Implementation Agreement

MEF 22.1.1

Mobile Backhaul Phase 2
Amendment 1 – Small Cells

July 2014

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Introduction

This amendment makes the following changes to MEF 22.1 [12]:

1. Backhaul, Midhaul and Fronthaul are defined in section 3
2. Small Cells, along with heterogeneous networks and radio coordination, are introduced in section 4
3. Use case variations are added in section 7.2.7
4. A new use case 3 is defined in section 7.2.8 for the midhaul case
5. CPOs for small cells with tight radio coordination are described in section 11.5.3
6. CPOs for small cells with split bearer are described in section 11.5.4
7. A new Appendix A.1 defines the Aggregation Node
8. A new Appendix D summarizes LTE radio coordination
9. Error correction in Figure 30 of Appendix C.6

The new figures in this amendment are sequenced alphabetically. Amended figures from MEF 22.1 [12] are indicated numerically.

List of Contributing Members

The following members of the MEF participated in the development of this document and have requested to be included in this list.

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1. Abstract

This is an amendment to MEF 22.1 that addresses the addition of technical content that may be required in certain small cells use cases.

2. Terminology and Acronyms

This section defines the terms used in this document. In many cases, the normative definitions to terms are found in other documents. In these cases, the third column of the following table is used to provide the reference that is controlling, in other MEF or external documents.

Term	Definition	Reference/Source
3GPP	3rd Generation Partnership Project	3GPP TS 21.905 [19]
ABS	Almost Blank Subframes	
aGW	Access Gateway in WiMAXor LTE networks. Also referred to as Access Service Network (ASN) Gateway in Wimax and S-GW/MME in LTE. In this IA aGW is one of the options for a RAN NC	WMF-T32-001[27] NGMN Alliance [28]
CSAG	Cell Site Aggregation Gateway	This IA
Backhaul	**Backhaul**: The CEN between the RAN BS and the RAN NC	This IA
BBF	Broadband Forum	
CBS	Committed Burst Size	MEF 10.2 [4]
CIR	Committed Information Rate	MEF 10.2 [4]
CDMA	Code Division Multiple Access	TIA IS-2000.1 [18]
CE	Customer Edge	MEF 10.2 [4]
CE VLAN ID	Customer Edge Virtual LAN identifier	MEF 6.2
CEN	Carrier Ethernet Network (used interchangeably with Metro Ethernet Network, MEN). Also referred to as CEN Operator or CEN Service Provider. The entity providing the backhaul service for a Mobile Operator.	MEF 12.1 [7]
CES	Circuit Emulation Services	MEF 3 [1]
CHLI	Consecutive High Loss Intervals	MEF 10.2.1 [5]
CoMP	Coordinated Multipoint	
CoS ID	**Class of Service Identifier**. The mechanism and/or values of the parameters in the mechanism to be used to identify the CoS Name that applies to the frame at a given External Interface (EI). See MEF 23.1 for options.	MEF 23.1[12] MEF 10.2 [4]
CoS Label	**Class of Service Label:** A CoS Name that is standardized in MEF 23.1. Each CoS Label identifies four Performance Tiers where each Performance Tier contains a set of performance objectives and associated parameters.	MEF 23.1[12]
CoS Name	**Class of Service Name:** A designation given to one or more sets of performance objectives and associated parameters by the Service Provider or Operator.	MEF 23.1 [12]
CPO	**CoS Performance Objective.** An objective for a given performance metric	MEF 23.1[12]
CPRI	Common Public Radio Interface	
CSG	Cell Site Gateway	BBF TR-221
DL	Down Link	
EBS	Excess Burst Size	MEF 10.2 [4]
EC	Ethernet Connection	MEF 12.1 [7]
EIR	Excess Information Rate	MEF 10.2 [4]
eNB	Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B is the Radio Base Station in LTE. Also referred to as eNodeB or eNB. In this IA an eNodeB is one of the options for a RAN BS	3GPP TS 36.300 [20]
EVC	Ethernet Virtual Connection	MEF 10.2 [4]
EICIC	Enhanced inter-cell interference coordination	3GPP TS36.133
FDD	Frequency Division Duplexing	
FD	Frame Delay	MEF 10.2 [4]

