The Role of MPLS Technology in the Evolution to 4G Mobile Networks

Doug Hunt, Alcatel-Lucent IP Division

April 2008

Agenda

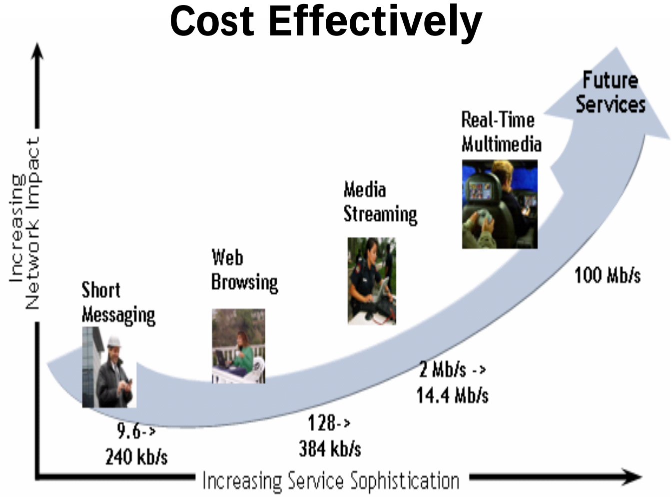
1. Operators' challenges
2. Network transformation drivers and evolution
3. 4G characteristics
4. 4G network infrastructure — WiMAX example
5. Critical success factors in mobile deployment
6. MPLS in Mobile Backhaul Initiative
7. Conclusion

1

Operators' challenges

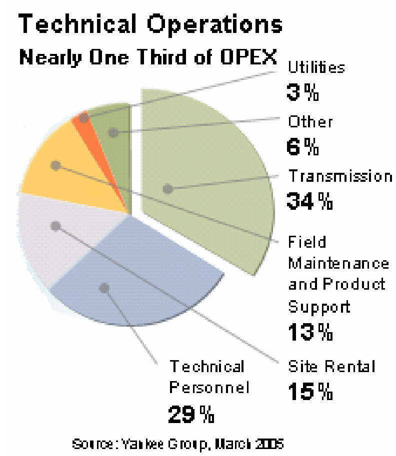
Operators' challenges

Delivering New Services Cost Effectively



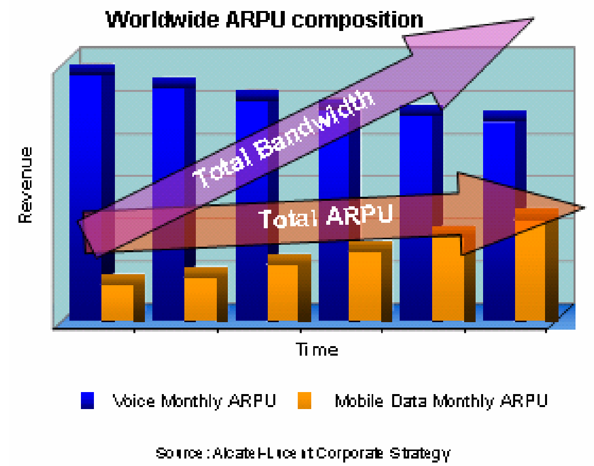
- Higher radio access speeds (2G→3G →4G)
- New bursty traffic mix (diff QoS handling)
- High data peak rates (dynamic bandwidth)

Managing Increasing Complexity



- Leveraging existing investments (TDM, ATM) while evolving to new (IP, Eth) technologies
- Diverse traffic types with complex SLAs

Revenue/Traffic Divergence



- Exponential growth in bandwidth-intensive data services
- Revenue not keeping up with capacity

The Mobile transport network must evolve to Ethernet/IP to support an order of magnitude more capacity at lower cost

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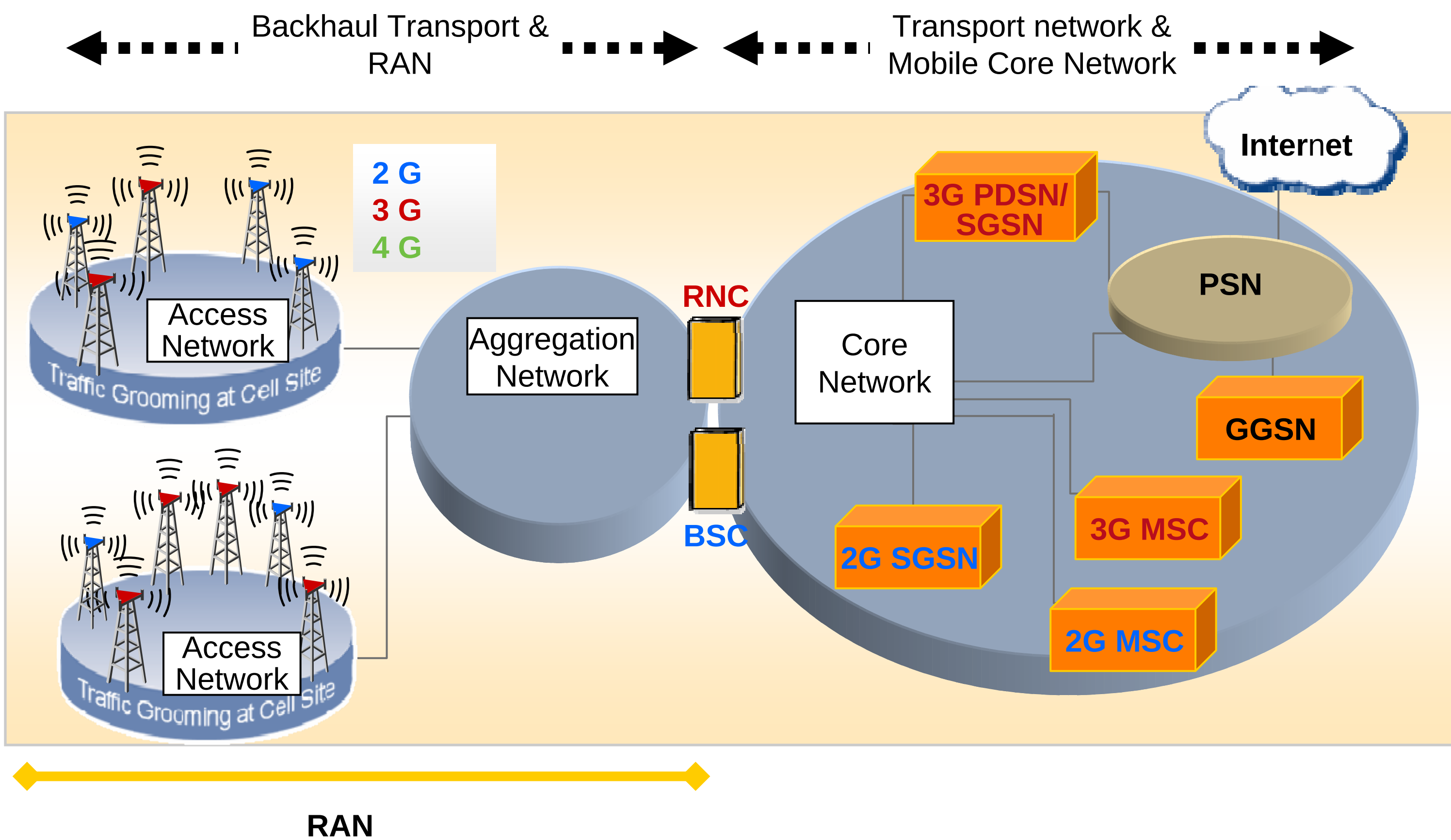
Mobile network — end-to-end view



Defining mobile backhaul network:

Network that connects cell sites with regional mobile hub/controller sites (e.g., network that connects base stations/Node Bs to BSC/RNC)

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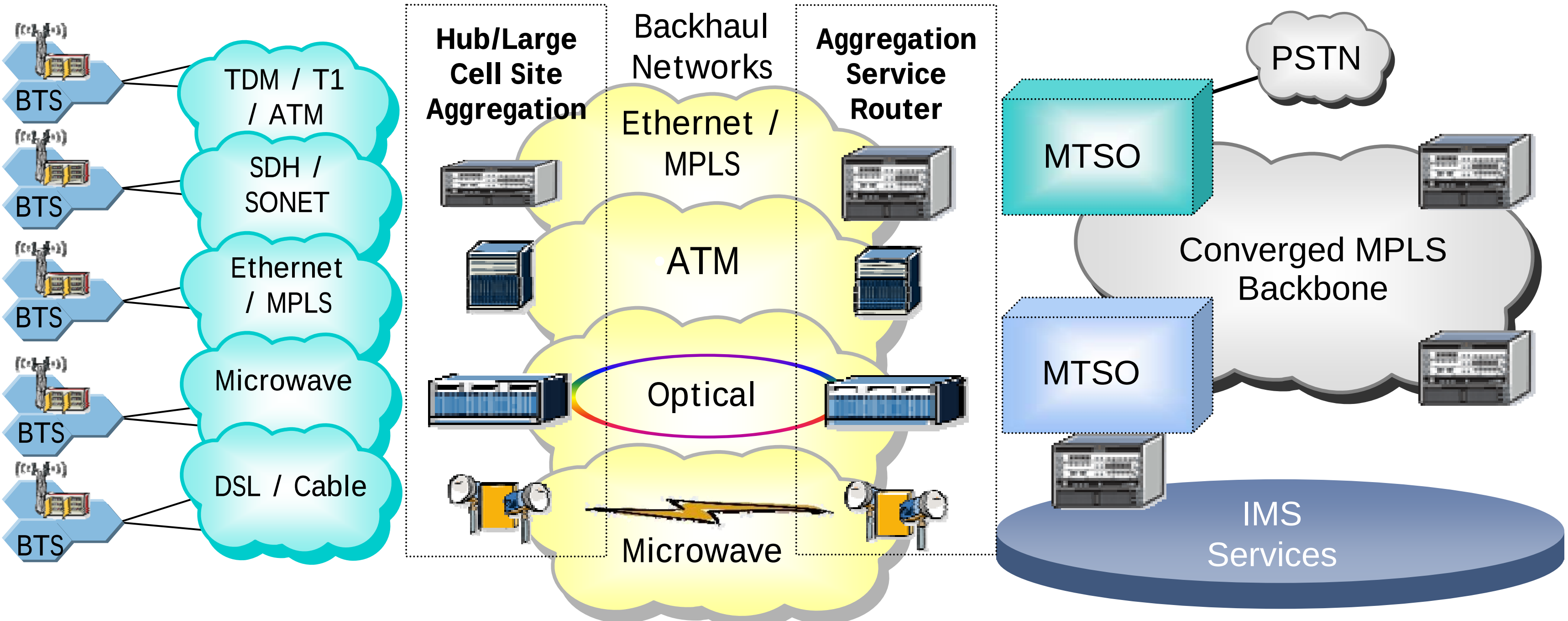
Wireless infrastructure / backhaul architectures

