Packet Based RAN for Mobile Operators

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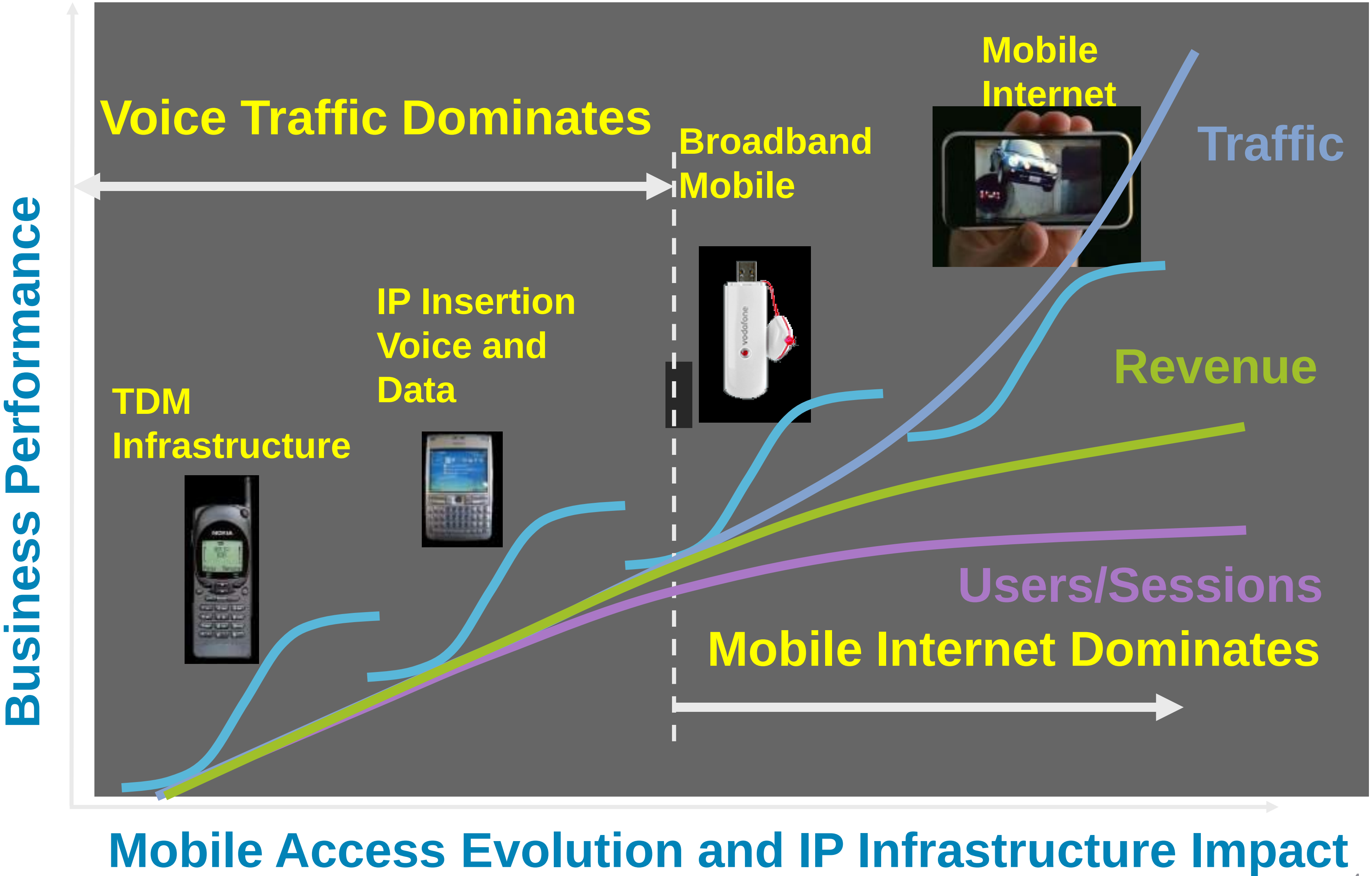
Agenda

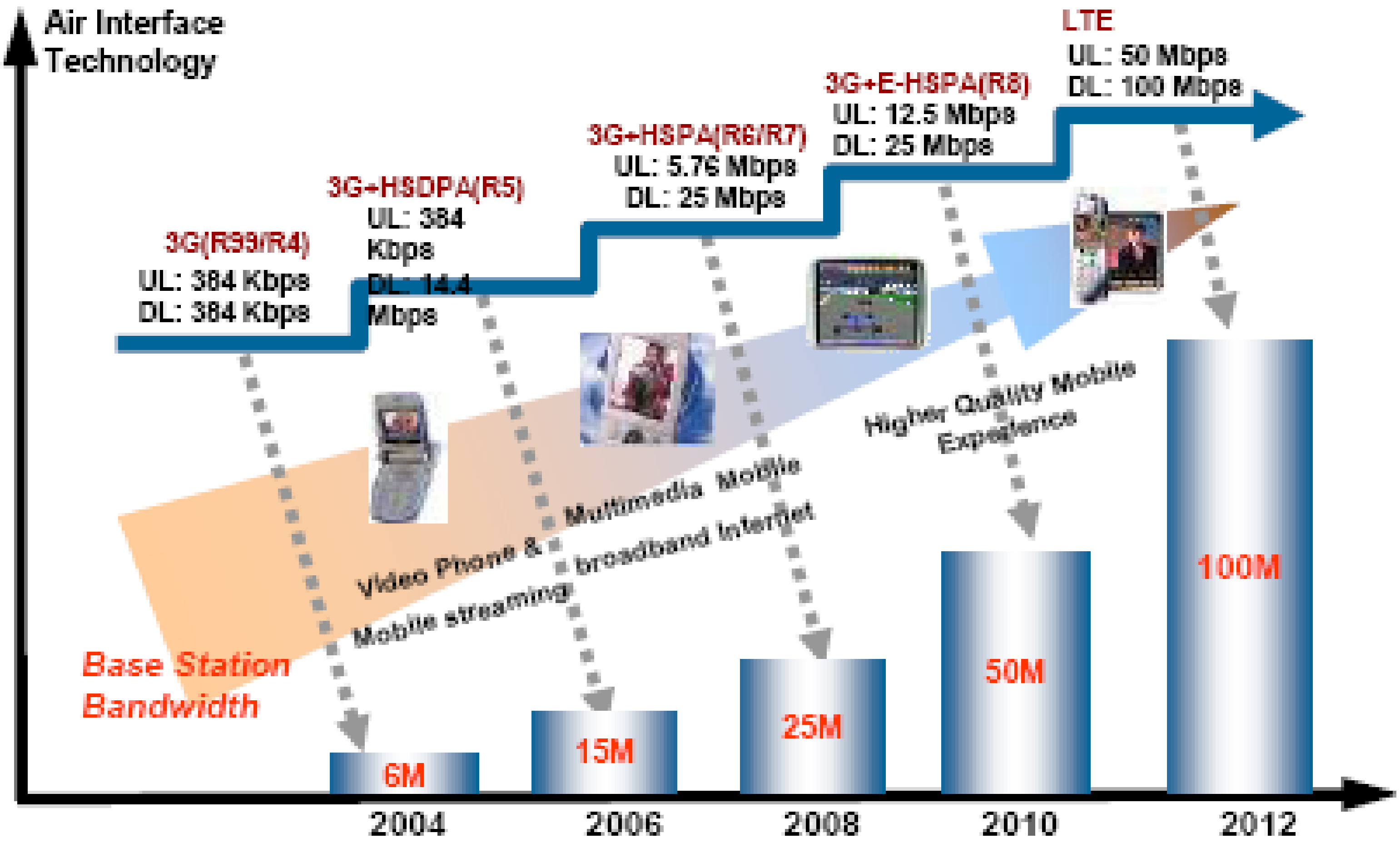
- Market Drivers for Next-Gen RAN
- Technical Requirements
- RAN Architecture Evolution
- Packet Based RAN Concepts
- Deployment Scenarios
- Mobile Backhaul Market Survey
- Summary

Market Drivers for Next-Gen RAN

Driving New Challenges for SPs



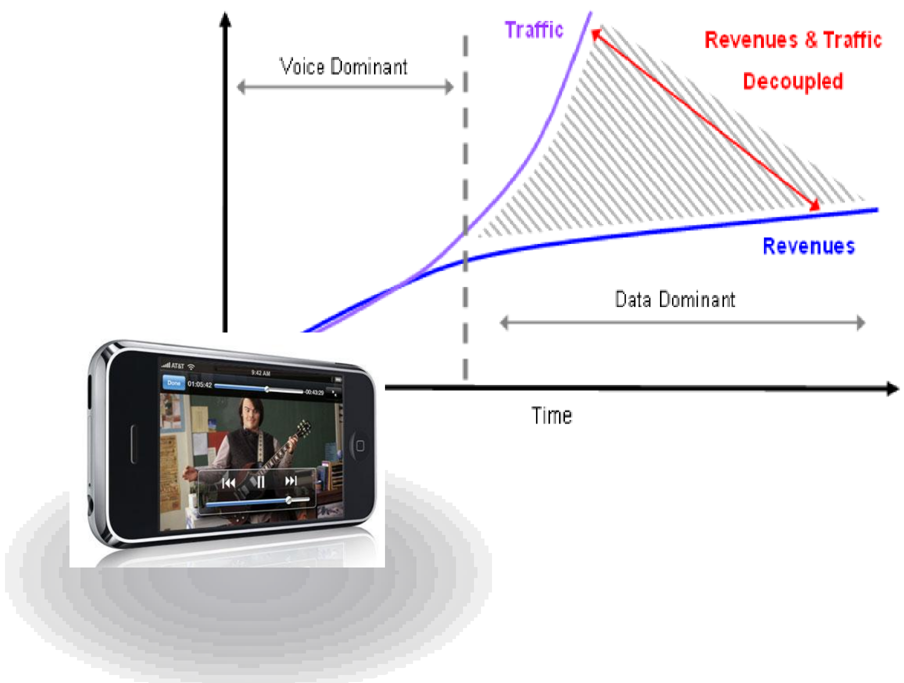
Radio technology evolution and bandwidth growth



Opportunities with Packet Based RAN

Reduce Operational Cost

- Backhaul of cell tower traffic and leasing T1s account for 20% of mobile operator OpEx
- Drive down “per bit” cost in exponentially



IP Based Converged Transport

- 2G networks use TDM circuits for RAN transport
- 3G (UMTS) networks use ATM for RAN transport
- 4G is all IP
- Service delivery over any access network

RAN Bacjhaul Scalability

- Easier addition of new RAN bandwidth
- Rollout new services faster
- Meet capacity demand , expected to grow 4x to 10x as migration to 3G and 4G proceeds
- LTE will drive 100Mbps – 1Gbps per cell-site

Technical Requirements

Next-Gen Backhaul Requirements

- Common and cheap transport
- Generation and service independent
- Traffic type awareness and prioritization (QoS)
- Scalability
- Service Resiliency
- Clock distribution mechanism
- Large scale provisioning and network visibility
- Work with existing backhaul interfaces (T1/ATM/Sonet)

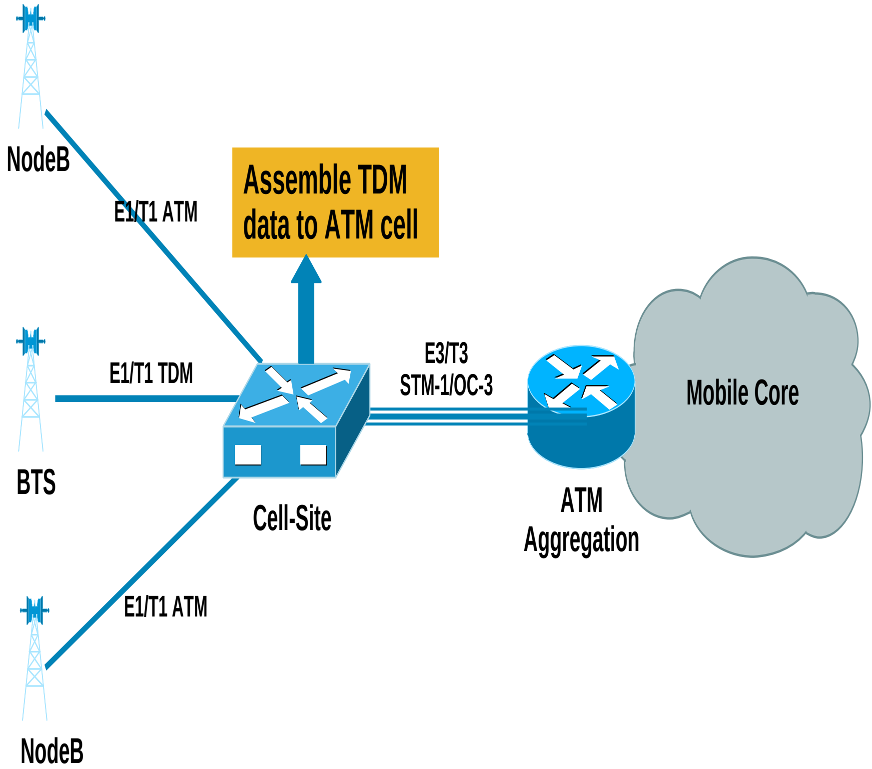
Mobile Operators Looking for Options

- Convergence over ATM
- RAN Optimization, with HSPA Offload
- Microwave
- Ethernet based BTS / Node-B
- IP/MPLS based transport

