MEF

Introducing the Specifications of the MEF

MEF 22.2: Mobile Backhaul Phase 3 Implementation Agreement

February 2017

MEF Reference Presentations

- **Intention**
  - These MEF reference presentations are intended to give general overviews of the MEF work and have been approved by the MEF Marketing Committee
  - Further details on the topic are to be found in related specifications, technical overviews, white papers in the MEF public site Information Center: http://www.mef.net/carrier-ethernet/technical-specifications

Outline

- **Approved MEF Specifications**
- **Implementation Guide Overview**
- **About MEF 22.2**
  - Overview, Concepts & Terminology
  - Use Cases
  - Service & Service Management
  - Resiliency
  - Frequency Synchronization
  - Multi Class of Service
  - Bandwidth Sharing
  - Multi-CEN
- **Summary**
- **Appendix**
  - LTE background
  - Small cells background
  - Migration from TDM

Approved MEF Specifications*

Specification	Description
MEF 2	Requirements and Framework for Ethernet Service Protection
MEF 3	Circuit Emulation Service Definitions, Framework and Requirements in Metro Ethernet Networks
MEF 4	Metro Ethernet Network Architecture Framework Part 1: Generic Framework
MEF 6.2	EVC Ethernet Services Definitions Phase 3
MEF 7.2	Carrier Ethernet Information Model
MEF 8	Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks
MEF 9	Abstract Test Suite for Ethernet Services at the UNI
MEF 10.3	Ethernet Services Attributes Phase 3
MEF 11	User Network Interface (UNI) Requirements and Framework
MEF 12.2	Carrier Ethernet Network Architecture Framework Part 2: Ethernet Services Layer
MEF 13	User Network Interface (UNI) Type 1 Implementation Agreement
MEF 14	Abstract Test Suite for Traffic Management Phase 1
MEF 15	Requirements for Management of Metro Ethernet Phase 1 Network Elements
MEF 16	Ethernet Local Management Interface
MEF 17	Service OAM Framework and Requirements

***Current at time of publication. See MEF web site for official current list, minor updates and superseded work (such as MEF 1 and MEF 5)**

Approved MEF Specifications

Specification	Description
MEF 18	Abstract Test Suite for Circuit Emulation Services
MEF 19	Abstract Test Suite for UNI Type 1
MEF 20	User Network Interface (UNI) Type 2 Implementation Agreement
MEF 21	Abstract Test Suite for UNI Type 2 Part 1: Link OAM
MEF 22.2	**Mobile Backhaul Phase 3 Implementation Agreement**
MEF 23.2	Class of Service Implementation Agreement Phase 3
MEF 24	Abstract Test Suite for UNI Type 2 Part 2: E-LMI
MEF 25	Abstract Test Suite for UNI Type 2 Part 3: Service OAM
MEF 26.2	External Network Network Interface (ENNI) and Operator Service Attributes
MEF 27	Abstract Test Suite For UNI Type 2 Part 5: Enhanced UNI Attributes & Part 6: L2CP Handling
MEF 28	External Network Network Interface (ENNI) Support for UNI Tunnel Access and Virtual UNI
MEF 29	Ethernet Services Constructs
MEF 30.1	Service OAM Fault Management Implementation Agreement Phase 2
MEF 31	Service OAM Fault Management Definition of Managed Objects

Approved MEF Specifications

Specification	Description
MEF 32	Requirements for Service Protection Across External Interfaces
MEF 33	Ethernet Access Services Definition
MEF 34	Abstract Test Suite for Ethernet Access Services
MEF 35.1	Service OAM Performance Monitoring Implementation Agreement
MEF 36.1	Service OAM SNMP MIB for Performance Monitoring
MEF 37	Abstract Test Suite for ENNI
MEF 38	Service OAM Fault Management YANG Modules Technical Specification
MEF 39	Service OAM Performance Monitoring YANG Modules Technical Specification
MEF 40	UNI and EVC Definition of Managed Objects Technical Specification
MEF 41	Generic Token Bucket Algorithm Technical Specification
MEF 42	ENNI and OVC Definition of Managed Objects Technical Specification
MEF 43	Virtual NID (vNID) Functionality for E-Access Services Technical Specification
MEF 44	Virtual NID (vNID) Definition of Managed Objects Technical Specification
MEF 45	Multi-CEN L2CP Technical Specification
MEF 46	Latching Loopback Protocol and Functionality Technical Specification

Approved MEF Specifications

Specification	Description
MEF 47	Carrier Ethernet Services for Cloud Implementation Agreement
MEF 48	Service Activation Testing Technical Specification
MEF 49	Service Activation Testing Control Protocol and PDU Formats Technical Specification
MEF 50	Carrier Ethernet Service Lifecycle Process Model Guidelines
MEF 51	OVC Services Definitions Technical Specification
MEF 52	Carrier Ethernet Performance Reporting Framework
MEF 53	Carrier Ethernet Services Qualification Questionnaire
MEF 54	Ethernet Interconnection Point (EIP): An ENNI Implementation Agreement
MEF 55	Lifecycle Service Orchestration (LSO): Reference Architecture and Framework

MEF 22.2 Implementation Agreement Overview

MEF 22.2: Mobile Backhaul Phase 3 Implementation Agreement	
Purpose	This presentation is an introduction to MEF 22.2
Audience	• Equipment manufacturers building devices that will carry mobile backhaul traffic over Carrier Ethernet • Useful for mobile backhaul service providers architecting their systems for Carrier Ethernet • For wire-line service providers architecting their systems for the inclusion of mobile backhaul traffic over Carrier Ethernet

Overview of MEF 22.2

Mobile Backhaul Phase 3 Implementation Agreement

MEF 22.2 and Relationship to Other SDOs

Other SDOs

TR.221

International Telecommunication Union

3GPP A GLOBAL INITIATIVE

SMALL CELL FORUM
HOME | ENTERPRISE | URBAN | RURAL

ngmn the engine of broadband wireless innovation

MEF 6.2

MEF 10.3

MEF 13

MEF 23.2

MEFs own work as the foundation

MEF 22.2

MEF
Implementation Agreement
MEF 22.2
Mobile Backhaul Phase 3
January 2016

Industry trends

TDM to Packet

3G to 4G/LTE

Virtualization/5G

Standardized reference points

Service Requirements (Service Types, CoS, Eth OAM, etc)

Synchronization Recommendations

MEF 22.2 Features

- Support all mobile generations over Carrier Ethernet
- Migration strategy for 2G and 3G
- A blueprint for implementing synchronization delivery
- “Tool Box” for Service OAM, Resiliency and Protection
- Multi CoS and Bandwidth Sharing for mobile traffic
- Lower latency X2 for Small Cells’ interference cancellation

MEF 22 Scope Comparison

	PHASE 1	PHASE 2	PHASE 3
UNI	✓	✓	✓
Service Types	✓	✓	✓
Link OAM	✓	✓	✓
Service OAM FM	✓	✓	✓
Service OAM PM		✓	✓
CoS	✓	✓	✓
Performance		✓	✓
Packet based sync	✓	✓	✓
SyncE		✓	✓
Resiliency Performance		✓	✓
OVC & multi-operator			✓
Token sharing			✓

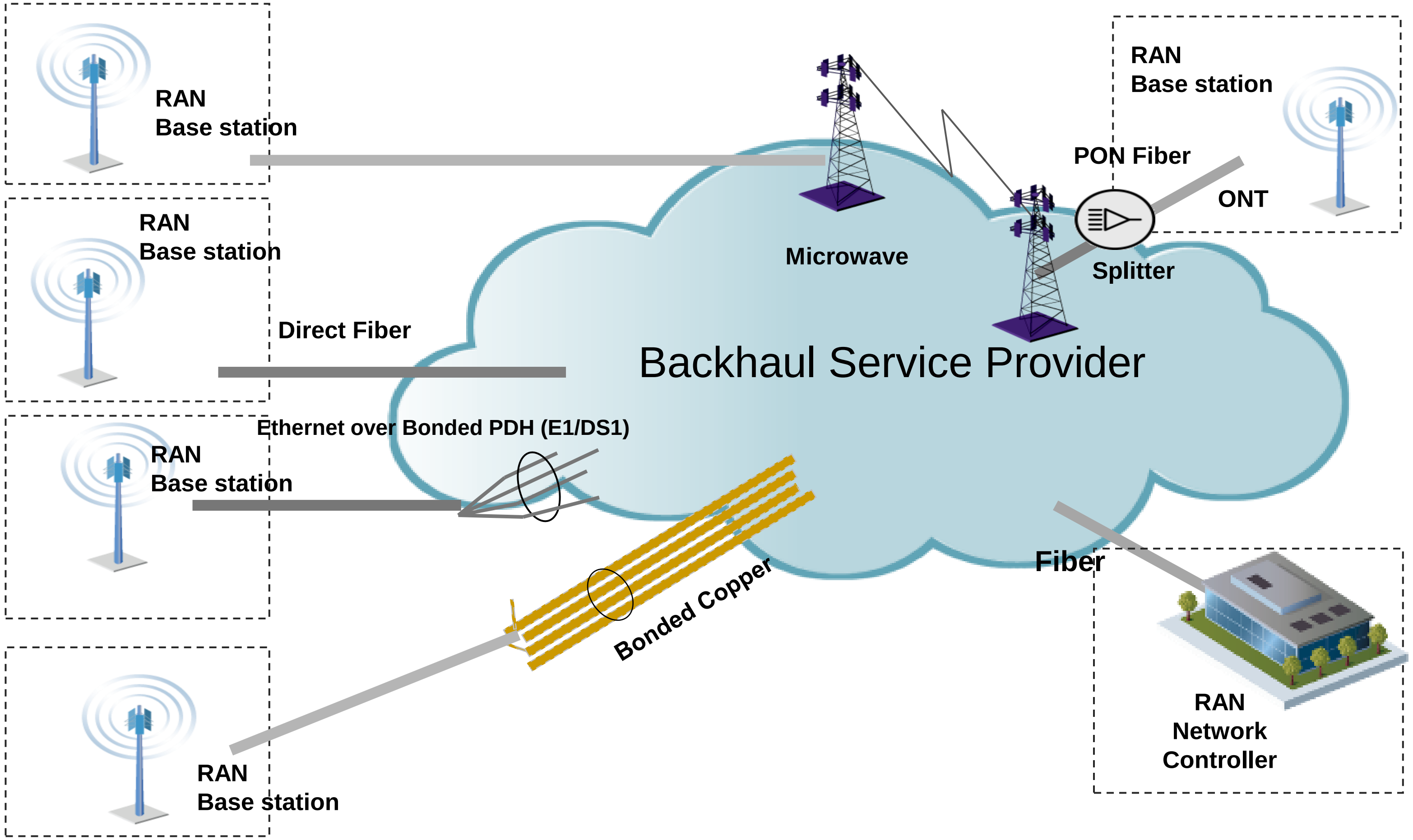
Introduction to the Revision

- The MEF 22.2 revision makes the following changes to MEF 22.1:
  1. Incorporation of MEF 22.1.1 Small Cells amendment, which included:
     a) Terminology of Backhaul, Midhaul and Fronthaul including Small Cells
     b) New use case 3 and use case variations, for the Midhaul case
     c) CoS Performance Objectives (CPOs) for small cells with tight radio coordination and split bearer
     d) Definition of the Aggregation Node
  2. Alignment with MEF 6.2 and MEF 10.3, which resulted in:
     a) addition or deletion of some User-Network Interface (UNI) and Ethernet Virtual Connection (EVC) attributes
     b) change in recommendation for Link Operations, Administration, and Maintenance (OAM) and Service OAM (SOAM)
     c) addition of token sharing, including guidance in Appendix
  3. Addition of multi-Carrier Ethernet Network (multi-CEN), which includes:
     a) Introduction of Ethernet Access (E-Access)
     b) Guidance on Operator Virtual Connection (OVC) use cases for Mobile Backhaul (MBH)

Carrier Ethernet and MBH Networks

Carrier Ethernet is transport technology agnostic

– being designed for delivery across all access transports

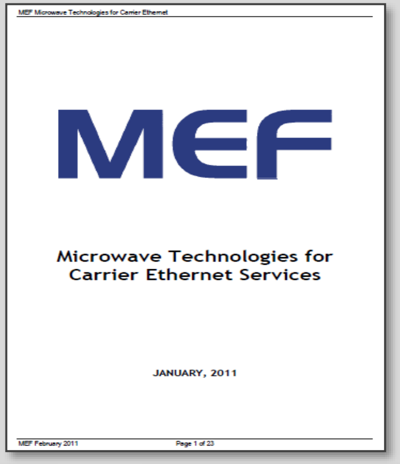


Educational Paper

Microwave Technologies For Carrier Ethernet Services

Published by MEF

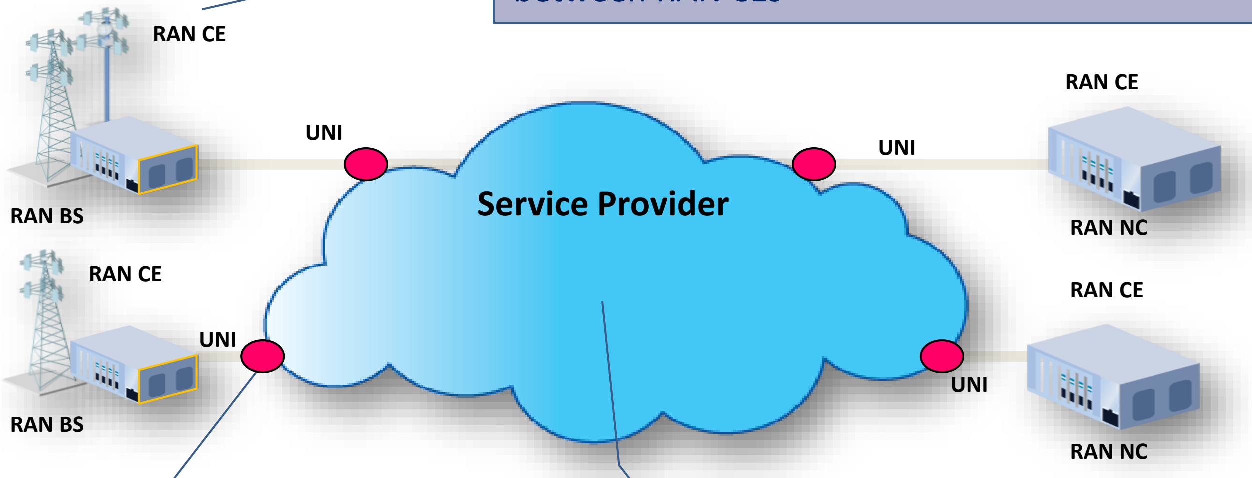
January 2011



Terminology and Concepts

Functional Elements as defined in MEF 22.2 Specification

Customer (Subscriber) is Mobile Operator & needs Mobile Backhaul between RAN CEs



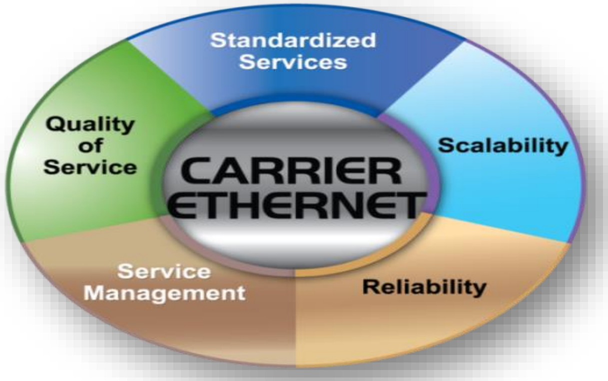
RAN	**Radio Access Network**
RAN BS	**RAN Base Station**
RAN NC	**RAN Network Controller**
RAN CE	**RAN Customer Edge –Mobile network node/site**
RNC	**Radio Network Controller**

Standard Demarcation

Service Provider (SP) offers Mobile Backhaul Service between demarcation points

Carrier Ethernet Mobile Backhaul Service

- Standard Demarcation
- Standard & Scalable Services with Quality of Service
- Service Management & Reliability



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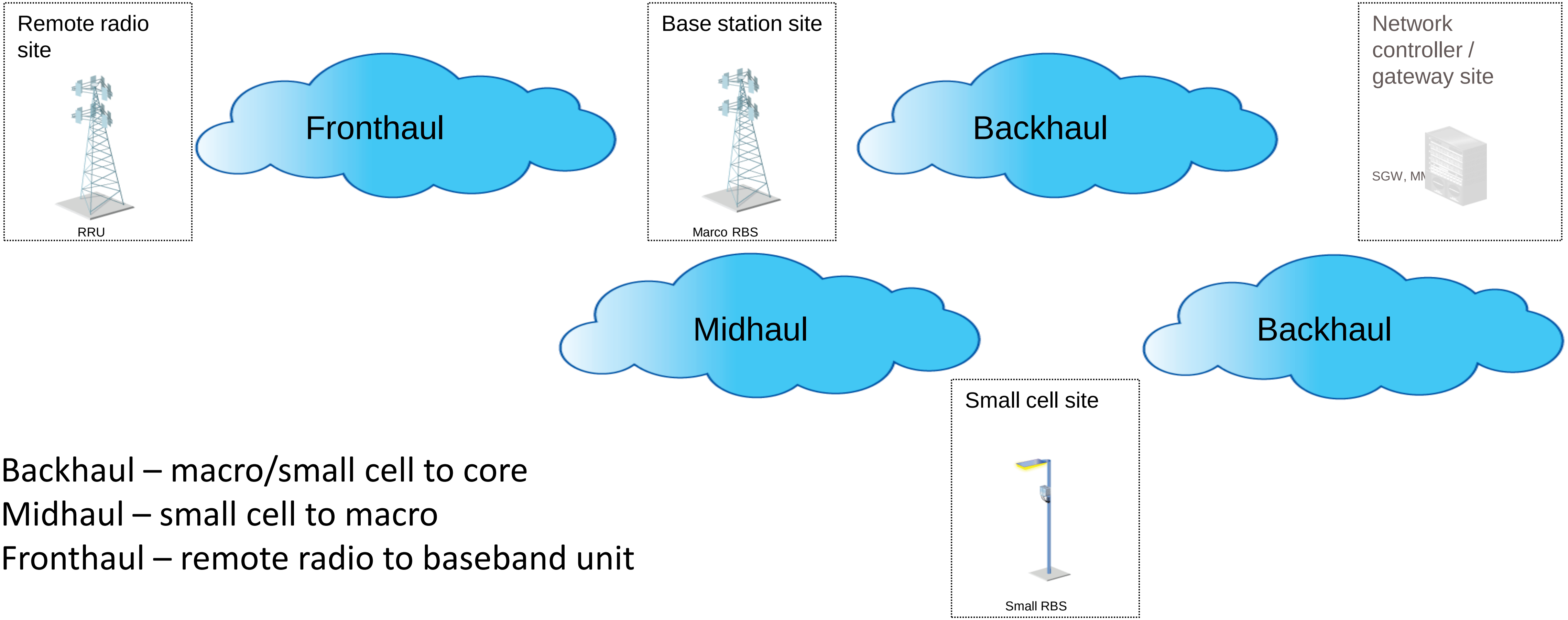
MEF 22.2 Terminology



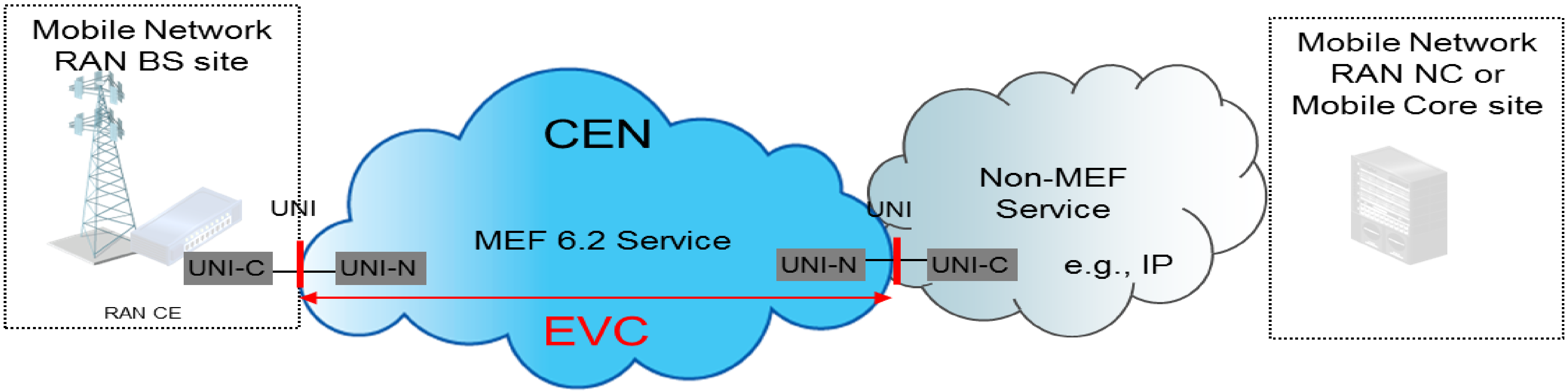
Backhaul – macro/small cell to core
Midhaul – small cell to macro
Fronthaul – remote radio to baseband unit

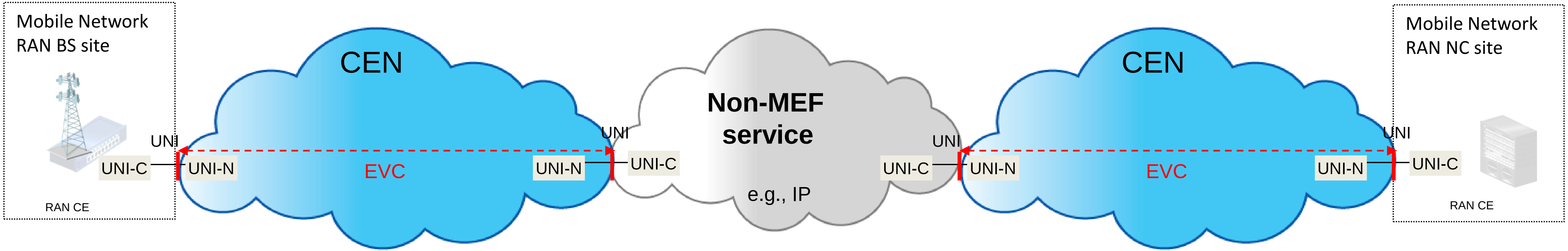
MEF 22.2 Use Cases

Mobile Backhaul Phase 3 Implementation Agreement

CEN and Non-CEN Hybrid

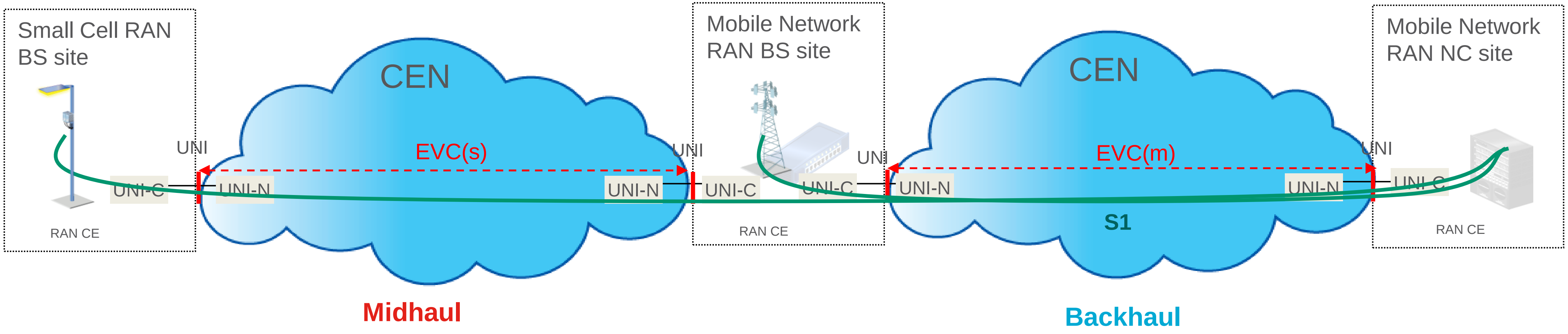
MEF MBH can be part of a multi-technology end-to-end backhaul



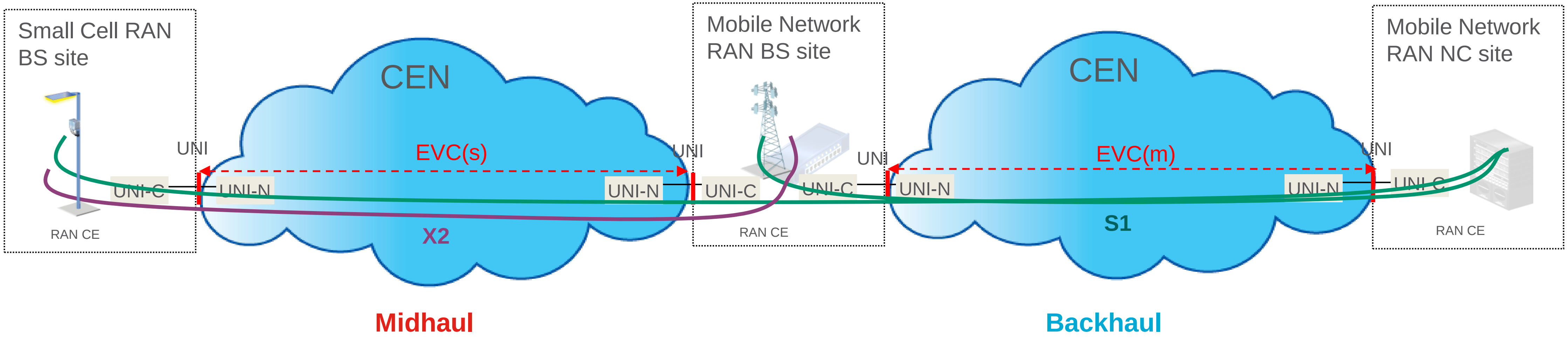


Backhaul with Small Cell Extension Use Cases

LTE S1 Backhaul:



LTE S1 & X2 Backhaul:



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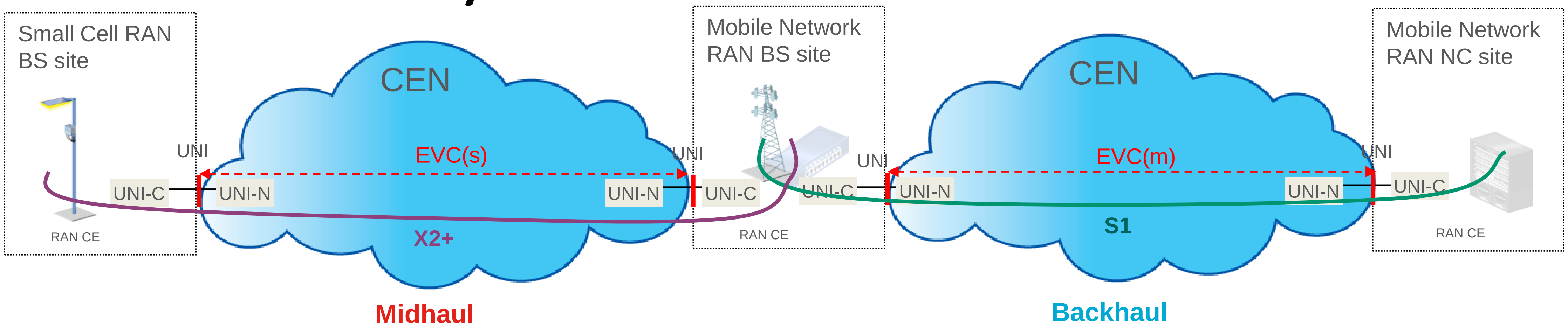
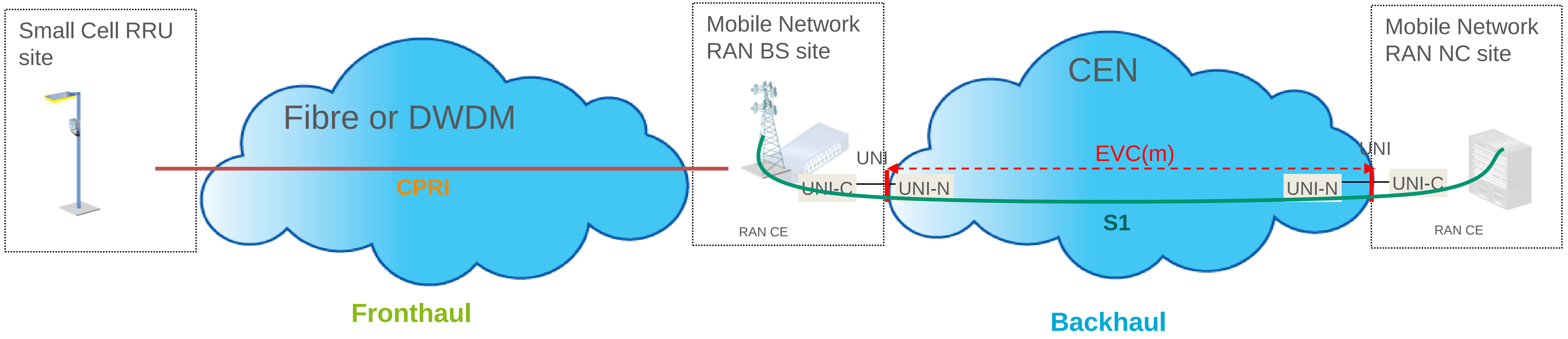
Backhaul with Small Cell Extension Use Cases (2)

LTE-A Dual Connectivity :



CPRI & Backhaul:



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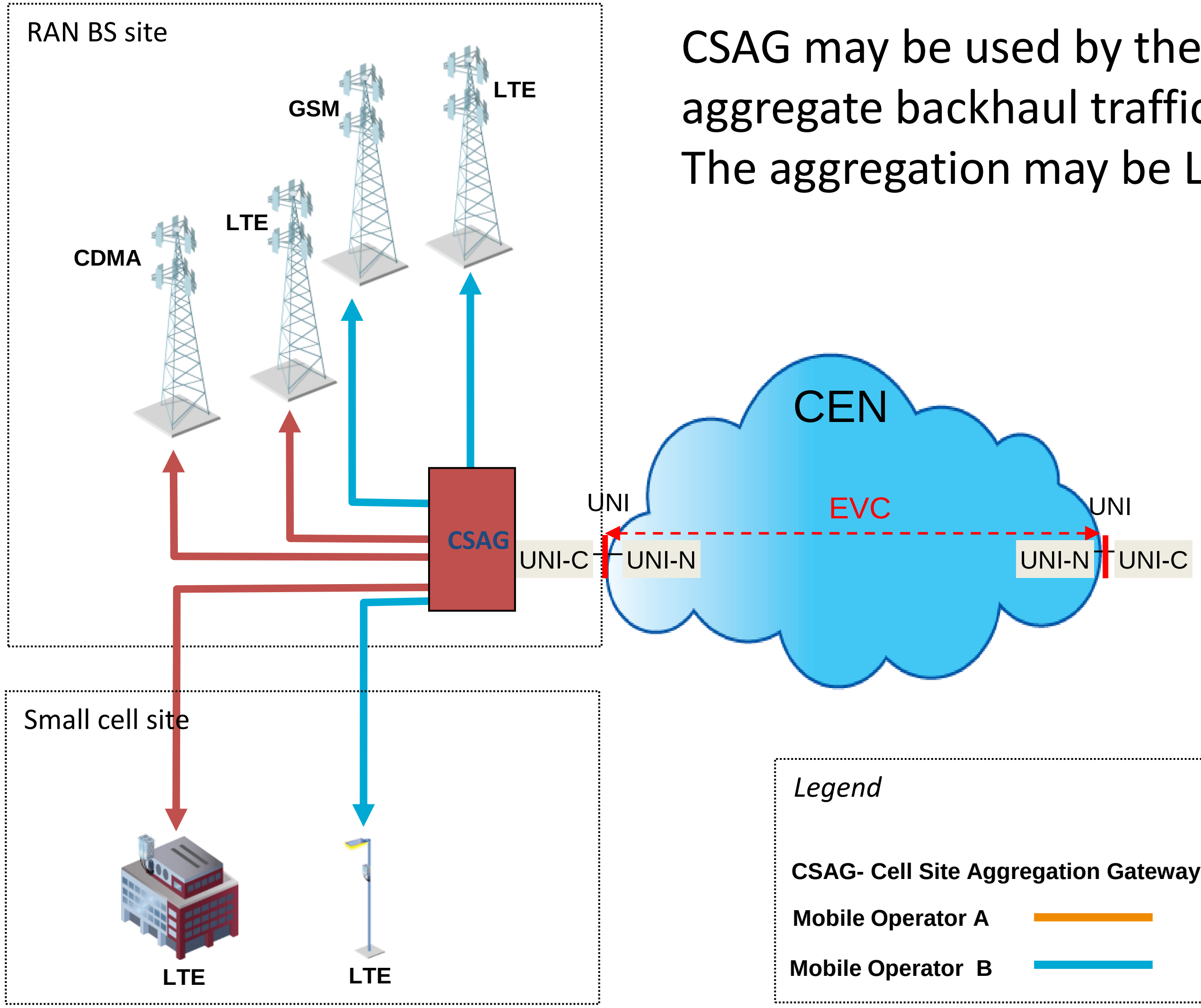
Generalized BS Aggregation



CSAG may be used by the mobile operator to aggregate backhaul traffic before the MEF UNI. The aggregation may be L2 or L3

Legend

CSAG- Cell Site Aggregation Gateway

Mobile Operator A

Mobile Operator B

Transport Requirements

- **Backhaul**
  - Macro – Core (eNB – EPC)
  - Packet based
- **Fronthaul**
  - Baseband – Radio Unit (Main-Remote)
  - Dedicated Fibre
- **Midhaul**
  - Macro – small cell (eNB-eNB)
  - Options
    - Same as backhaul
    - Support tight coordination
    - Support X2+

Latency ~20ms

Latency ~50us

Latency ~20ms

Latency ~1ms

Latency ~50ms

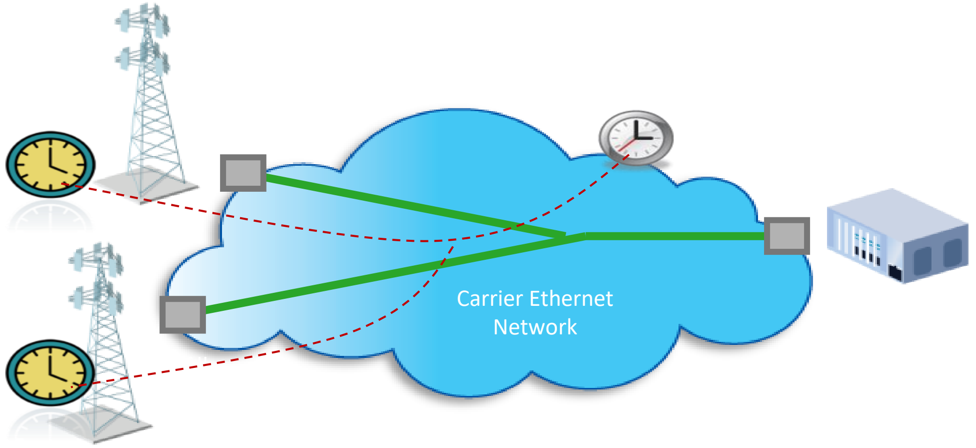
Note: Latency requirements are one way, and are supported with one way delay attributes

Service and Service Management

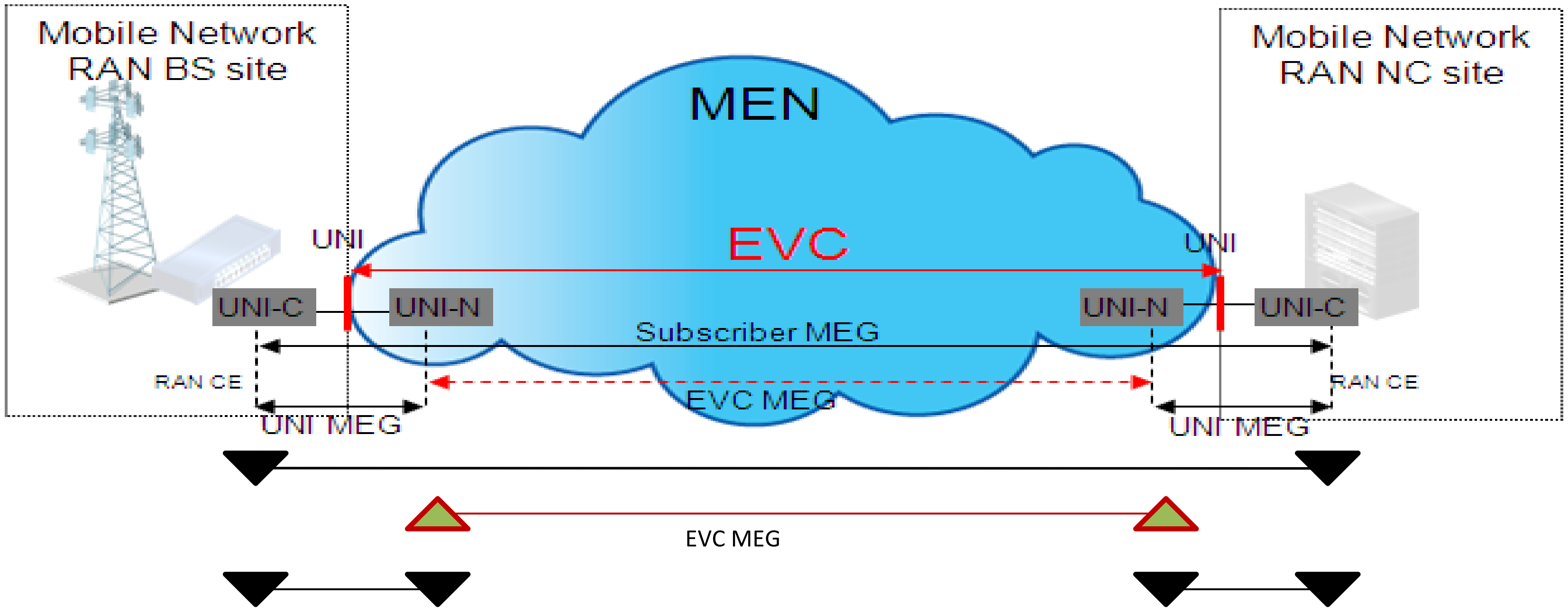
Mobile Backhaul Phase 3 Implementation Agreement

A Few Key Service Attributes

- **UNI Type (MEF 13 & 20)**
- **UNI Service Attributes (MEF 10.3, MEF 6.2)**
  - Mode: Asynchronous Full Duplex
  - >1 EVC & capability to support max # of EVCs
  - Bandwidth profiles per UNI
- **EVC per UNI Service Attributes (MEF 10.3, MEF 6.2)**
  - EVC Classification: CE-VLAN ID to EVC Map
  - Bandwidth profiles per EVC
- **EVC Service Attributes (MEF 10.3, MEF 6.2, MEF 23.2)**
  - EVC Type and UNI List with Type (Root or Leaf)
  - CE-VLAN and Class of Service (CoS) preservation
  - EVC Performance per CoS ID for one or more Classes of Service



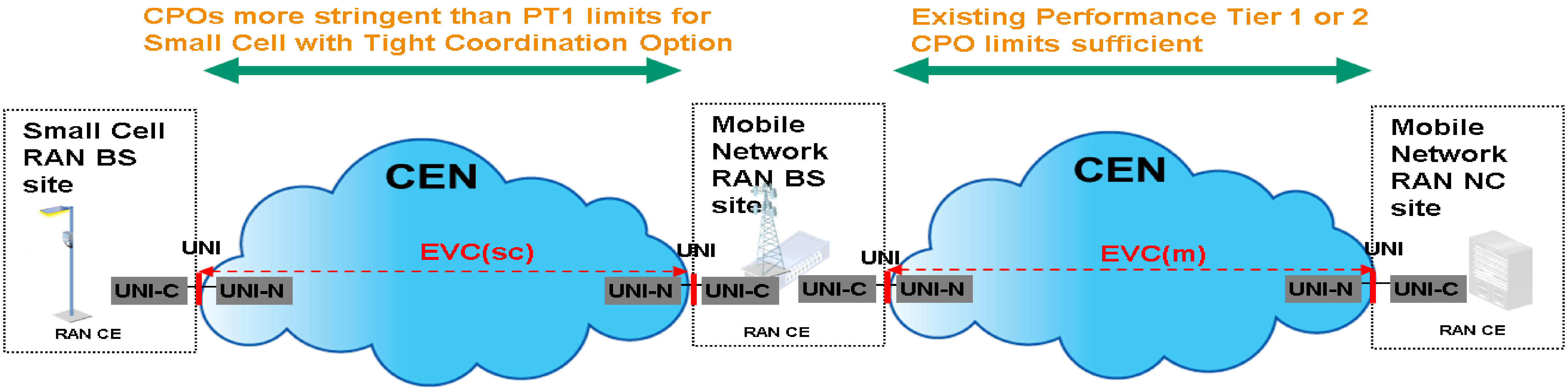
Service Management



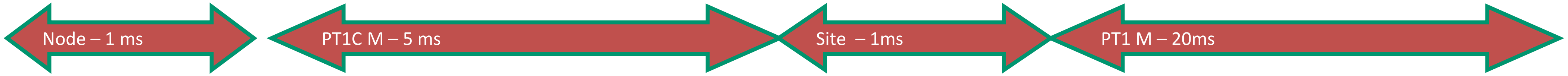
- **Subscriber MEG for Mobile Operator (as Customer/Subscriber)**
- **EVC MEG (or Operator MEG) for MEN Operator (as Service Provider)**
  - Fault and Performance Management to report EVC Performance
- **UNI MEG used to monitor MEF compliant UNI**
  - e.g.. RAN CE & MEN using UNI Type 2 with Service OAM capability

New CPO for Tight Coordination

Constrained PT1 : FD of 1ms (CoS Name H) – 10ms (CoS Name L)



E2E budget example for S1: 1+5+1+20=27ms for CoS Name M

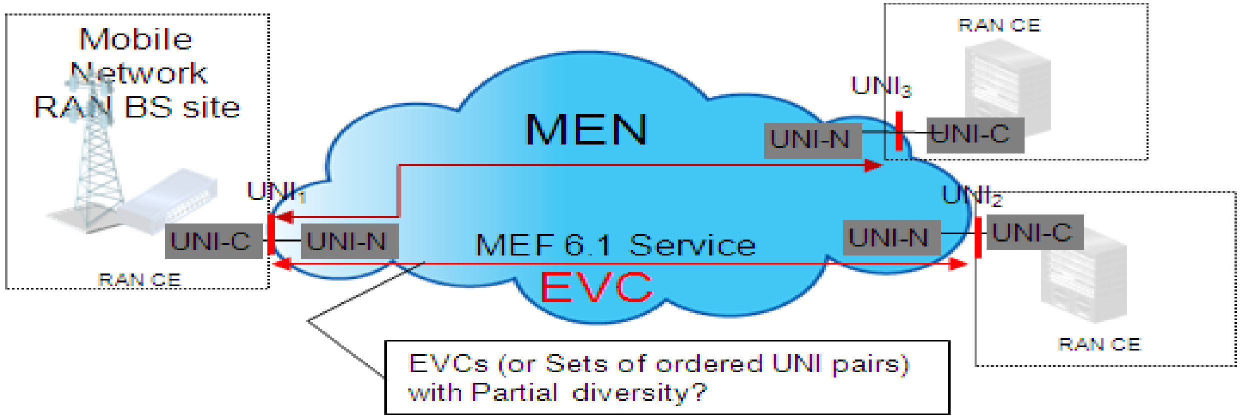


Resiliency

Mobile Backhaul Phase 3 Implementation Agreement

Resiliency Performance

- **Resiliency Performance depends on both UNI and EVC**
- **UNI Resiliency with Link Aggregation (UNI Type 2)**
- **Diversity for higher Availability**
  - MEN Resiliency Model vs RAN Resiliency Model
  - Partial vs Full Diversity
  - Use Case: S1-flex in LTE
  - Use Case: Multiple Primary Reference Clocks
- **Group Availability: e.g. Set of EVCs**



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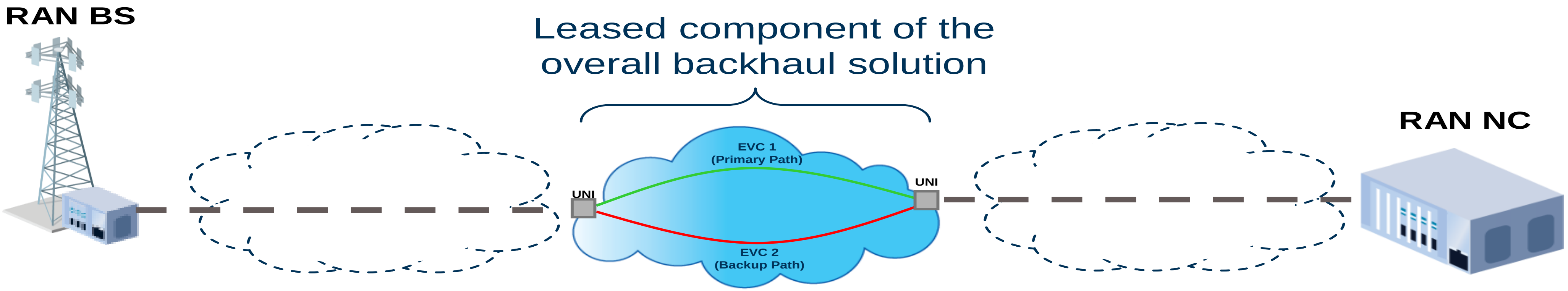
Resiliency/Protection

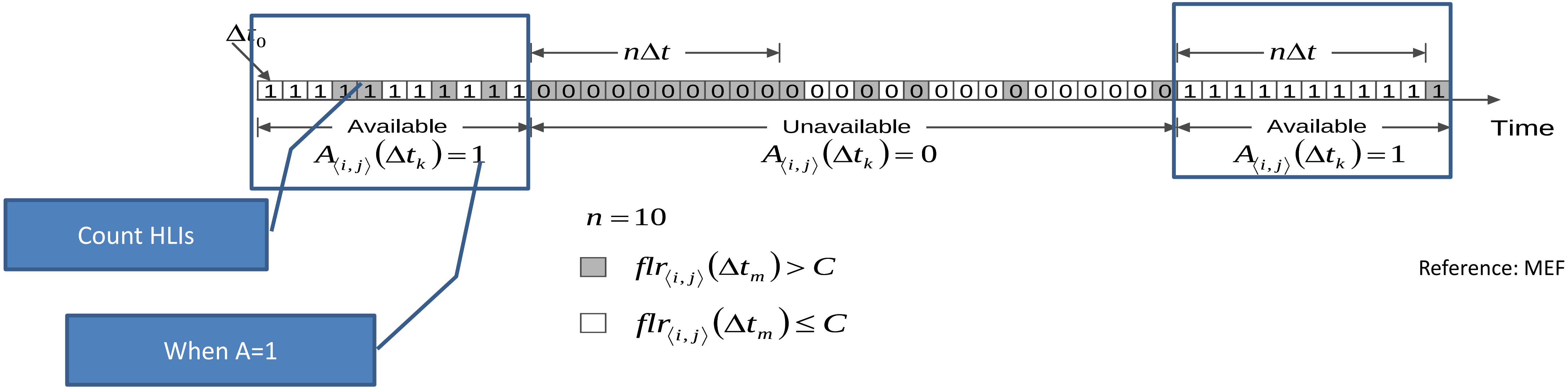
- **MEF Service Specifications augment industry standards**
- **In totality, they address port and service protection, fault detection and restoration**
  - At the UNI ports
  - At the ENNI (for direct and Exchange connections)
  - For UNI to UNI (EVCs)
  - UNI-ENNI OVCs
- **The following is one option for Mobile Backhaul showing Active/Standby**

Protection
✓ 1+1 APS
✓ LAG (802.1ax LACP)
✓ Dual Homing
✓ Ring (G.8032)
✓ Linear Protection (G.8031)



Resiliency Performance

- **Long term disruptions**
  - EVC Performance attribute: Availability
  - Example: performance over a month
- **Short term disruptions (1 or more Δt intervals)**
  - EVC Performance attribute: High Loss Interval (HLI) count
    - similar to Severely Errored Seconds (SES) in SONET/SDH
  - Why: 1-2s loss in signaling can bring down a cell site



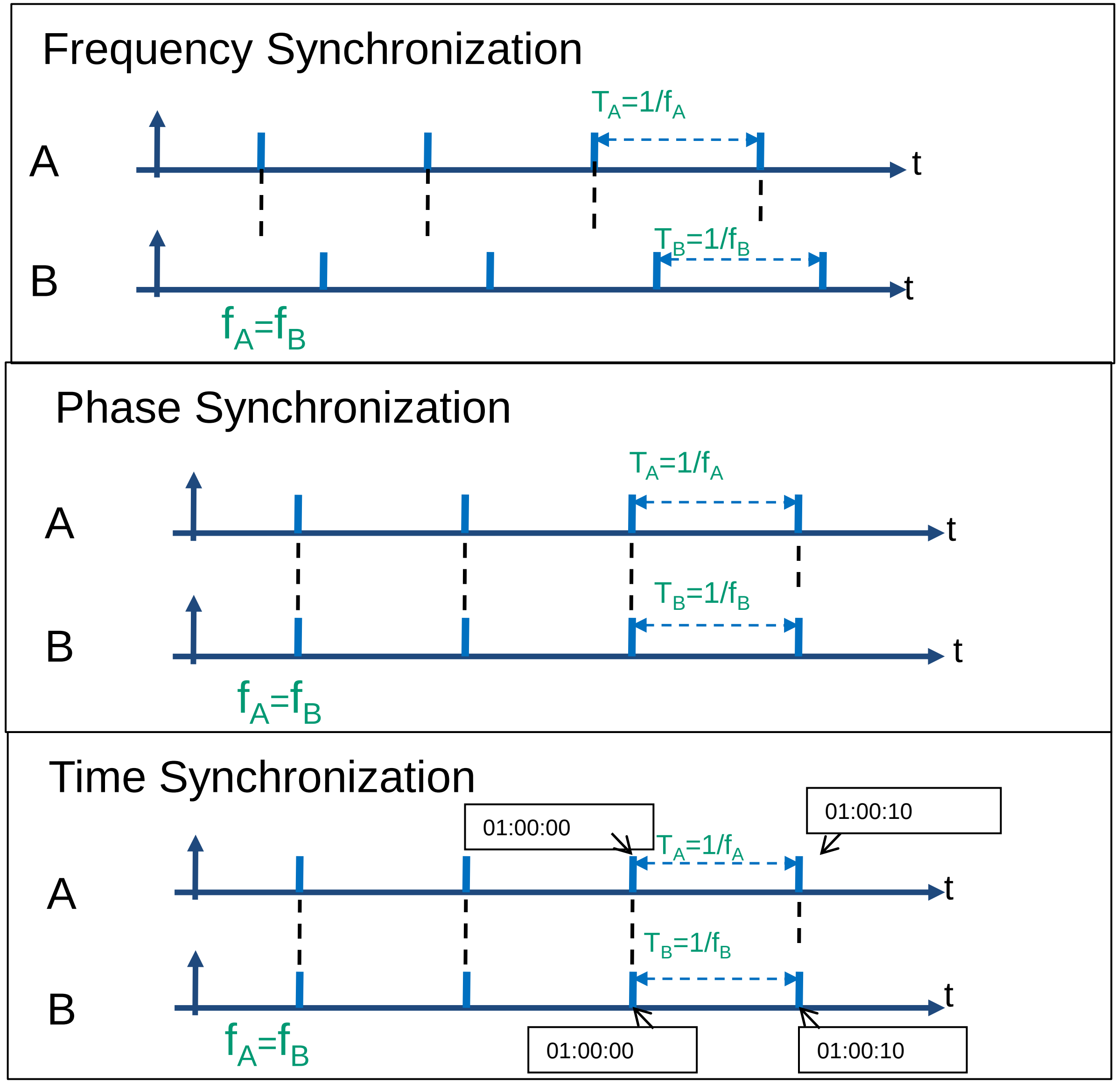
Reference: MEF 10.3

MEF

Frequency Synchronization

Mobile Backhaul Phase 3 Implementation Agreement

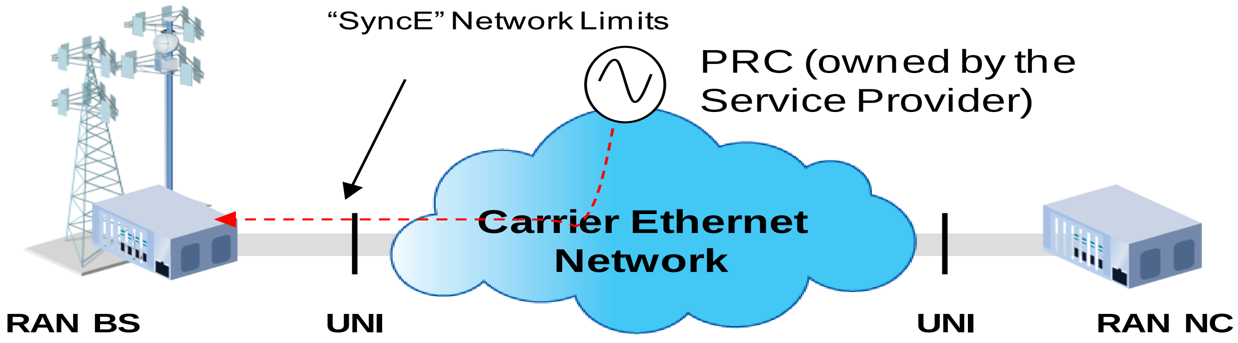
Synchronization Requirements



Mobile Network Architecture	Frequency Sync	Time-of-day / Phase Sync
CDMA2000		✓
GSM	✓	
UMTS-FDD	✓	
LTE-FDD	✓	
UMTS-TDD	✓	✓
LTE-FDD with MBMS-Single Freq. Network	✓	✓
LTE-TDD	✓	✓
Mobile WiMAX	✓	✓
TD-SCDMA	✓	✓