- Many RAN access / aggregation transport options
- Mobile infrastructure moving to end-to-end IP (backbone and RAN)
- Backhaul aggregation offered over many transports
  - Native Ethernet/MPLS, ATM, optical, and microwave



Every network has a different starting point and each site may have different requirements

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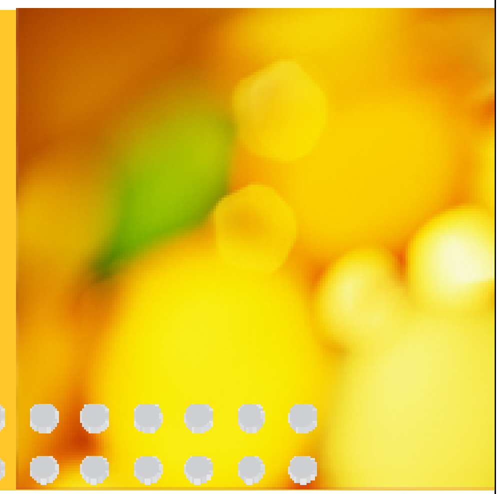
2 Network transformation drivers and evolution



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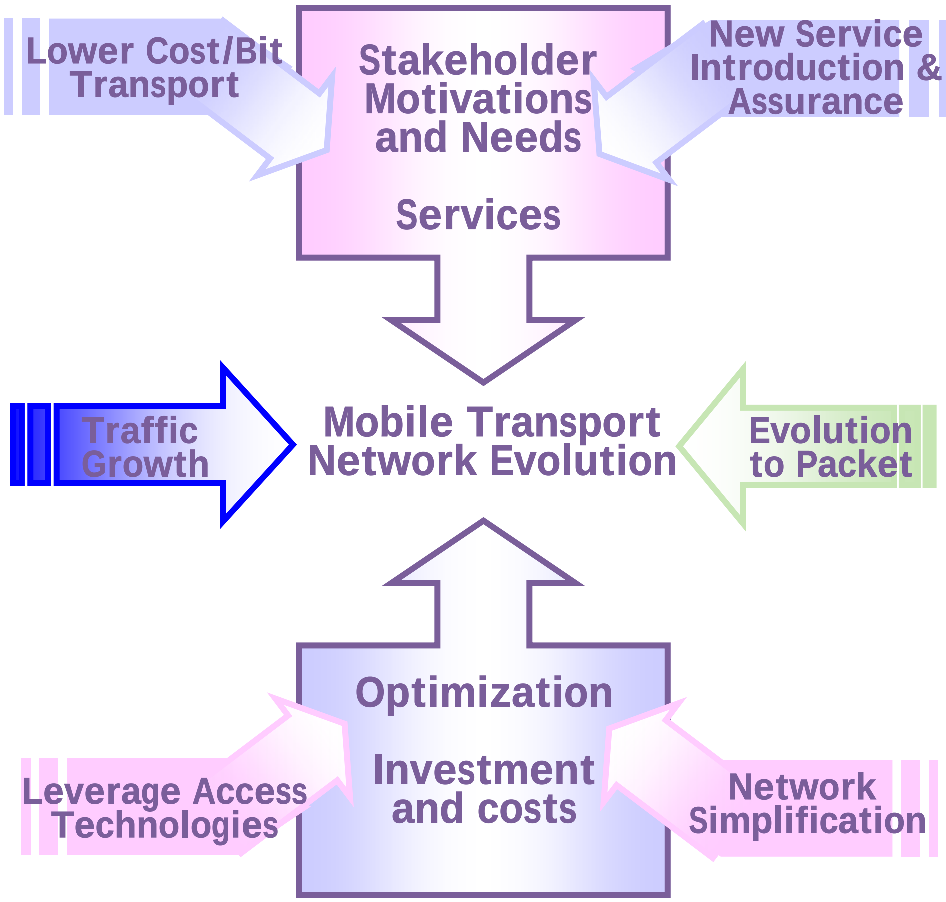
Fundamental forces drive need for network transformation

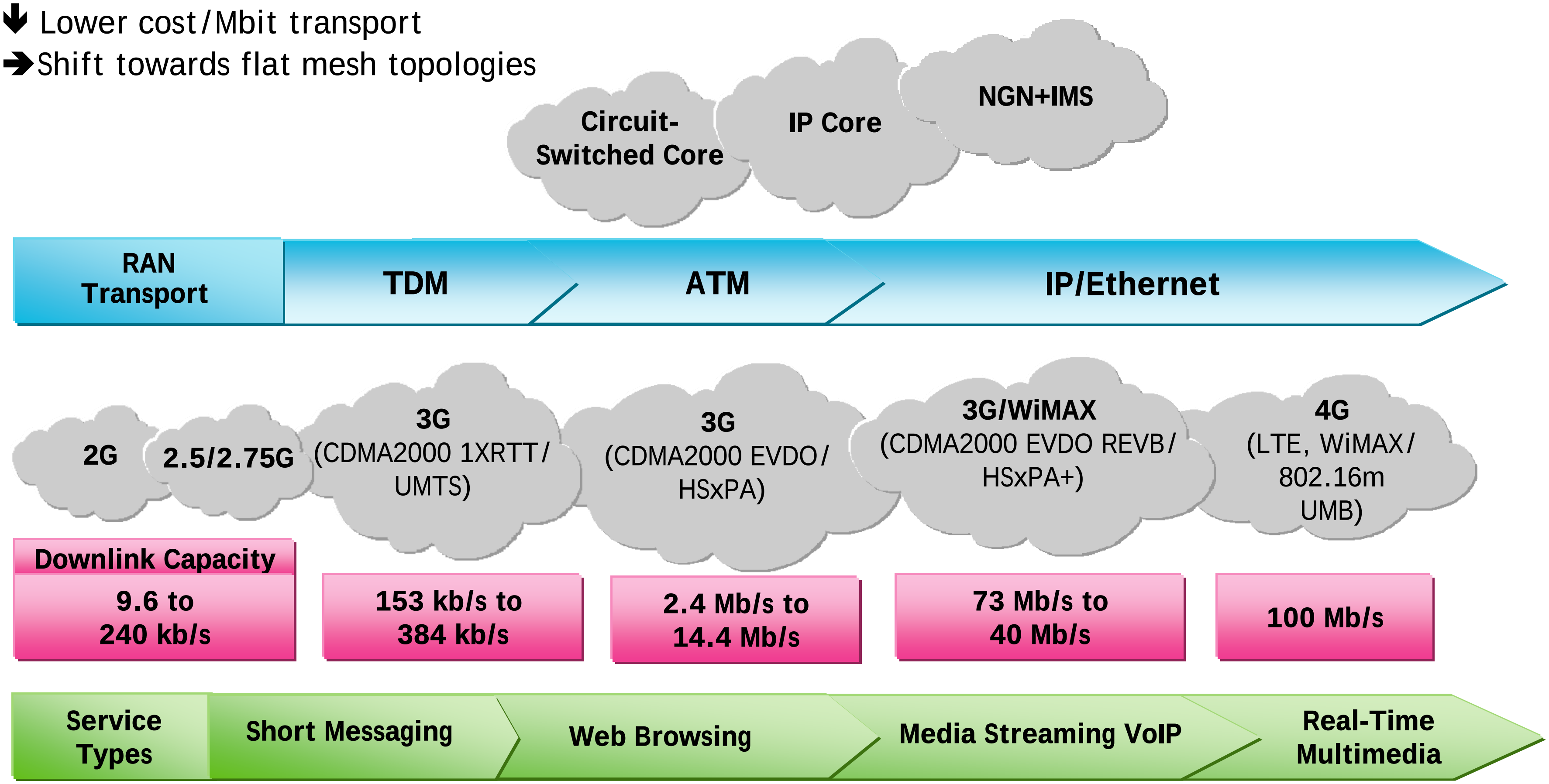


Transformation drivers

- Enabling lower cost transport of all services
- Addressing requirements for real time multimedia services (e.g., QoS)
- Aligning backhaul with expanded air interface capacities (e.g., HSPA/EVDO/WiMAX/LTE/UMB)
- Providing enhanced and personalized services and mobility to end users to increase loyalty and reduce churn
- Smooth evolution to packet, leveraging multiple access network technologies (microwave, optical, DSL, MPLS)
- Network simplification by improving operational agility and accuracy