Winner: IP/MPLS based transport

Convergence Over ATM

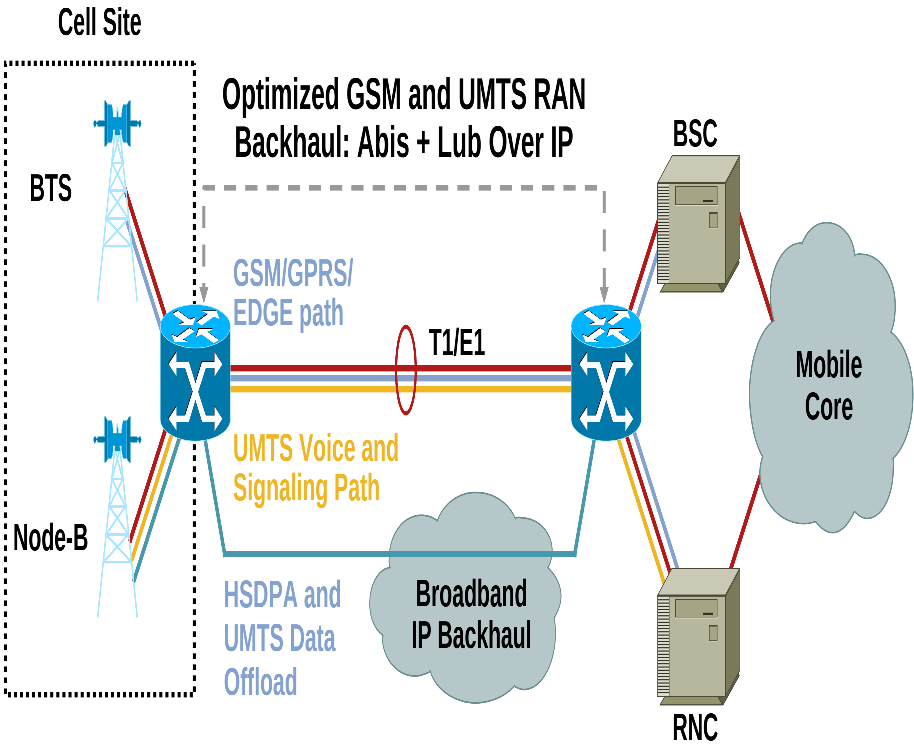
- Aggregate 2G/3G traffic using single ATM access link
- Incremental deployment of 3G with existing 2G
- Not flexible enough to deliver statistical / bursty traffic
- Cost per mobile phone increases significantly faster than ARPU
- Multicast not easy
- Not future proof



Aggregate traffic from 2G/2.5G BTS or 3G Node-B on a single ATM trunk

RAN-Optimization with HSPA Offload

- Optimization by suppressing silence/repetitive frames, compressing headers
- Data offloading to DSL while 2G and 3G voice still over T1/E1
- Temporary solution, Not future proof
- Reduction in voice quality
- Not necessarily standards based



- 50% efficiency gain on GSM, 15-90% on UMTS
- HSPA offloaded to DSL, Eth etc

Microwave

- Point to multipoint microwave radio links
- On demand bandwidth allocation for Node-B’s
- Nodal concept simplifies the end to end provisioning
- Geography based limitations (Line of sight)
- Spectrum / license availability
- Requires contract renegotiations / new permits in buildings
- Cheap until 16 E1 then cost goes up significantly

Ethernet Enabled NodeB

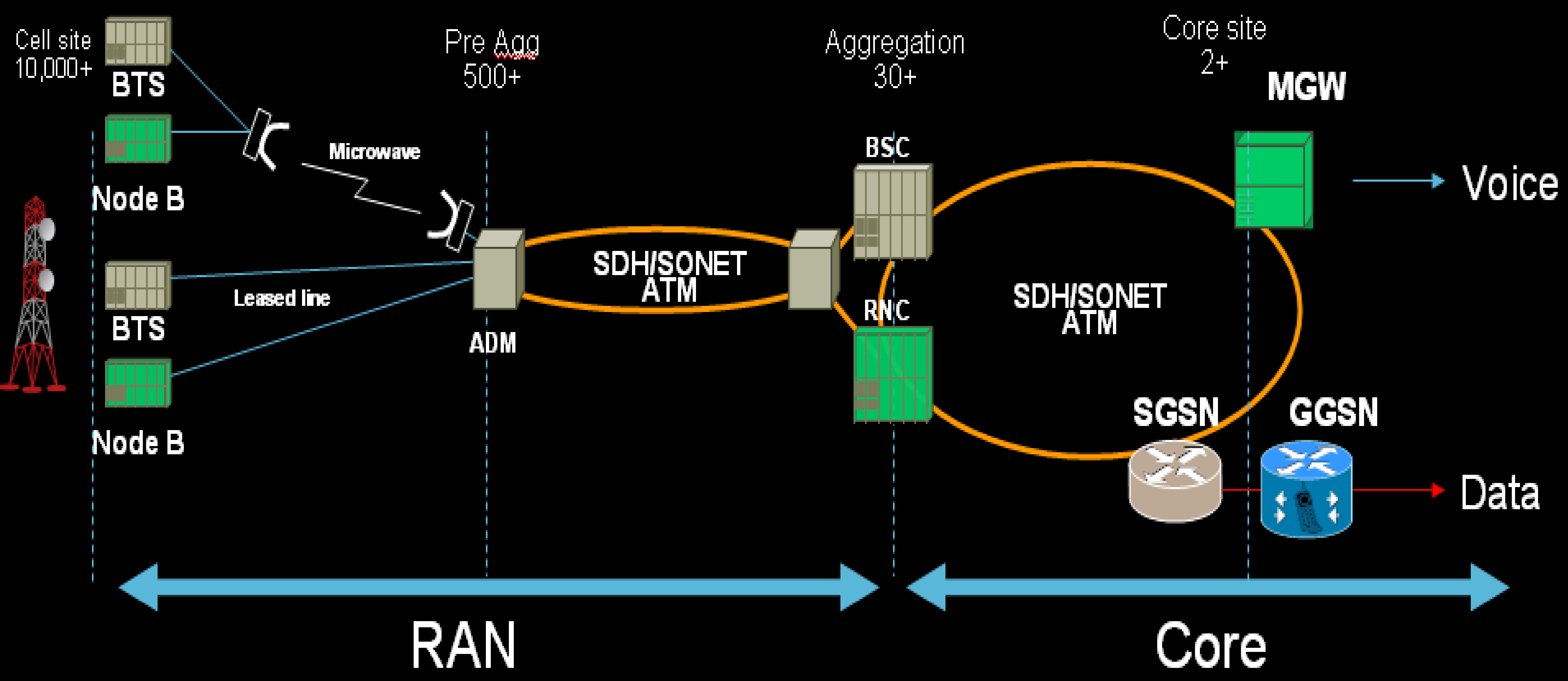
- Makes data offloading easier
- For voice traffic, NodeB must originate PWE
- In most cases, basic ethernet connectivity – not sufficient for end-to-end reliable transport
- Not necessarily standards based
- RAN vendors have no MPLS legacy
- Provisioning / troubleshooting MPLS advanced features on NodeB is a challenge
- Subject to inherent security risks of IP / MPLS

IP/MPLS Based Transport

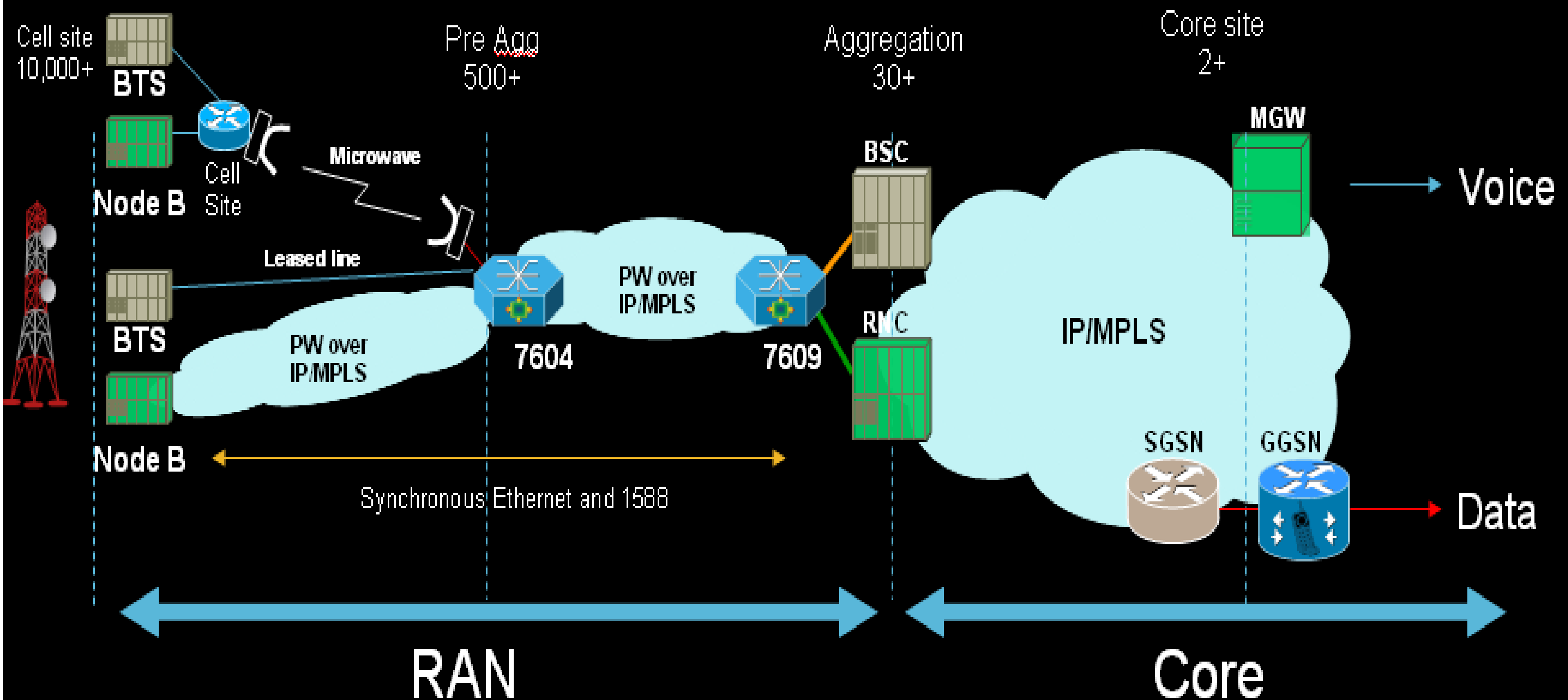
- High capacity packet network
- Access Agnostic
- Unified transport
- Widely deployed
- Ethernet to cell site results in even more cost savings
- Operational experience with their existing IP/MPLS core
- Proven QoS, high availability and security
- Clock synchronization over packet network is relatively new

RAN Architecture Evolution

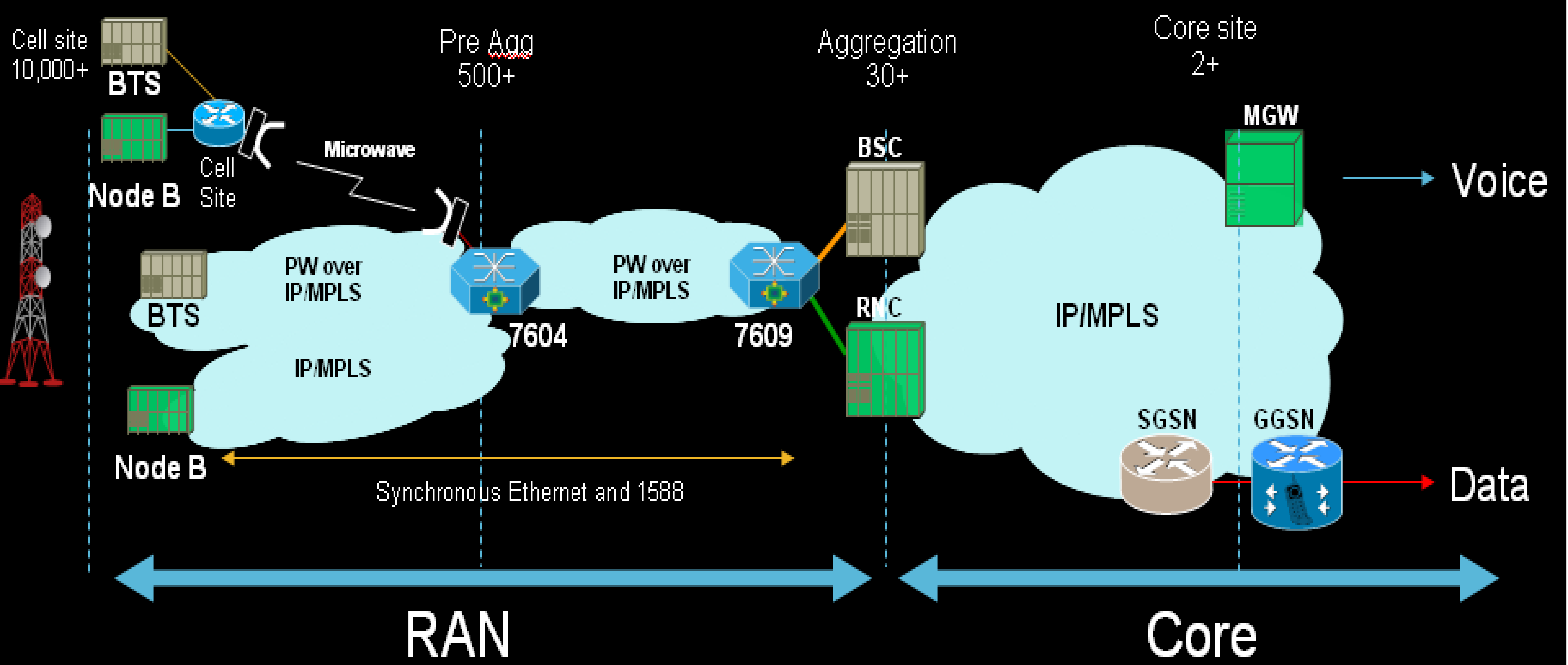
How does the RAN Look Today?



How Could the RAN look in 0-12 Months?