Term	Definition	Reference/Source
FDR	**Frame Delay Range.** The difference between the observed percentile of delay at a target percentile and the observed minimum delay for the set of frames in time interval T.	Adapted from MEF 10.2 [4] MEF 23.1[12]
FDV	Frame Delay Variation	MEF 10.2 [4]
FLR	Frame Loss Ratio	MEF 10.2 [4]
Fronthaul	**Fronthaul**: A connection from the RAN BS site to a remote radio unit. Typically the connection is for transport of CPRI.	This IA
GIWF	Generic Inter-working Function	This IA
GSM	Global System for Mobile communication	GSM 01.04 [17]
GNSS	Global Navigation Satellite System	
GPS	Global Positioning System	
HetNet	Heterogeneous Networks	
HLI	High Loss Interval	MEF 10.2.1[5]
IA	Implementation Agreement	This IA
IFDV	Inter Frame Delay Variation	MEF 10.2 [4]
ICIC	Inter-cell interference coordination	3GPP TS36.133
IP	Internet Protocol. IPv4 is for version 4 (RFC 791) and IPv6 is for version 6 (RFC 2460)	RFC 791 [24] RFC 2460 [26]
LTE-A	Long Term Evolution –Advanced	3GPP TS 36.300 [20]
LTE	Long Term Evolution	3GPP TS 36.300 [20]
MASG	Mobile aggregation site gateway	BBF TR-221
MBH	Mobile Backhaul	This IA
MFD	Mean Frame Delay	MEF 10.2 [4]
MME	Mobility Management Entity is an LTE function and located in the Mobile core network (site). In this IA MME is included when referring to a RAN NC	3GPP TS 36.300 [20]
Midhaul	**Midhaul**: The CEN between RAN BS sites. Typically one of these sites would be a macro RAN BS site.	This IA
Mobile Operator	The entity obtaining the Backhaul service from a SP or CENOperator. Also referred to as Subscriber in this IA	This IA
MTU	Maximum Transmission Unit	MEF 10.2 [4]
N/S	Not specified	This IA
NodeB	WCDMA Radio Base Station. In this IA a NodeB is one of the options for a RAN BS	3GPP TS 21.905 [19]
OFDM	Orthogonal frequency-division multiplexing	
OAM	Operations, Administration, and Maintenance	MEF 17 [9]
PCEF	Policy and Charging Enforcement Function	3GPP TS 23.203
PCP	Priority Code Point	IEEE 802.1Q-2005 [13]
PDH	Plesiochronous Digital Hierarchy	ITU-T G.705 [16]
PT	Performance Tier for CoS Performance Objective. The MEF CoS IA defines different PTs.	MEF 23.1[12]
PTP	Precision Time Protocol	IEEE 1588™-2008 [14]
RAN	Radio Access Network	3GPP TS 36.300 [20]
RAN BS	RAN Base Station	This IA
RAN CE	RAN Customer Edge	This IA
RAN NC	RAN Network Controller	This IA
RBS	Radio Base Station defined in this IA and referred generally as Base Station in 3GPP TS 21.905	This IA

Term	Definition	Reference/Source
RNC	Radio Network Controller	3GPP TS 21.905 [19]
RPS	Reduced Power Subframes	
S-GW	Serving Gateway is an LTE function and located at the Mobile core network (site). In this IA S-GW is one of the options for RAN NC	3GPP TS 36.300 [20]
SLA	Service Level Agreement	MEF 10.2 [4]
SLS	Service Level Specification	MEF 10.2 [4]
Small Cell	**Small Cell**: operator-controlled, low-powered radio access nodes, which typically have a range from 10 metres to several hundred metres	SCF [89]
SP	Service Provider. The organization providing Mobile Backhaul Service to a Mobile Operator.	This IA
Subscriber	The organization purchasing Ethernet Service from a SP. In this IA this refers to the Mobile Operator.	MEF 10.2 [4]
TDD	Time Division Duplexing	
UE	User Equipment	
UL	Up Link	
UNI	User Network Interface as the physical demarcation point between the responsibility of the Service Provider (CEN Operator) and the responsibility of the Subscriber (Mobile Operator)	MEF 4 [2] MEF 10.2 [4]
UNI-C	The ETH sub-layer functional components of UNI that is managed by the Subscriber (Mobile Operator), i.e., at the BS and NC sites.	MEF 4 [2] MEF 11 [6] MEF 12.1 [7]
UNI-N	The ETH sub-layer functional components of UNI that is managed by the SP (CEN Operator).	MEF 4 [2] MEF 11 [6] MEF 12.1 [7]
VLAN	Virtual LAN	MEF 10.2 [4] IEEE 802.1Q-2005 [13]
WCDMA	Wideband Code Division Multiple Access	3GPP TS 21.905[19]
WiMAX	Worldwide Interoperability for Microwave Access	WMF-T32-001[27]
WLAN	Wireless Local Area Network (aka IEEE Std. 802.11)	