Drivers for mobile network transformation — multimedia services, packet traffic growth

- ↑ Higher access bandwidth
- ↑ New subscriber apps
- ↓ Lower cost/Mbit transport
- → Shift towards flat mesh topologies



IP is the basis for new multimedia services and multiservice transport

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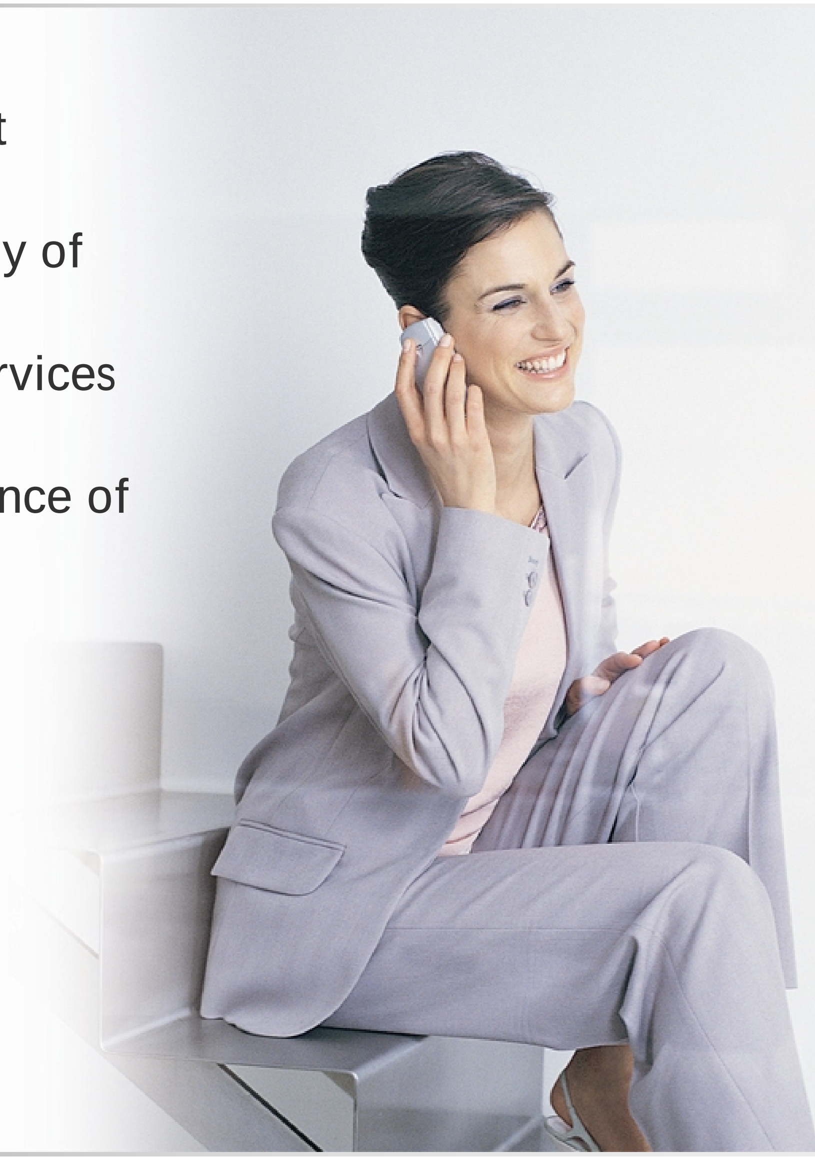
Mobile backhaul evolution — objectives and approach

- **Objectives**
  - Scalable, efficient solution, leveraging cost points of carrier-grade Ethernet
  - Retain determinism, control and availability of current solutions
  - QoS capabilities to support the range of services for 3G and 4G
  - Future-proof network elements — coexistence of new and legacy interfaces
- **Approach — network convergence**
  - 2G/3G/4G networks
  - Mobile/fixed networks
  - Convergence lowers cost per bit of traffic transferred, taking advantage of:
    - Single network infrastructure
    - Single management approach
    - Maximum statistical multiplexing



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Why Ethernet and MPLS for mobile backhaul networks

Ethernet as a transport medium

- Economical — provides a low-cost backhaul alternative to leased lines
- Ubiquitous — well-established in transport networks and evolving towards the cell site
- Scalable — supports bandwidth-intensive broadband applications

MPLS adds carrier-grade capabilities

- Scalability — millions of users/endpoints
- Traffic engineering plus QoS — support for current and future services
- Multiservice — support for 2G, 3G ATM and IP RAN, 4G IP RAN
- Resiliency — high availability including rapid restoration
- Manageability — ease of troubleshooting & provisioning

Carrier Ethernet has been proven in multiple service provider deployments

Why MPLS for mobile backhaul

MPLS is a proven and mature technology based on an approved set of standards

MPLS pseudowires support transport of traffic from a range of interface types including TDM, ATM, MLPPP/HDLC and Ethernet

- Allows legacy RAN equipment to continue to be utilized (CAPEX protection) while leveraging the advantages of new packet transport options

MPLS offers both dynamic and static provisioning alternatives

MPLS provides a range of resiliency and OAM functions that can be used to ensure the reliability of the mobile backhaul network

MPLS provides traffic engineering capabilities that can be leveraged for better management of network resources in the transport network, increasing the ROI of the operator

MPLS enables the operator to leverage a range of underlying transport infrastructures, including SDH/SONET and switched Ethernet using MPLS to provide transport services to the mobile backhaul network

3 4G characteristics

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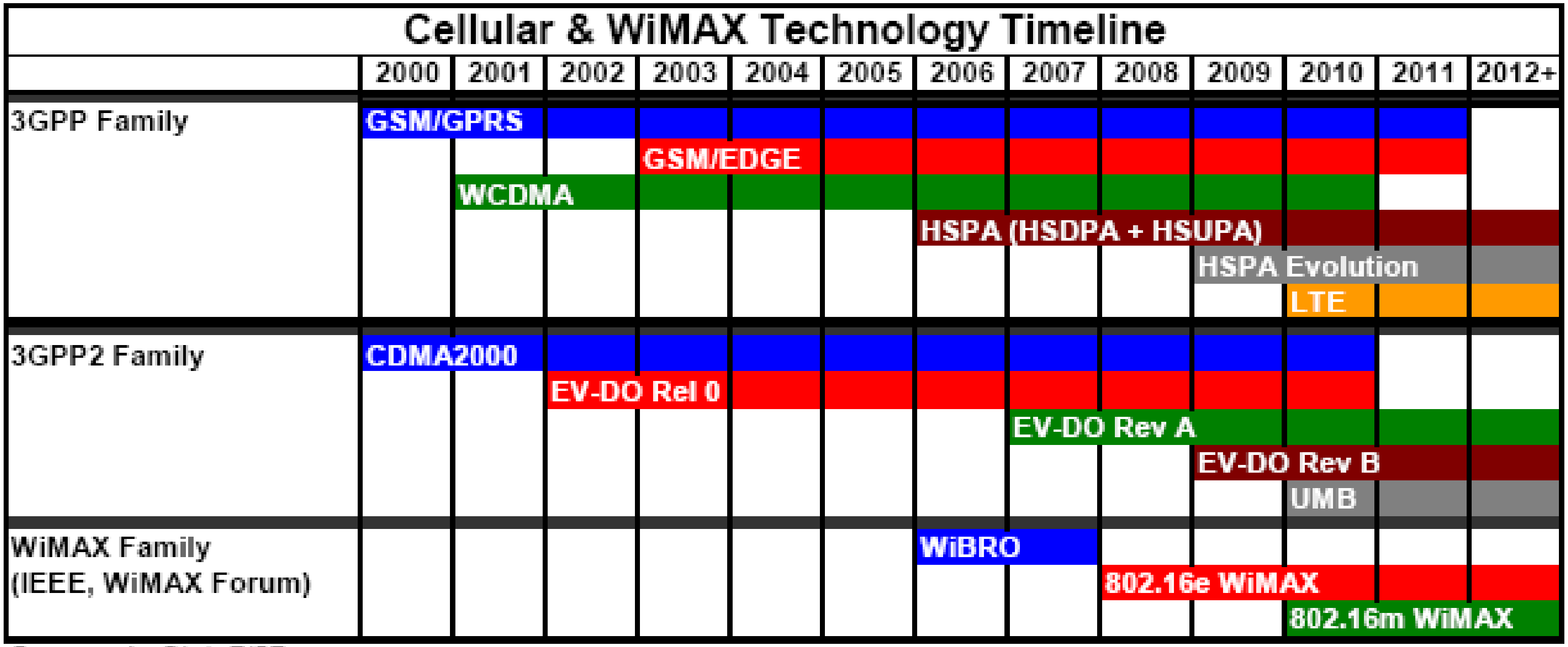
What is 4G?