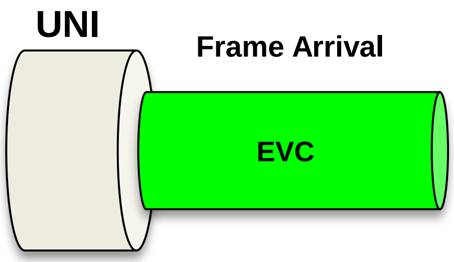
Synchronous Ethernet

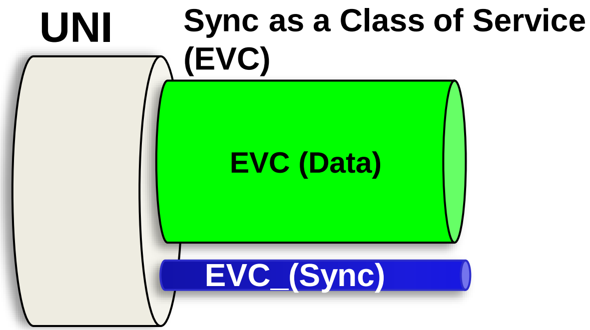
- **UNI PHY**
  - Synchronous mode of operation (Synchronous Ethernet)
    - Locked to Ethernet Equipment Clock (EEC)
- **Interoperable operation of Synchronous Ethernet**
  - Synchronous messages: Generation & processing rules
  - Clock Quality Level (QL) indication & processing rules
  - Direction of clock distribution: MEN to Base Station
- **Recommendation to support QL processing in Base Station**
  - Failure conditions & Switchover to alternate Primary reference

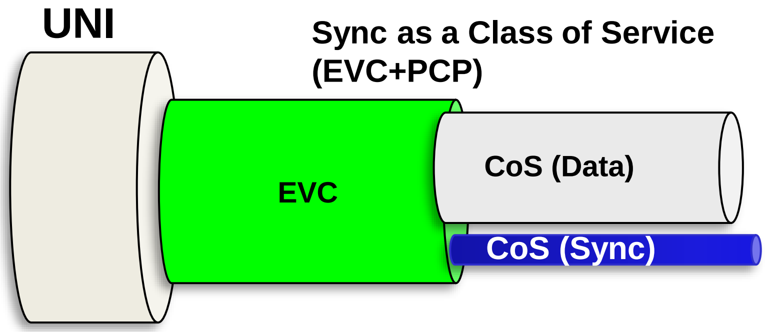


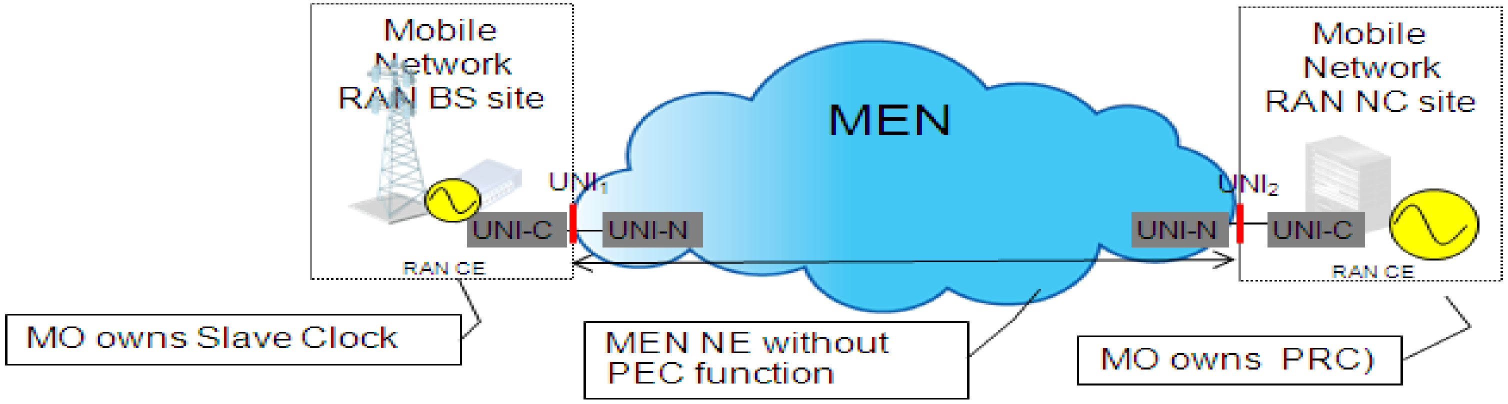
Service Class for Sync Traffic

- **Using Service Frames in the EVC**
  - Frame arrival rate with Adaptive Clock Recovery (ACR)
    - Stringent performance, egg. Frame Delay Range
  - Can also use CES RTP optional header for synchronization timestamps
- **Using a control protocol (e.g.. IEEE1588v2)**
  - Separate Class of Service with stringent performance, if needed









MO: Mobile Operator
NE: Network Element
PEC: Packet Equipment Clock

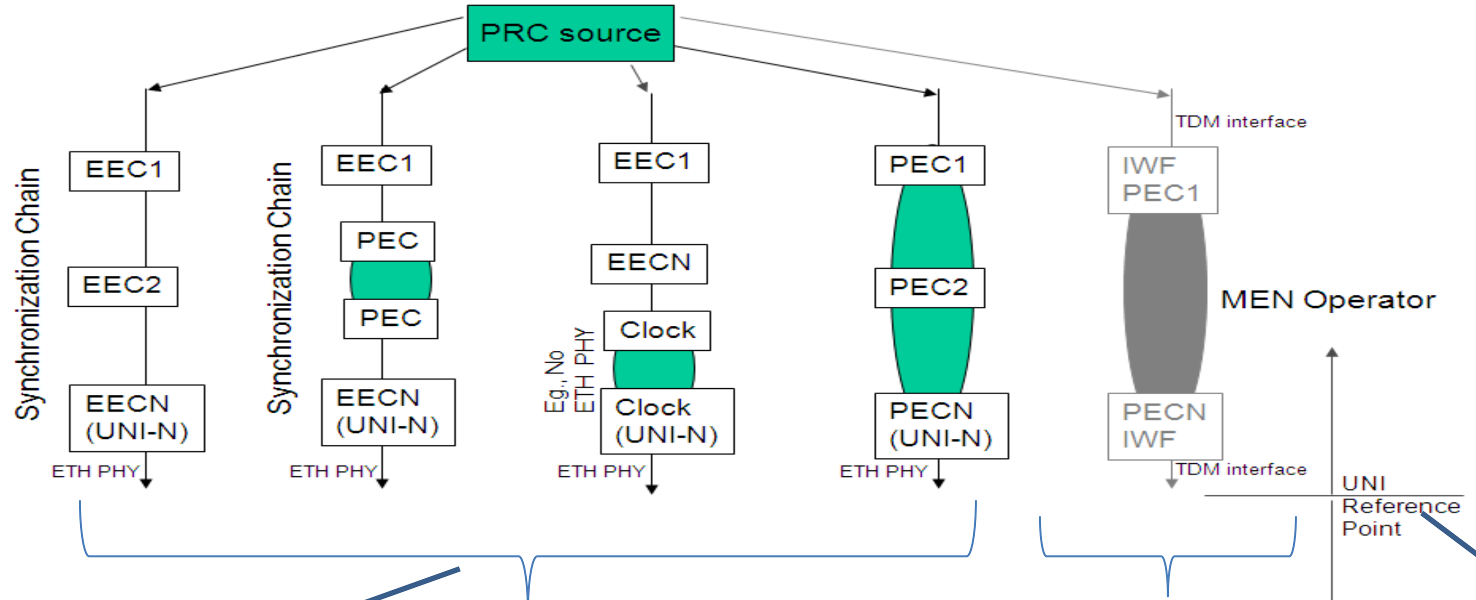
PRC: Primary Reference Clock
PCP: Priority Code Point

Synchronization Distribution Methods

- ✗ Distributed (GPS)
- **Centralized (PRC) and chain of Equipment Clocks (ECs)**
  - ✗ Physical Layer (legacy): SONET/SDH Equipment Clock (SEC)

In Scope

- ✓ Physical Layer: Ethernet Equipment Clock (EECs)
- ✓ Packet Equipment Clocks (PECs) with timestamps (1588v2) or frame arrival rate (Adaptive Clock Recovery (ACR))



Enhancement of UNI attributes?

For RAN CEs with MEF UNIs (Ethernet)

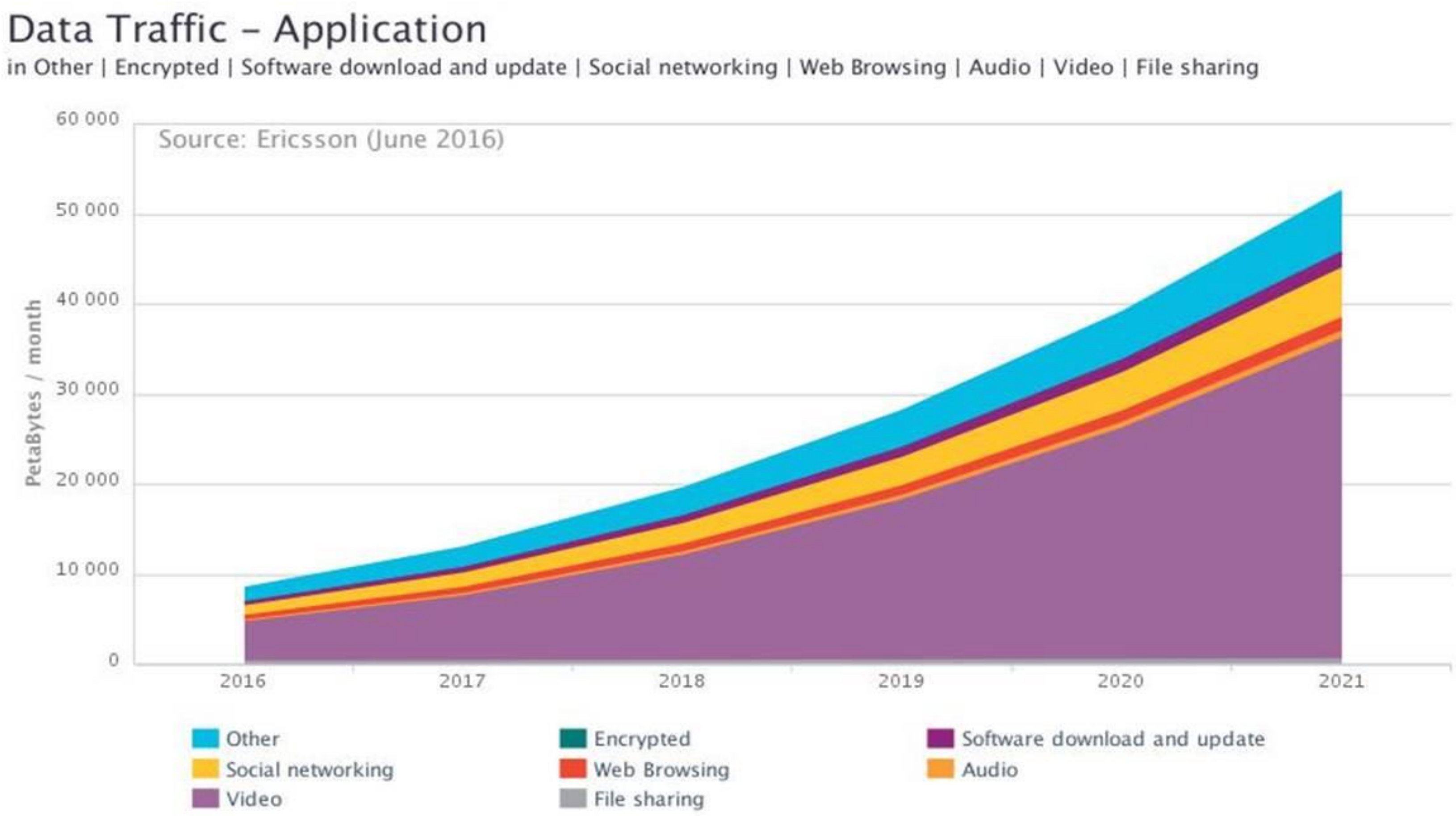
Legacy RAN CE

Performance:
Interface Limits for Jitter & Wander at demarcation

Multi Class of Service

Mobile Backhaul Phase 3 Implementation Agreement

Traffic Profile Forecast



Multi-CoS gets increasingly important as the non FD, FDV sensitive traffic volumes grows.

Traffic Profile Used in the Positioning Paper

Representative traffic profile for a 500Mbit/s backhaul circuit used as a basis in the paper to compare Multi-CoS backhaul with Single-CoS backhaul

Traffic Type	Required Bandwidth (Mbit/s)	Required Performance across the Access Provider network		
		One-way Frame Delay (ms)	One-way Delay Variation (ms)	Frame Loss (%)
Synchronization	1.5	10	5	0.01%
Voice/Conversational & Control	10.5	15	5	0.01%
Streaming Media	260	20	10	0.01%
Interactive and Background	228	37	Not required	0.1%

Only 2-4% of traffic is FD, FDV sensitive.

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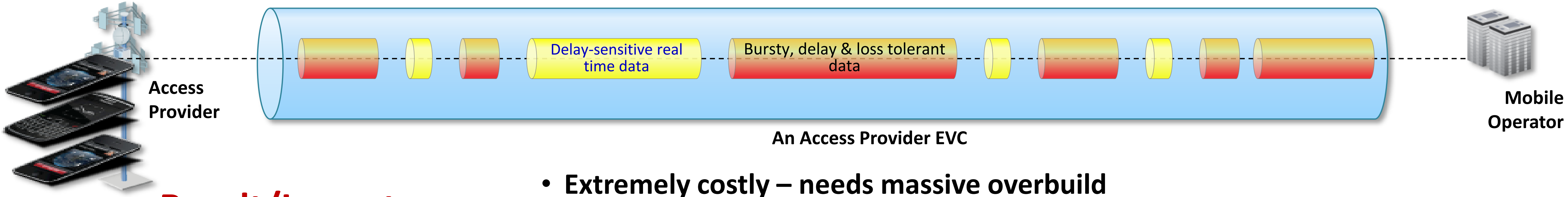
Single Class vs. Multi Classes (1)

All one Class of Service: simple but costly

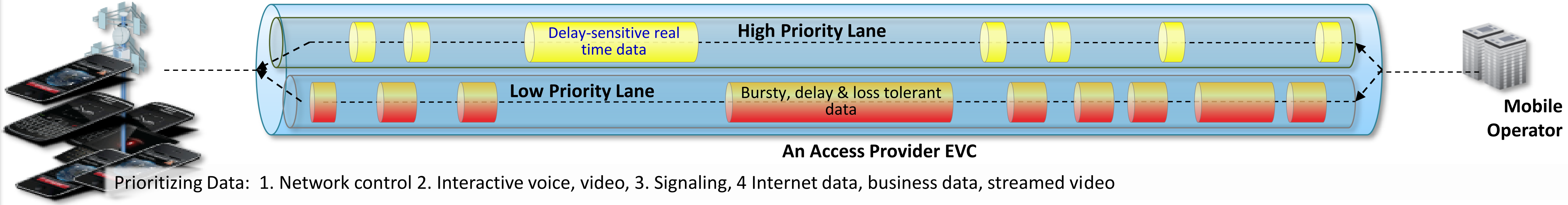


Result/Impact

- Extremely costly – needs massive overbuild
- Does not scale - recipe for going out of business
- High Priority traffic subject to delay – especially during traffic bursts and peaks

Single Class vs. Multiple Classes of Service (2)

Multiple-Classes of Service: more complex but great rewards



Result/Impact

Backhaul Operators (aka Access Providers)

- More Revenue for same cost: more users supported, more responsive QoS
- Avoids costly over-building network to ensure integrity, QoS
- Squeezes best performance to maximize profitability by leveraging the statistical multiplexing of Ethernet

Mobile Operators:

- Enables resolution of their most critical challenge:

"Handling unprecedented growth of data efficiently while preserving or improving QoS."

MEF

Service Mapping (MEF 22.2)

- **The following shows how backhaul services can be integrated between mobile operators and access providers even when the services offered are not the same:**

CoS Names	Generic Traffic Classes Mapping to CoS Names			
	4 CoS Names	3 CoS Names	2 CoS Names	2 CoS Names
Very High (H+)	Synchronization	-	-	-
High (H)	Conversational, Signaling, Network Management and Control	Synchronization, Conversational, Signaling, Network Management and Control	Synchronization, Conversational, Signaling, Network Management Control, and Streaming media	Synchronization, Conversational, Signaling, Network Management, Control, and Streaming media
Medium (M)	Streaming media	Streaming media	-	Interactive and Background
Low (L)	Interactive and Background	Interactive and Background	Interactive and Background	

MEF 22.2: Examples of MBH Traffic Classes mapping to CoS Names in a Carrier Ethernet Backhaul network

Value to Mobile Operator: Know what performance each 3GPP traffic class will get

Value to MEN Operator: Standard CoS offering with default performance objectives

Enhancements: Performance Tier (PT) objectives

One way CPOs across PT 1 (metro) for Point-to-Point Mobile Backhaul service

CoS Name	Ingress Bandwidth Profile*(2)*	One Way CPO for Mobile Backhaul Service {S, CoS ID, PT}									
		FD	**MFD**	**IFDV**	**FDR**	**FLR**	**A**	**L**	**B**	**FPP**	**CPM**
Very High *(H^+)*	*CIR>0 EIR=0*	*≤10 ms*	*≤7 ms*	*N/S*	A_{FDR}	*≤.01 % (i.e., 10^{-4})*	$\geq A_{Avail}$	$\leq A_{HLI}$	$\leq A_{CHLI}$	*(3)*	*(4)*
High *(H)*	*CIR>0 EIR≥0*	*≤10 ms*	*≤7 ms*	*≤3 ms*	*≤5 ms*	*≤.01 % (i.e., 10^{-4})*	TBD	TBD	TBD	*(3)*	*(4)*
Medium *(M)*	*CIR>0 EIR≥0*	*≤20 ms*	*≤13 ms*	*≤8 ms or N/S*	*≤10 ms or N/S*	*≤.01 % (i.e., 10^{-4})*	TBD	TBD	TBD	*N/S*	*N/S*
Low *(L)*	*CIR≥0 EIR≥0(1)*	*≤37 ms*	*≤28 ms*	*N/S*	*N/S*	*≤.1 % (i.e., 10^{-3})*	TBD	TBD	TBD	*N/S*	*N/S*

One Way CPO for Mobile Backhaul Service

with Tight Radio Coordination – constrained PT1 {S, CoS ID, PT}

CoS Name	Ingress Bandwidth Profile**	One Way CPO for Mobile Backhaul Service with tight radio coordination {S, CoS ID, PT}							
		FD	MFD	IFDV	FDR	FLR	Availability	L	B
High *(H)*	*CIR>0* *EIR≥0*	*≤1 ms*	*≤0.7 ms*	*≤0.3 ms*	*≤0.5 ms*	*≤.01 %* *(i.e., 10^{-4})*	*TBD* $\geq A_{Avail}$	*TBD* $\geq A_{HLI}$	*TBD* $\geq A_{CHLI}$
Medium *(M)*	*CIR>0* *EIR≥0*	*≤2.9 ms*	*≤2 ms*	*≤0.9 ms or N/S*	*≤1 ms or N/S*	*≤.01 %* *(i.e., 10^{-4})*	*TBD* $\geq A_{Avail}$	*TBD* $\geq A_{HLI}$	*TBD* $\geq A_{CHLI}$
Low *(L)*	*CIR≥0* *EIR≥0**	*≤10 ms*	*≤8 ms*	*≤2.8 ms or N/S*	*≤2.9 ms or N/S*	*≤.1 %* *(i.e., 10^{-3})*	*TBD* $\geq A_{Avail}$	*TBD* $\geq A_{HLI}$	*TBD* $\geq A_{CHLI}$

MEF

Bandwidth (Token) Sharing

Mobile Backhaul Phase 3 Implementation Agreement

Bandwidth Allocation - Current State

Current approaches to Bandwidth requirements for Mobile Backhaul

1. Dedicate a single CoS Name for all bandwidth between RAN BS and RAN NC
2. Use 2, 3 or 4 CoS Names per backhaul service, with fixed bandwidth allocation per CoS Name
    - Table 8 in MEF 22.2 provides and example that maps generic traffic classes to CoS Names

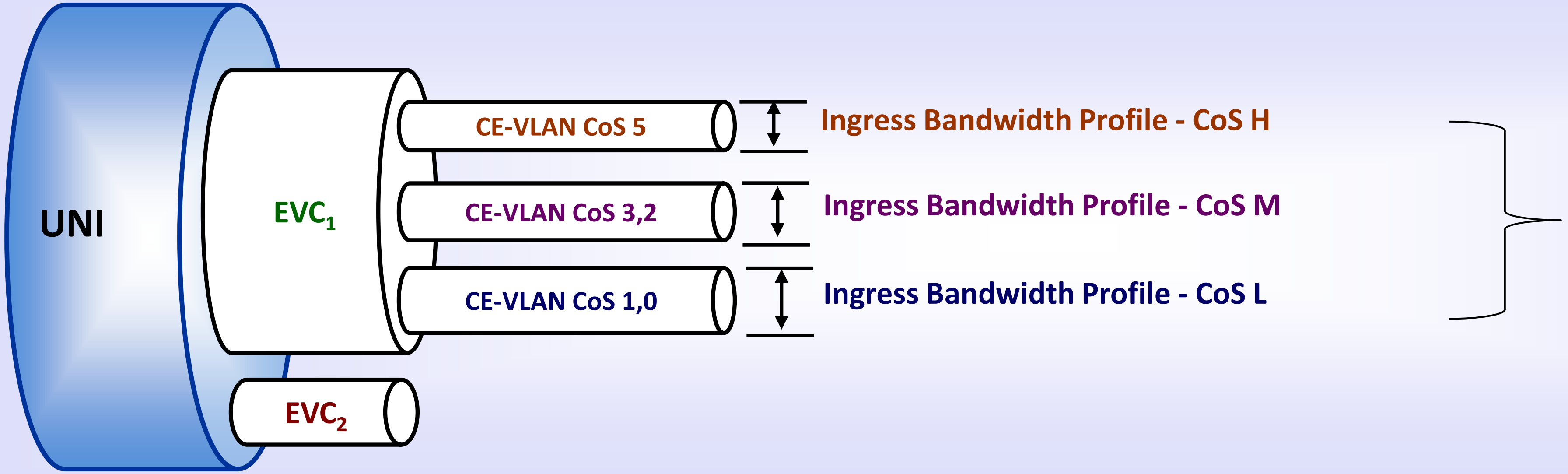
Problems with these approaches

1. Both delay/jitter sensitive traffic and bursty data traffic are in the same service (forwarding class) – all traffic is treated equally. The Backhaul Provider will need to over-engineer the network links, resulting in higher cost for the network (likely, also for the MO).
2. Because of variable traffic mix, each CoS Name has to have enough headroom to support the maximum bandwidth required. This leads to provisioning more bandwidth per service than is needed.