Table A: Terminology and Acronyms

3. Introduction

Note: This amendment replaces the second paragraph with the text below

This Implementation Agreement uses the term Mobile Backhaul to refer to the network between the Base Station sites and the Network Controller/Gateway sites for all generation of Mobile Technologies. Additionally, this IA introduces a variant of Mobile Backhaul termed Midhaul that refers to the network between basestation sites (especially when one site is a small cell site). It is useful to also use the term Fronthaul to refer to the intra-basestation transport -- that is between the baseband unit and radio unit. These terms are shown in Figure A. The NGMN Alliance [28] defines Backhaul Solution for LTE and Wimax as including the transport module in the base station (e.g. eNB in LTE or Base Station in Wimax) to the transport module in the controller (aGW). When the transport modules in the eNB or aGW also support MEF's UNI-C functions then the NGMN Alliance's definition of Backhaul is equivalent in scope to MEF's UNI-C to UNI-C Subscriber EC (MEF 12.1[7]) and this IA's Mobile Backhaul. In some cases, MEF UNI-C might be supported on co-located platforms owned by the Mobile Operator (e.g., cell site gateway router) instead of on the eNB or aGW. This case is in scope for this IA thus making this IA's Mobile Backhaul scope different from the NGMN Alliance's definition of Backhaul. In Broadband Forum TR-221[23], Mobile Backhaul, these platforms are identified as a cell site gateway (CSG) and a mobile aggregation site gateway (MASG) and have scope limited to the case where they are MPLS PEs and exclude CES over Ethernet. BBF TR-221[23] does not explicitly provide the case for Mobile Operator owned CSG or MASG providing aggregation and UNI-C, but it is not excluded.

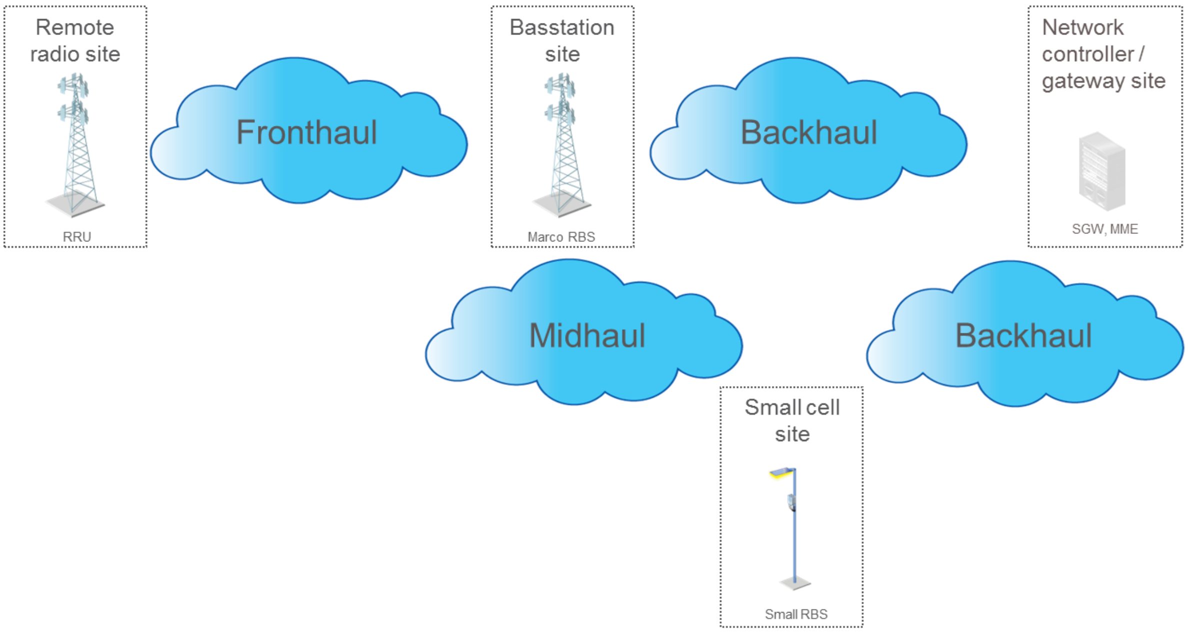

Figure A: Mobile Backhaul, Midhaul and Fronthaul (see 7.2.8)

4. Mobile Network Topologies

Note: This amendment adds subsection 4.1 Small Cell / Heterogeneous Networks and 4.2 Aggregation Node .