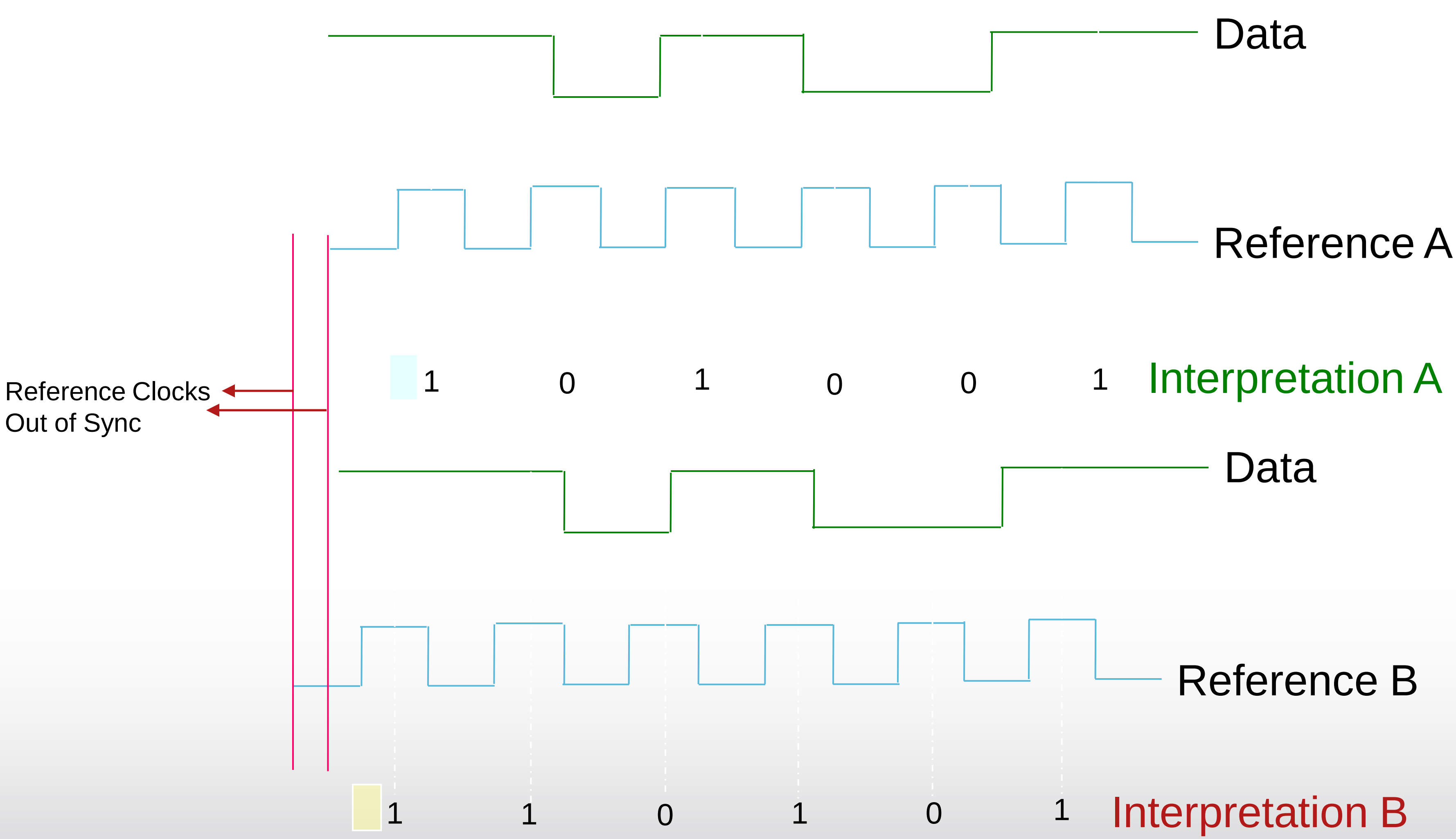


How Could the RAN look on 1-3 Years?



Packet-Based RAN Concepts

Why is clocking important?

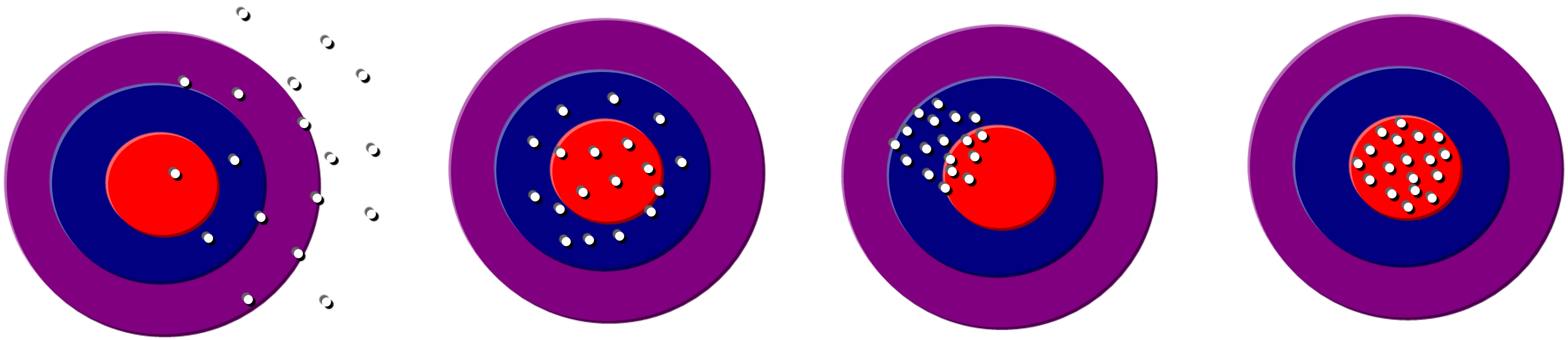


Bad Clocking will………

- Result in slips on TDM interface to cell site or take the interface down
- Cell sites out of sync with rest of network can still initiate calls but handoffs will fail between cell towers (yes even in all IP- you need clocking because of this)

Frequency and Phase Introduction

Frequency= Stability
Phase=Precision

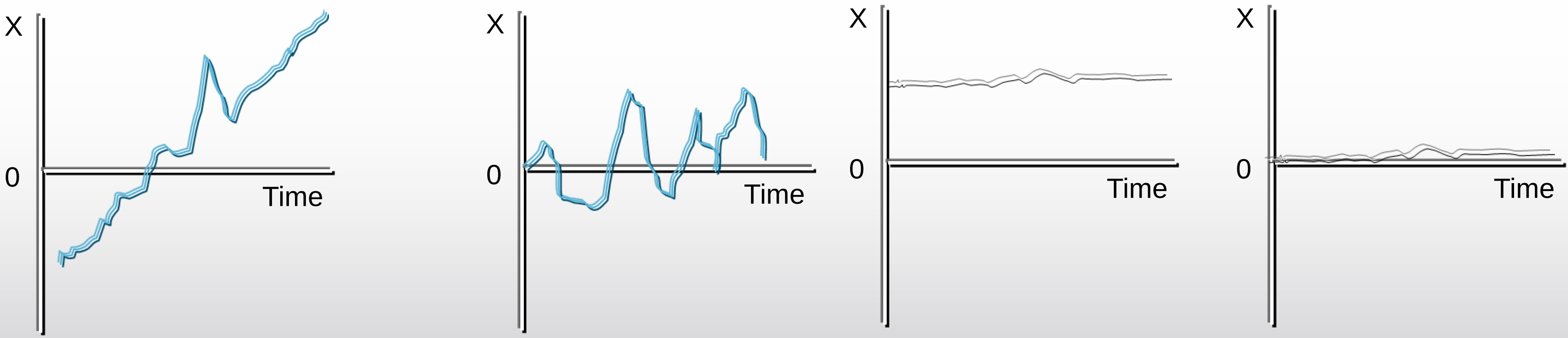


Not Stable
Not Accurate

Not Stable
Accurate

Stable
Not Accurate

Stable
Precise



Not Stable and
Not Accurate

Not Stable
but Accurate

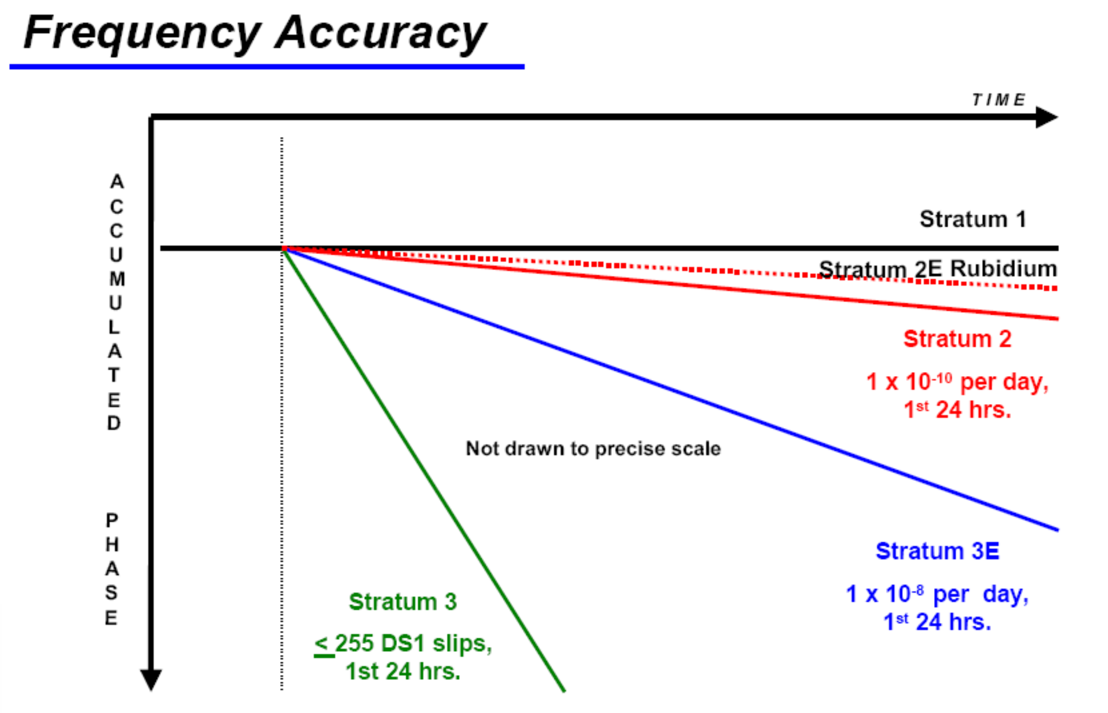
Stable but
Not Accurate

Stable
And Accurate

Clock Sources

- Cesium PRC/SDH
  - Uses Cesium resonate frequency
- GPS
  - Stratum level 1 via GPS satellites frequency and phase
- SyncE
  - Physical layer Ethernet frequency
  - Head node takes PRC and outputs SyncE
- 1588-2008
  - Packet based frequency and phase
  - Uses Grandmaster with PRC input and outputs timing packets
  - Uses Slave to accept timing packets and replay SDH/other based timing
- NTPv4
  - Similar to 1588-2008 but is strictly layer 3, unicast only, dynamic server selection, lacks 1588-2008 like follow-up messages

Comparison of Stratum Levels



- Stratum level is important from a clock source perspective since it drives the network clocking during normal ops
- Stratum level is important from a clock receiver perspective since it drives the ability of the device to maintain frequency and phase during failure of the clock source

Ethernet Clocking Mechanism Comparisons

	Advantages	Disadvantages	
GPS	**Reliable PRC** **Relatively cheap** **Frequency and phase**	**Antenna required** **US Govt owned**	
PRC/BITS	**Reliable PRC** **Generally Available**	**No Phase** **Need to maintain TDM in all Ethernet deployment**	
1588-2008	**Frequency and Phase**	**Requires Master w/ PRC** **Performance influenced by network**	
SyncE/ESMC	**Physical layer Frequency**	**No Phase** **Every node in chain needs to support**	
NTPv4			

Clock Deployment Guide

- SyncE
  - Always use SyncE if possible if SDH or GPS clock is not available
  - End ⬄ end SyncE support required (all nodes in chain have to support)
  - If all that is required is frequency, SyncE is sufficient and preferred

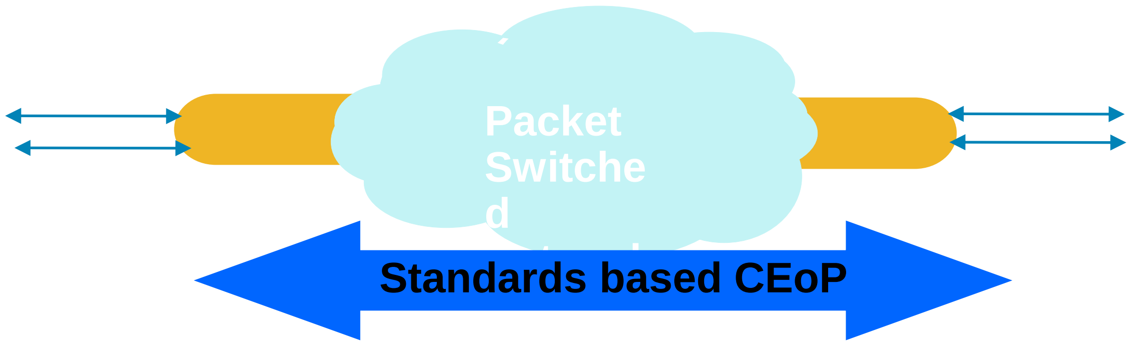
Clock Deployment Guide

- 1588-2008
  - Use if no SDH, GPS clock or SyncE for frequency
  - Packet Delay Variation (PDV) is your enemy. PDV is the variance in the delay of 1588 packets. The slave can not lock with excessive PDV. To minimize PDV:
  - Packets need to be L2 switched or L3 forwarded in HW
  - 1588-2008 traffic must receive proper QoS prioritization
  - Tests have shown that any packets processed in a non dedicated CPU caused excessive PDV

Clock Deployment Guide

- Hybrid Mode
  - Hybrid mode combines SyncE for frequency accuracy and 1588-2008(PTPv2) for phase alignment.
  - SyncE transfers accurate clock over the physical layer, hence there is virtually no clock wander.
  - 1588-2008 master transfers ToD and 1PPS to a 1588-2008 slave using PTP timestamps and SyncE frequency to recover ToD and 1PPS.
  - Phase is very stable due to SyncE stability

Circuit Emulation Over Packet (CEoP)



- Circuit Emulation = imitation of a physical communication link
- CEoP imitates a physical communication link across Packet network
- Allows the transport of any type of communication over Packet
- Ideal for TDM or Leased Line replacement and legacy network consolidation

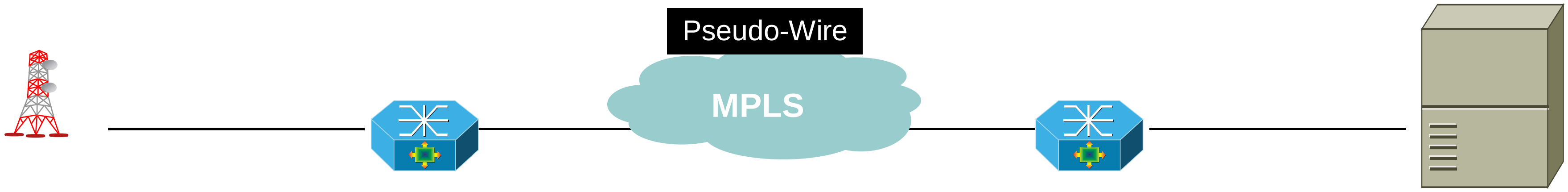
Pseudowire Types Used in RAN Transport

- ATM pseudowire
  - Used for 3G only
  - Inefficient for a single cell but only sends traffic when required
  - Use of cell packing can reduce overhead with minimal impact on latency

- TDM pseudowire
  - Used for 2G; can be used for 3G
  - Just as a real TDM circuit, bandwidth is wasted when the circuit is not being fully utilized.