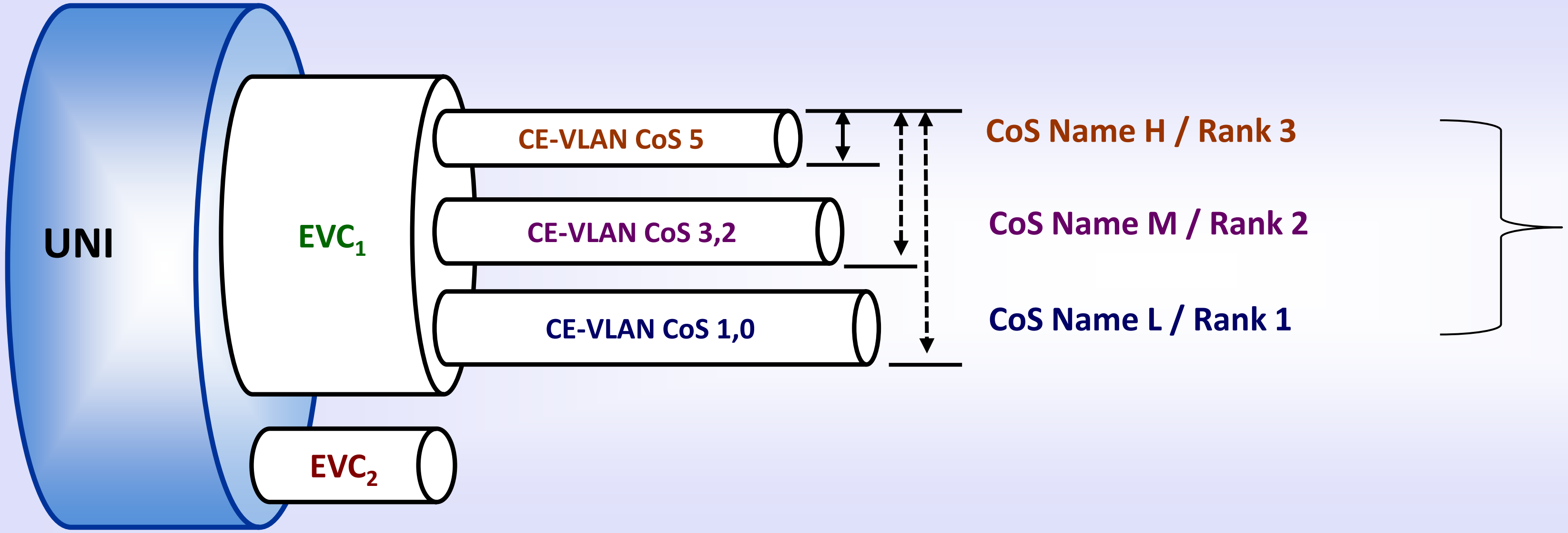
The Solution - Bandwidth Sharing

- **The Solution → Bandwidth Sharing**
  - Follows actual traffic mix changes (adaptive bandwidth allocation)
  - All leased capacity can be fully utilized
  - Different traffic types have different treatment
    - More efficient use of network resources (cost savings)
  - The new functionality lies in the Backhaul Provider’s network, and in the simplest case, no changes should be needed in the MO’s equipment

Bandwidth Sharing



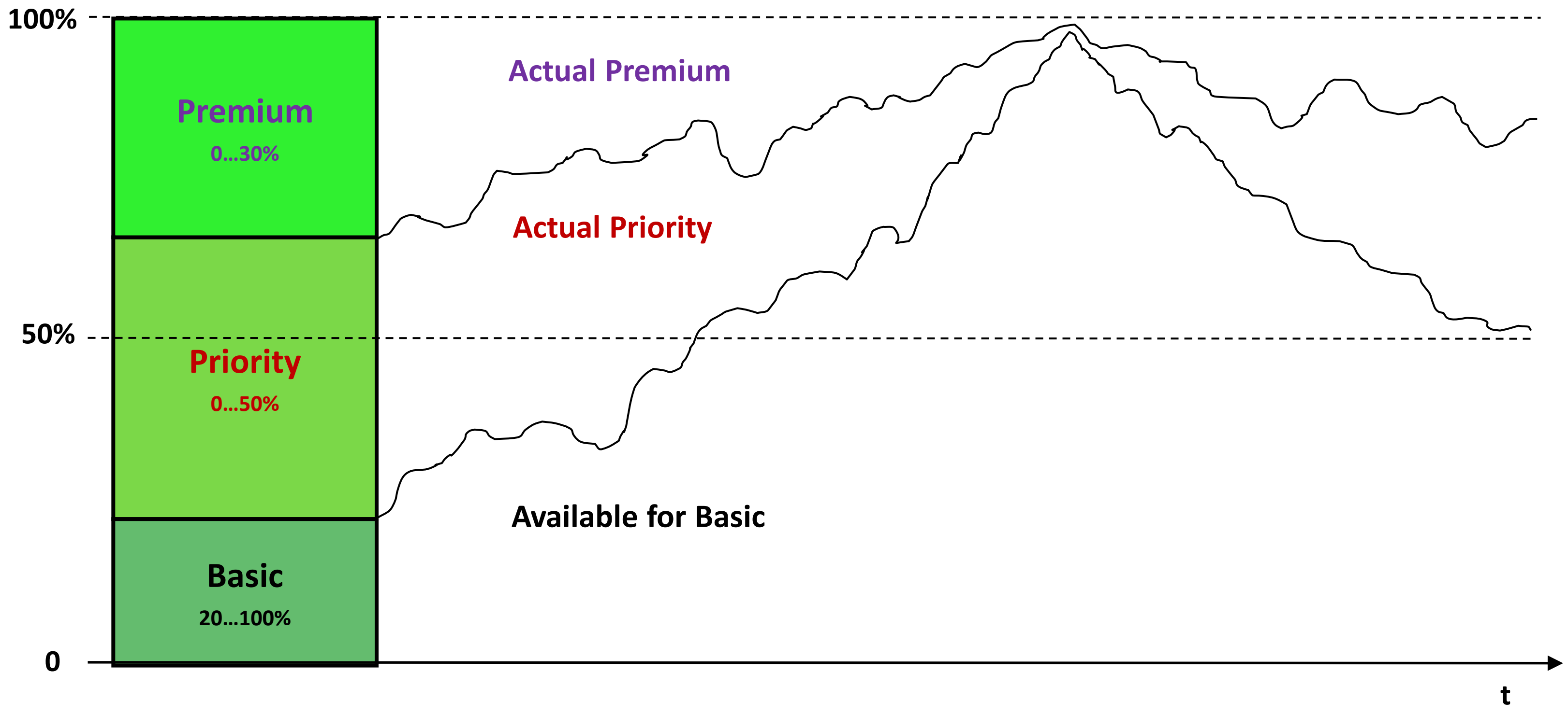
Bandwidth per Class: Use it or lose it!



Ingress Bandwidth Profile Per Class of Service Name
Allows lower Rank flows to share of any unused bandwidth

The Principle of Bandwidth Sharing

The principle of Bandwidth Sharing



As traffic mix changes dynamically, more bandwidth is made available for the lower ranked traffic classes, allowing for full utilization of the provisioned bandwidth.

MEF

Multi-CoS Bandwidth Sharing in MEF 22.2

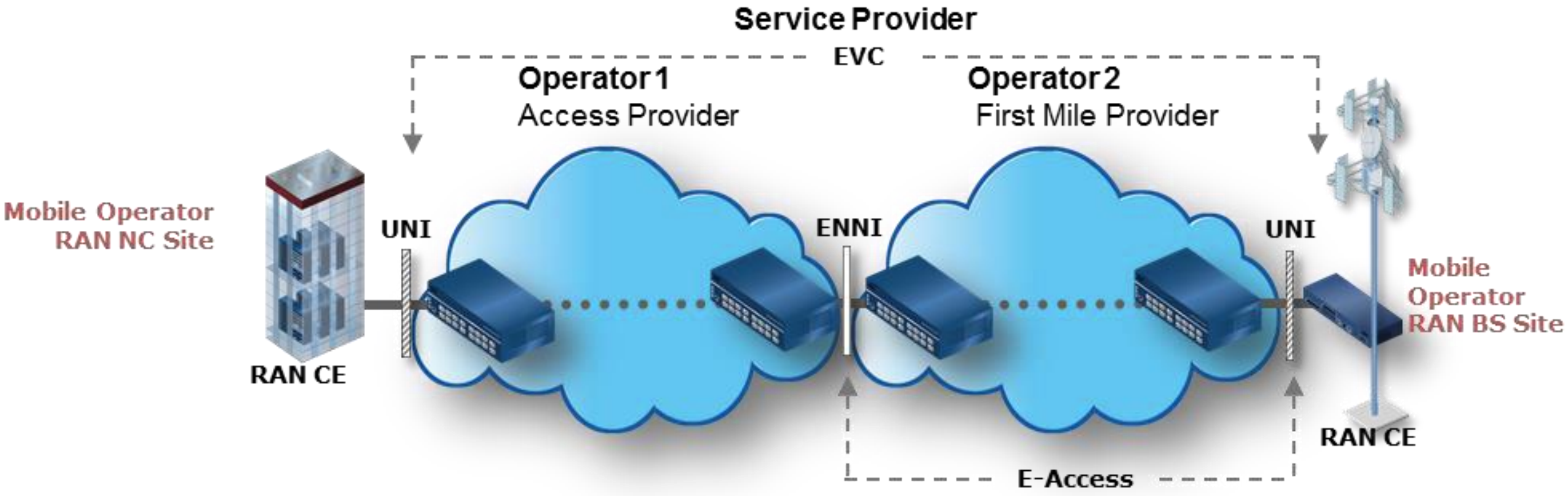
- **Bandwidth sharing based on token sharing**
  - Token sharing is a rate enforcement model that allows for bandwidth sharing across two or more Bandwidth Profile Flows in an envelope
  - Flexible model for supporting multi-CoS backhaul
- **Summary of MEF 22.2 token sharing recommendation**
  - Section 11.5: recommends Operator support for token sharing for 4 Bandwidth Profile Flows
    - (i.e., H+, H, M, L) per envelope (EVC)
  - Support for green (committed) and yellow (excess) traffic per CoS Name
    - With ability to convert excess green tokens at bottom rank to yellow tokens for feeding the top rank yellow token bucket
- **Informative Appendix (Appendix D)**
  - Description of multi-CoS backhaul with token sharing
  - Description of the basics of Token sharing
  - Example of token sharing for mobile backhaul

References: MEF 10.3 defines the bandwidth profile algorithm and parameters supporting token sharing

Multi-CEN

Mobile Backhaul Phase 3 Implementation Agreement

Multi-CEN in MEF 22.2



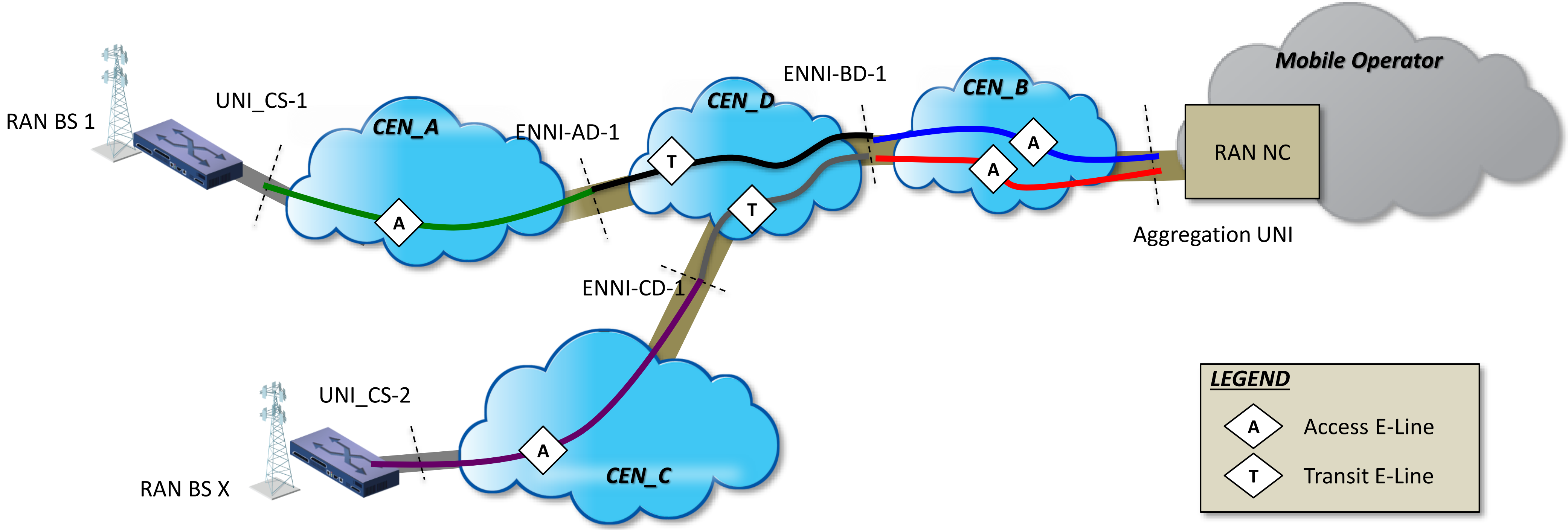
- Why Multi-CEN?
  - There are many occasions where the first mile provider (the one providing access to the RAN BS) and the Access Provider (the one connecting to the RAN NC site) are different. Typically, the two Ethernet service Operators connect together using an ENNI (External Network Network Interface).
- Summary of MEF 22.2 multi-CEN requirements
  - Section 8.3: When E-Access service is used (UNI-to-ENNI), MEF 22.2 requires Operator to meet mandatory requirements in MEF 51 for Access E-Line (for point-to-point access) or Access E-LAN (for multipoint access)
- Appendix F - Multi-CEN mobile backhaul use cases
  - Example of 3 CENs supporting EVPL services with Access E-Line services
  - Example of 4 CENs supporting EVPL services with Access E-Line and Transit E-Line services
  - Example of four CENs supporting EVP-LAN with Access E-Line and Transit E-LAN services
  - Example of supporting distributed EVP-LAN services with Access E-Line, Access E-LAN and Transit E-Line services

Reference: MEF 51 defines OVC services, i.e., Access E-Line, Access E-LAN, Transit E-Line and Transit E-LAN services

MEF

Multi-CEN MBH Example – 3 CENs in a Chain

Combining E-Access and E-Transit Services for end-to-end solution



This example shows three CENs in a chain, with CEN D providing Transit E-Line services, and CENs A, B and C providing Access E-Line services, to facilitate the end-to-end mobile backhaul EVPL services.

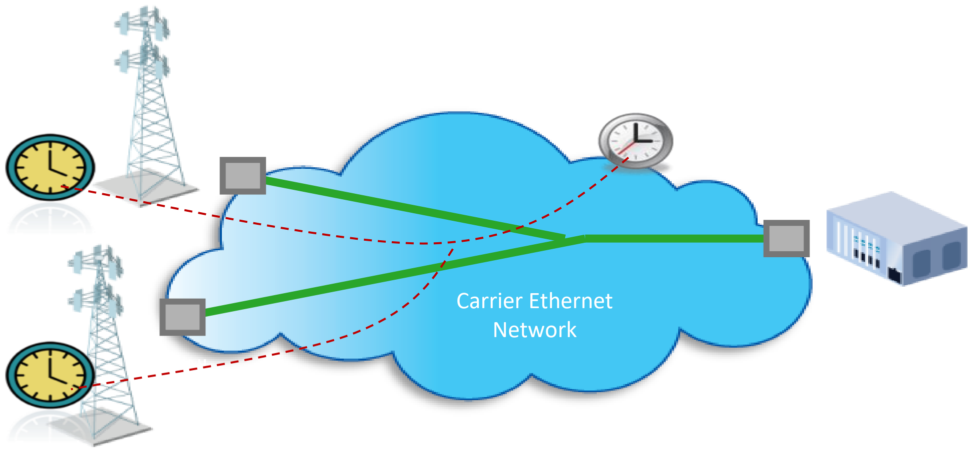
This configuration might be required in some deployments - improved reach (e.g., due to small cell deployments or Ethernet backhaul to S-GW) or for ease of connectivity to the 'last mile' Operators.

Summary of MEF 22.2

Mobile Backhaul Phase 3 Implementation Agreement

Summary of MEF 22.2

- Support all mobile generations over Carrier Ethernet
- Migration strategy for 2G and 3G
- A blueprint for implementing synchronization delivery
- “Tool Box” for Service OAM, Resiliency and Protection
- Multi CoS and Bandwidth Sharing for mobile traffic
- Low latency for Small Cells’ interference cancellation



Background for MEF 22.2

SAE/LTE

Concepts and Abbreviations

LTE - *Long Term Evolution*

SAE – *System Architecture Evolution*

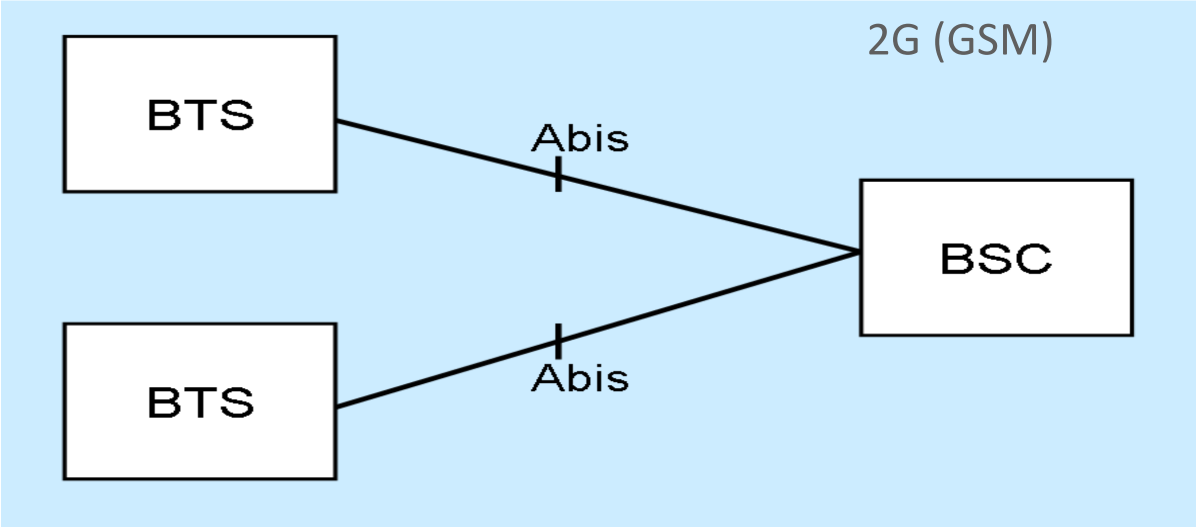
eUTRAN – *Evolved UMTS Terrestrial RAN*

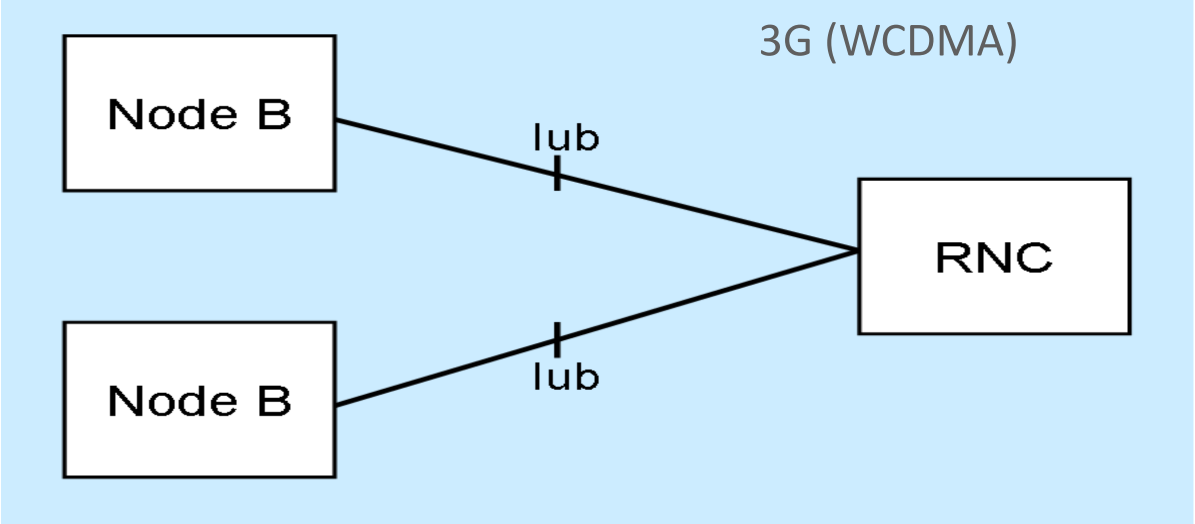
EPC – *Evolved Packet Core*

EPS – *Evolved Packet System*

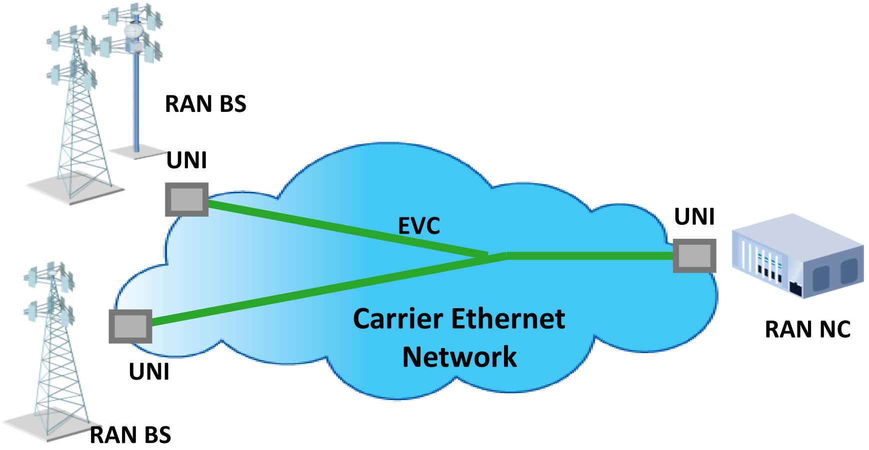
Architecture Overview

Mobile Backhaul IA – Phase 1
2G + 3G Reference Interfaces

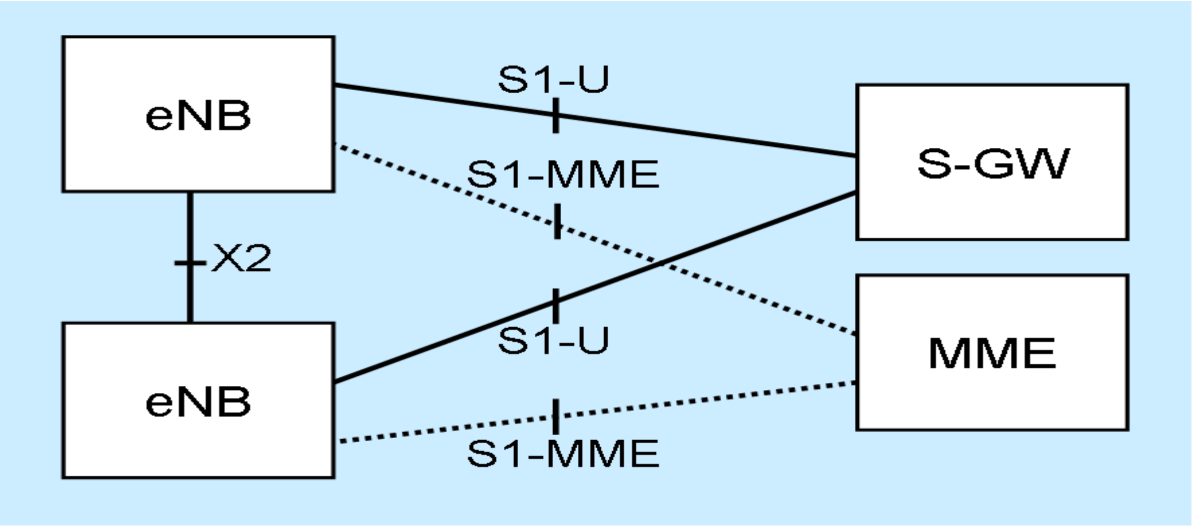




- **In 2G and 3G all traffic (user data and control) is sent directly between base stations and radio controller nodes.**
- **EVCs defined to provide connectivity with base station sites (RAN BS) and controller sites (RAN NC).**
- **No connectivity between RAN BSs expected.**



LTE Reference Architecture

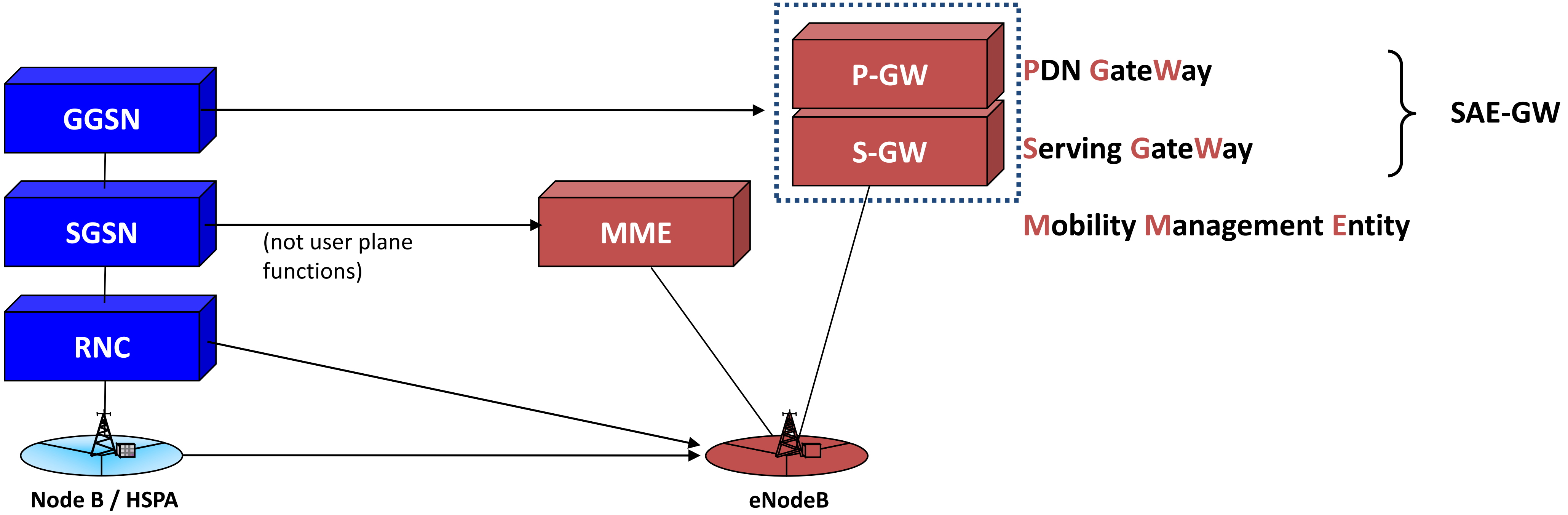


- LTE radio base stations (eNB) are connected to multiple core network nodes through the S1 interface: S-GWs (S1-U) and MMEs (S1-MME)
- eNB connects directly to core nodes, in 2G and 3G there were controller nodes sitting between base stations and the core nodes
- New interface specified between eNBs

SAE/LTE Architecture (release 8)