4.1 Small Cell / Heterogeneous Networks

The Small Cell Forum notes that 'small cell' is an umbrella term for operator-controlled, low-powered radio access nodes, which typically have a range from 10 metres to several hundred metres [28] . These contrast with a typical mobile macrocell that might have a range of up to several tens of kilometres. For the purposes of this IA, we introduce a classification of small cells based on the type of backhaul. The following types of small cells are envisioned:

1. Femto: Backhaul is for the femto interfaces, and via an untrusted backhaul to a centralized Security Gateway and Femto gateway. The mobile RAN loses visibility of the user device when the device connects to a femto.

2. Pico/Micro: This is an eNB or NB that is exactly the same as a macro eNB/NB only smaller in size and power. It uses Iub, S1, X2 interfaces on the backhaul and is visible to the macro layer.

MEF services, and this IA, are focused on "pico/micro" small cells. While not prohibited, MEF services used for "femto" small cells are outside the scope of this IA. Note that the base stations described previously in Figure 1 (BTS, nodeB), Figure 2 (eNB) and Figure 3 (BS) may be "pico/micro" small cells.

'Heterogeneous' refers to the different types of base stations (e.g., macro, micro, pico) that are used together in the same wireless network to build the coverage and capacity that end-users demand from their operator. This is in contrast to 'homogeneous' networks that are built with one type of base station, often the macro. As a result, a heterogeneous network (HetNet) provides a seamless broadband user experience for mobile customers independent from their location. Note that the small cells (e.g., micro, pico) can include additional radio access technologies, such as WLAN, which share the small cell backhaul.

As can be seen with the lower (purple dotted) line in Figure B, the available capacity for a subscriber depends on their location. There are three improvements (identified in the in Figure B) that HetNet could address for operators:

1. To increase the capacity on existing cells and for the network as a whole.
2. To improve performance in the cell edges.
3. To provide coverage or to improve performance indoors.

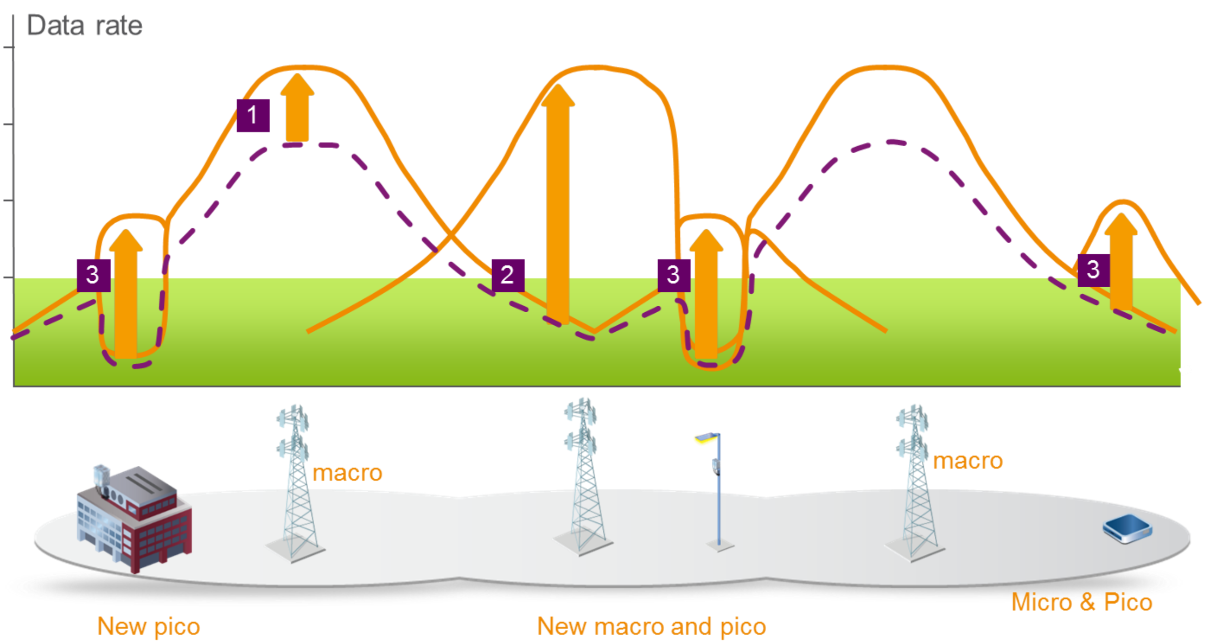

Figure B: Increase capacity & coverage for better mobile end user experience

Figure B, Solution 1 (indicated by 1 in the figure), Macro Optimization:
Usually, the most effective first step in improving overall performance in a mobile network is to optimize existing macro sites by updating technology, aligning antennas, adding frequencies and sectors, etc.

Figure B, Solution 2, Cell Split:
Should Solution 1 not be sufficient, the common next step is to add additional macro sites that are similar to existing macro sites. A cell split typically dramatically increases capacity in the cell edge and results in more consistent network coverage with better performance.