- For 3G networks an ATM pseudowire offers an advantage over a TDM pseudowire

Pseudowire Basics



- Pseudowire (PW): A mechanism that carries the essential elements of an emulated service from one Device to one or more other Devices over a Packet Switched Network (PSN).
- Within the context of PWE3, this uses IP or MPLS network as the mechanism for packet forwarding.
- Having a common PW layer provides the simplification of deployment, management and provisioning.
- Industry has GOOD experience deploying some of these PW types already, and the concept now can be extended to TDM & ATM for RAN purpose.

SAToP Standards

RFC 4553: Structure-Agnostic Time Division Multiplexing (TDM) over Packet (SAToP)

This specification describes edge-to-edge emulation of the following TDM services described in [G.702]:

- E1 (2048 kbit/s)
- T1 (1544 kbit/s)
- E3 (34368 kbit/s)
- T3 (44736 kbit/s)

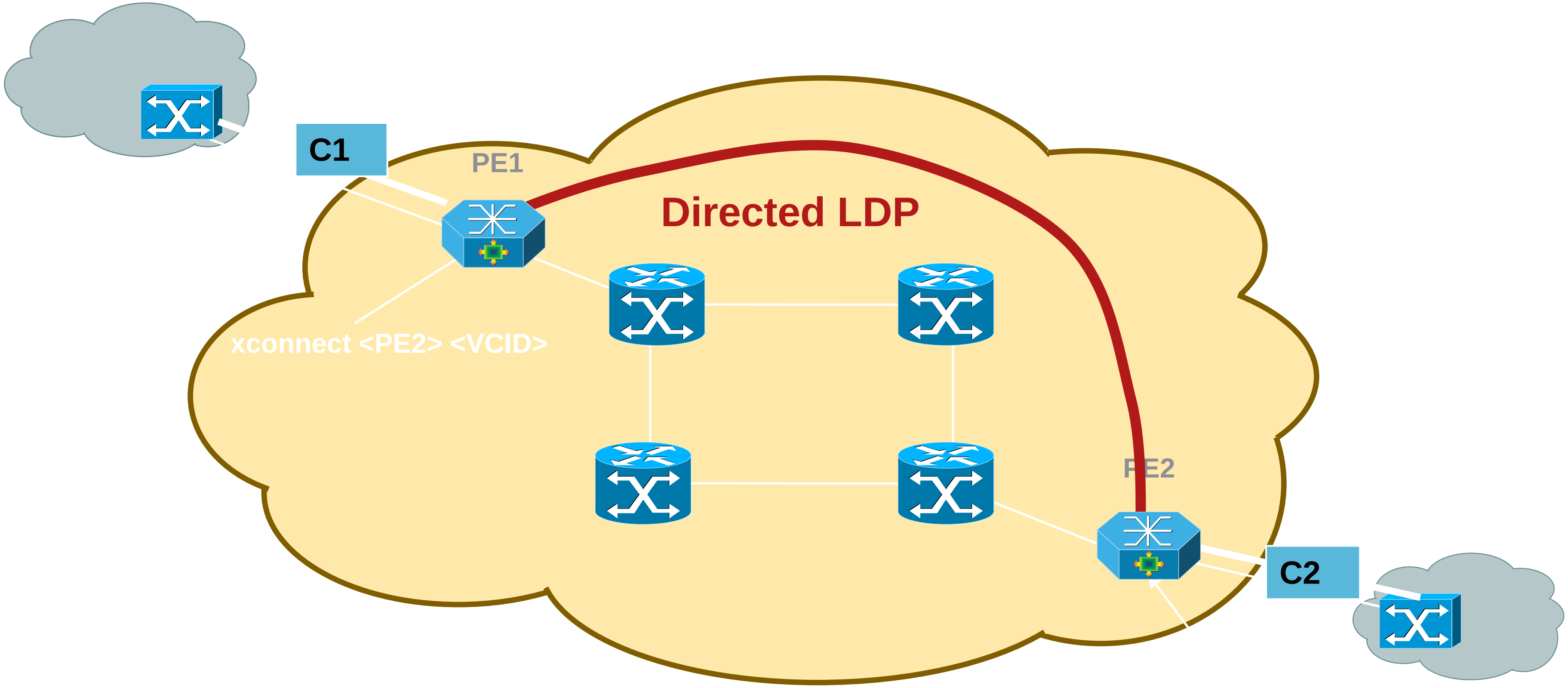
The protocol used for emulation of these services does not depend on the method in which attachment circuits are delivered to the PEs.

CESoPSN Standard

CESoPSN protocol designed to meet the following constrains:

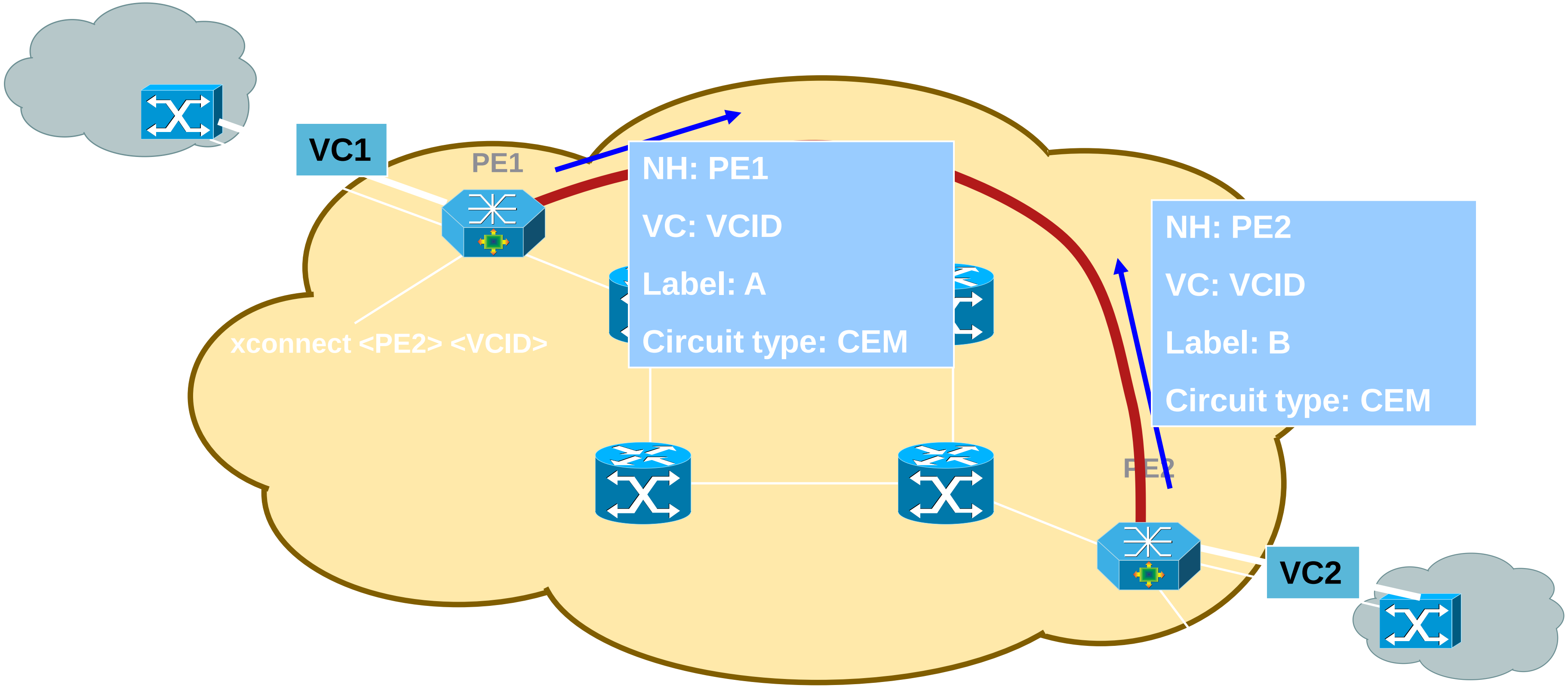
- Fixed amount of TDM data per packet: All the packets belonging to a given CESoPSN PW MUST carry the same amount of TDM data.
- Fixed end-to-end delay: CESoPSN implementations SHOULD provide the same end-to-end delay between a given pair of CEs regardless of the bit-rate of the emulated service.
- Packetization latency range:
  - SHOULD support packetization latencies in the range 1 to 5 milliseconds
  - Configurable packetization latency MUST allow granularity of 125 microseconds
- Common data path for services with and without CE application signaling.

MPLS Core: Pseudo-Wire Signalling



Based on xconnect command, both PE's will create directed LDP session if doesn't exist already

MPLS Core: VC Label Distribution



VC Label distributed through directed LDP session

FEC TLV tells the circuit type

LDP: Pseudo-Wire id FEC TLV

<table>
<tr><td>VC TLV</td><td>C</td><td>VC Type</td><td>VC info length</td></tr>
<tr><td colspan="4">Group ID</td></tr>
<tr><td colspan="4">VC ID</td></tr>
<tr><td colspan="4">Interface Parameter</td></tr>
</table>

VC TLV = 128 or 0x80

VC Type:	0x0011	E1 (SaToP)
	0x0012	T1 (SaToP)
	0x0013	E3 (SaToP)
	0x0014	T3 (SaToP)
	0x0015	CESoPSN basic mode
	0x0017	CESoPSN TDM with CAS

C: 1 control word present

Group ID: If for a group of VC, useful to withdraw many labels at once

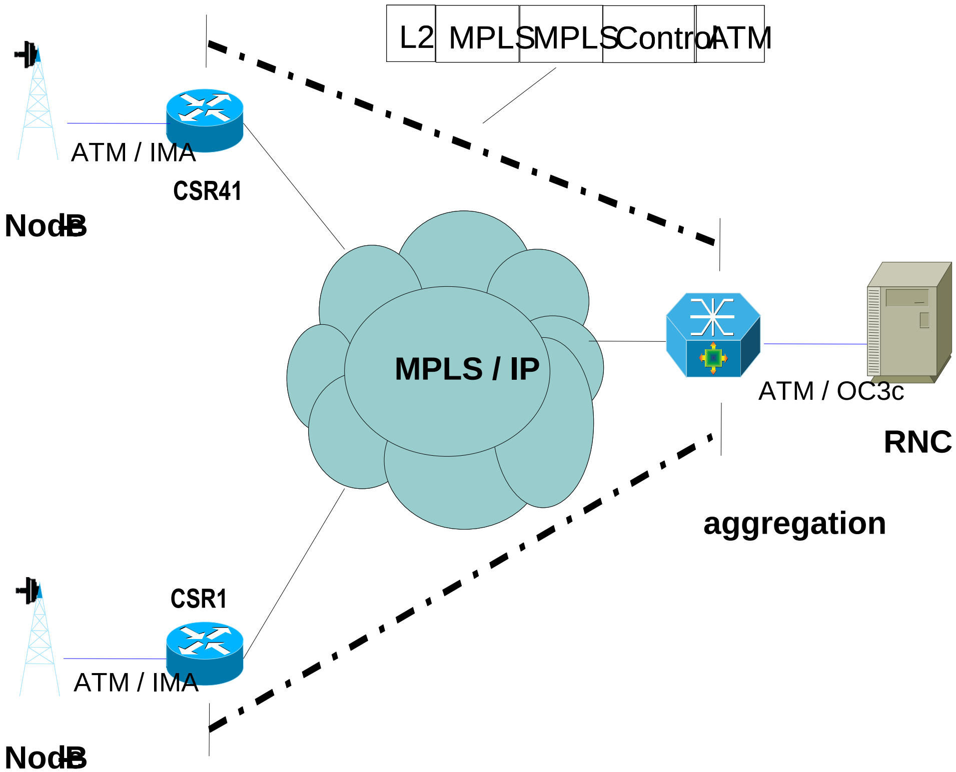
VC ID : ID for the transported L2 vc

Int. Param: classical + IETF-PWE3-TDM-CP-Extension

ATM / IMA Over Psuedowire

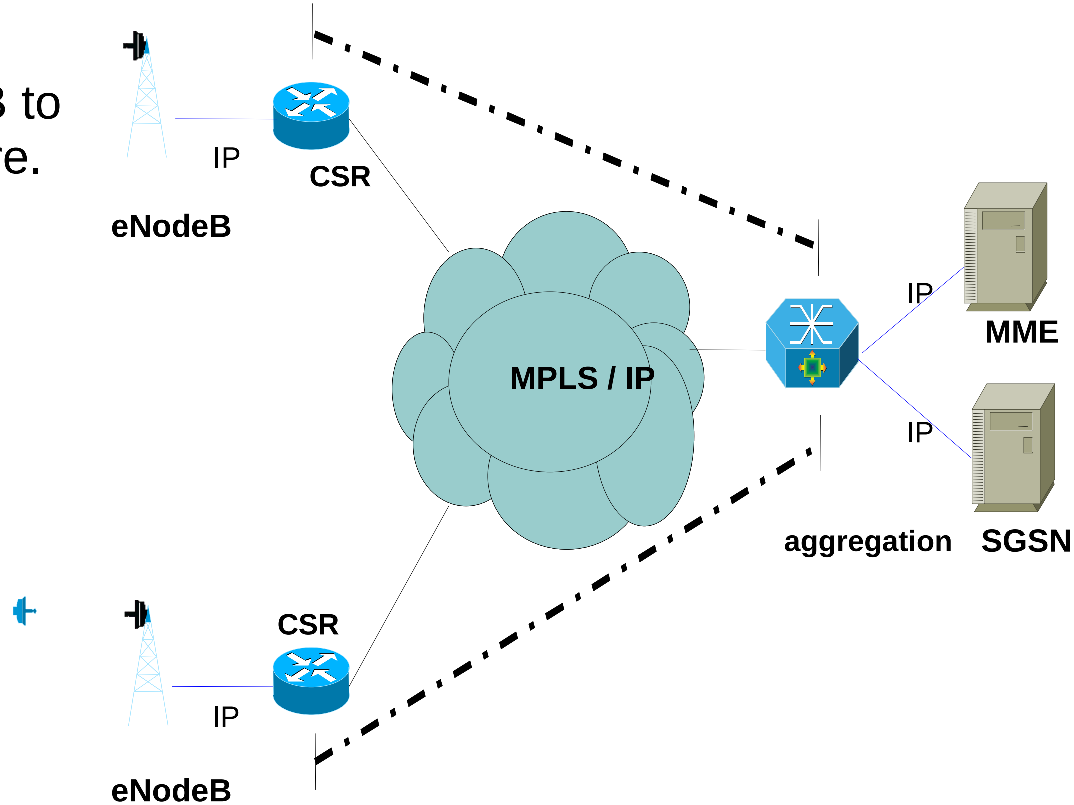
- IMA terminated on Cell-site router.
- ATM psuedowire between cell-site and aggregation router.
- Aggregation router can map VCs from psuedowire to ATM OC3 Clear Channel towards RNC.