Source: In-Stat, 7/07

Technology timelines



Source: In-Stat, 7/07

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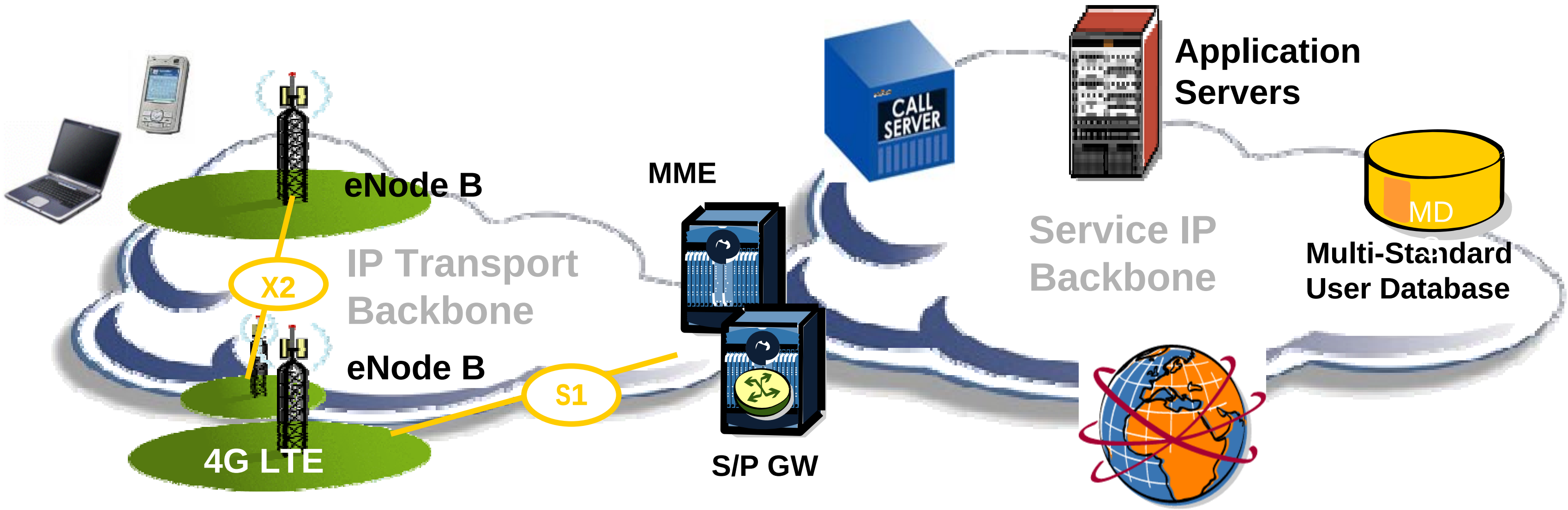
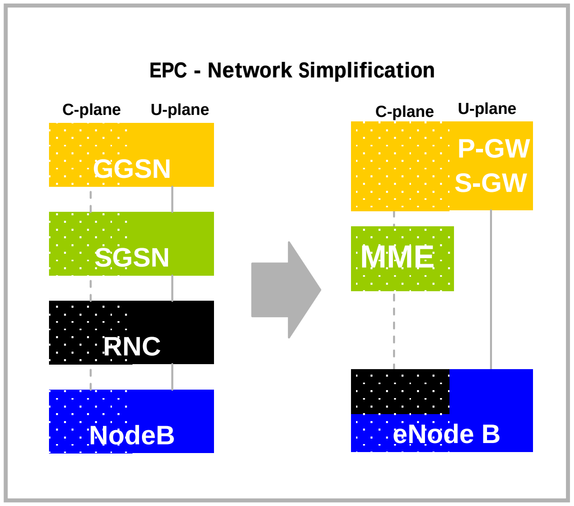
4G mobile architectures have introduced simplifications



Network simplification

- **User plane**:
  - Three functional entities: eNode B, serving gateway and PDN gateway (the gateways can be combined into a single physical entity)
  - GGSN → S/P-GW
- **Control plane**:
  - SGSN → MME (Mobility Management Entity)
  - RNC → eNode B



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Next Generation Mobile Network initiative

www.ngmn.org

NGMN is an alliance founded by mobile operators who are seeking a common long-term vision for broadband wireless service delivery.

NGMN includes Members (17 mobile operators), Sponsors (28 technology vendors), and Advisors (2 universities)

One key area of focus: optimized backhaul

- Backhauling segmentation (access types, providers) with end-to-end management
- Support for any-G mobile technology — including 4G, 3G, 2.5G, 2G
- Efficient bandwidth management with QoS correlation to mobile service classes
- Optional convergence with fixed networks
- Network synchronization/clock distribution over packet
- Network resiliency
- Network security

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4 4G network infrastructure - WiMAX example

Mobile WiMAX reference architecture

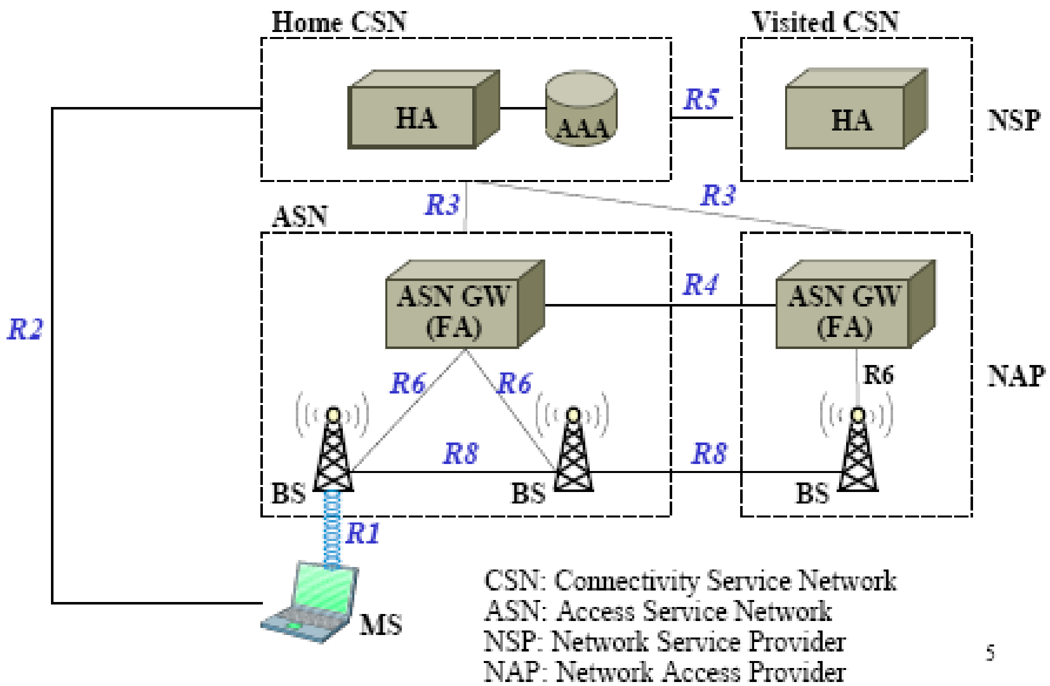

Table 1. Reference network model interfaces

R1	Interface between the MS and the BS. Functionality: air interface
R2	Interface between the MS and the CSN. Functionality: AAA, IP host configuration, mobility management.
R3	Interface between the ASN and CSN. Functionality: AAA, policy enforcement, mobility management.
R4	Interface between ASNs. Functionality: mobility management.
R5	Interface between CSNs. Functionality: internetworking, roaming.
R6	Interface between BTS and ASN gateway. Functionality: IP tunnel management to establish and release MS connection.
R8	Interface between BTSs. Functionality: handoffs.

- R6/R8/R2 interfaces have to be backhauled over PSN fixed networks
- Only IP connectivity is standardized in WiMAX Forum between BS and ASN GW at service transport level
- This WiMAX reference architecture is quite close to LTE architecture (flat and simplified architecture relying on IP protocol)

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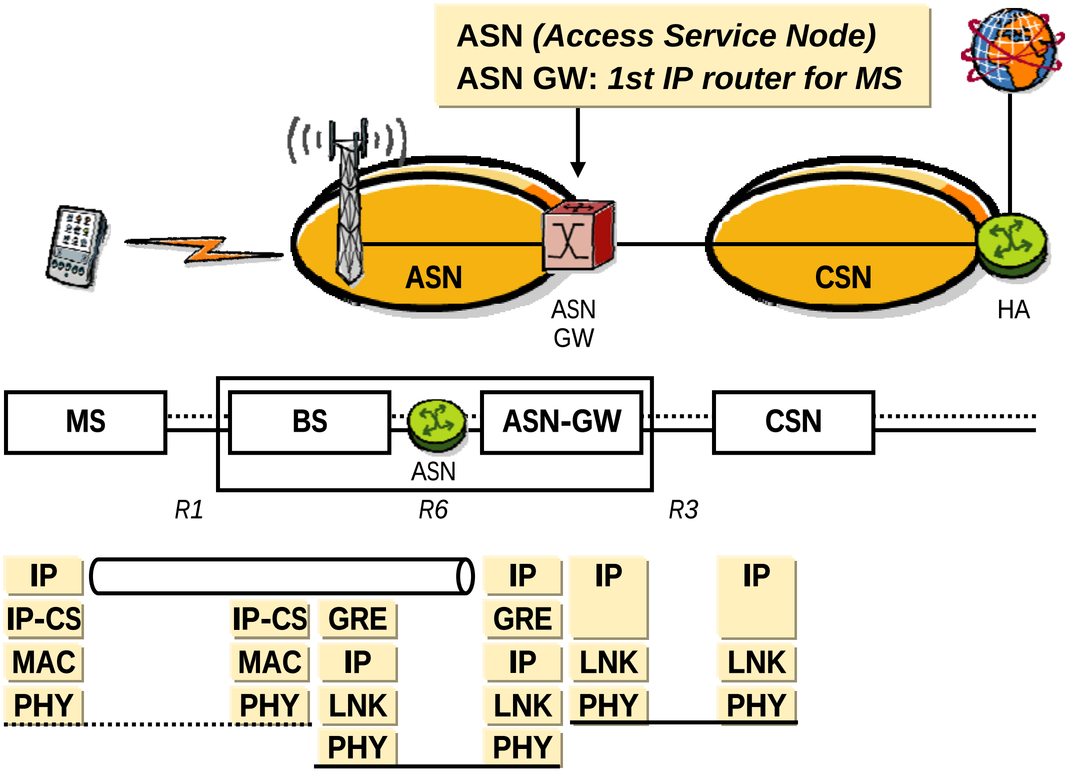
IP transport network layer (TNL)