Figure B, Solution 3, Small Cells Additions:
Additionally, the operator can choose to deploy small cells to solve coverage holes or to increase capacity in some regions. In fact, these coverage and capacity issues might exist even if the operator implemented Solutions 1 and 2. There can be several micro and pico small cells required within a macro cell coverage area with each offloading a small percentage of the macro capacity. Other areas that can benefit from the addition of these "small cells" will again be cell edges where speed and throughput benefit from a well placed small cell. Example use cases support indoor areas such as homes or businesses to provide better coverage and/or increase capacity.

4.1.1 Radio Coordination

Radio coordination is a concept that is very important with respect to HetNet. To clarify, consider the extremes. If one is using separate frequencies for small cells and the macro cell, there is no need for coordinating the radio resources. Similarly, coordination is not needed when an indoor cell is shielded from the external macro cells using the same frequencies and radio resources.

The other extreme is when the same frequencies are used and interference impedes performance. In this case, some form of tight radio coordination is required to optimize performance. In this scenario, the macro cell and the small cells are communicating with each other and coordinating simultaneous use of resources. For example, a terminal can use the downlink from a macro cell and the uplink from a small cell with resource utilization coordinated between the cells. This helps to mitigate the performance issues associated with interference, but it places very stringent requirements on delay, synchronization and in some cases, bandwidth.

The need for coordination varies significantly. The "very tight coordination" case is the most extreme in terms of requirements and performance. The backhaul/midhaul can support a lesser degree of coordination to enhance the performance and total bandwidth in an area by way of incremental differences in the radio technology (e.g., certain LTE or LTE-A features)and associated requirements on the backhaul transport characteristics. MEF Ethernet service solutions with relatively stringent performance, including low latency and sufficient bandwidth, meet these "tight coordination" requirements in some cases. With the use of GNSS/GPS or the addition of more accurate network-delivered synchronization solutions (e.g., packet-based method with full timing support to the protocol level from the network [15], also known as PTP with "on-path"support) to deliver improved time alignment between cells, it might be possible to use more demanding radio coordination features. Additional Synchronization requirements for phase and time synchronization associated with these radio technologies that provide for coordination are described in Appendix D.

Defining radio network function coordination levels is useful for understanding use cases and the associated requirements. This grouping will allow a common treatment for backhaul/midhaul performance. The three defined levels of radio coordination are shown in Figure C: no coordination, moderate coordination and tight coordination. They all assume that there are at least two cells (e.g., macro and small cell) that require coordination. While most commonly involving a small cell, radio coordination is not limited to small cells only. The impact of small cells on backhaul/midhaul requirements depends significantly on the level of coordination. Below is a taxonomy for levels of coordination that are in-scope for this IA.

- **No coordination**- uncoordinated deployment with femtos or picos/micros (usually for coverage use cases) in a macro network. Note that femtos are out of scope for this IA**.**
- **Moderate coordination** - deployment of small cells using radio coordination with the macros.
    - E.g. range expansion, adaptive resource partitioning, ICIC and EICIC. (Appendix D)
- **Tight coordination** - coordinated scheduling (on air interface) of uplink and/or downlink
    - E.g., CoMP feature including UL/DL scheduling and link adaptation (Appendix D)
        - In addition to the CoMP functional requirements, for LTE FDD this implies additional synchronization requirements including phase and time synch, associated with more stringent backhaul/midhaul performance requirements. This will be addressed in a future deliverable of MBH IA Phase 3.

Figure C: Radio Coordination Types

The following level of coordination is out of scope for this IA:

- **Very tight coordination**- coordinated deployment with remote radio units (usually for capacity use cases in dense urban congested environments) from a common baseband unit. This is in contrast to a distributed baseband architecture that supports moderate/tight radio coordination for small cells as shown in Figure D.
    - E.g., CoMP feature including UL/DL beamforming and joint transmission/reception (see Appendix D)

- The main/remote interface is a specialized radio over fiber interface, e.g., the internal Common Public Radio Interface (CPRI) interface [28]. Supporting CPRI requires several "gigabits per second" of bandwidth and other highly stringent performance characteristics like extremely low latency and jitter. CPRI is often carried directly over fiber, over microwave or with wavelength division multiplexing (WDM).
- MEF Ethernet Services cannot currently support the fronthaul of CPRI