- ATM VC mode allows VPI and VCI rewrite.
- ATM VP mode allows VPI rewrite.

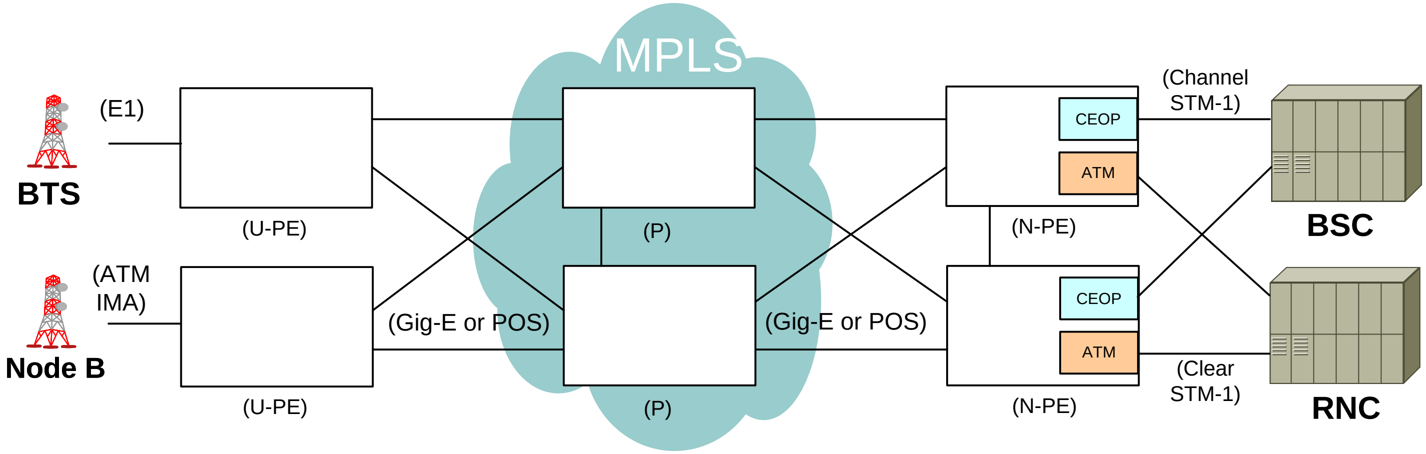


Native IP Over MPLS

- Pure IP routing from eNode-B to MME/SGSN in the mobile core.
- Utilize MPLS/IP core
  - Leased Eth or Own-built
- Efficient to operate, avoids routing in the entire core



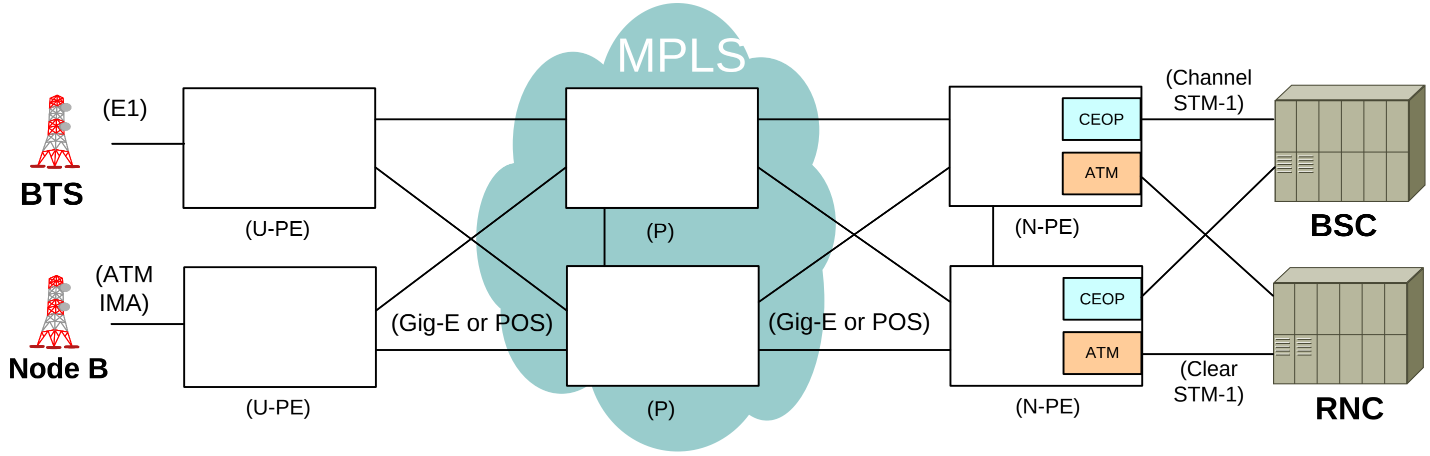
Redundancy @ Box-Level



- Cell-site router redundancy
  - Redundant Power Supply
- Aggregation router redundancy
  - Redundant Power Supply
  - Redundant Supervisor

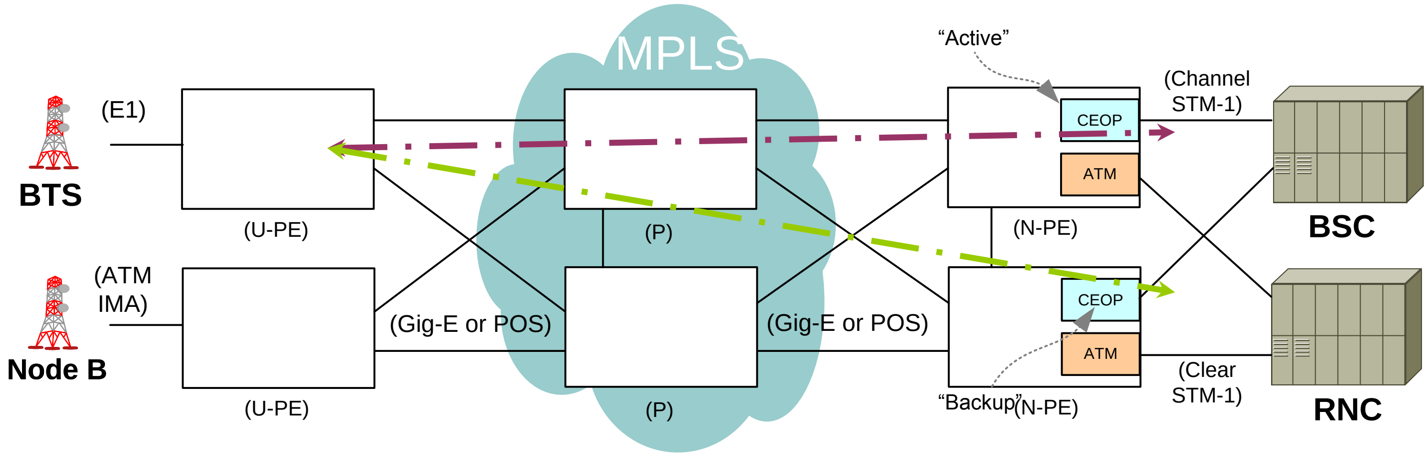
    Non-Stop Forwarding (NSF/SSO)
  - Redundant line-cards
  - Redundant aggregation device (optional)

Redundancy @ Link-Level



- Cell-site router redundancy
  - Multiple links to BTS / Node-B
    - T1 (TDM or IMA)
    - Eth
  - Multiple links to MPLS Core
    - Load-balanced
- Aggregation router redundancy
  - Multiple links to BSC / RNC
    - Sonet (APS)
    - Eth (STP / Routing)
  - Multiple links to MPLS Core
    - Load-balanced

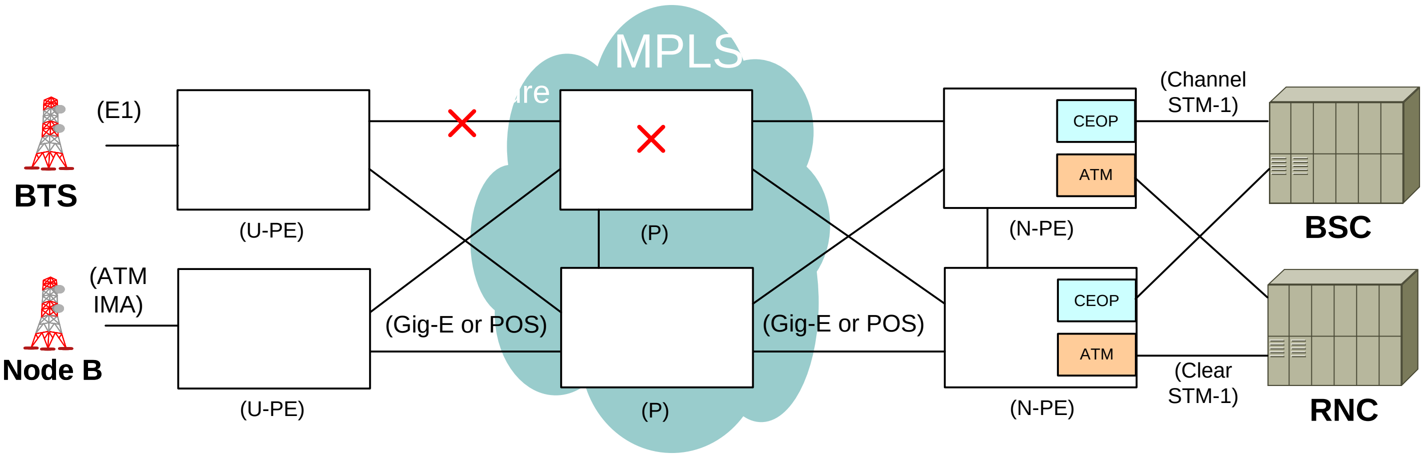
Redundancy @ PW-Level



Example setup:

- RNC and BSC are using MR-APS (traditional)
- "Primary PWE3" from NodeB (ATM) and BTS (TDM)
- "Backup PWE3" from NodeB (ATM) and BTS (TDM)
- Force APS failover on RNC and BSC, MR-APS on Aggregation router

Redundancy in MPLS Core



MPLS Core:

- TE Fast Re-Route (FRR) – Link and Node
- Tunnel selection
- Well proven mechanisms
- Leased or Built

Why QoS?

- Latency – time taken for a packet to reach its destination
- Jitter – change in inter-packet latency within a stream over time i.e. variation of latency
- Packet loss – measure of packet loss between a source and destination

- QoS provides:
  - Congestion Avoidance
  - Congestion Management
- Prioritize critical traffic over best-effort
  - Signaling and Clocking <-> Voice <-> Real-time <-> Data

Factors Affecting End-to-End Latency

- Packetization delay – segment, sample, process data and convert to packets
- Serialization delay – time taken to place bits of the packet on to the physical media
- Processing delay – time taken to accept packet, place it on the input queue, decide output interface, place it in the output queue
- Propagation delay – time taken to transmit the bits across the physical media
- Queuing delay – how long the packet stays in the output queue before being sent out

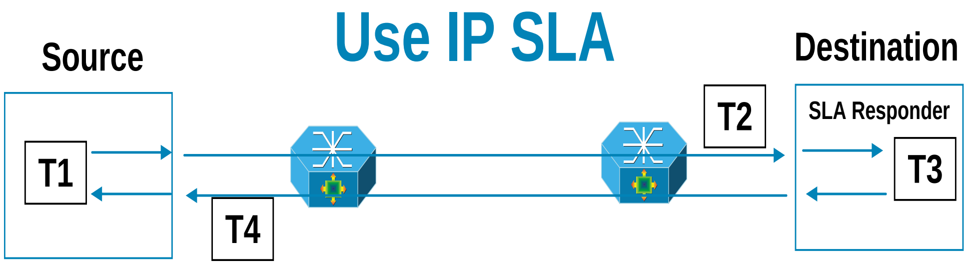
Fixed Delays

Variable Delays

QoS addresses Queuing delay
TE addresses propagation delay

Proactive Approach – Measure Performance

- Run IP SLA between the cell-site and Aggregation routers
- Collect Latency, Jitter and Packet Loss