- GRE over IP is standardized in WiMAX Forum to be used to tunnel user plane traffic between BS and ASN GW
- For the IP TNL, tunneled traffic will be IP packets (“IP convergence sublayer”) or IP/Ethernet (“Ethernet convergence sublayer”)
  - IP convergence sublayer shown in illustration



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WiMAX QoS classes

QoS Class	Characteristics
UGS	Real-time service flow with fixed packet size on a periodic basis, such as T1/E1 and voice over IP without silence suppression
RTPS	Real-time service flow with variable size packet on a periodic basis, such as MPEG video
ERTPS	The scheduling mechanism builds on the efficiency of both UGS and RTPS. The BS provides unicast grants in an unsolicited manner like in UGS, thus saving the latency of a bandwidth request. However, where UGS allocations are fixed in size, ERTPS allocations are dynamic, for applications like VoIP with silence suppression
NRTPS	Delay-tolerant data streams (a minimum data rate is required), variable sized packets, such as FTP
BE	Best-effort service

Communication Path Between Base Stations – Mobile WiMAX's "R8" Interface

Handover involves changing a Mobile Station's (MS's) association from the current "anchor" Base Station a new anchor Base Station

Two optimized handover methods are identified in the 802.16 standards

- Fast Base Station Switching (FBSS)
- Macro Diversity Handover (MDHO)

For each of these handover methods, there is a "diversity set" of BSs associated with each MS, selected according to signal strength and other criteria

To support optimized handovers, a BS will need to communicate with one or more neighboring BSs over the R8 interface

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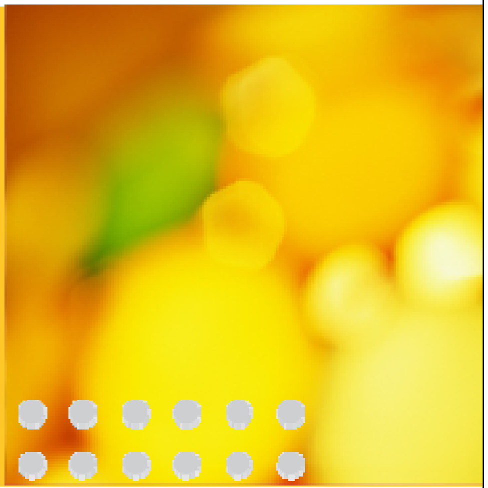
5 Critical success factors in mobile deployment



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MPLS mobile backhaul networks — critical success factors

Carrier-grade MPLS services

- High availability
- Fast reconvergence
- Ensure required QoS performance (delay, jitter, packet loss)
- Flexible correlation to mobile QoS

Scalability to large numbers of cell sites

Multi-domain environments

Multi-technology environments

Base station synchronization

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Carrier-grade MPLS services — MPLS protection edge-to-edge
MPLS Fast Reroute (FRR)

Restoration time

- Recovery times need to meet the needs of real-time applications over 4G networks, such as VoIP
- User traffic can be redirected onto backup LSP tunnels in tens of milliseconds
- Failover transparent to edge service protection mechanisms

Resource efficiency

- Leverages statistical gains over use of optical or SONET/SDH layers

Robustness

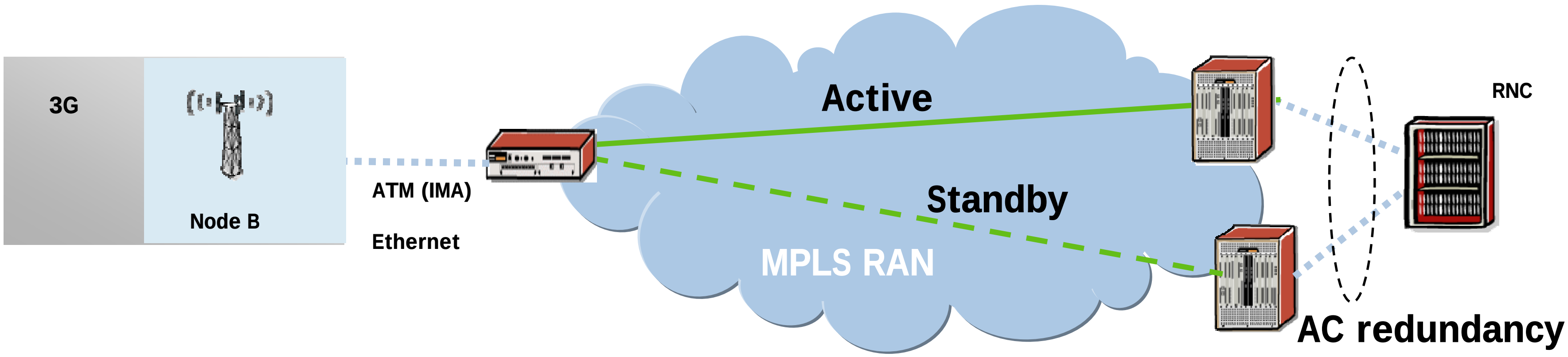
- Route pinning avoids transient LSP behavior when SPF routing changes

Interoperability

- MPLS provides standardized protection in multivendor environments
- RFC 4090: Fast Reroute extensions to RSVP

Carrier-grade MPLS services — MPLS protection plus dual homing pseudowire-level protection with pseudowire redundancy

draft-ietf-pwe3-redundancy- & draft-ietf-pwe3-redundancy-bit-



Protects against PE and AC failures

- PE can be configured with multiple pseudowires per VPWS instance with multiple endpoints
- 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)

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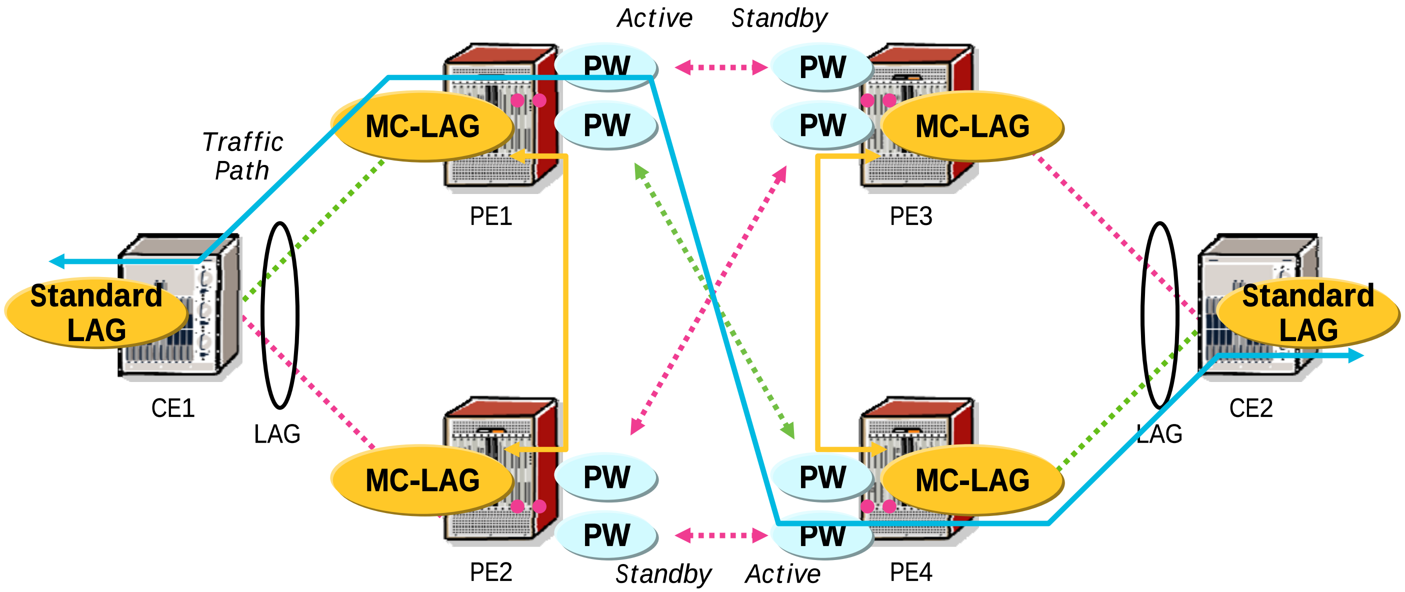
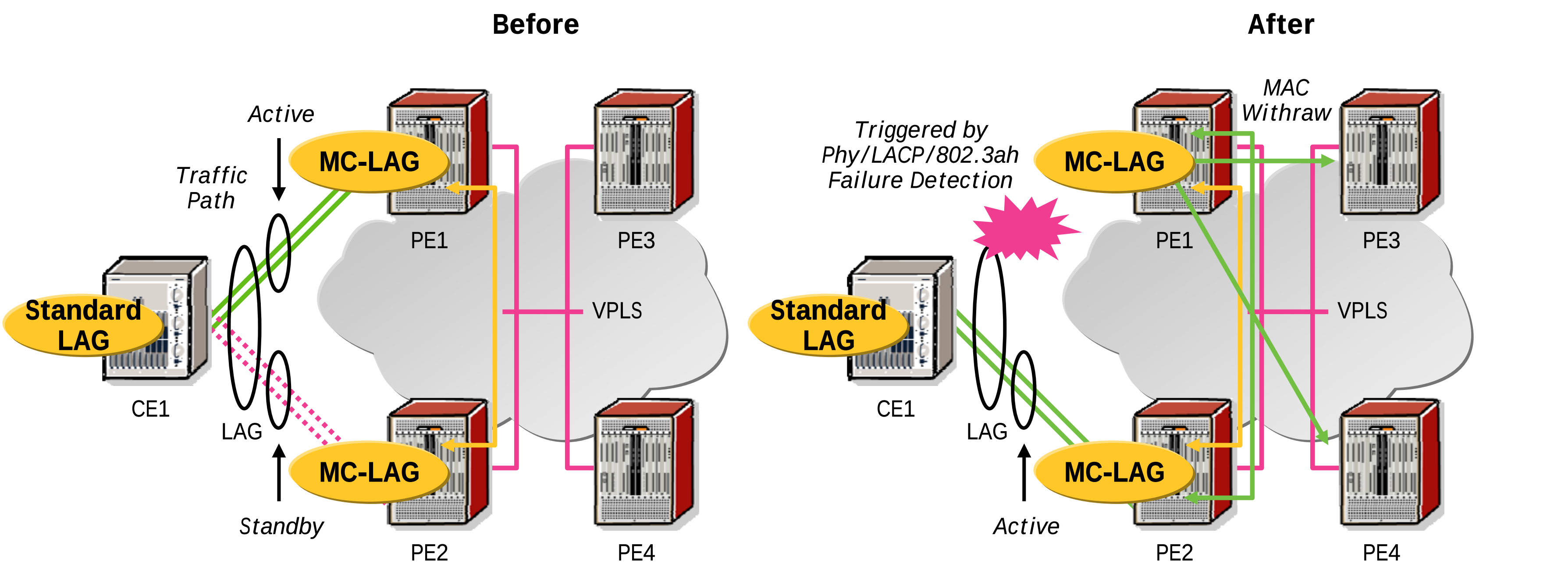
Pseudowire redundancy and MC-LAG on a VPWS