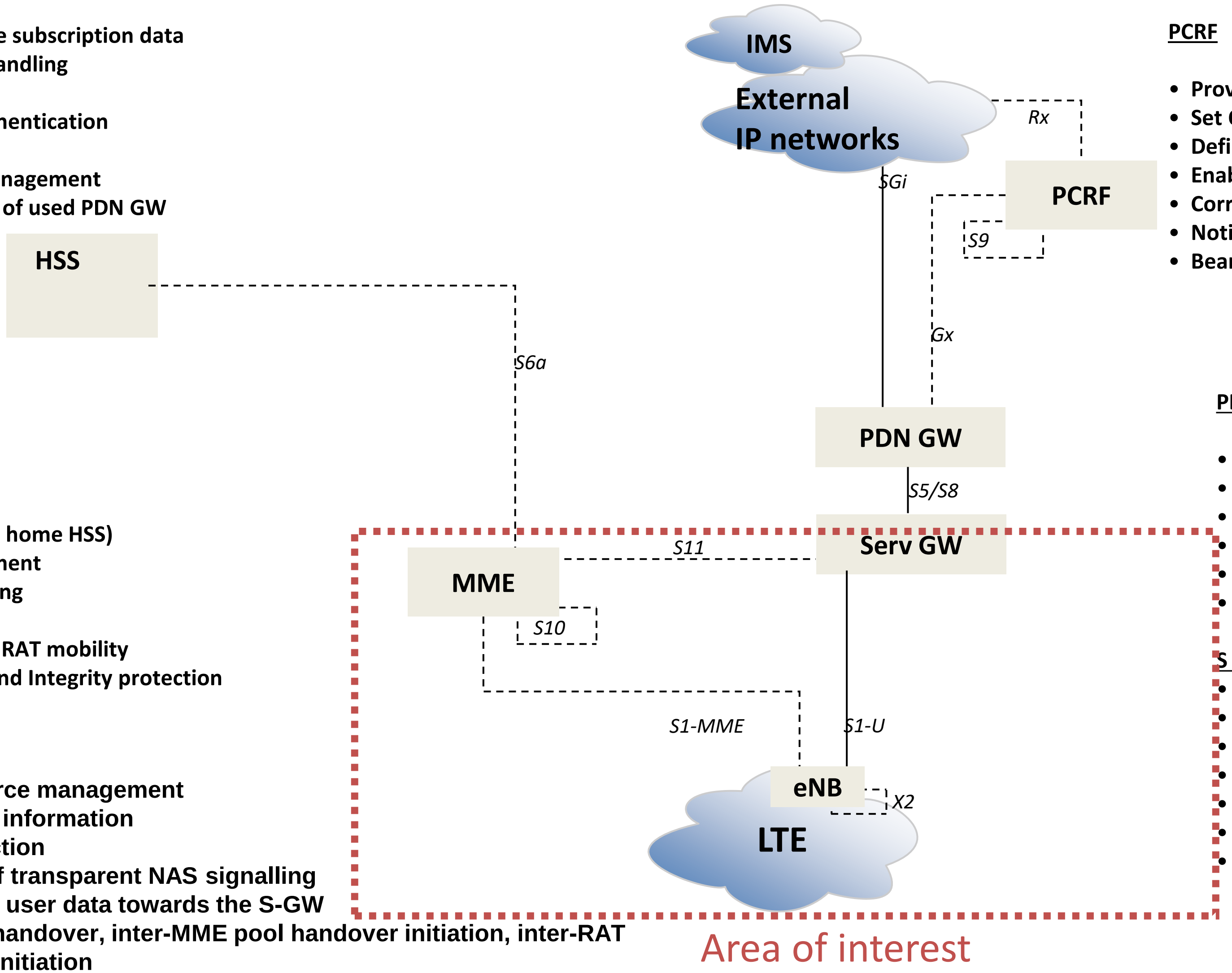
Functional changes compared to the current WCDMA Architecture

This means that all RNC functions are moved to the Node B …
…, SGSN Control Plane functions to the MME, and GGSN functions to the S-GW and P-GW



SAE/LTE architecture details (Informational)

HSS
- Maintain and provide subscription data
- User Identification handling
- Access Authorisation
- Provide Keys for Authentication and Encryption
- User Registration management
- Maintain knowledge of used PDN GW



PCRF
- Provides Service Data Flow gating
- Set QoS for each Service Data Flow
- Define Charging for each Service Data Flow
- Enables Bearer QoS Control
- Correlation between Application and Bearer charging
- Notification of bearer events to application function
- Bearer bindings towards Serv-GW for PMIP based S5

MME
- Authentication
- NAS signalling
- GW selection
- Roaming (S6a to home HSS)
- Bearer management
- Idle mode tracking
- Paging
- Inter-MME and IRAT mobility
- NAS Ciphering and Integrity protection

eNodeB
- Cell resource management
- Broadcast information
- MME selection
- Transfer of transparent NAS signalling
- Routing of user data towards the S-GW
- Intra-LTE handover, inter-MME pool handover initiation, inter-RAT handover initiation
- QoS realization
- Security

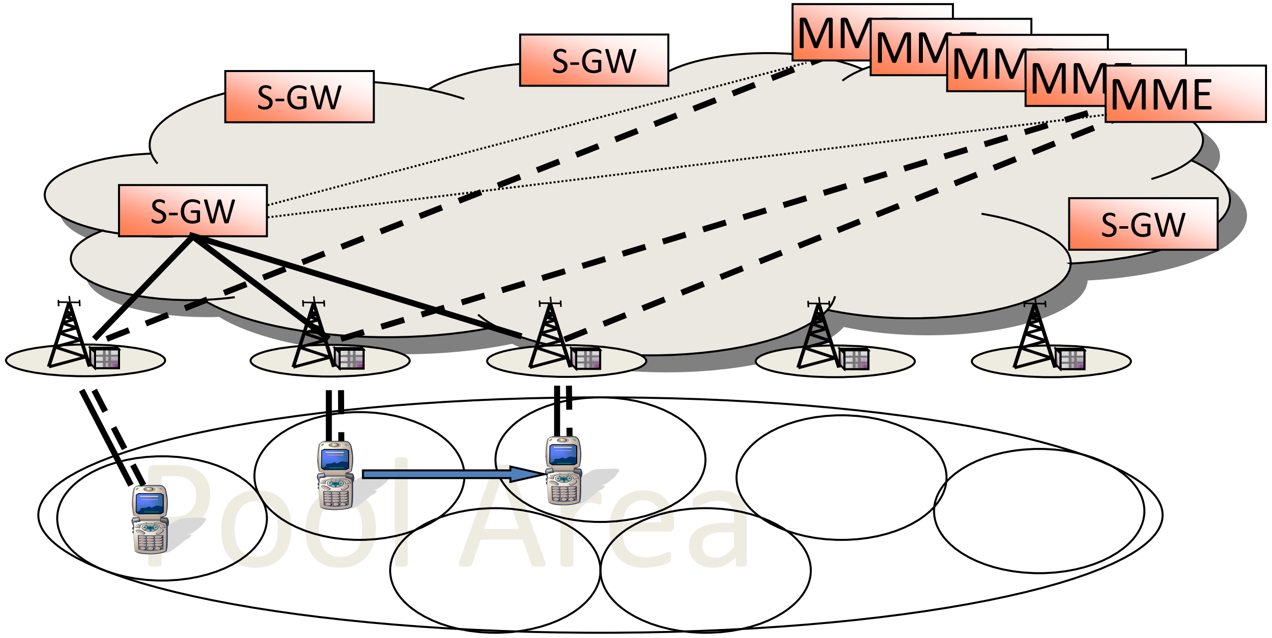
PDN GW part:
- External IP point of interconnect
- IP address allocation
- Packet routing & forwarding
- Lawful intercept
- Policy enforcement
- In home or visited network

S GW part
- In visited network in case of roaming
- Intra-LTE mobility anchor
- Packet routing & forwarding
- Lawful intercept
- LTE idle mode DL buffering
- Charging per UE, PDN and QCI
- Bearer bindings for PMIP S5/S8

Resource pooling

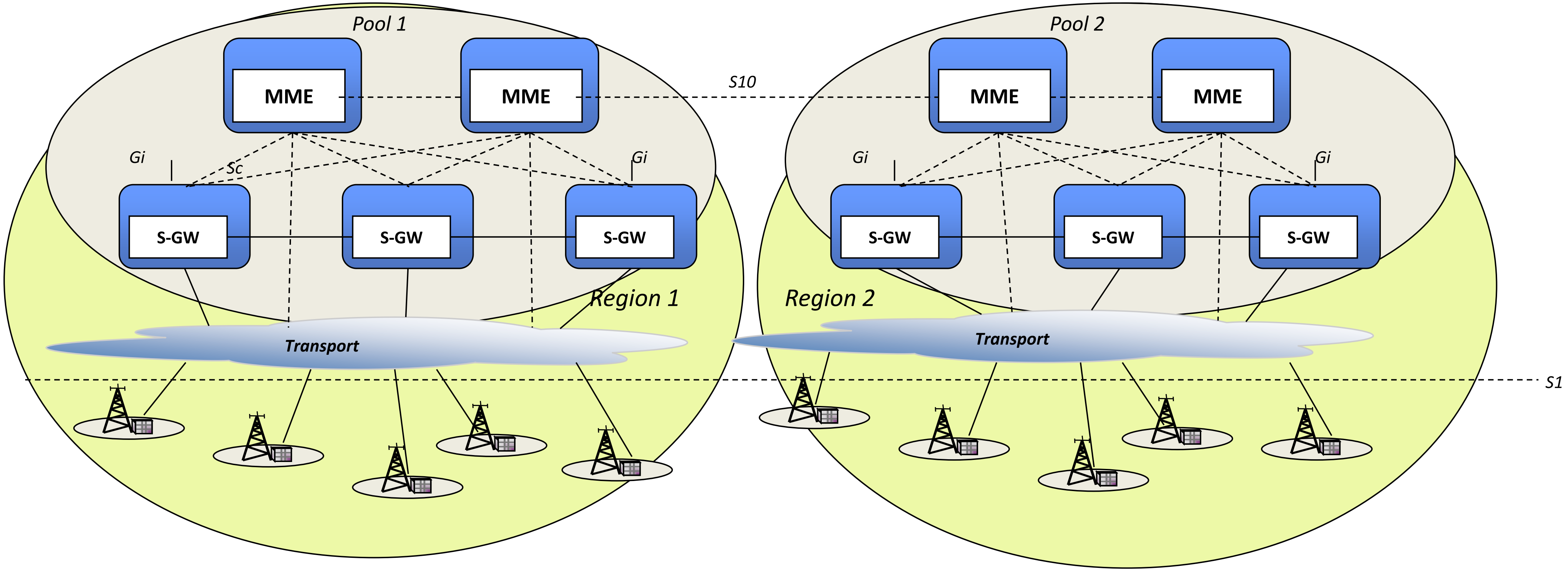
S1 Flex Concept - "MME Pool"

- The MMEs in an operators network will be pooled (in one or several pools)
- The eNodeB is assigned an MME within the pool to connect to for a certain UE
- The MME selects the Serving GW and PDN GW based on the PDN the UE would like to reach and the locality of Serving GW
- Serving GWs are also pooled for resource efficiency



MEF

S-GW Selection and S-GW Pools

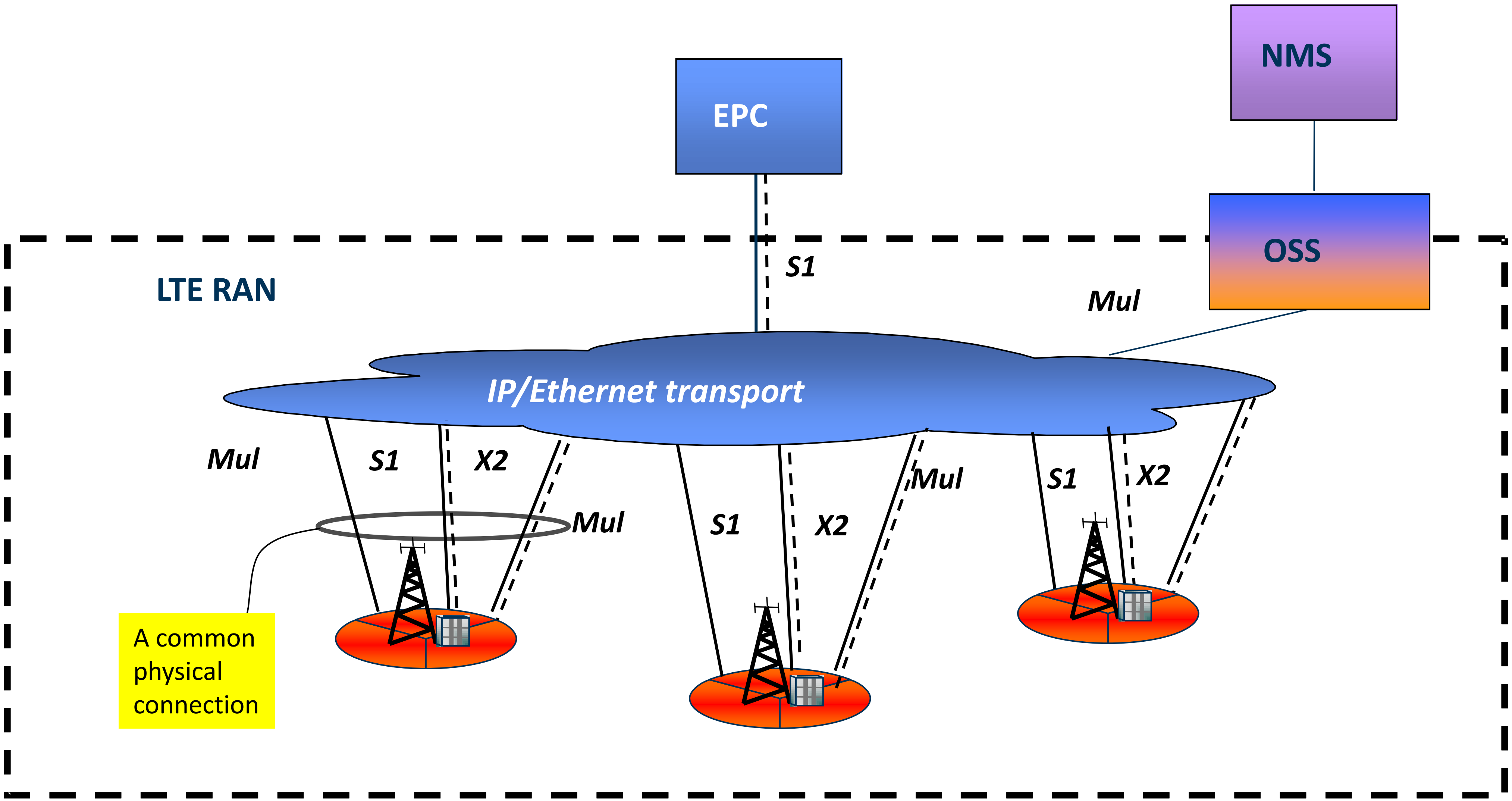


- **Pooling provides capacity and redundancy gains**
- **S-GW can be placed close to eNodeB for transport gains**
- **S-GW selection takes place when a session is established**
  - Different sessions over the same eNB may connect to different S-GWs
  - S-GW is indicated to eNB as IP address of GTP-U tunnel endpoint
  - Selection can be based on simple round-robin, load balancing, location, type of service etc.

MEF

X2 handover

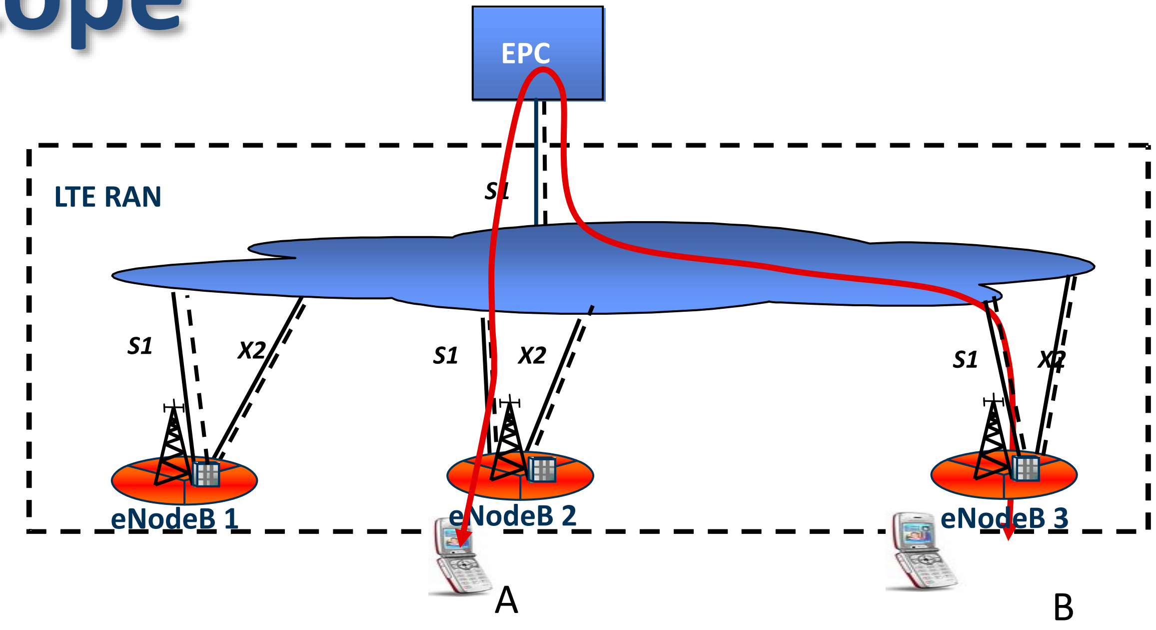
LTE RAN Transport Network



MEF

X2 Scope

- **eNBs require direct inter-connectivity only for ”RF related triggers”, i.e. intra-LTE handover, for both signalling and forwarding of user data.**
  - Each single eNodeB requires connectivity to all eNodeBs with neighboring cells (and no others!)
  - Neighbor nodes may not be known at startup, but learned by a SON feature, Automatic Neighbor Relations (ANR)
  - **No requirement to have Ethernet connectivity, one or more IP hops are allowed**



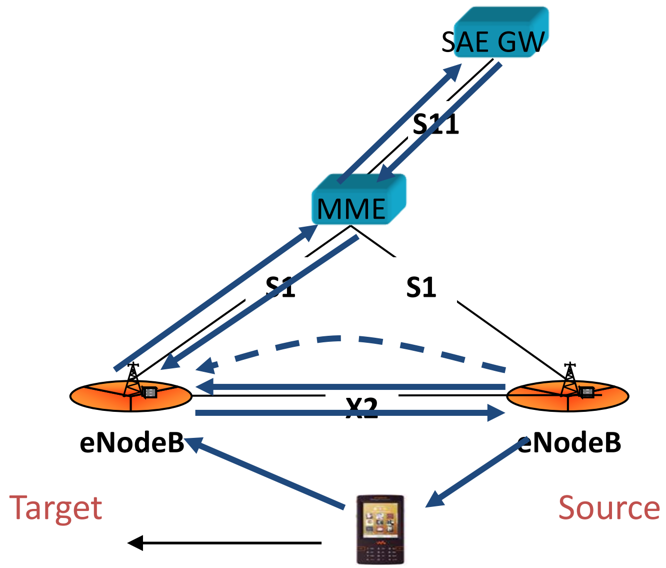
In a scenario with a mixture of macro and micro base stations this results in one eNodeB needing connectivity to up to about 20 – 30 other eNBs.

MEF

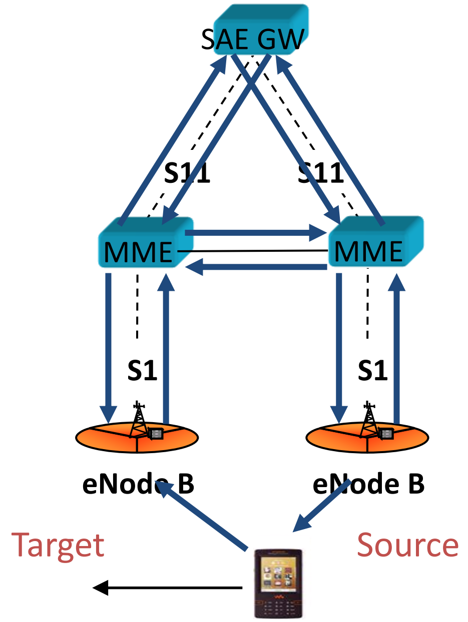
Intra-LTE Mobility

2 handover mechanisms

- **Handover within one MME (pool)**
  - Via the X2 interface
  - User data:
    Packet forwarding (source → target)

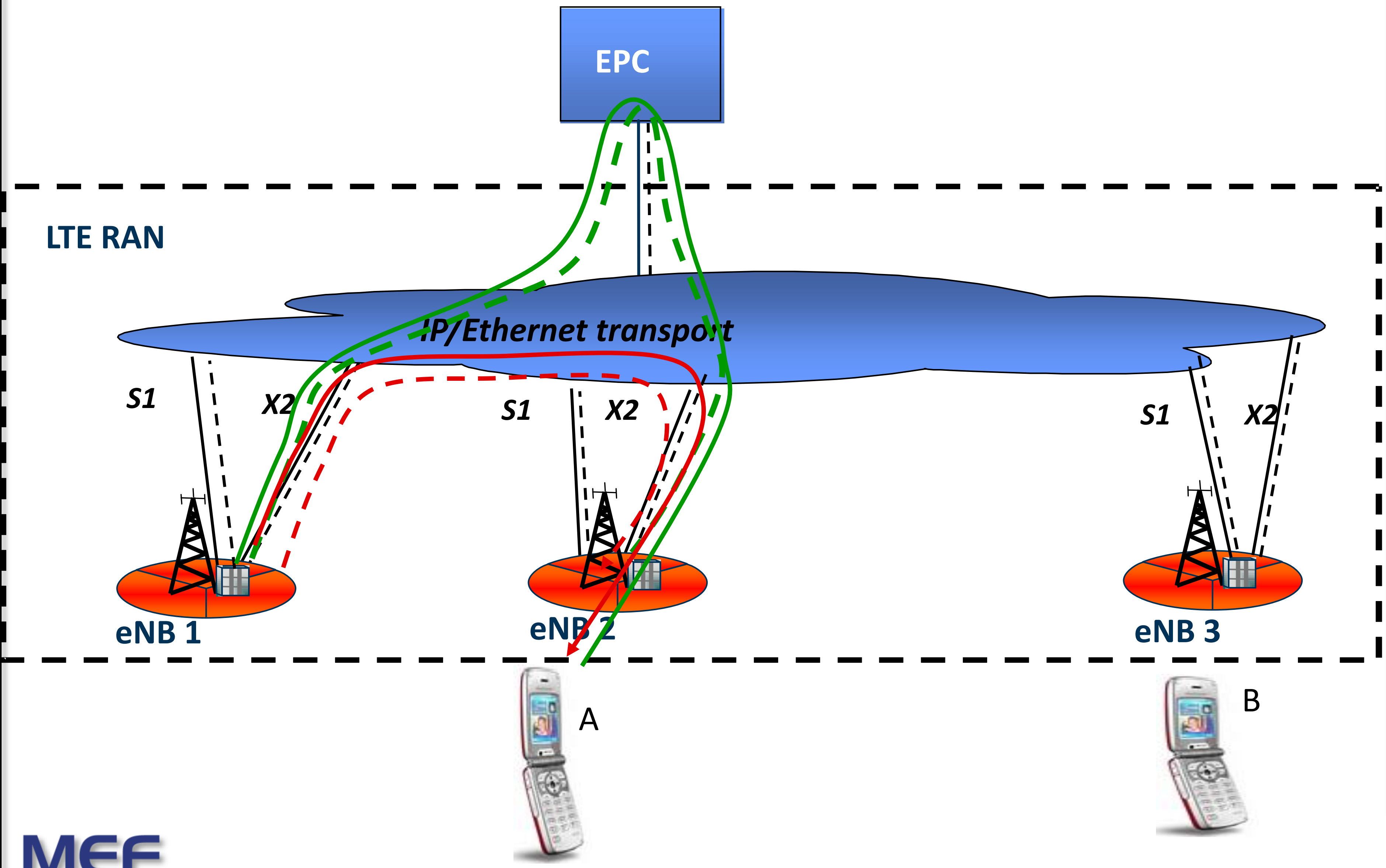


- **Handover between MMEs (MME pools)**
  - Via the S1 interface
  - User data:
    Packet forwarding (source → target),
    either via GW (in-direct) or direct



MEF

Where Should X2 Traffic be Turned?



1. **At the EPC site.**

   Advantage: May make network simpler, especially when IPsec is used in RAN

   Or

2. **Close to the base station, e.g., at the first common switching point.**

   Advantage: Lowest latency at handover when long transmission lines to the EPC site.