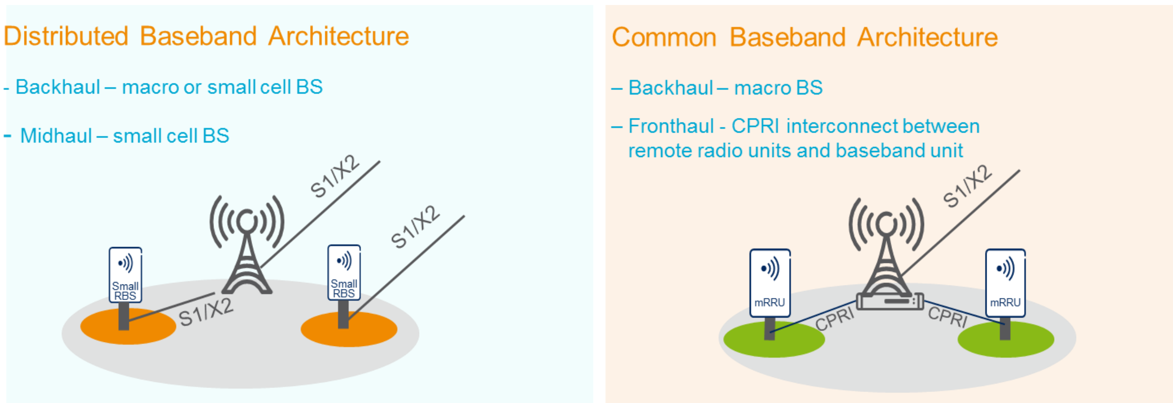

Figure D: Distributed vs Common Baseband

Additional detail on several LTE and LTE-A features, their latency and synchronization requirements, and their allocation into this taxonomy is described in Appendix D.

Capacity driven use cases are most likely to leverage tight coordination, and coverage cases are least likely since they tend to be more isolated from the macro cell. In addition, when small cells are deployed in dense clusters they are more likely to benefit from tight coordination.

In many cases, radio characteristics can be adapted to backhaul transport. However, in general better performing backhaul transport allows better performance of the small cell and therefore higher overall mobile system performance.

4.2 Aggregation Node

Aggregation nodes can be utilized at the RAN BS site or the RAN NC site to aggregate traffic onto common backhaul whether or not small cells are involved. For example, a BS aggregation node can be used for aggregating various nearby BS sites via Mobile Operator transport, such as microwave, at a hub BS site or to aggregate different radio access technologies at a BS site. These BSs can be a macro or small cell. In various industry documents this BS aggregation node might also be referred to as a cell site aggregation gateway (CSAG) or cell site router.

There are particular benefits for aggregation nodes for small cells. Without aggregation nodes, the deployment of many small cells per macro cell would significantly increase the number UNIs and/or EVCs required in the backhaul network. For many deployments, a small cell BS aggregation node, such as a cell site aggregation router, for backhaul might be beneficial to aggregate the BSs onto a single MBH interface. A typical use for such an aggregation node would be in a building with a number of small cell BSs as shown in Figure E. While this aggregation node is not an eNB/NB, it can be considered a RAN BS in the context of this IA, requiring a single backhaul. This is similar to the case in macro cell site backhaul whereby a BS aggregation node is used to aggregate multiple macro base stations and/or multiple radio technologies onto a single backhaul UNI.