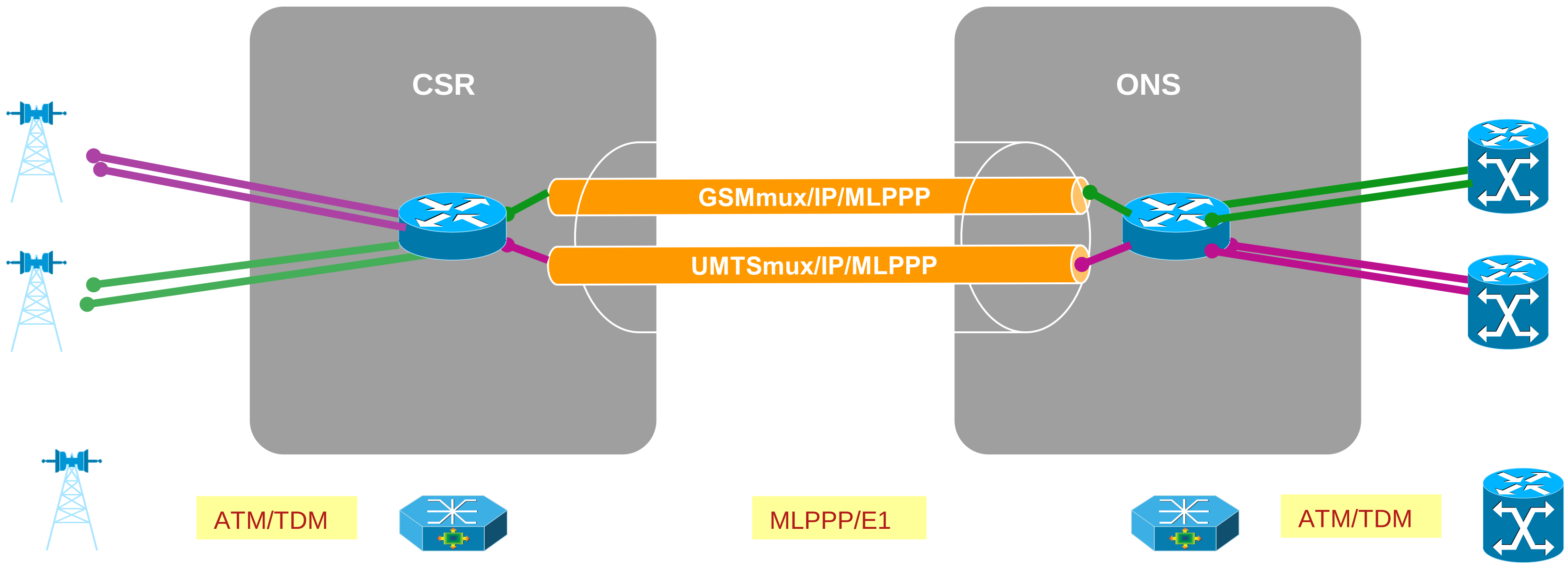


Security

- Service Provider Best practices for box-level security:
  - Lock-down VTYs, telnet
  - Disable unused services
  - Multiple bad password attempts
- Protection from cell-site router hijack
  - ACLs on aggregation router
  - Control Plane Policing on aggregation router
- Eavesdropping
  - 3GPP has recommended using IPSEC security for signaling

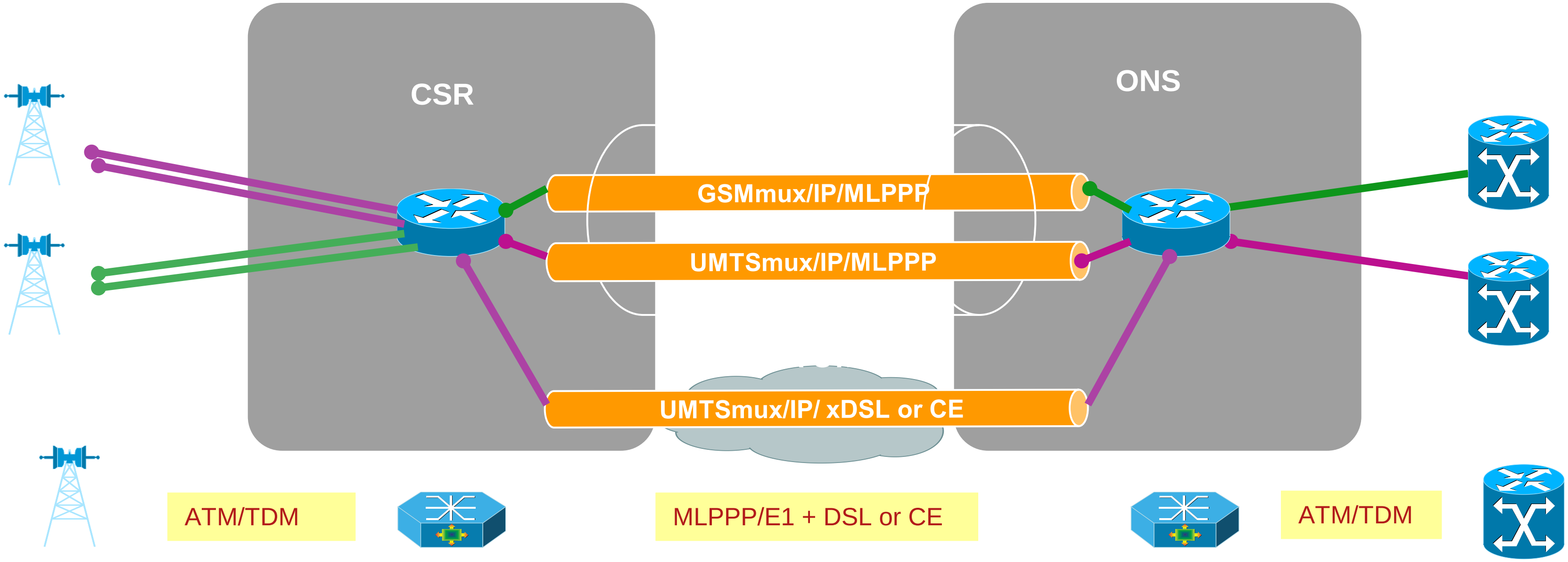
Deployment Scenarios

Deployment Scenario – 1



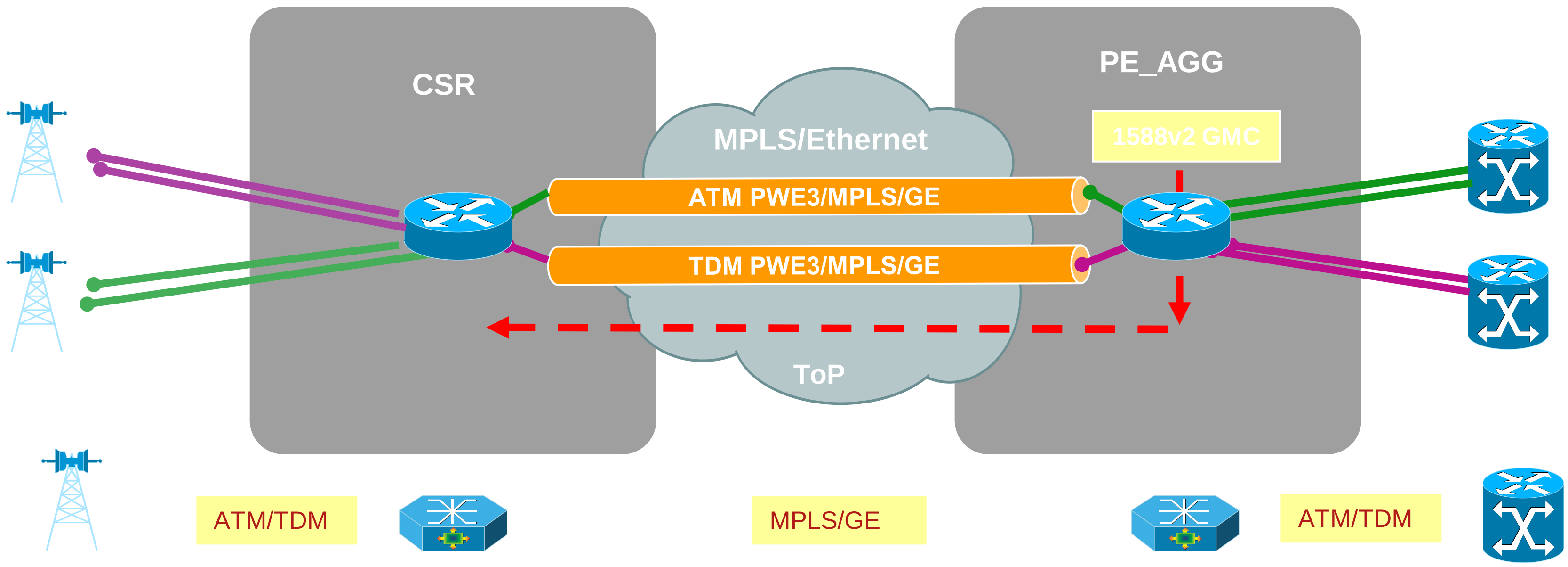
- CSRin a RAN Optimization deployment scenario
- Optimized PW (GSMmux or UMTSmux) & MLPPP

Deployment Scenario – 2



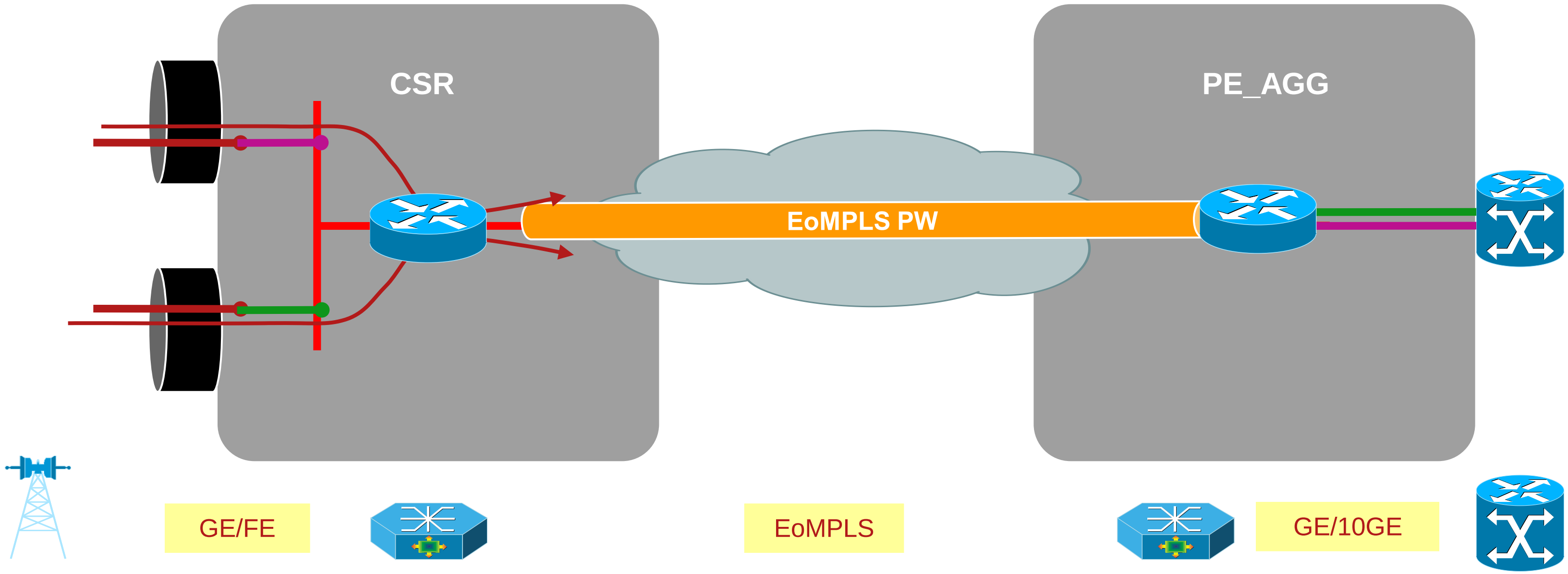
- HSDPA Offload to DSL or CE
- Optimized PW (GSMmux and UMTSmux) & MLPPP

Deployment Scenario – 3



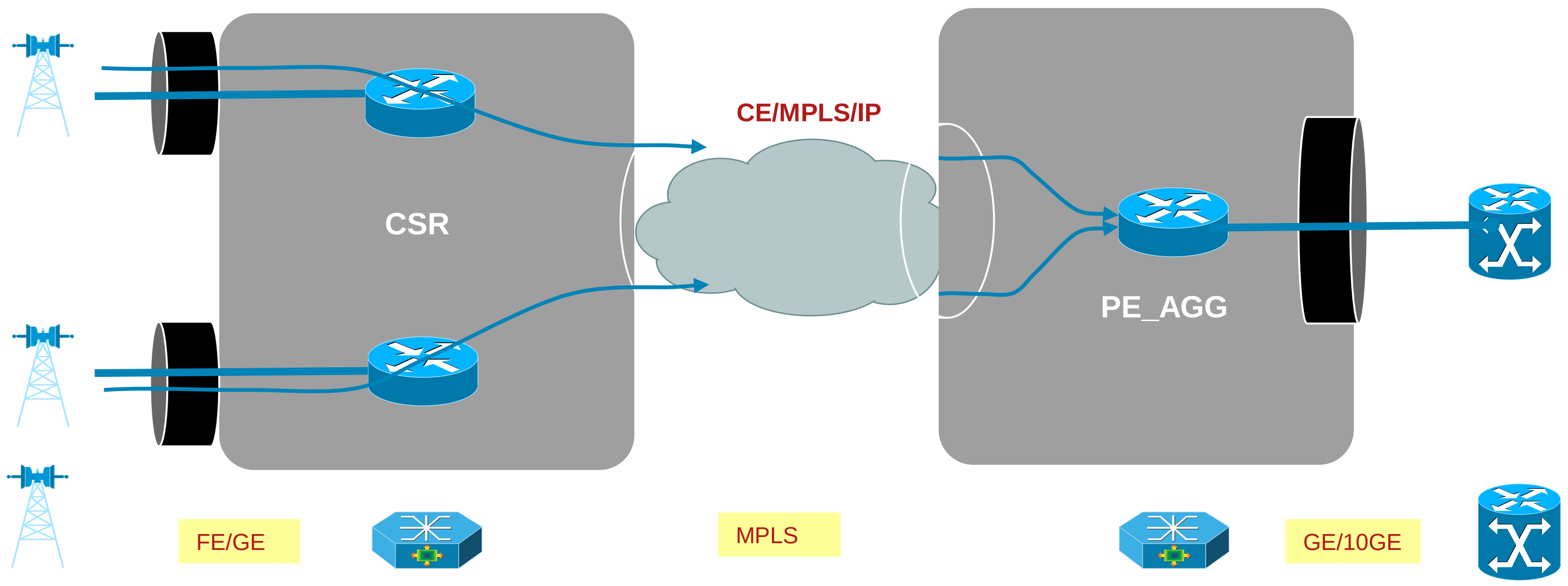
- CSR in a PWE3/MPLS deployment scenario
- Standard PW (TDM and ATM PWE3) & MPLS
- CSR recovers clock from 1588v2 or ACR ToP