Using MC-LAG to protect access to a VPLS



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Supporting CoS Policies in the MPLS Mobile Backhaul Infrastructure

The evolution to 4G leads to a wider range of service classes available over the air interface (e.g. 5 CoS for WiMAX)

The mobile backhaul and core networks must be capable of supporting this wider range of CoS, with flexible mappings from air interface CoS to transport CoS

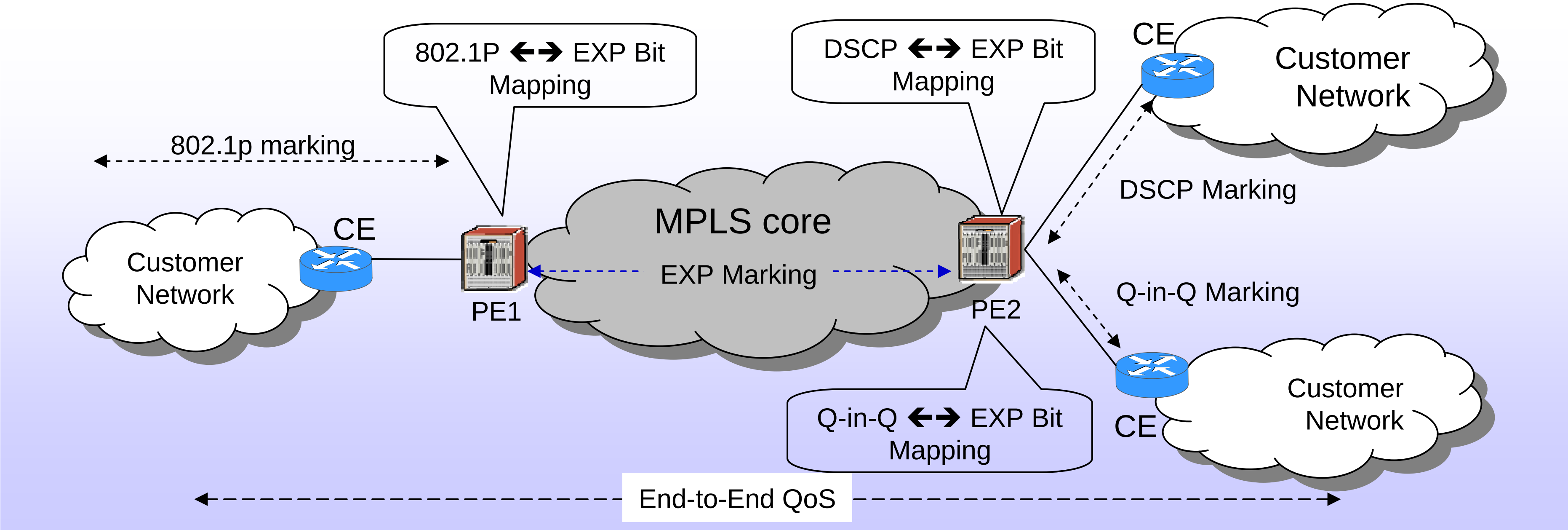
For transport of the IP TNL over MPLS, the MPLS network may take the CoS settings into account at the ingress, while at the same time tunneling these CoS settings through the network for use beyond the egress

- RFC 3270 -- MPLS Support of Differentiated Services
- RFC 4448 –- Encapsulation Methods for Transport of Ethernet over MPLS Networks

Layer 2 and Layer 3 encapsulation fields can be used to classify and mark traffic

- Layer 2 802.1p marking: user priority ➔ 3 bits
- Layer 2 Q-in-Q marking: based on 802.1p
- Layer 3 DSCP marking: 6 bits
- MPLS EXP bits marking: 3 bits

Mapping traffic marking in the network boundary



DSCP ←→ EXP mapping (RFC 3270 – default behavior)

- IP to Label — DSCP bits (precedence bits) in the incoming IP packet are mapped to the MPLS EXP bits in all pushed labels
- Label to Label — No change in the EXP bits
- Label to IP — EXP bits are not copied to the IP precedence/DSCP field of the encapsulated IP packet since the DSCP bits are preserved

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Flexible CoS Mappings over MPLS Transport

In Diff-Serv model, the DSCP identifies a "per-hop behavior" or PHB (i.e. queuing and scheduling)

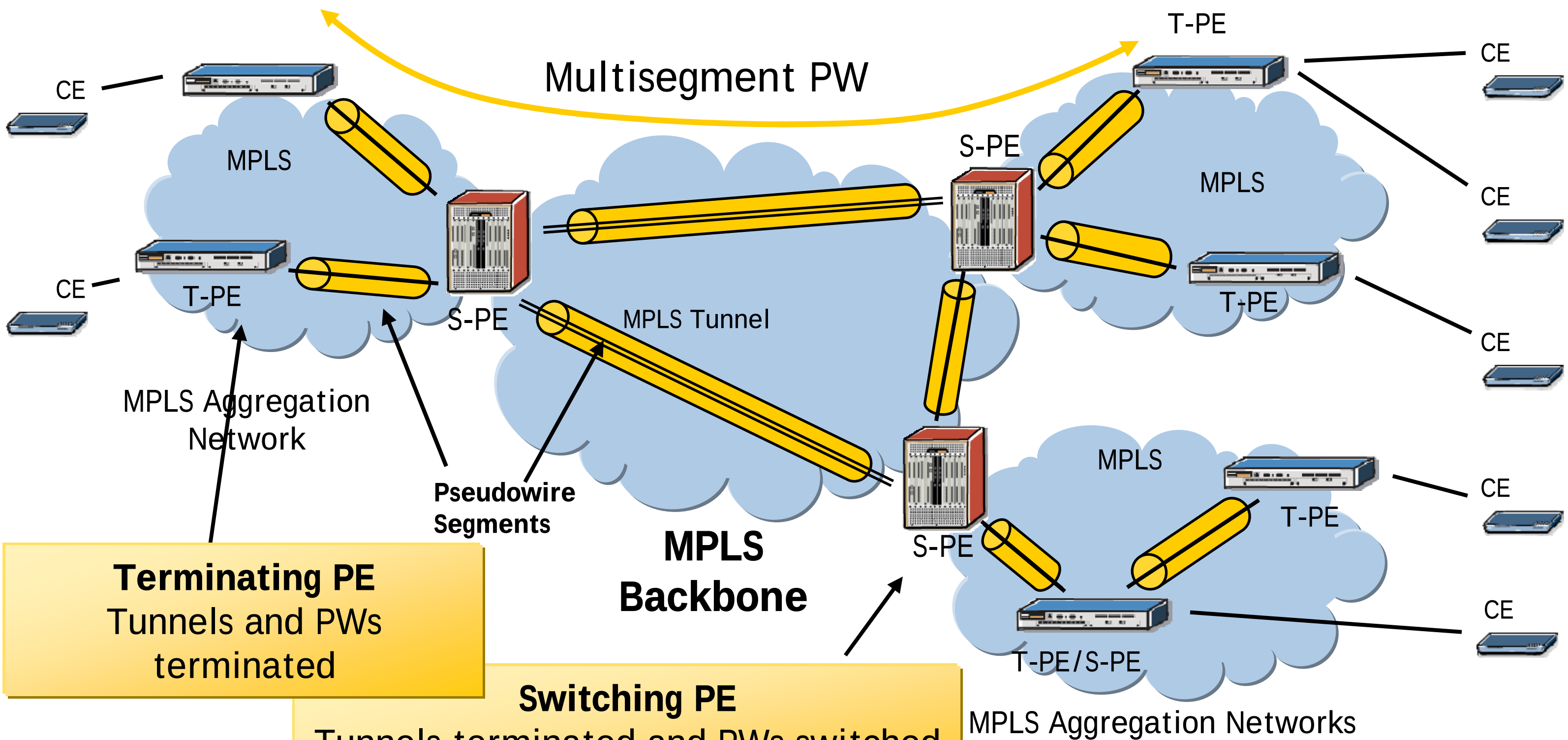
The DSCP value can be represented in an MPLS header value

