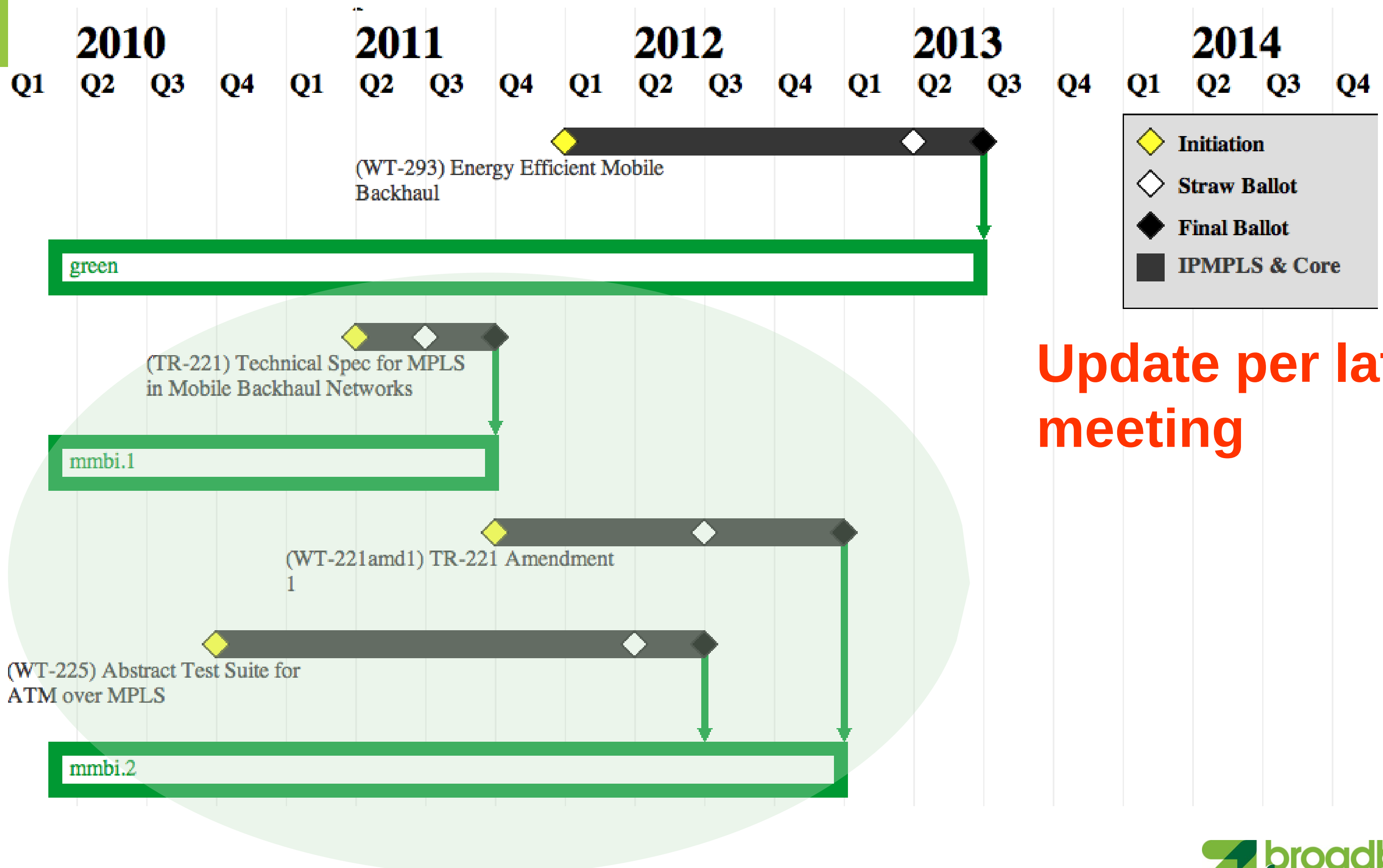
MMBI Work Plan - 2012



Update per latest meeting

Summary

Summary of Success Factors

Summary

- LTE networks will co-exist with 2G/3G/4G networks
- MPLS architecture is an efficient way to support IP centric LTE network traffic
- MPLS backhaul delivers the performance LTE requires (latency, synchronization, resiliency, etc) and scalability to address traffic growth
- TR-221 technical specifications provide the backhaul foundation for 2G/3G/4G and Beyond
  - Simplifies operations and improves operators’ bottom line
  - Flexibly supports all NGMN deployment scenarios

Thank you for attending the MPLS Mobile Backhaul Evolution – 4G LTE and Beyond tutorial

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Related Standards Organizations & Consortiums

- **3GPP:** http://www.3gpp.org
- **Broadband Forum:** http://www.broadband-forum.org
- **IEEE:** http://www.ieee.org
- **IETF:** http://www.ietf.org
- **ITU-T SG 15:** **http://www.itu.int/ITU-T/studygroups/com15/index.asp**
- **Metro Ethernet Forum (MEF):** http://metroethernetforum.org
- **Next Generation Mobile Network Initiative (NGMN):** http://www.ngmn.org

Abbreviations

2G – Second generation mobile network
3G – Third generation mobile network
4G – Fourth generation mobile network
AC – Attachment Ciruit
AG – Access gateway
aGW– Access gateway
ASN – Access service node
BFD - Bidirectional Forwarding Detection
BS – Base station
BSC – Base station controller
BTS – Base transceiver station
CDMA – Code division multiple access
CoMP - Coordinated multiple point
CS – Circuit switched
CSG – Cell site gateway
EDGE – Enhance data rates for GSM evolution
eICIC: Enhanced inter-cell interference coordination
eMBMS - evolved Multimedia Broadcast Multicast Service
eNB - – 4G/LTE base station
eNode B – 4G/LTE base station
EPC – Evolved packet core
EUTRAN – Evolved UTRAN
EV-DO – Evolution data optimized
FEC – Forwarding equivalence class
FRR – Fast Re-route
GGSN – Gateway GPRS support node
CSG - Cell Site Gateway
GIWF – Generic Interworking Function
GPRS – General packet radio service
GSM – Global system for mobile communications
GW – Gateway
HSPA – High speed packet access
HSS – Home subscriber server
H-VPLS - Hierarchical Virtual Private LAN Service
IES - **Internet-Enhanced Service**
ICMP - Internet Control Message Protocol
LSP – Label switched path
LTE – Long term evolution

MASG – Mobile aggregation site gateway
MGW – Message gateway
MMBI – MPLS in mobile backhaul initiative
MME – Mobility management entity
MPLS – Multiprotocol label switching
MPLS-TP – MPLS Transport Profile
MSC – Mobile switching center
MTSO – Mobile telephone switching office
Node B – Base station transceiver with UMTS/WCDMA
PCRF – Policy and charging function
PDN – Packet data network
PDSN – Packet data serving node
PM – Performance Monitoring
P-GW – PDN gateway
PS – Packet switched
PW – Pseudowire
RAN – Radio access network
RNC – Radio network controller
RSVP – Resource reservation protocol
SeGW - Security Gateway
SGSN – Serving GPRS support node
S-GW – Serving gateway
SOAM – Service OAM
TE – Traffic engineering
TNL – Transport network layer
ToD – Time of Day
TLV - Type Length Value
TNL – Transport Network Layer
TTL – Time to Live
UE – User equipment
UMB – Ultra mobile broadband
UMTS – Universal mobile telecommunications system
VCCV - Virtual Circuit Connectivity Verification
VLAN – Virtual local area network
VoLTE – Voice over LTE
VPLS - Virtual Private LAN Service
VPWS - Virtual Private Wire Service
VPN – Virtual private network