   Or

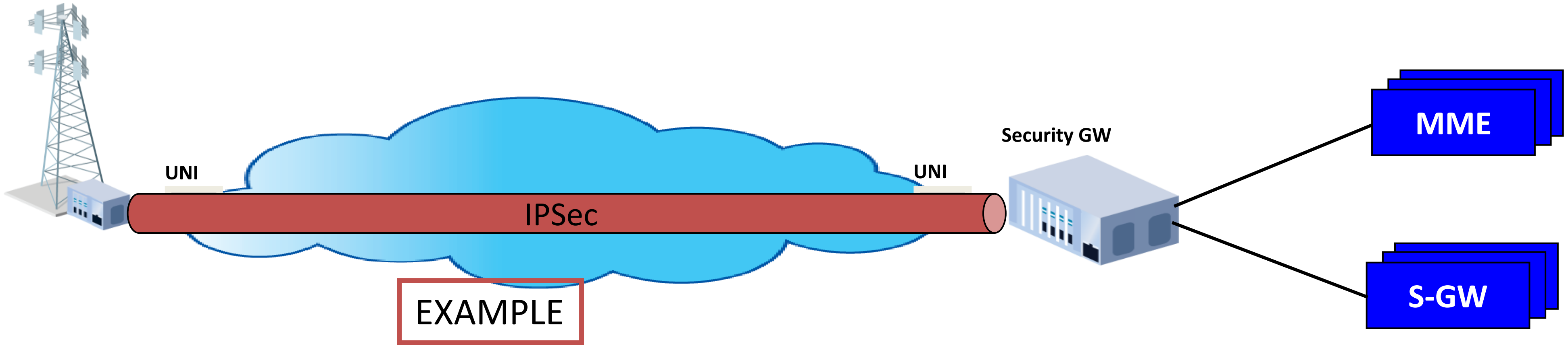
3. **Anywhere found feasible in between those two extremes.**

MEF

Security

Security

- **S1 and X2 traffic may be encrypted using IPSec**
  - Optional in 3GPP
- **Likely to be used in leased scenarios (untrusted domains)**
- **This will impact the network architecture and the connectivity between nodes depending on how the IPSec tunnels are configured**



QoS

QoS terms

- **QoS Class Identifier (QCI)**
  - A scalar that is used as a reference to node specific parameters that control packet forwarding treatment (e.g., scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.), and that have been pre-configured by the operator owning the access node
- **Allocation and Retention Priority (ARP)**
  - The primary purpose or ARP is to decide if a bearer establishment/modification request can be accepted or rejected in case or resource limitation
- **Guaranteed Bit Rate (GBR)**
- **Maximum Bit Rate (MBR)**
- **Service data flows (SDF) are specific packet flows identified by 5-tuple to a service requiring special treatment**
  - SDFs are mapped into EPS bearers at the UE (for UL) and at the PGW (for DL) via Traffic Flow Templates (TFT) which are a set of filter rules

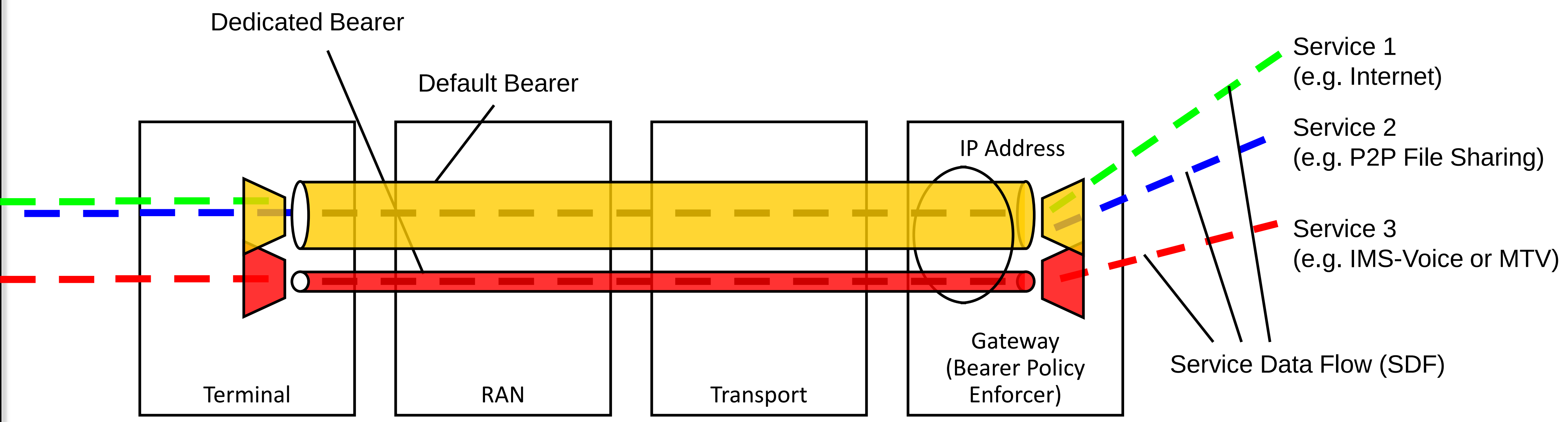
QCI + ARP + GBR + MBR

Service Data Flow (SDF)

MEF

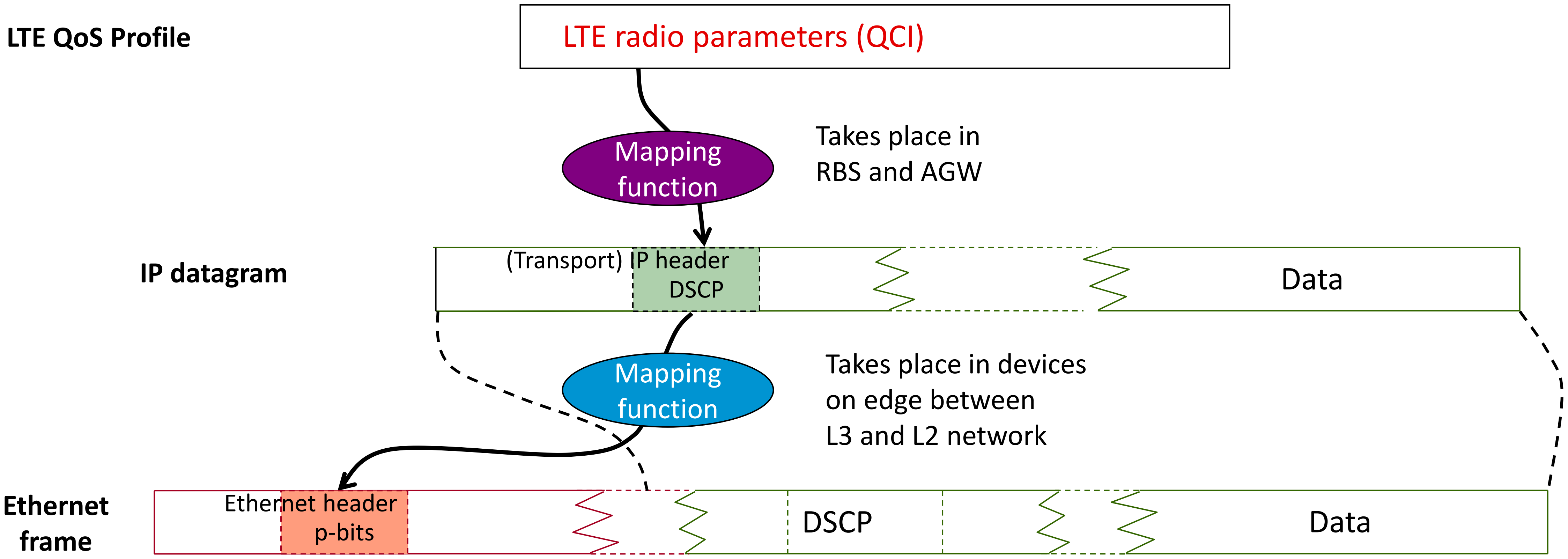
QoS in LTE/SAE

- **In RAN:**
  - Providing different services to/from one terminal means using one or more bearers
  - Bearers can be Non-GBR or GBR, have different characteristics
- **In Transport:**
  - All services with same QoS class are handled the same, regardless of how many terminals using that service



It must be ensured that a service is handled consistently from Terminal<->CN

LTE RAN QoS Mapping – RN to TN



- **DSCP (Diff Serv Code Point): Allows QoS differentiation between traffic types by scheduling, policing, shaping traffic (RFC 2475)**
- **Pbits (Priority Bits): Priority queuing, enabling some Ethernet frames to be forwarded ahead of others within a switched Ethernet network (IEEE 802.1P/D)**

Delay in the Backhaul

- **Higher level applications (e.g. TCP)1 set delay requirements**
  - Large latency on S1/X2=> lower end-user throughput, excessive retransmissions, slower rate increases, lower utilization on LTE RAN (backhaul and Uu interface)

- **“End-to-End” performance recommendations in 3GPP 23.203 v8.3.1**
  - Backhaul allocated subset of performance budget (20..50ms)
  - Switch/router delay close to wire-speed performance (< 0,1 ms) in a lightly loaded network
  - Fibre: typically 1 ms delay per 200km introduced

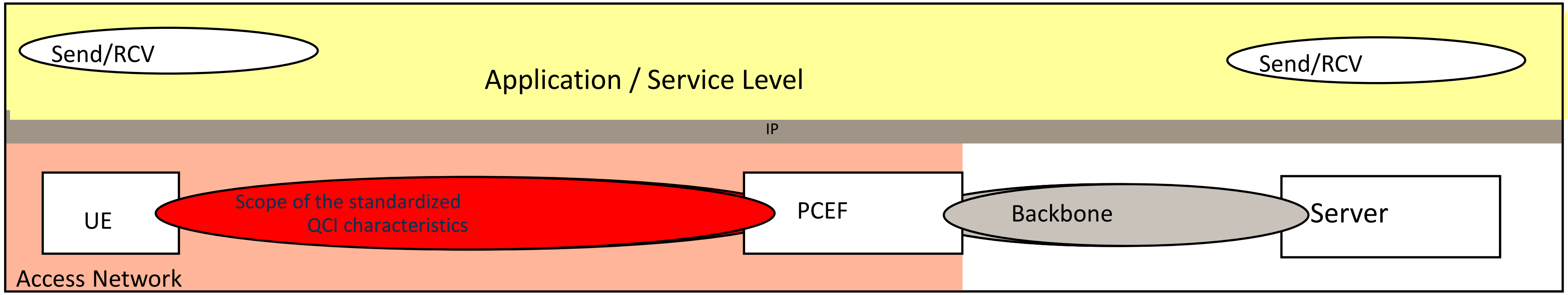
- **10ms user plane RTT target from 3GPP specs**
  - depends on UE processing delay, eNodeB processing delay
  - No backhaul involved!

Note 1: See RFC 1323 TCP Extensions for High Performance

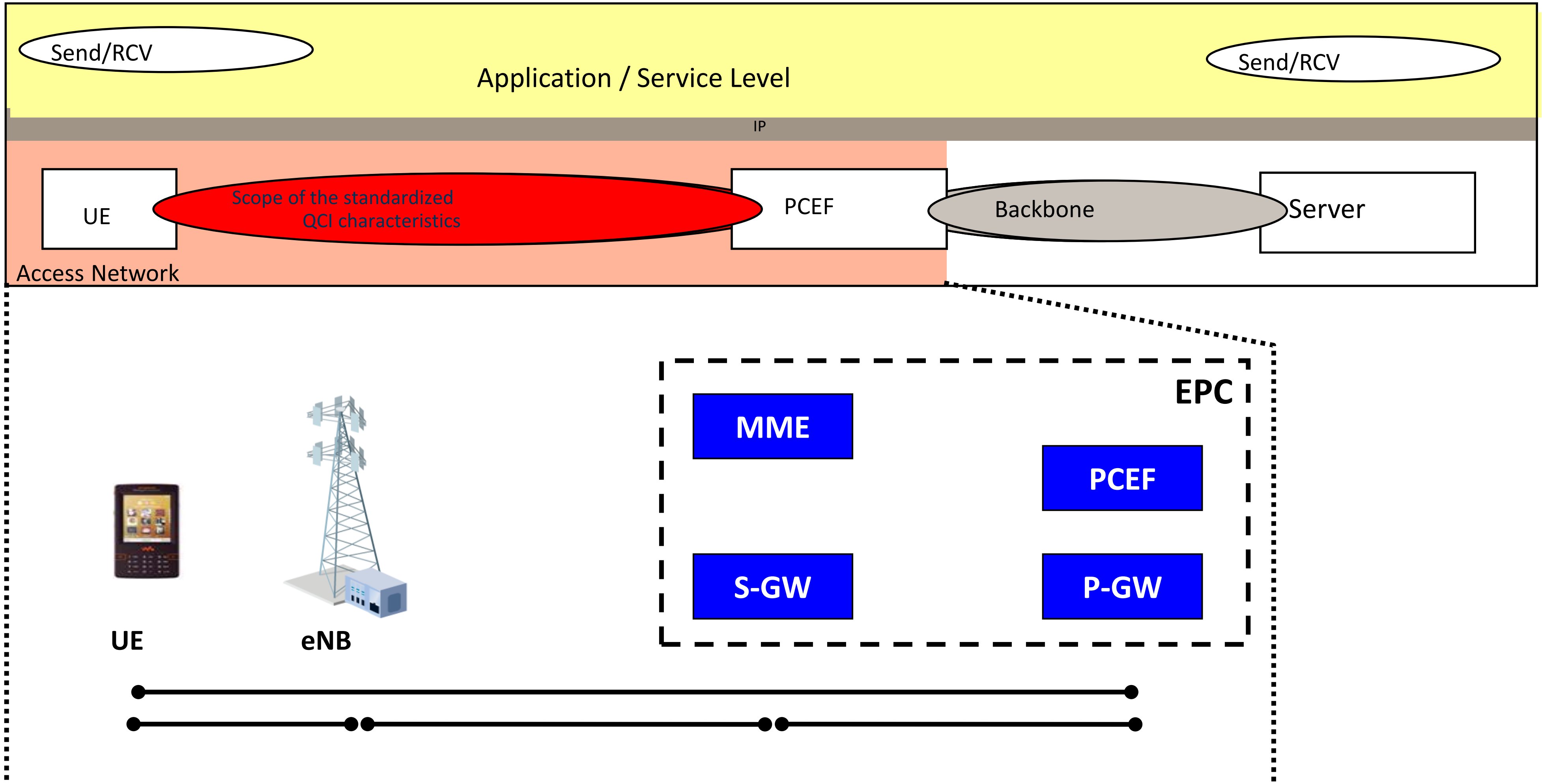
Extract from 3GPP TS 23.203 (Table 6.1.7)

Recommended QCI characteristics

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss	Example Services
1	GBR	2	100 ms	10-2	Conversational Voice
2		4	150 ms	10-3	Conversational Video (Live Streaming)
4		3	50 ms	10-3	Real Time Gaming
5	Non-GBR	1	100 ms	10-6	IMS Signalling
7		6	300 ms	10-6	Video (Buffered Streaming) TCP-based (e.g.www, e-mail, chat, ftp, p2p file sharing, progressive video, etc)
9		9			



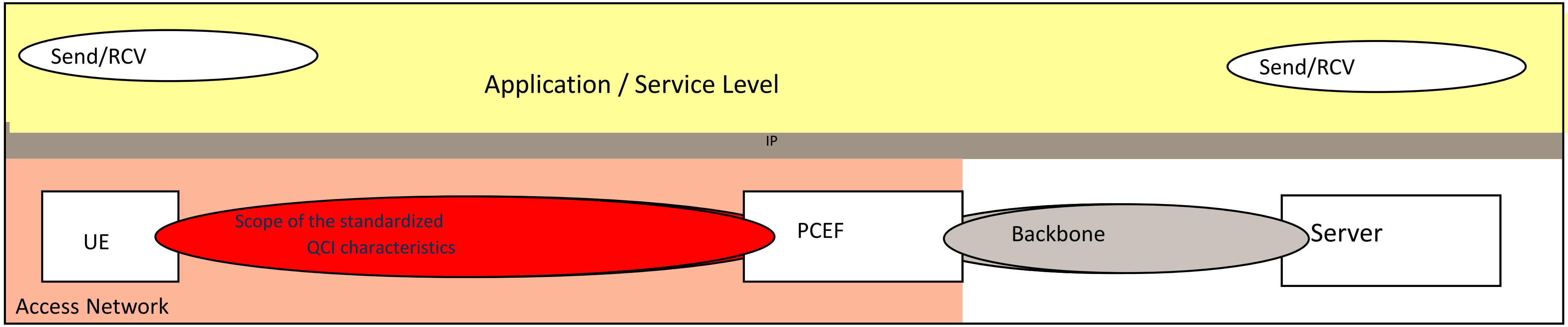
Look Closer at the Diagram, Between Which Nodes Do the Recommendations Apply?



Need to break down total budget and allocated part of it to each network domain between UE and PCEF

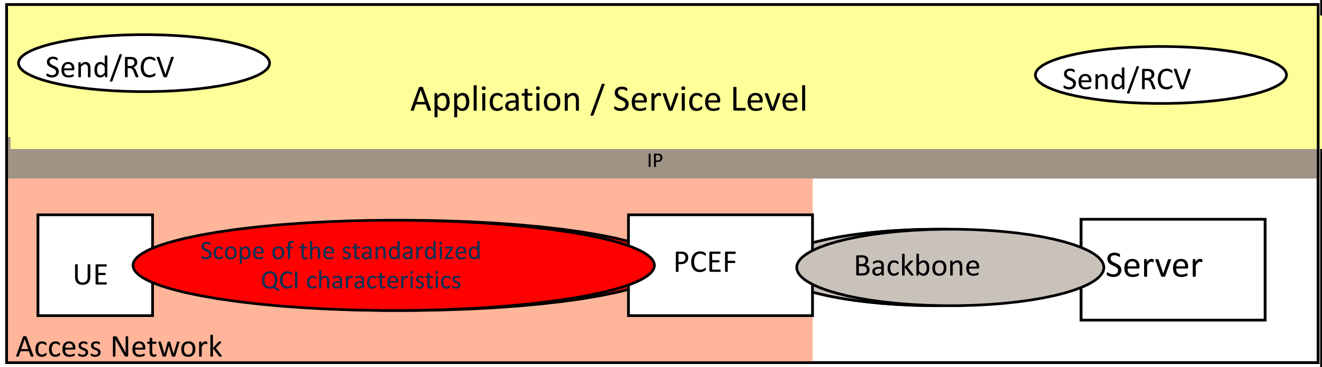
Packet Loss

- TCP: Application handles packet loss by temporarily reducing send rate by 50% for a packet loss (worse case) - after which the send rate will increase linearly until the next packet loss occurs or the maximum TCP rate is reached for outstanding data.
- E2E performance recommendations for packet loss specified in 3GPP 23.203 v8.3.1, ranges from $10^{-6}..10^{-2}$, depending on service type



3GPP Packet Delay Budget

- Guidelines for E2E characteristics to achieve good application performance experience by end user
- Packet Delay Budget => max one way delay between UE and PCEF[1] with confidence level of 98%
- eNodeB –PCEF ~= Total RAN backhaul delay[2]
- Assuming router/switch hops add delay of <0.1ms
- Assuming a 200km/ms propagation delay in fiber=> 10ms delay per 2000km
- One way delay UE-eNodeB =< 5ms (ideal radio conditions)



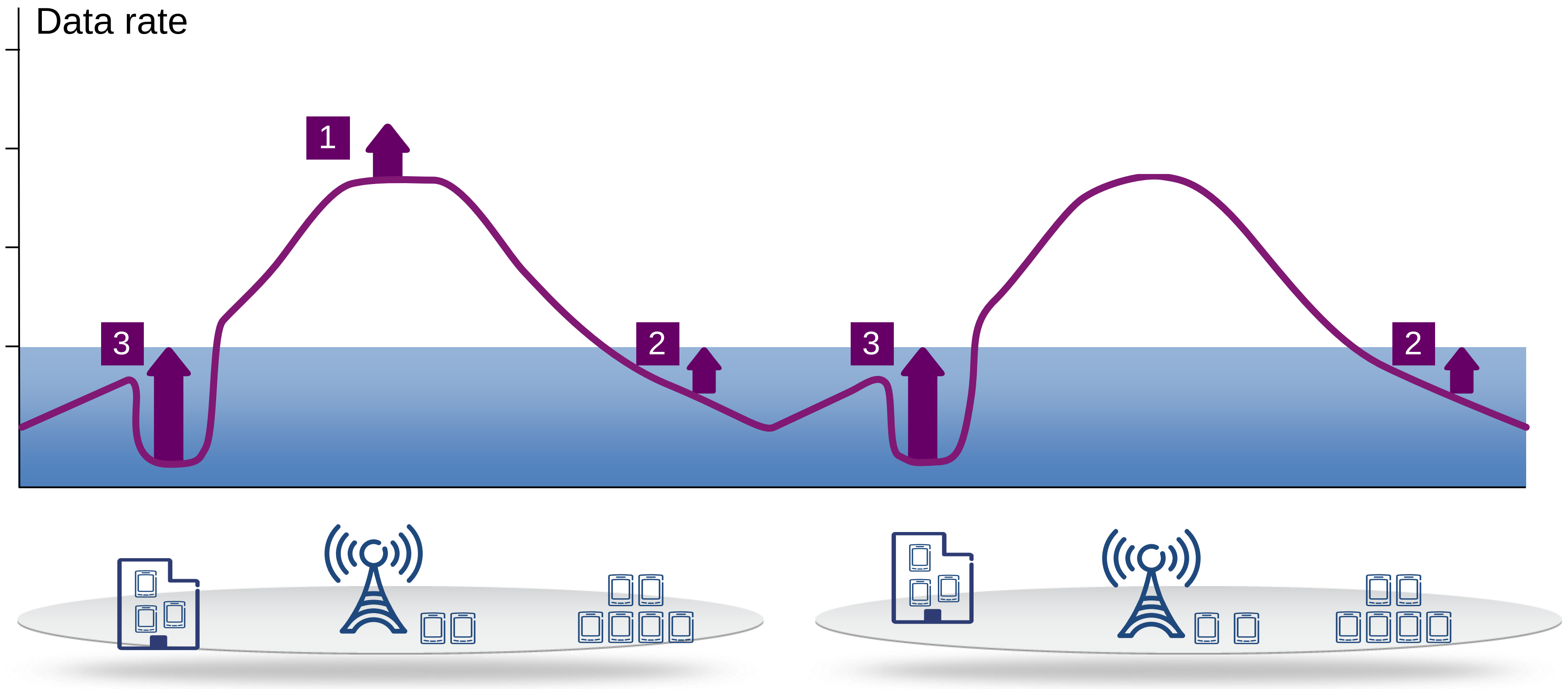
Note1: PCEF is an integrated part of the PDN GW

Note 2: For roaming cases, between 10..50ms is due to roaming, depending on whether national or international roaming where 50ms could be delay between Europe and U.S. West Coast