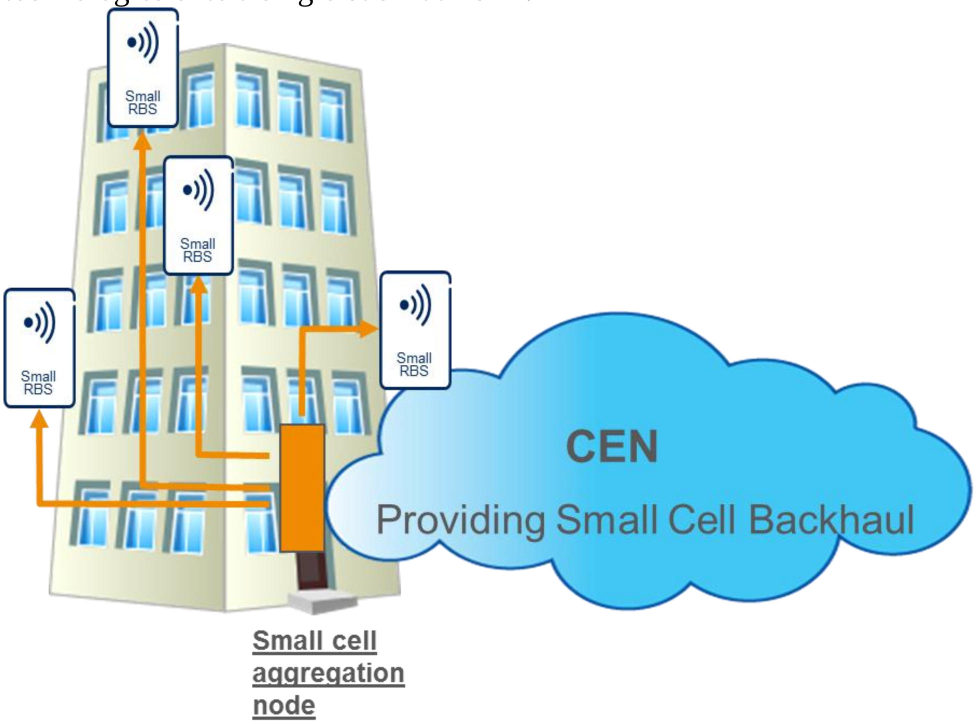

Figure E: Small Cell BS aggregation node

BS aggregation nodes are a type of RAN CE. They are normally owned by the Mobile Operator and thus considered CE from a MEF perspective. BS aggregation nodes will not be normatively specified in this IA (See appendix A.1). BS aggregation nodes can implement generic MEF functionality that is attributed to CE and UNI-C functions in various MEF specifications. A generic view is shown in Figure F that encompasses a multi-operator aggregation, multi-standard radio aggregation and small cell aggregation. There are many variations that are possible for deployment. The common element in all deployments is the CSAG function.