Deployment Scenario – 4



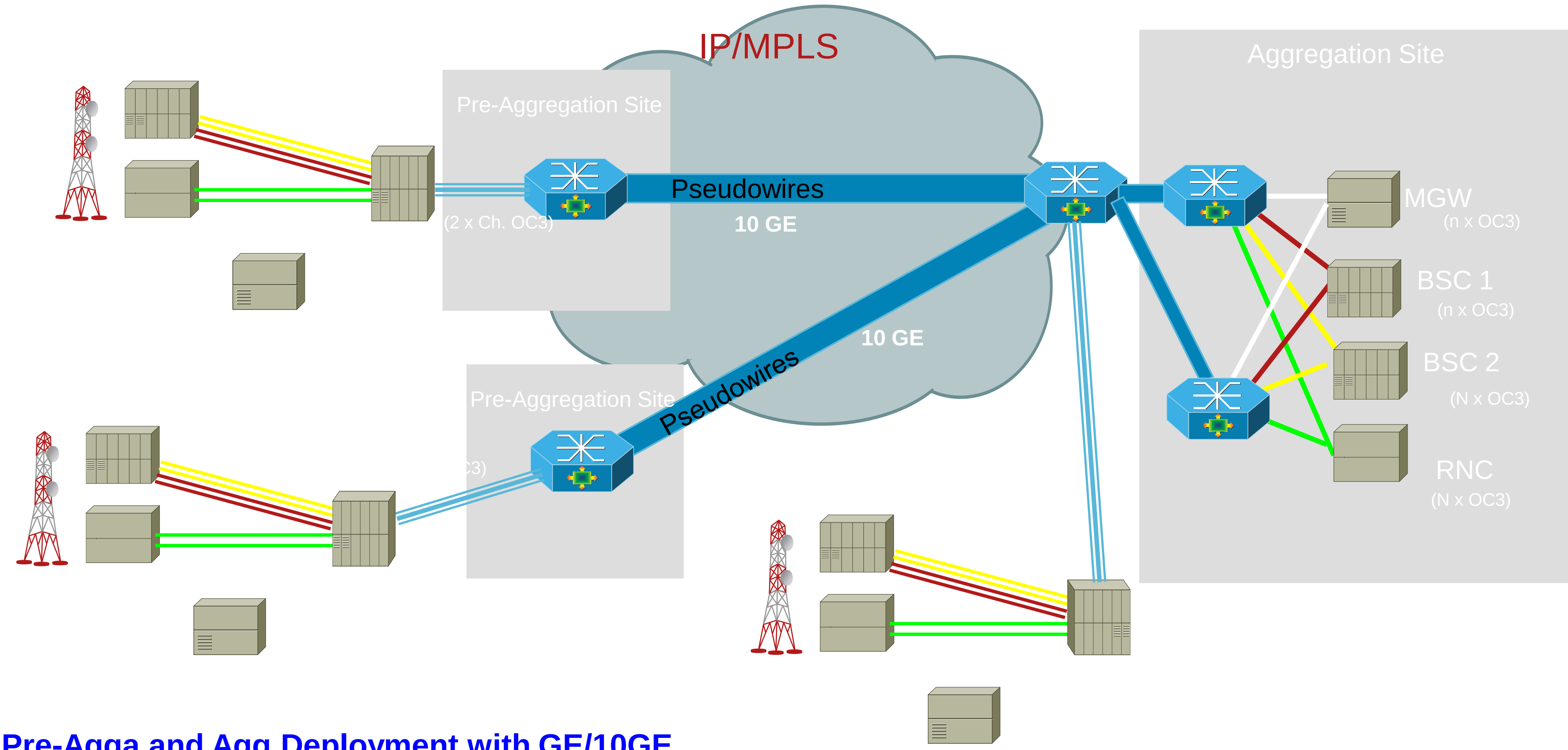
- Ethernet Node B & End to End L2 Transport
- EoMPLS Pseudowire & EOAM features

Deployment Scenario – 5



- Ethernet Node B & End to End L3 Transport
- Fast Convergence IGP & BFD

Deployment Scenario -6



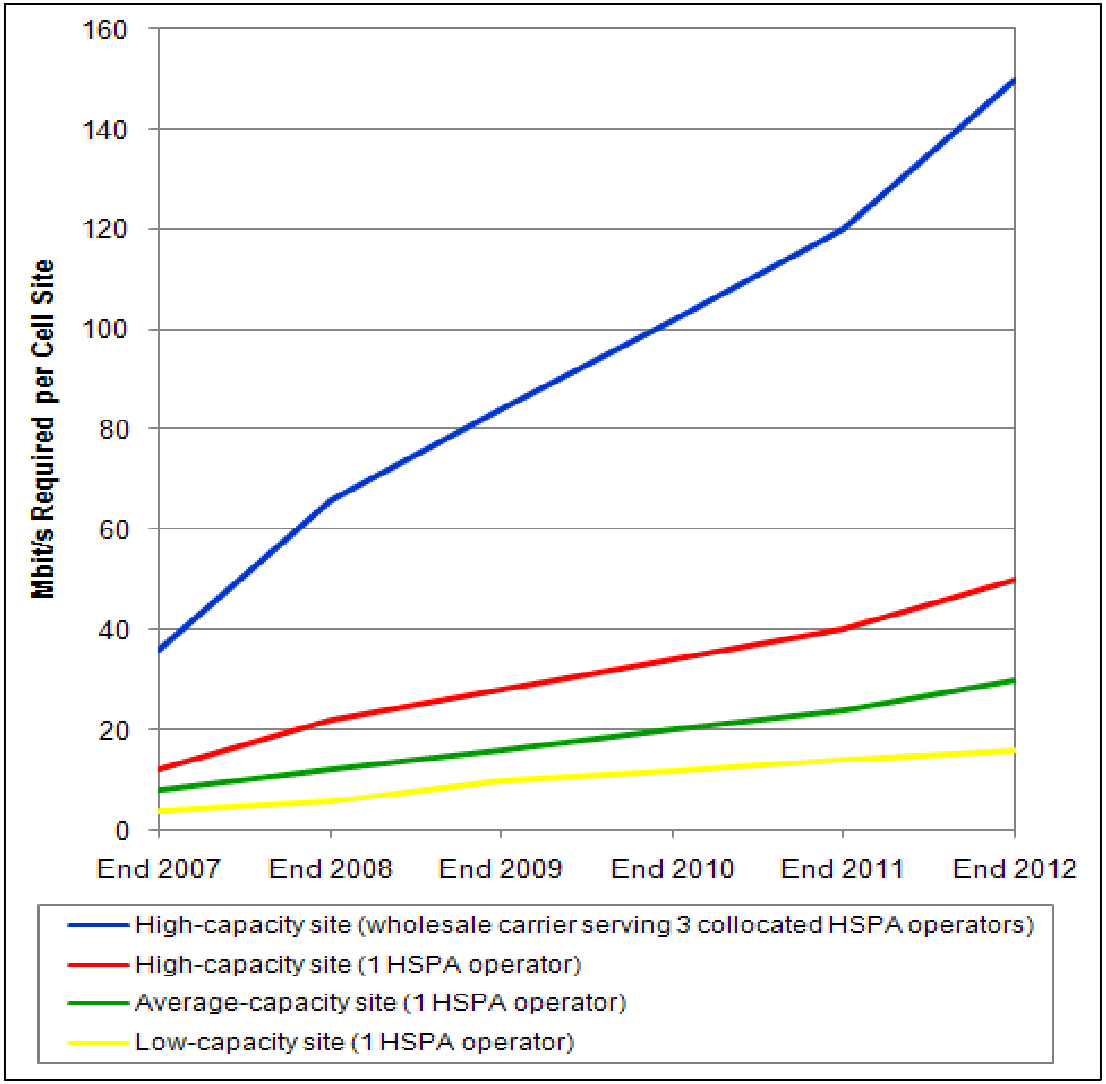
Pre-Agga and Agg Deployment with GE/10GE

Ready for ATM Backhaul

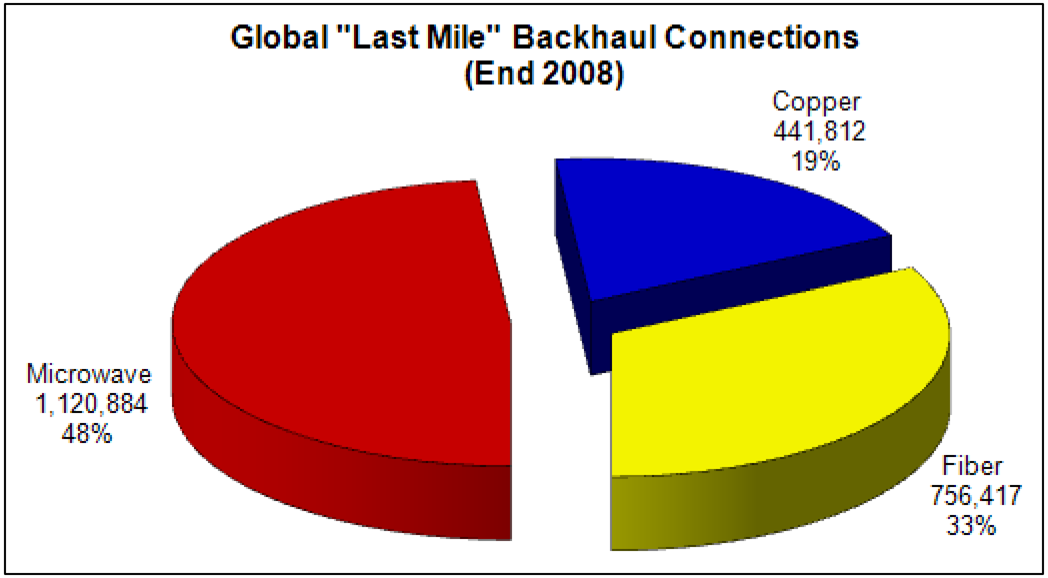
TDM Rooming and High Availability

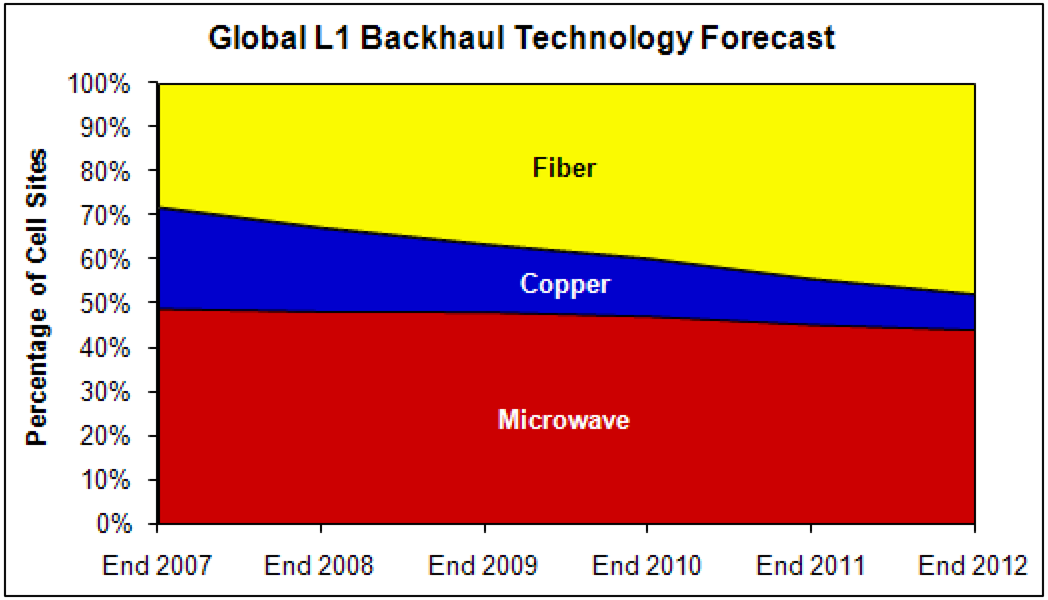
Mobile Backhaul Survey

Backhaul Capacity Requirements at the Cell Site

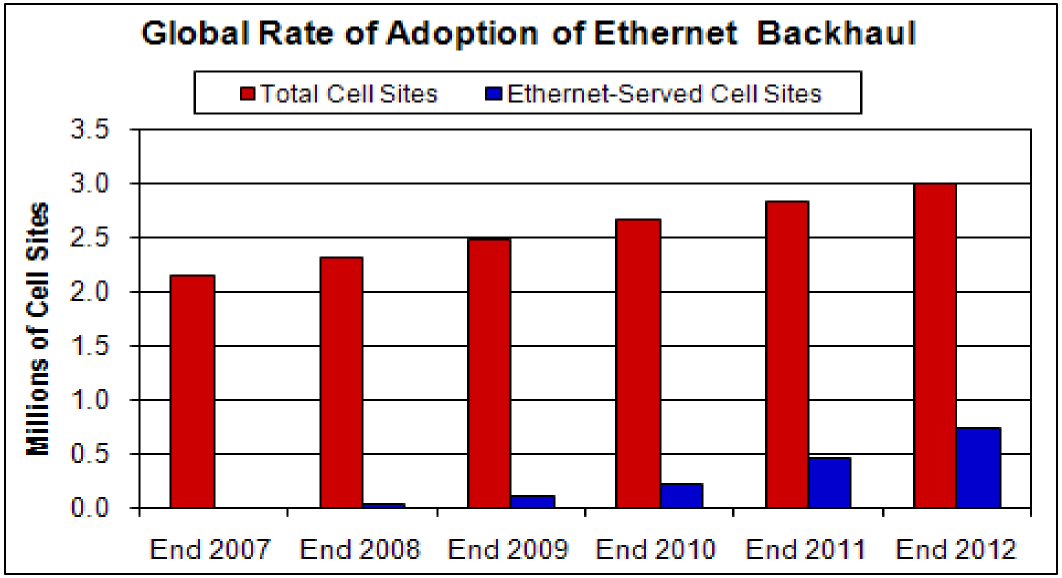


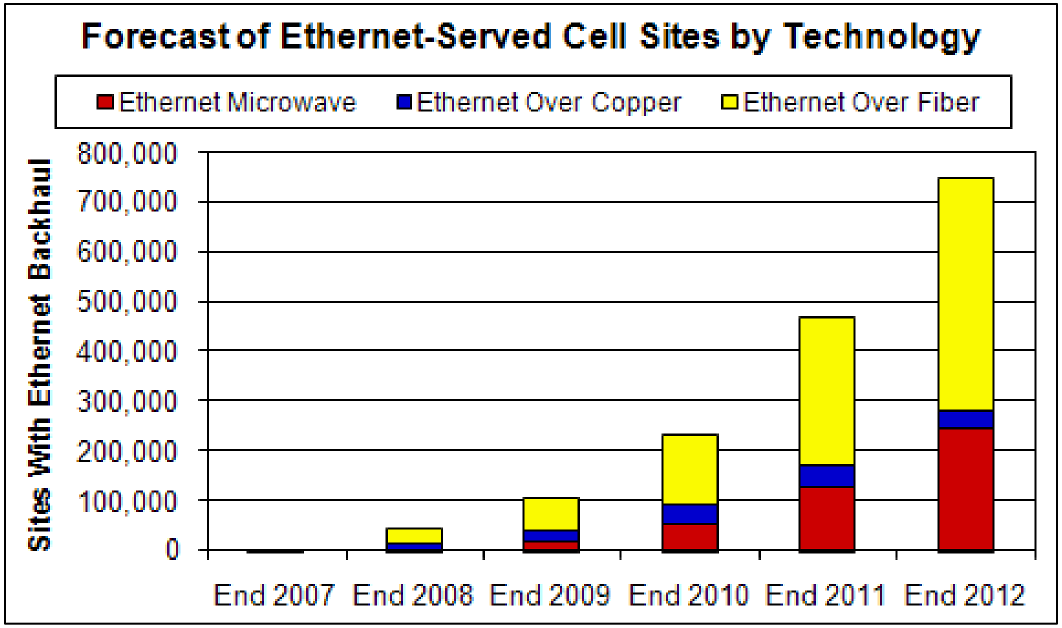
L1 Access Technologies: Global Estimate And Forecast