The solution for supporting Diff-Serv Behavior Aggregates over an MPLS network [RFC 3270]:

- Gives Service Providers flexibility in selecting how Diff-Serv classes of service are Routed or Traffic Engineered within their domain (e.g., separate classes of services supported via separate LSPs and Routed separately, all classes of service supported on the same LSP and Routed together)
- Allows the CoS policies of a service provider using leased facilities to be mapped as appropriate to the CoS policies in the leased portion of the network
- Allows consistent application of CoS policies in portions of a service provider's network that are interconnected over the MPLS infrastructure
- Allows multiple service providers to share a given leased facility, with independent CoS treatment for each
- Offers flexibility for support of PHBs that may be defined in the future

Multisegment pseudowire architecture

draft-ietf-pwe3-ms-pw-arch-02.txt



Terminating PE
Tunnels and PWs terminated

Switching PE
Tunnels terminated and PWs switched between ingress/egress tunnels

Natively switch PWs without native service processing in S-PEs
No implication on underlying IGP domains
Transparency to end-to-end Layer 2 VPN service

Multisegment pseudowires — applicability to mobile backhaul networks (draft-ietf-pwe3-ms-pw-requirements-06.txt)

Many of the use cases envisioned for MS-PWs apply to the evolution of mobile backhaul networks

Scalability — to hundreds of base stations connecting to RNC/BSC site

- MS-PWs allow for a partial mesh, versus a full mesh, of tunnels
- PWs from many PEs in the access domain may be aggregated into a small number of PSN tunnels in the aggregation domain

Multi-domain operation — including multiprovider backhaul networks

- MS-PWs allow for per-domain operation and maintenance procedures such as control plane security (e.g., MD5 key administration for LDP sessions)
- Policies (e.g., admission control, QoS mappings) may be applied to PWs at domain boundaries

Multi-technology operation

- Interconnect domains of static PWs with T-LDP signaled PWs
- Interworking of PSNs: leverage mechanisms from non-MPLS access infrastructures

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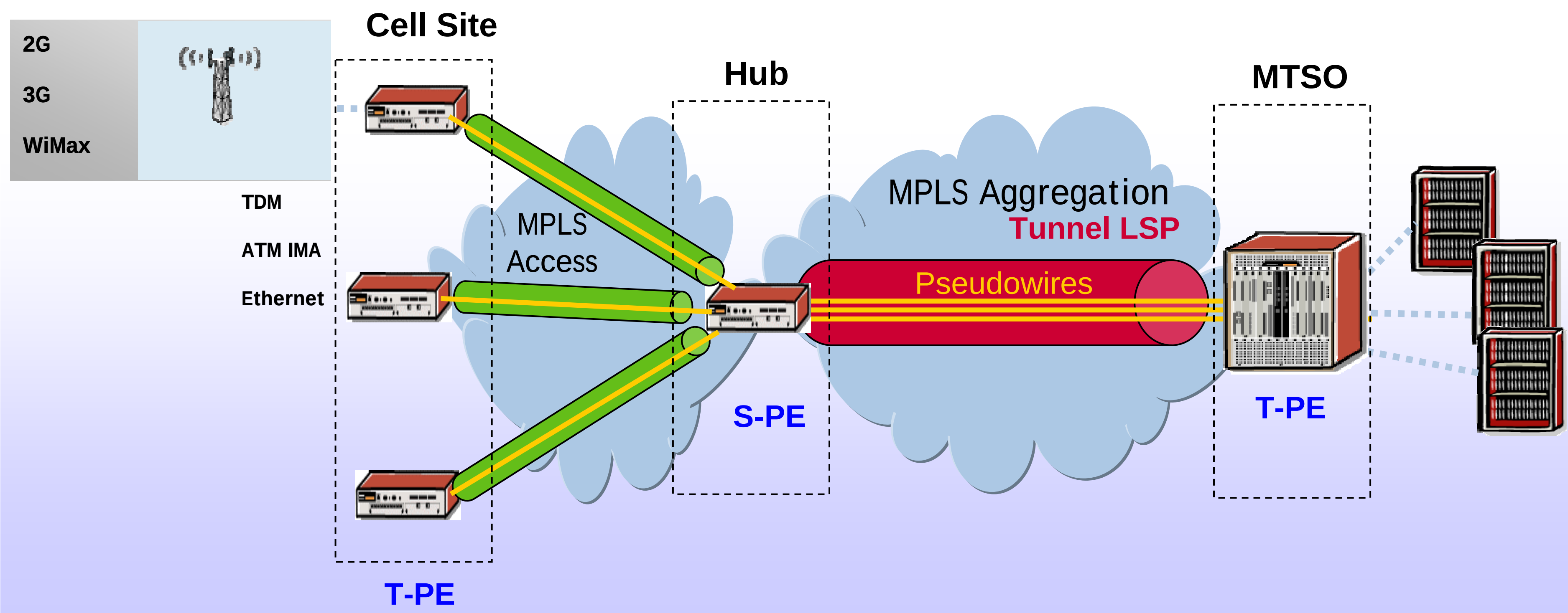
MPLS MS-PWs for mobile backhaul — an example

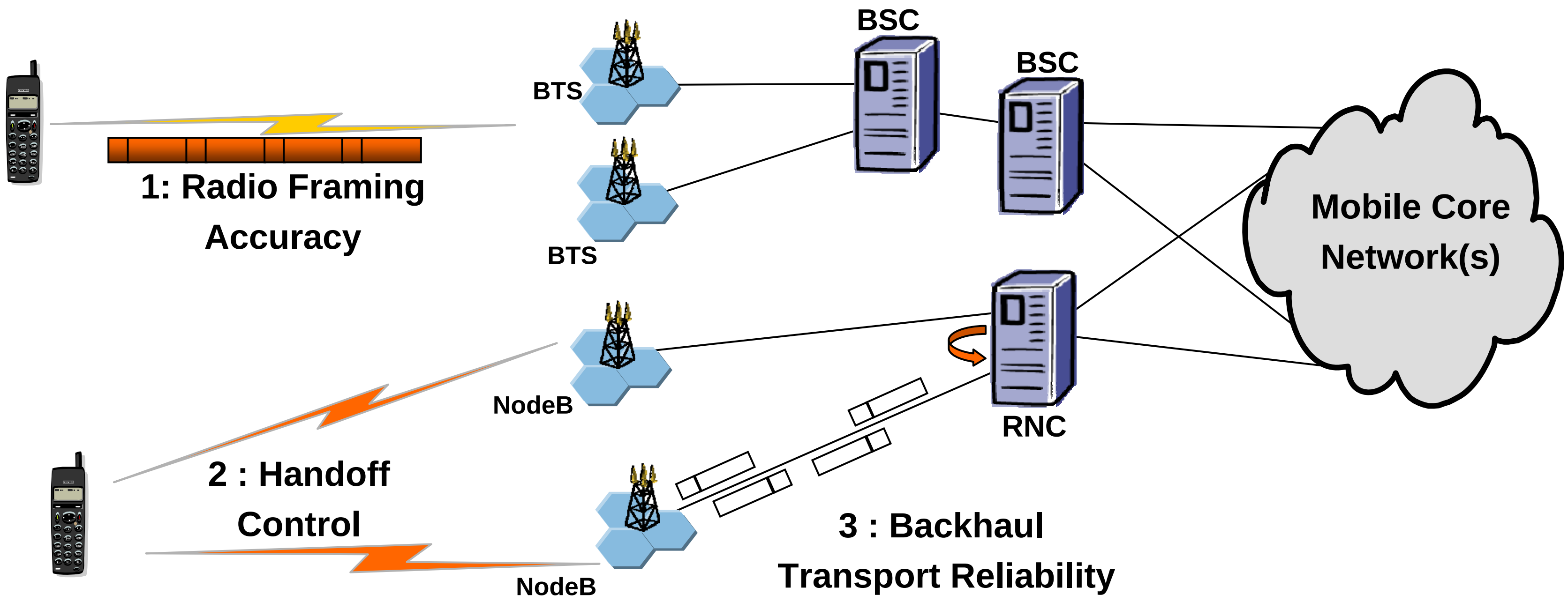
- PW segments switched from access to aggregation networks at S-PE
- PW segments are configured or dynamically established using T-LDP
- MS-PW reduces the number of TE tunnels/signaling sessions that must be supported by edge devices
- S-PEs can aggregate the PWs carrying like services into common TE tunnels



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:



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Addressing base station synchronization requirements

For base stations using Carrier Ethernet transport, there are several approaches for timing and time synchronization:

- GPS synchronization
- PDH/SDH clocking
- Synchronous Ethernet
- Adaptive and differential clock recovery
- Packet-based timing protocols (e.g. IEEE 1588 v2, NTPv4+)

A packet-based timing protocol is likely to be one of the approaches used

Packet-based timing protocols require a network infrastructure that can support stringent packet QoS and resiliency requirements

Timing Approaches -- Observations

Many new options evolving to meet timing requirements

- ITU, IEEE, IETF, MEF, IP/MPLS Forum

Adaptive recovery

- Adaptive clock recovery solutions conforming to G.823/G.824 Sync Interface using ITU G.8261-defined scenarios are available

IEEE 1588v2

- Suitable for service Provider Timing Over Leased Packet Aggregation Networks
- 1588v2 packets may be distributed over PW to Cell Site Gateway

Synchronous Ethernet (ITU G.8261)

- Suitable for service Provider Timing Over Facility Based Aggregation Networks
- Any timing solution that had Synchronous L1 technology within a given span can be deployed with Synchronous Ethernet

Providers are exploring new standards as they emerge, and are successfully deploying a number of clock recovery mechanisms now

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6

MPLS in Mobile Backhaul Initiative

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What is the MMBI?