Background for MEF 22.2

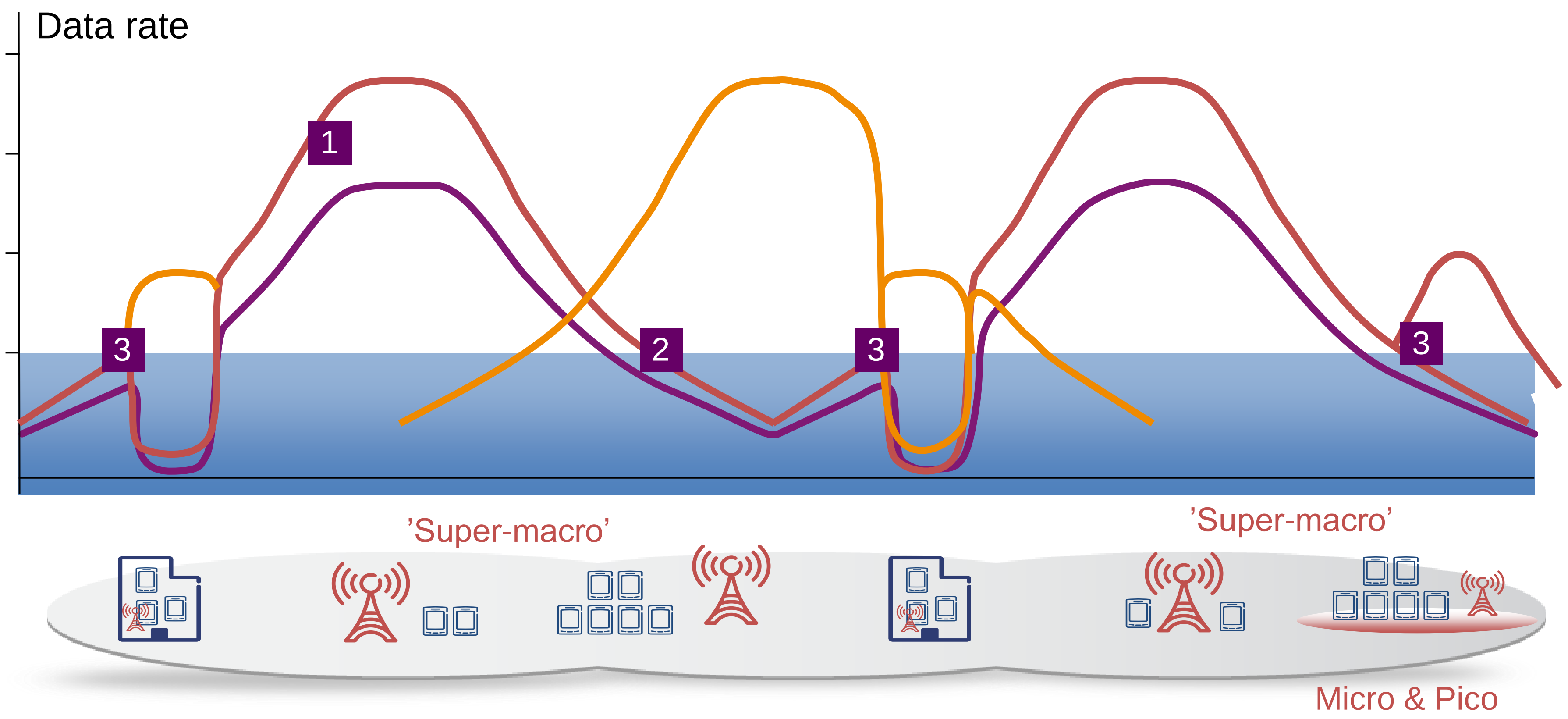
LTE/LTE-A Small Cells

End-user Experience Challenges



1. Increase overall cell site performance
2. Increase cell edge data rates
3. Increase indoor data rates

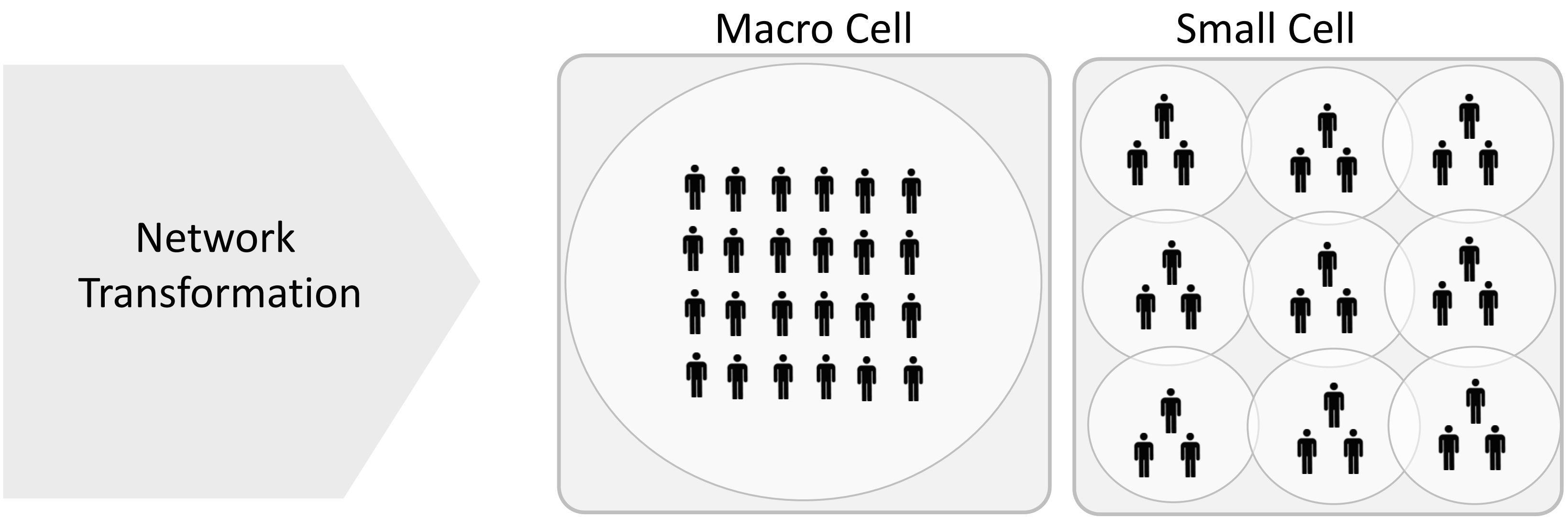
Increase Capacity and Coverage



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

MEF

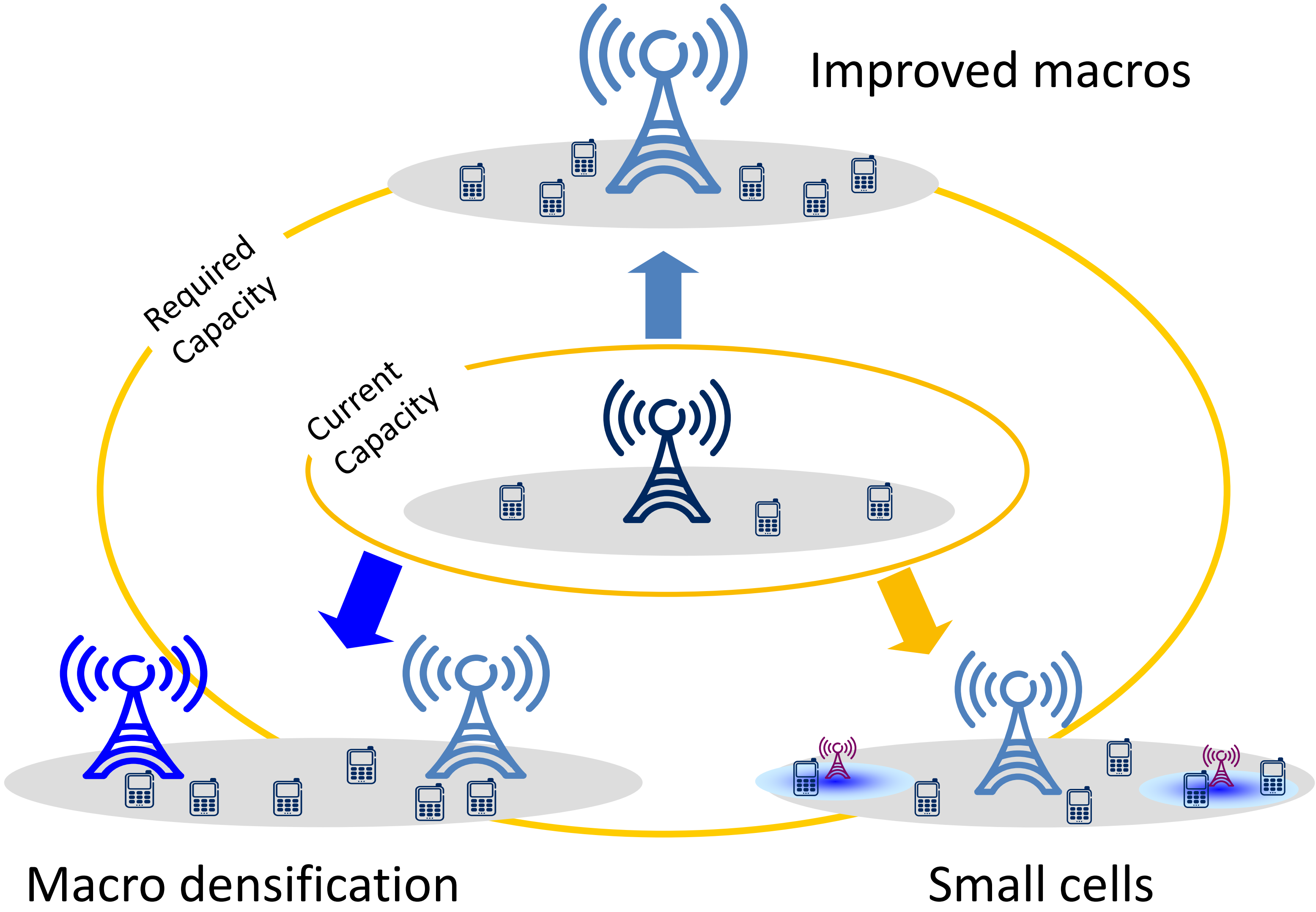
Increasing Network Capacity with Small Cells



Target capacity per cell	100 to 300 Mbps	25 to 100 Mbps
Cell density relative to macrocell	1	5 to 25
Total capacity	100 to 300 Mbps	125 Mbps to 2.5 Gbps
Indoor coverage	Poor	Good
Impact of SON / coordination	Low	High

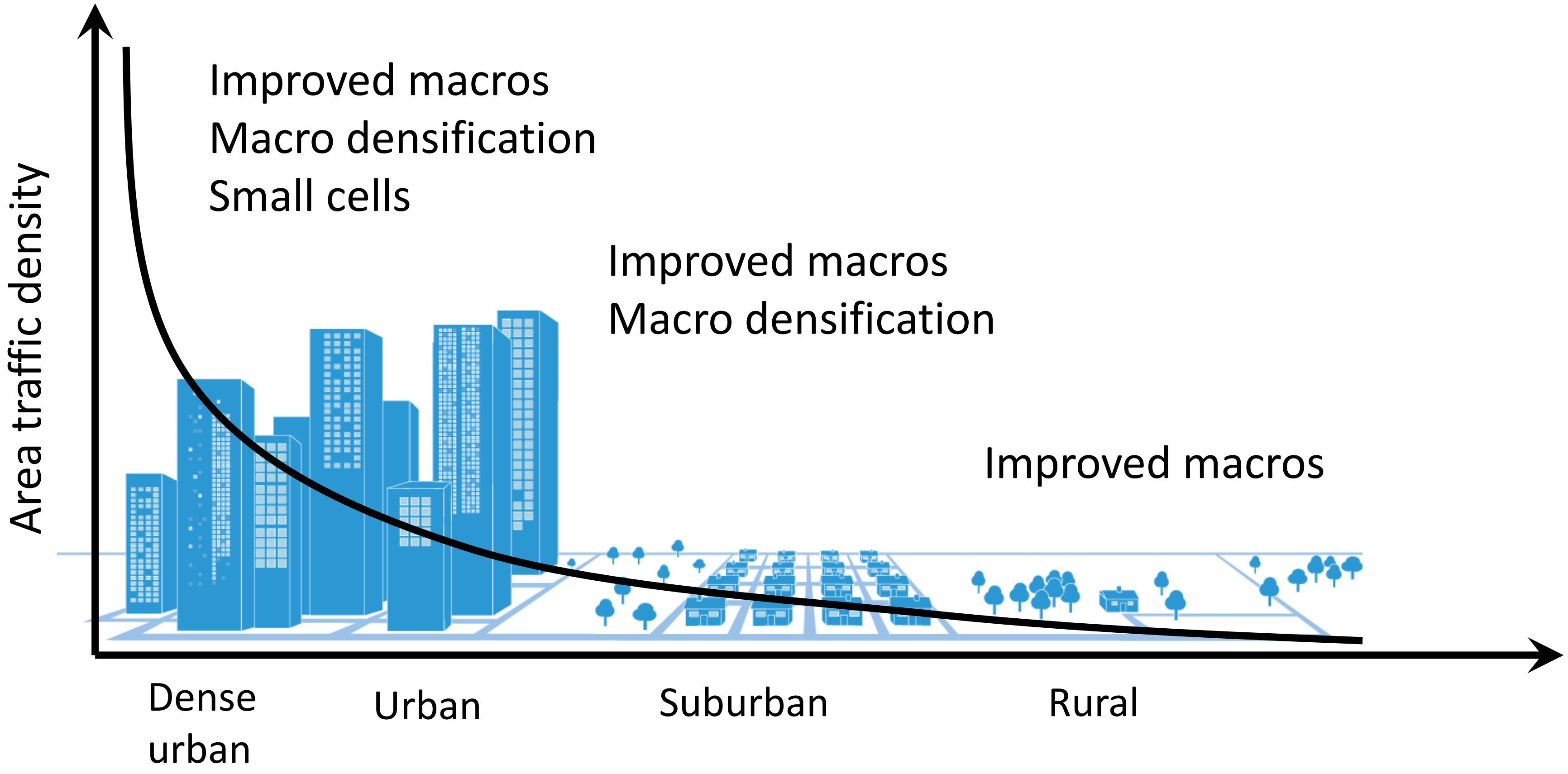
Small cells are best to meet the demand challenge

Heterogeneous Network



Heterogeneous Network Deployment

Small Cells advantage is greater in Metropolitan Areas
but also in other areas to increase coverage and/or capacity

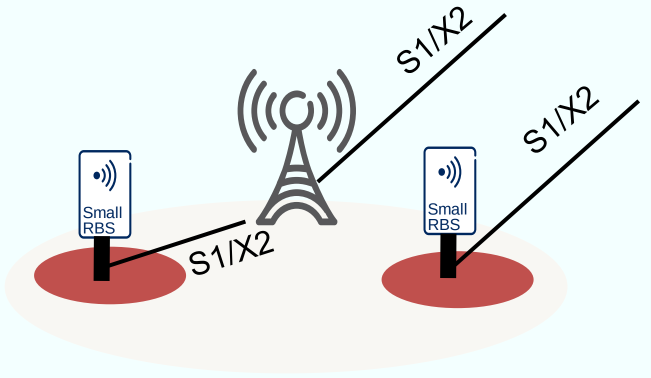


Small Cell Coordination

Small Cell Alternatives

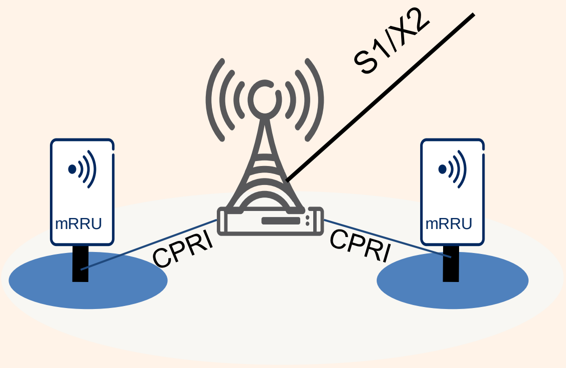
Distributed Baseband Architecture

- Backhaul – macro or small cell BS to core
- Midhaul – small cell to macro



Common Baseband Architecture

– Backhaul – macro BS to core
– Fronthaul - CPRI interconnect between remote radio units and baseband unit



Small cells are operator-controlled, low-powered radio access nodes, which typically have a range from 10 meters to several hundred meters. They may be a complete base station (distributed as on the left) or just the radio/antenna (common as on the right)

Small Cells and Radio Coordination

- **Improve uplink coverage**
  - i.e. cell edge throughput
- **Increase capacity**
  - Capacity improves as coverage improves
- **Offload congested macro cells**
- **Enhance quality by reducing the distance between the phone and the tower**
- **Why is Radio coordination needed?**
  - Interference coordination between macro and small cells will Boost coverage and capacity

Small cells improves coverage and capacity

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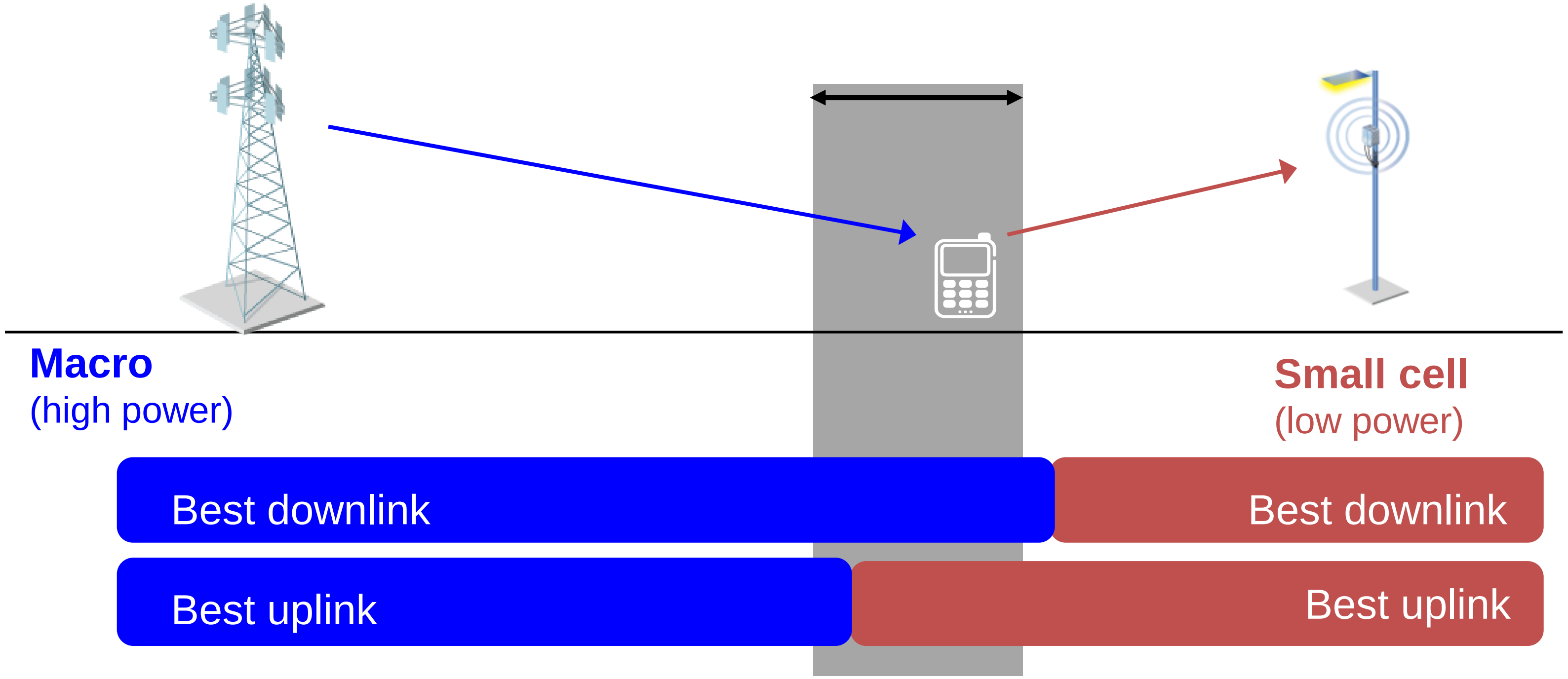
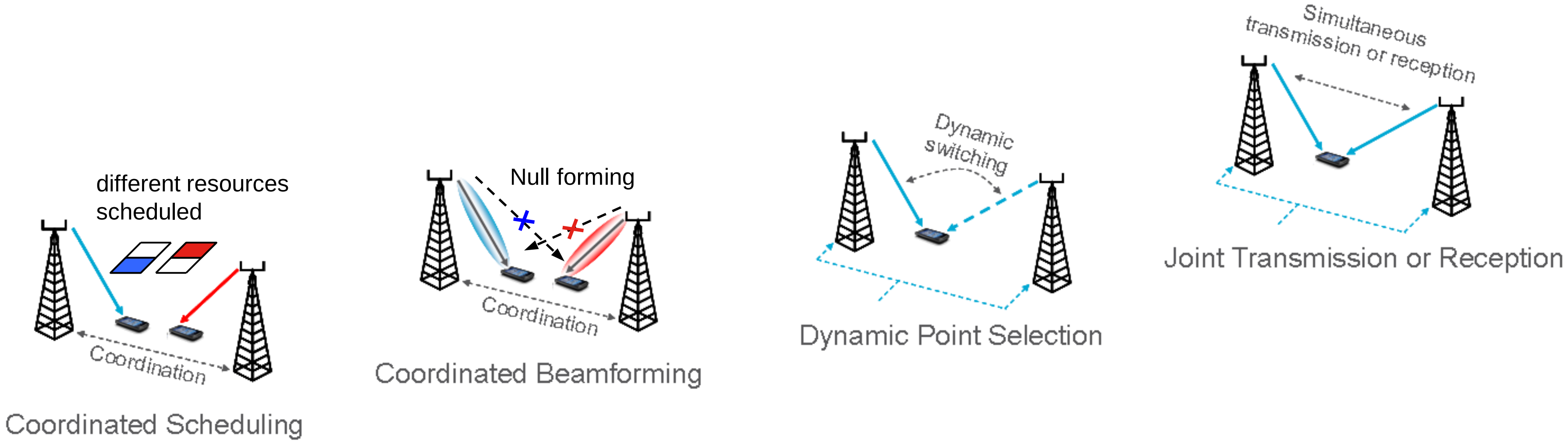
Interference Coordination

- **Small cells provide better cell-edge performance, particularly for the uplink, than macro cells**



What is CoMP?

- **Coordinated MultiPoint**
- **Multiple schemes and possibilities, often used in combination**
  - Coordinated scheduling
  - Coordinated beamforming (null forming)
  - Dynamic point selection
  - Joint transmission/reception
  - …



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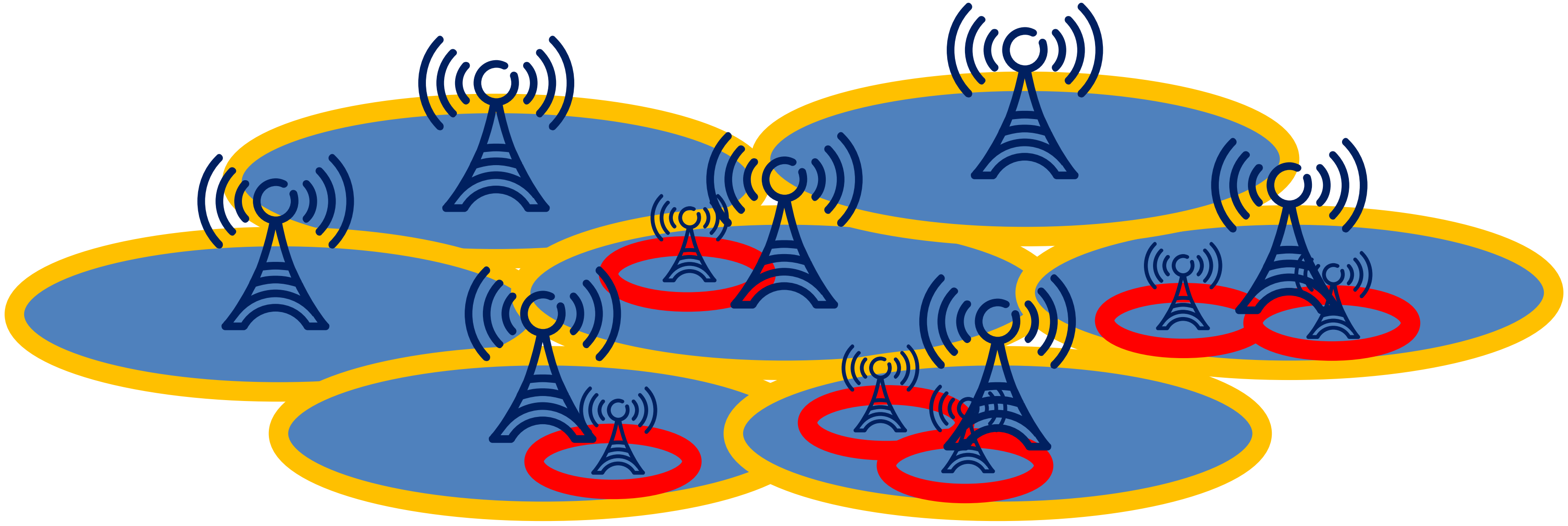
Where Are the CoMP Gains?

The majority of the uplink/downlink bandwidth gain is on the cell edge between the small cell and the macro it shares a footprint with



Blue	No CoMP Gain
Yellow	CoMP Bandwidth Gain: Uplink ~30-50%, Downlink ~15%
Red	CoMP Bandwidth Gain: Uplink ~50-100%, Downlink ~30%

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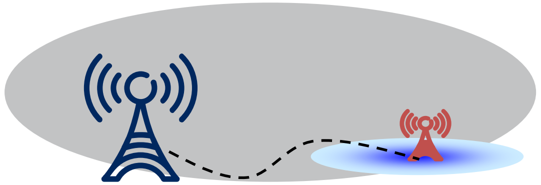
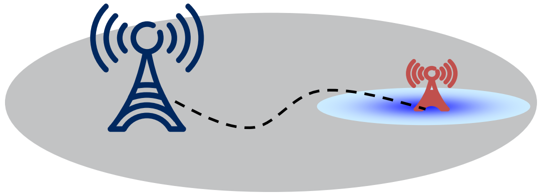
Different Degrees of Macro Cell Coordination

- **No coordination**
  - Example: uncoordinated deployment with femto cell in a macro network

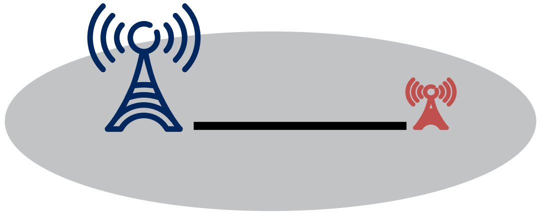
- **Moderate coordination**
  - Example: Coordinated deployment of pico cell in a macro network using range expansion or eICIC (enhanced Inter-Cell Interference Coordination)



- **Tight coordination**
  - Example: Coordinated deployment of pico cell in a macro network using features such as coordinated scheduling



- **Very tight coordination**
  - Example: DU/RU radio network using features such as joint scheduling (air interface) over CPRI (Common Public Radio Interface)



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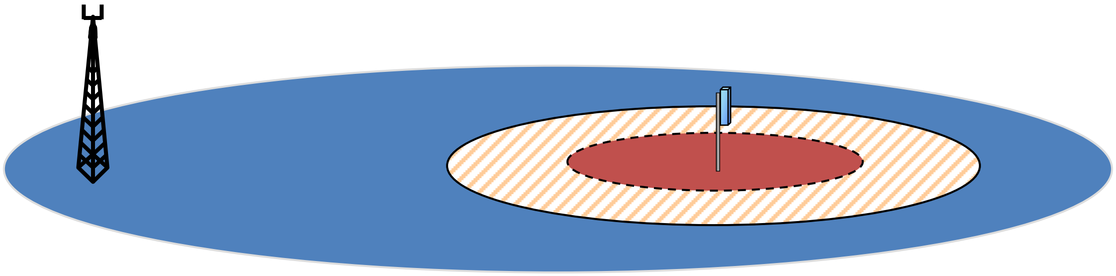
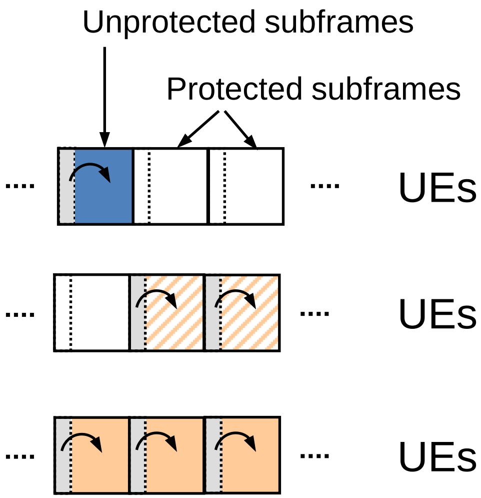
eICIC - Moderate Coordination

- **Macro cell avoids scheduling in "protected" subframes**
  - Capacity loss in macro layer and pico layer
  - Reduced interference from macro cell in "protected" subframes
- **Advanced Rx in Ue required for range expansion**
- **Cell size: Dense urban environment**
- **Time alignment: +/- 5us required between macro and small cell**
- **Latency: No special demands**
- **Bandwidth Needs: Low**





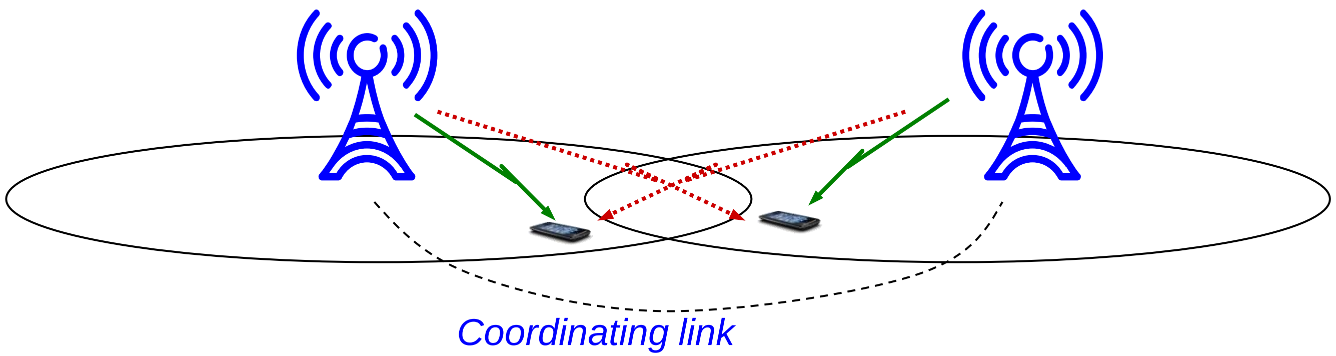
UEs in macro cell scheduled in non-protected subframes only

UEs in range expansion zone scheduled in protected subframes only

UEs in inner part of pico cell scheduled in any subframe

Time alignment is needed

DL Coordination Scheduling - Tight Coordination



- Down Link
- Share information.
- Based on received information, perform coordinated scheduling
- Cell size: Dense urban environment
- Time alignment: +/-1.5us required between macro and small cell
- Latency: 1..10ms – the lower the latency, the better the cell edge gain
- Bandwidth: Up to 20Mbps, per coordinated cell pair