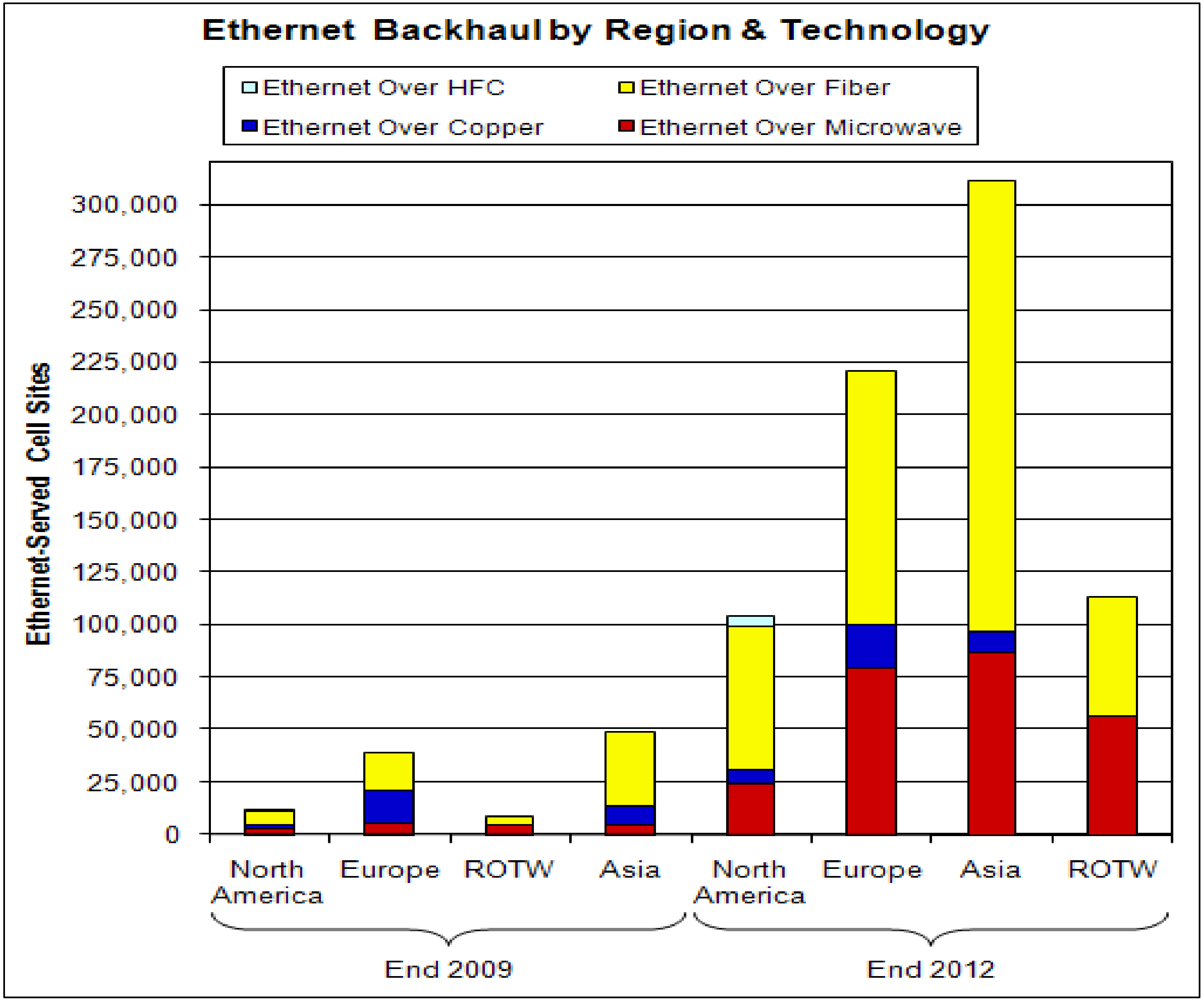


Global Demand for Ethernet Backhaul to the Cell Site

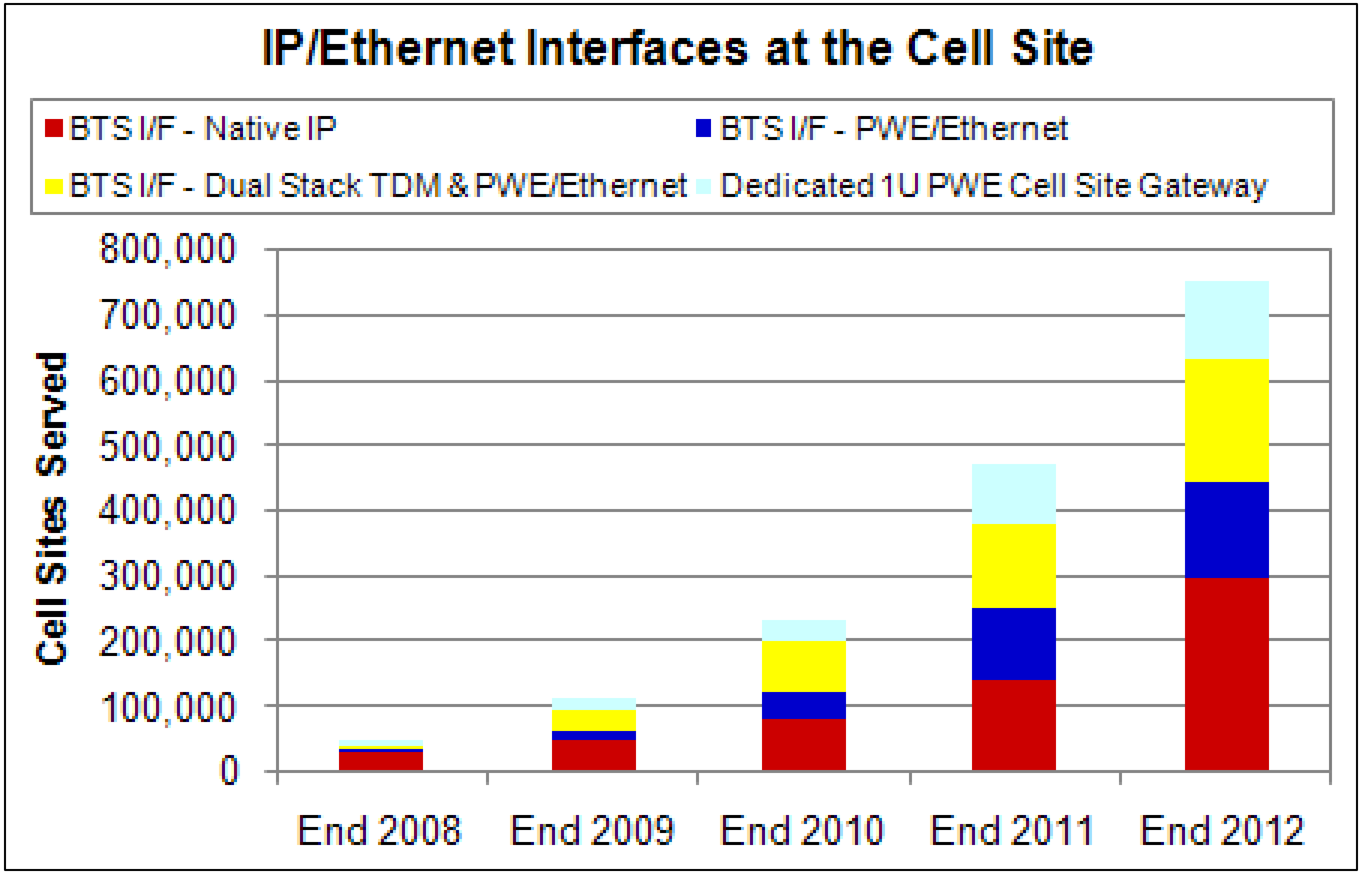




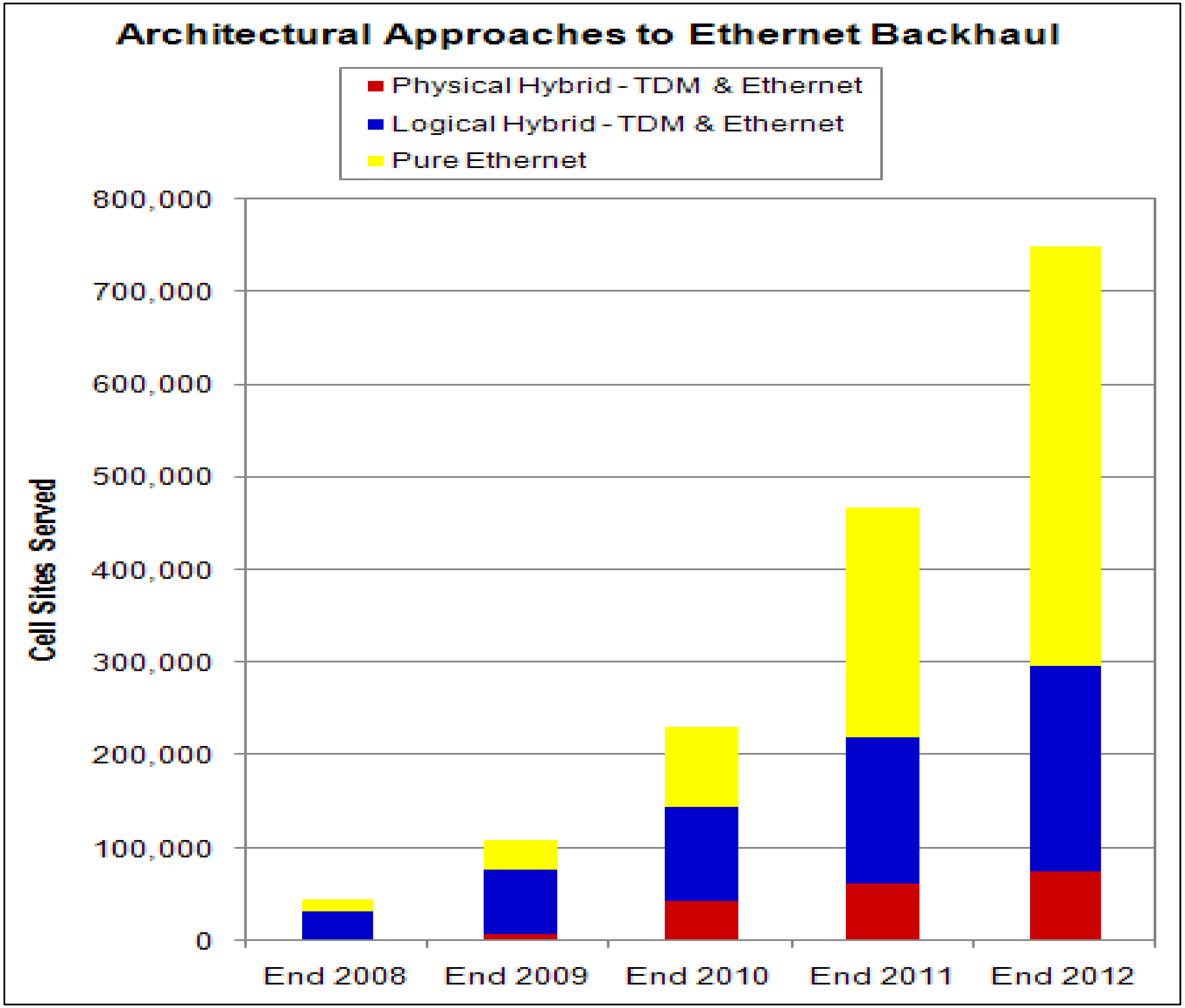
Regional Demand



IP/Ethernet Interfaces At The Cell Site



"Hybrid" & "Pure" Ethernet Backhaul Architecture choices



Overall Design Procedure

- Calculate bandwidth requirements for the cell-site and aggregation location
- Choose the right “packet based RAN option / design”
- MPLS Core – Leased or Built, customer dependant
- Choose appropriate redundancy and connectivity between:
  - Cell-site router and Node-B / BTS
  - Aggregation router and RNC / BSC
- Routing protocol between aggregation and cell-site routers
- Ensure clocking / clock recovery at every node
- Ensure resiliency for every failure type – link and node
- Apply QoS and Security