MPLS in Mobile Backhaul Initiative

- Work item underway in IP/MPLS Forum
- Defining role of IP/MPLS technologies in mobile backhaul (2G, 3G, 4G)

MMBI objectives

- Improve mobile operator's bottom line and simplify operations
  - Converging technology-specific backhaul networks to single multiservice packet infrastructure
  - Based on proven benefits of MPLS while leveraging cost-benefits of Ethernet
- Help to extend the future value of investments
- Enhance experience for mobile users with new data services and applications, along with voice
- Expedite mobile broadband deployment
  - HSPA/HSPA+/LTE, EV-DO/UMB, WiMAX

What is the MMBI scope?

- Focus on MPLS technology to bring solutions to transport mobile traffic (user plane and control plane) over access, aggregation and core networks
- Cover multiple generations (2G/2.5G/3G/4G) of mobile network infrastructures
- Consider RAN and core equipment with range of physical interfaces (including E1, STM-1/OC-3, DSL, FE, GE) and technologies (such as PDH, SDH, ATM and ATM/IMA, PPP, Frame Relay, Ethernet), either directly attached or through an intervening access network
- Support for different kinds of access transmission technologies: point-to-point access (xDSL, microwave, point-to-point fiber), point-to-multipoint access (GPON)
- Address coexistence of legacy and next-generation mobile equipment in the same network infrastructure
- Support a smooth migration strategy for network operators as newer Transport Network Layers (TNLs) are introduced and legacy TNLs are phased out

What is the MMBI scope? (continued)

- Consider MPLS facilities in access and/or aggregation networks leased from a third party, and which may be shared by more than one mobile operator
- Allow for converged access/aggregation network supporting both wireline (including residential and enterprise) and wireless services
- Specify QoS requirements for support of distinct service types (e.g., real-time services and associated delay and jitter requirements)
- Provide requirements on the MPLS network for supporting clock distribution to the base stations, e.g. to support IEEE 1588v2
- Include requirements for resiliency capabilities in the reference architecture, taking into account failover times appropriate for wireless backhaul networks
- Specify OAM requirements to support the reference architecture
- Provide support for BS – Access Gateway as well as BS – BS interconnection, as seen in 4G networks, over a common MPLS-based mobile backhaul network

MMBI Reference Model – Scenarios for Access Technologies and MPLS Infrastructure

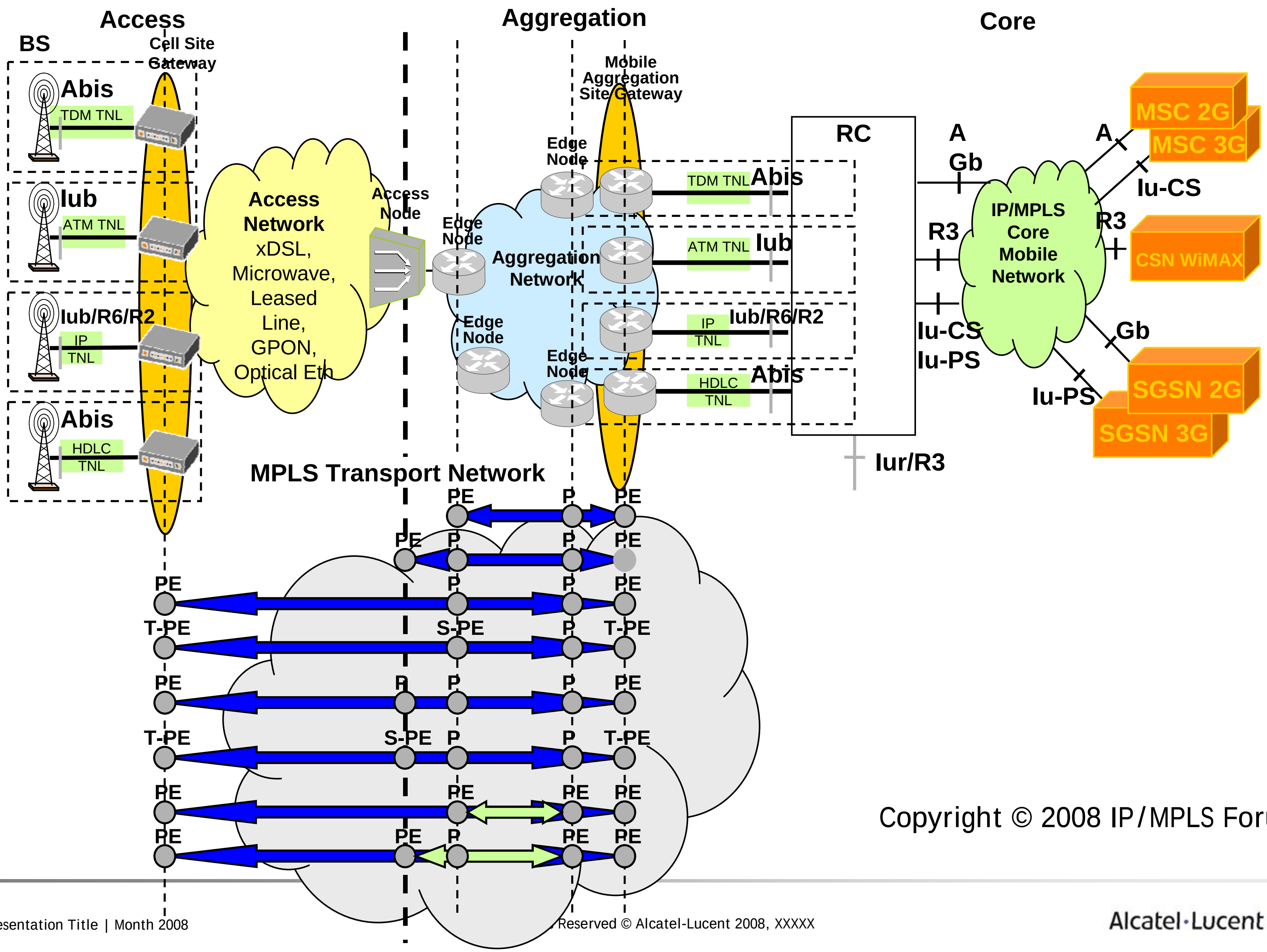
TNL scenarios — support for a range of access technologies at base stations and controller elements

- Case 1: TDM TNL
  - Base stations and controller elements communicating using TDM bit streams
- Case 2: ATM TNL
  - Base stations and controller elements communicating using ATM cells
- Case 3: IP TNL
  - Base stations and controller elements communicating using IP packets
- Case 4: HDLC TNL
  - Base stations and controller elements communicating using HDLC-encoded bit streams (e.g., CDMA)

Deployment scenarios — location for MPLS functions is intended to be flexible

- MPLS interworking functions could be located either:
  - In the edge node, or
  - In the access node to, or
  - In the access gateway or
  - Directly integrated into the base station

MPLS in Mobile Backhaul Reference Model



7 Conclusion

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Conclusion

Mobile backhaul networks to support next-generation services characterized by

- Steady growth of bandwidth from broadband applications
- New base stations with Ethernet/IP interfaces
- Increasingly diverse traffic types with complex SLAs
- Diversity in access technologies and embedded investments recognizing that there is no "one size fits all"

Ethernet in combination with MPLS lowers the cost of transport

- Carrier-grade capabilities including scalability, resiliency, manageability and traffic engineering plus QoS are added
- Use of MPLS pseudowires for backhauling traffic such as TDM and ATM allows legacy equipment to be used while leveraging the advantages of packet transport
- MPLS provides a carrier-grade infrastructure that is 4G-ready

Ongoing work within standards bodies and industry forums will expedite evolution of the IP RAN

Selected relevant industry standards specifications and work in progress

IETF PWE3

Pseudowire Emulation Edge-to-Edge (PWE3) Architecture – RFC 3985

…and many others

ITU-T

- Recommendation G.8261 "Timing and Synchronization in Packet Networks"

IEEE

- IEEE draft standard 1588 v2 (Precision Clock Synchronization Protocol) – work in progress

IP/MPLS Forum

- MMBI Specifications – work in progress

Metro Ethernet Forum

- Mobile Backhaul Project Implementation Agreements – work in progress

WiMAX specifications

The IEEE 802.16 Working Group on Broadband Wireless Access Standards

http://www.ieee802.org/16/

The WiMAX Forum

http://www.wimaxforum.org/home/

Current public document release

WiMAX Forum Network Architecture Stage 2 - 3: Release 1, Version 1.2

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