Time alignment and low latency is needed

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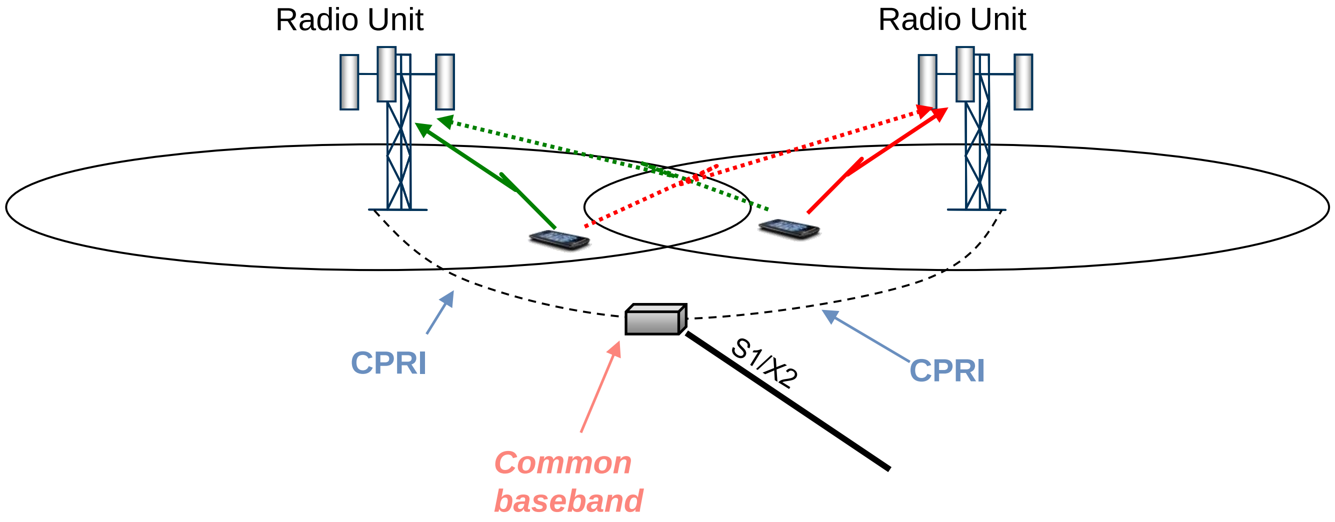
UL Joint Reception - Very Tight Coordination



- **Up Link - Schedule UEs.**
- **Receive transmitted data.**
- **Share received data and jointly process it (Communicate back ACK/NACK to BS responsible to certain UE.)**
- **Cell size: Dense urban environment**
- **Time alignment: +/-1.5us required between cells**
- **Latency: <0.5ms one way**
- **Bandwidth: 1Gbps per antenna, internal RBS interface**

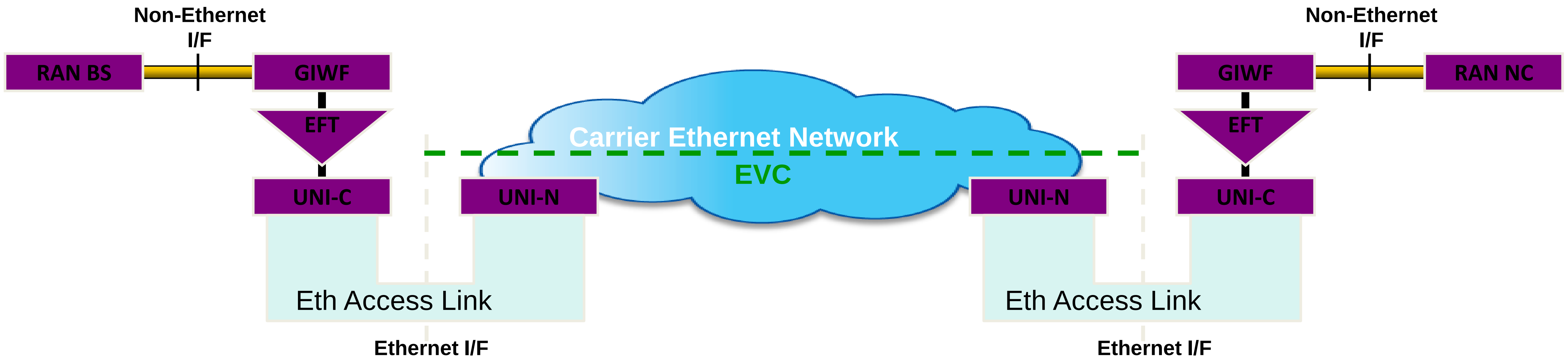
Time alignment, high bw & very low latency => baseband internal only

Time alignment, high bandwidth &very low latency is needed

Background: Migration from TDM

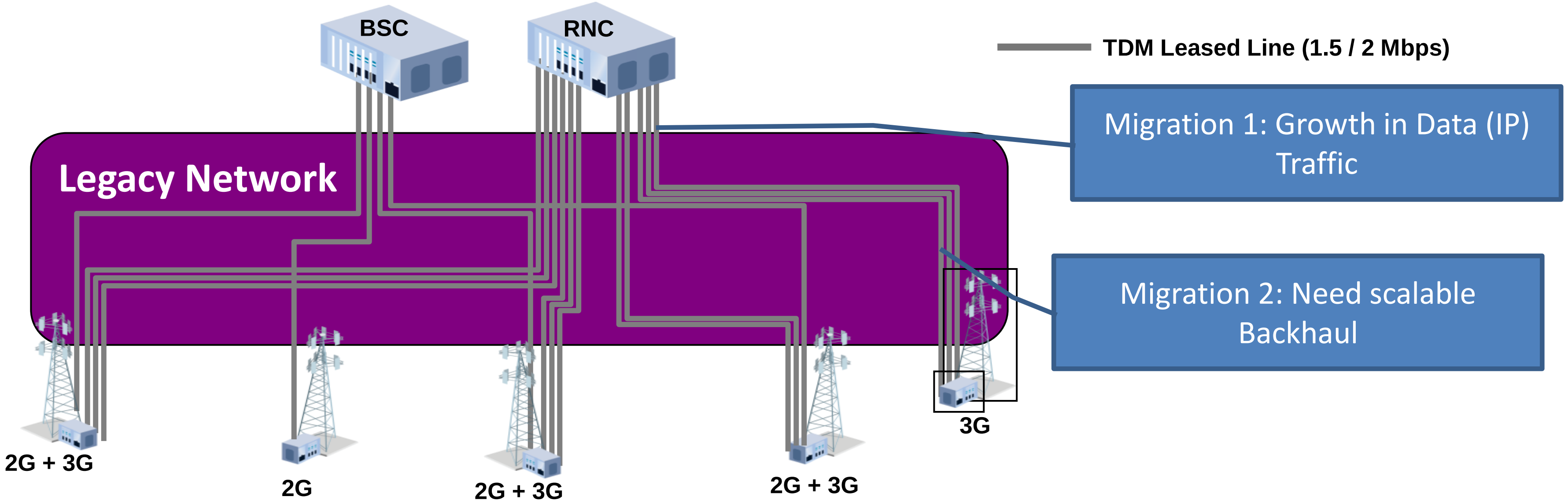
UNI for TDM-based Base Stations

- **Generic Interworking Function (GIWF)**
  - Adaptation and interconnection between legacy mobile equipment at the BS/NC and the Carrier Ethernet network at the UNI
  - Enables backhaul of any combination of 2G/3G legacy and Evolved-3G & 4G voice and data traffic over a single Carrier Ethernet RAN
  - Implementation based on TDM circuit emulation standards as well as ATM/HDLC pseudo-wire standards



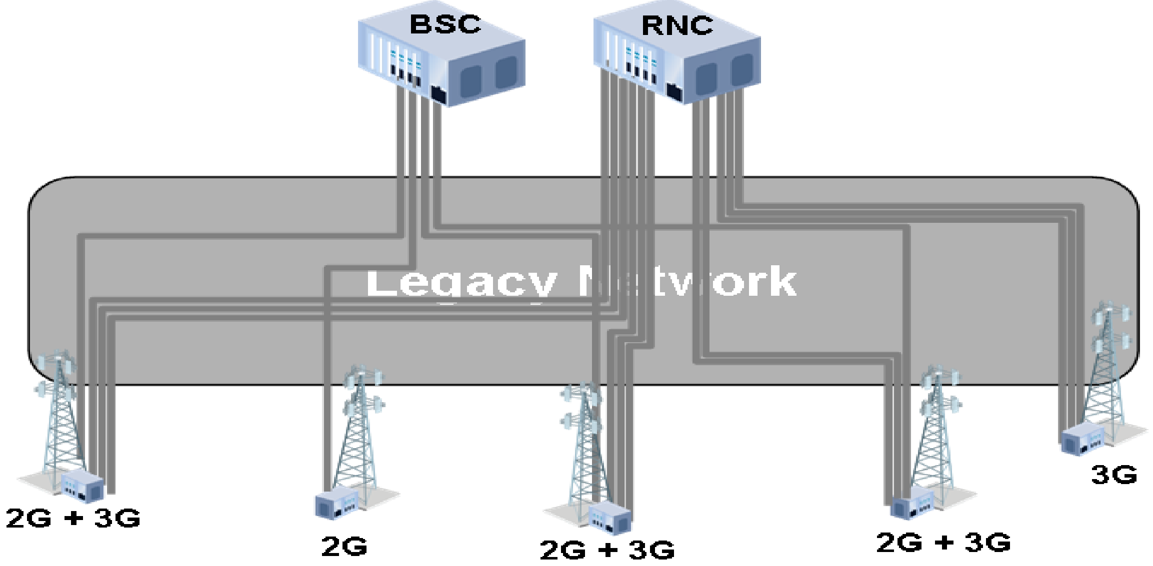
Use Case: Migration to 3G with Ethernet

- Mobile Operator operates 2G and 3G mobile networks
- RAN Base Station Sites with both 2G and 3G radios
- Frequency synchronization required – assume no GPS
- Mobile Operator has TDM leased Lines between BS and NC sites



Migration to 3G with Ethernet: Challenges

- **Problem:**
  - Capacity increase not cost-effective on TDM Leased Lines
- **Requirements**
  - Standard Services
  - Manageability
  - Reliability
  - Quality of Service
  - Synchronization
- **Solution:**
  - Carrier Ethernet Network
  - MEF 8 and 6.x Services

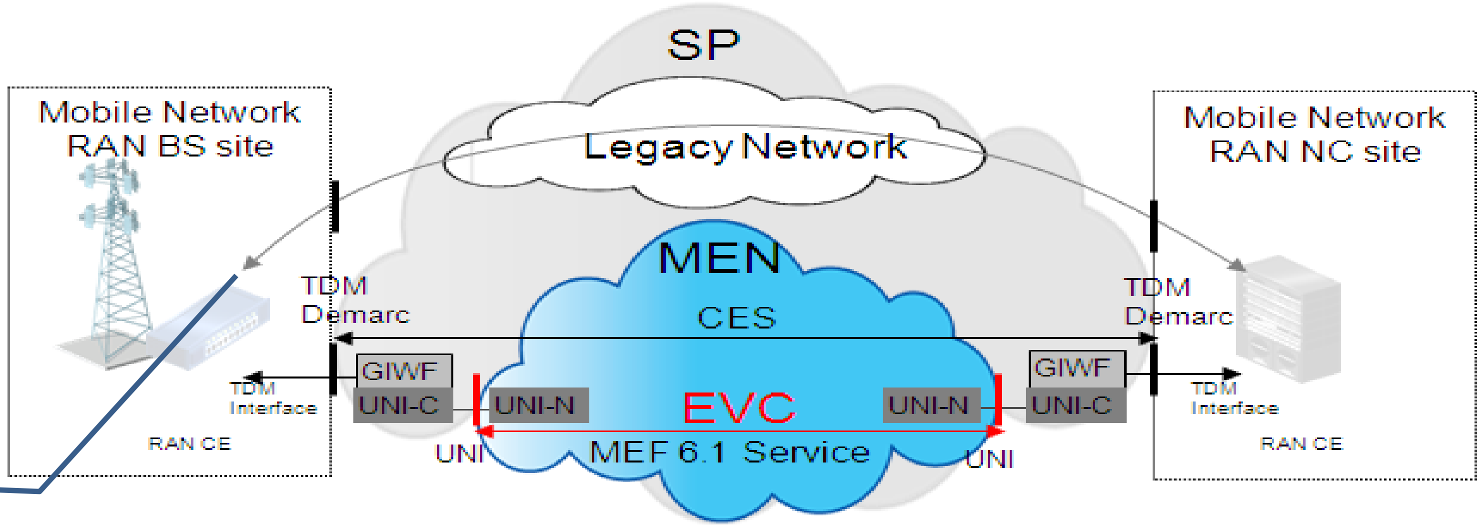


Mobile Backhaul for 2G Legacy RAN

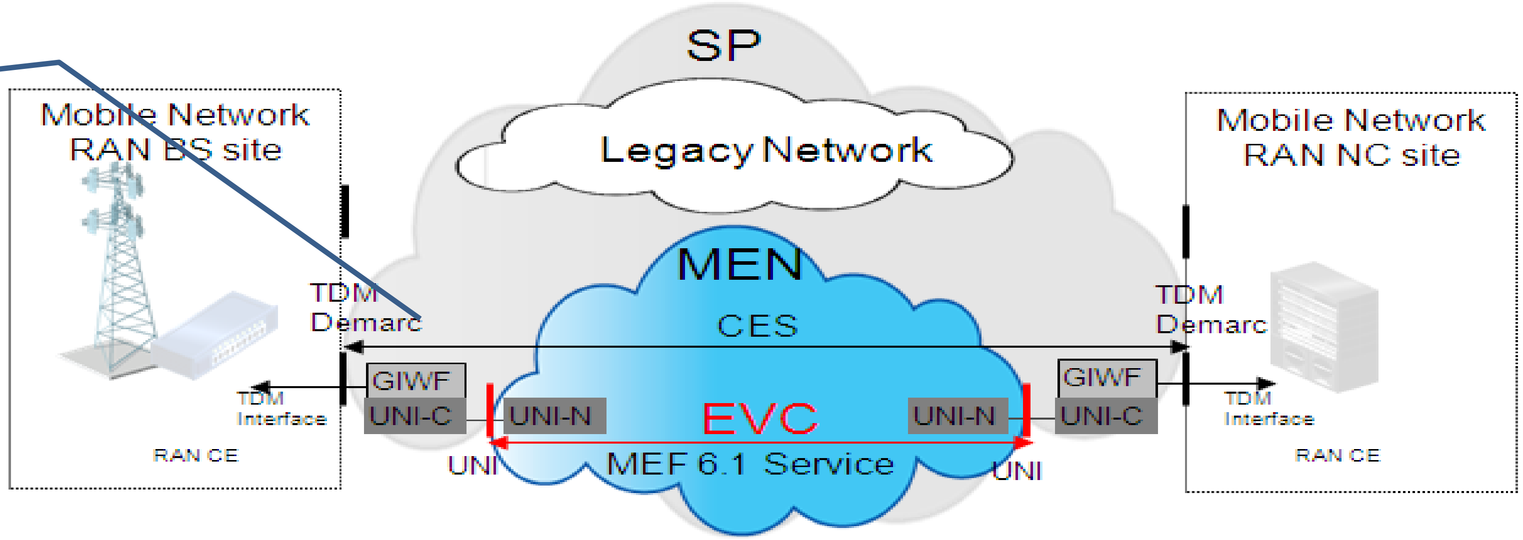
Use Case 1a:
RAN CEs with TDM interfaces

Packet offload with CES

Frequency Synchronization can be with TDM Physical method



Frequency Synchronization can be with ACR/Packet method



Use Case 1b:
RAN CEs with TDM interfaces

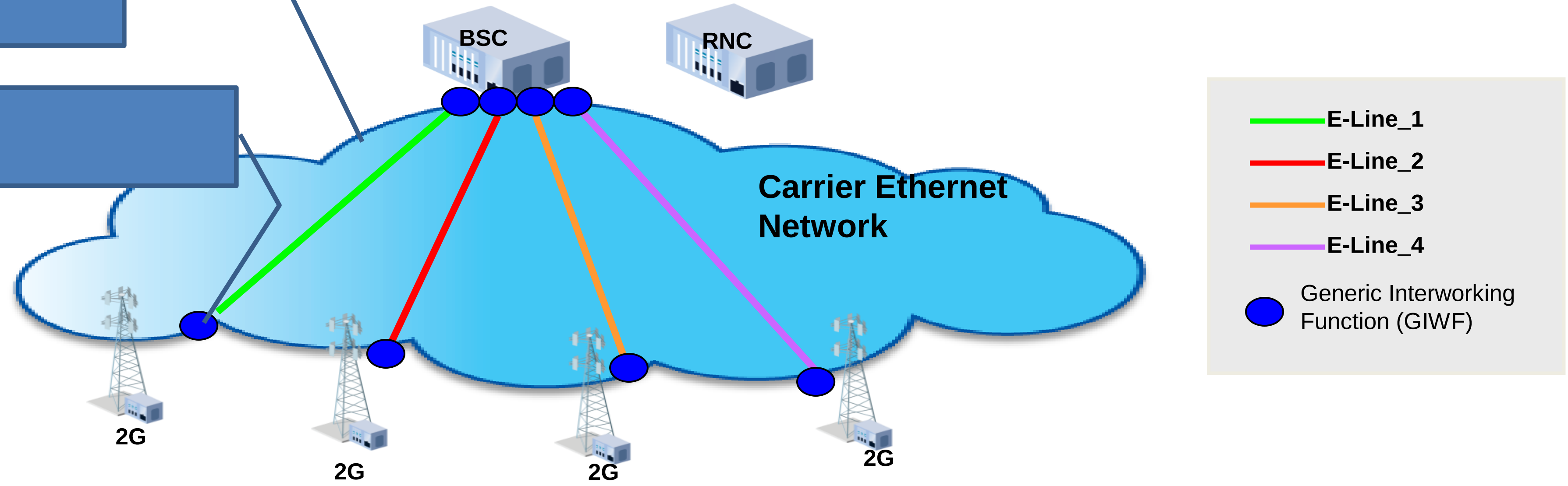
All traffic with CES across MEN

MEF EVC Services to Support CES

- **GIWF helps map legacy circuits**
- **E-Line (EPL) between GIWFs**
  - CIR>0, CBS>0 & EIR = 0, EBS=0 for guaranteed bit rate
  - Service Level Specification (SLS) in Service Level Agreement (SLA)
    - Frame Delay, Frame Delay Range, Frame Loss Ratio, Availability

CEN Operator to design network to match service requirements

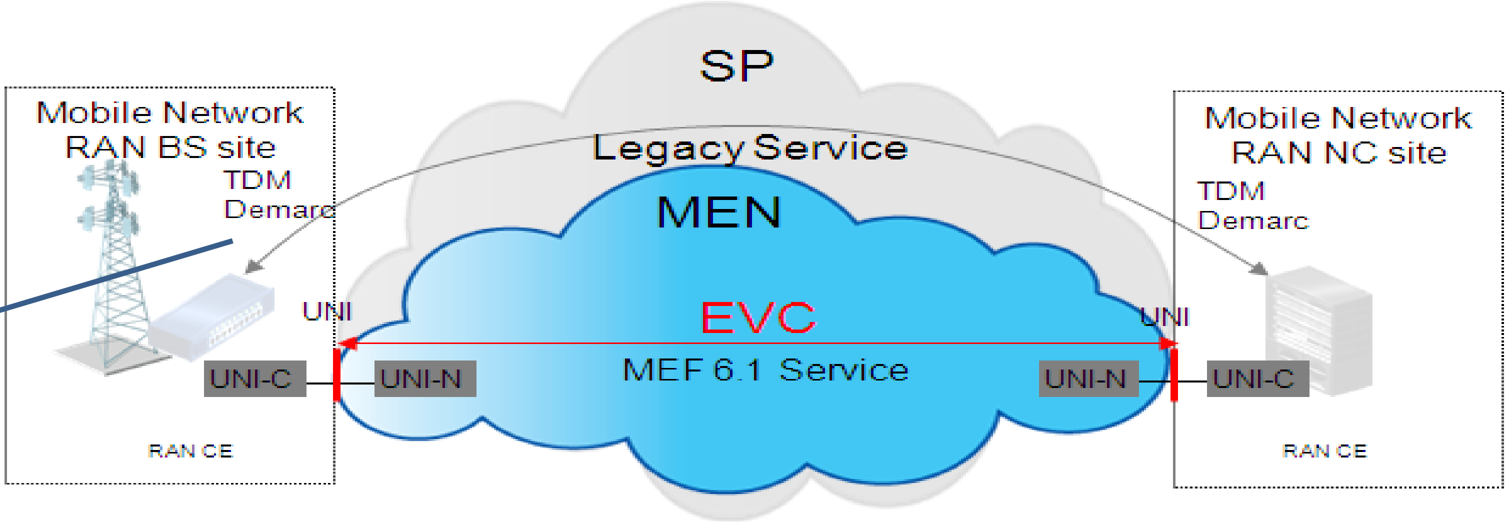
Frequency Synchronization
Interface Limits (Jitter/Wander) at UNI



Ethernet RAN Mobile Backhaul Migration

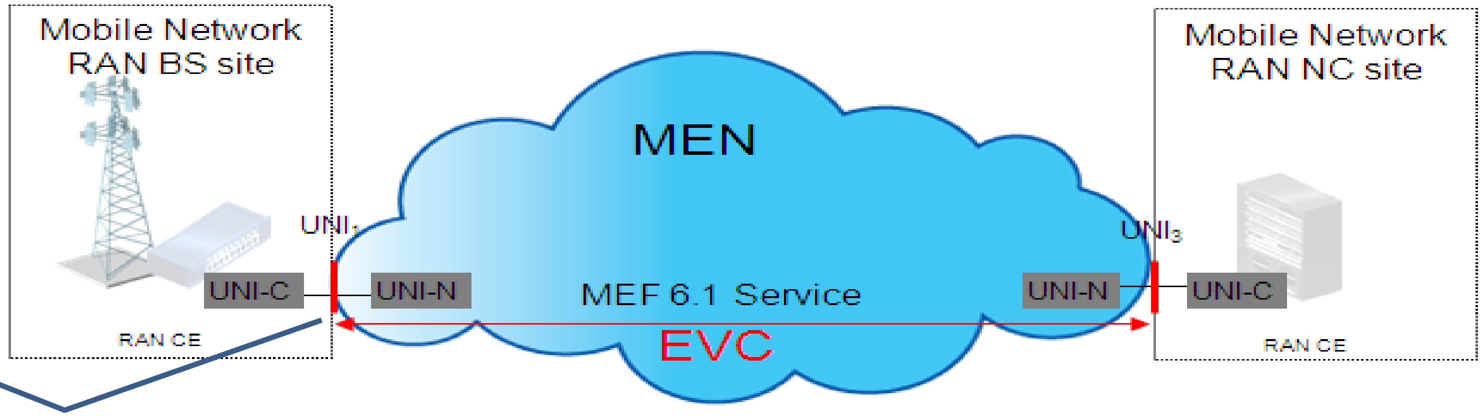
Use Case 2a
RAN CEs with TDM and Ethernet Interfaces

Frequency Synchronization can be with TDM service



Use Case 2b
RAN CEs with Ethernet Interfaces

Frequency Synchronization service from the MEN



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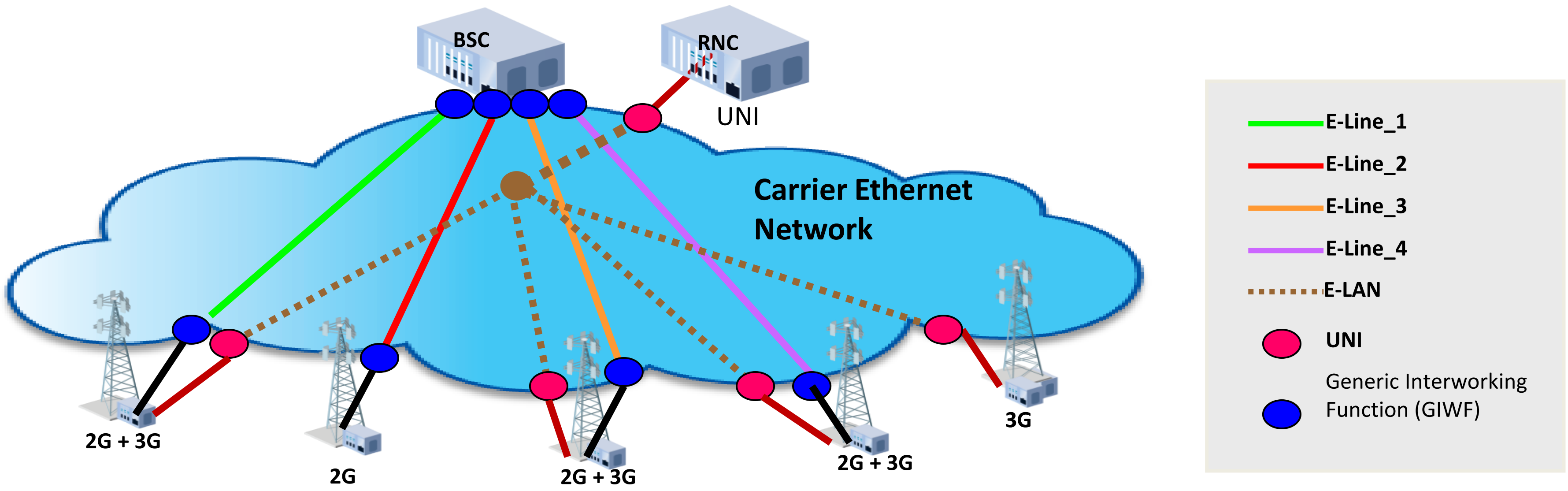
MEF Services for 3G RAN CEs

- **Mobile Operator has MEF Compliant UNIs on RAN CEs**
- **MEN Operator (as Service Provider) has MEF Compliant UNIs**
  - MEF Compliant UNIs for MEF Compliant MEF 6.x services
  - 1 or more Class of Service (CoS), e.g.. 3 CoS
  - Service Level Specification (SLS) in Service Level Agreement (SLA)



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Accelerating Worldwide Adoption of Carrier-class Ethernet Networks and Services

MEF.net