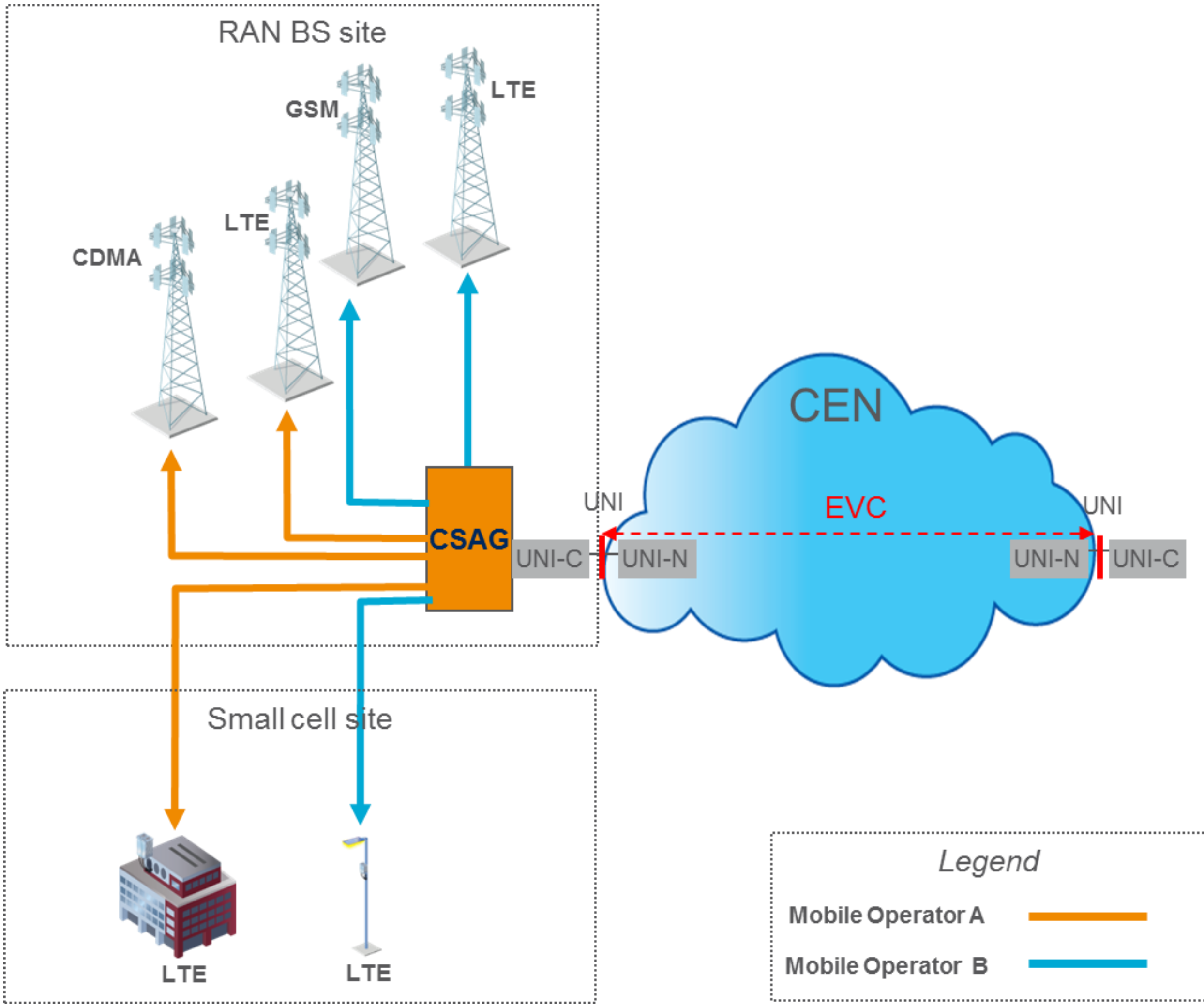

Figure F: Generalized BS aggregation node

5. Scope

Note: This amendment replaces section 5 with the following

5.1 In Scope

The following are within the scope of this phase of Implementation Agreement:

- Mobile backhaul and midhaul, for macro and small cells, for mobile technologies referenced in standards: GSM, WCDMA, CDMA2000, WiMAX 802.16e, and LTE.
- Support a single MEN with External Interfaces being only UNIs for Mobile Backhaul between RAN BSs and RAN NC.
- Utilize existing MEF technical specifications with required extensions to interface and service attributes.
- Provide requirements for UNI-C and UNI-N beyond those in [8] and [10].
- Define requirements for Mobile Backhaul with Ethernet Services specified in MEF 6.1 [3].
- Provide requirements for Link OAM, Service OAM Fault Management.

- Provide requirements for CoS and recommend performance objectives consistent with MEF 23.1 [12], where possible.
- Specify frequency synchronization requirements where possible for packet based synchronization methods and Synchronous Ethernet.
- Define functional requirements applicable to Generic Inter-Working Function interfaces.
- Specify resiliency related performance requirements for Mobile Backhaul.

5.2 Out of Scope

Topics that are not within the scope of this phase of Implementation Agreement include:

- Consider Multiple MENs or External Interfaces such as ENNI
- Provide an architectural and functional description of the MEN internals.
- Provide a normative definition or implementation specification of the Generic Inter-working Function.
- Provide details regarding other technologies for Backhaul Networks (e.g. Legacy ATM or TDM or IP transport).
- Specify time and phase synchronization methods and requirements.
- Specify multiple clock & time domain synchronization methods and requirements.
- Define synchronization architectures or promote any particular synchronization technology.
- Define mobile network evolution scenarios.
- Provide fronthaul between a baseband unit and a radio unit (e.g., “very tight coordination” case using CPRI)
- Specify backhaul for femto interfaces

6. Compliance Levels

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in IETF RFC 2119[25]. All key words must be in upper case, bold text.

Items that are **REQUIRED** (contain the words **MUST** or **MUSTNOT**) will be labeled as **[Rx]** for required. Items that are **RECOMMENDED** (contain the words **SHOULD** or **SHOULDNOT**) will be labeled as **[Dx]** for desirable. Items that are **OPTIONAL** (contain the words **MAY** or **OPTIONAL**) will be labeled as **[Ox]** for optional**.**

A paragraph preceded by [CRa]< specifies a conditional mandatory requirement that MUST be followed if the condition(s) following the “<” have been met. For example, “[CR1]<[D38]” indicates that Conditional Mandatory Requirement 1 must be followed if Desirable Requirement 38 has been met. A paragraph preceded by [CDb]< specifies a Conditional Desirable Requirement that SHOULD be followed if the condition(s) following the “<” have been met. A paragraph preceded by [COc]< specifies an Conditional Optional Requirement that MAY be followed if the condition(s) following the “<” have been met.

7. Mobile Backhaul Service Model

Note: This amendment modifies Subsection 7.1.2 and adds Subsections 7.2.7 and 7.2.8 at the end of this section.

7.1.2 Use Case Variations

Note: Add a new paragraph to the end of this section.

The RAN CE basestation shown in Figures 7, 8 and 9 represents both small cells and macro cells. That is, for this use case either could be present.

7.2.7 Use Case Variations for small cells

This section describes and provides examples of variations to use cases 1 and 2 for different Small Cells, including mixed CEN and IP MBH.

In all cases, the RAN BS can be relatively larger (e.g., macro cell) or smaller (e.g., small cells such as micro, pico, femto). While use cases 1 and 2 can be applied to macro as well as small cell BS, use case 2b will be a common use case for small cells since small cells are relatively new and do not usually include TDM interfaces.

The addition of small cells will require an increase in backhaul capacity to the macro site (especially if small cells are aggregated there – see Appendix A.1) or providing new backhaul/midhaul to the additional small cell BS sites. The performance requirements on the backhaul/midhaul will be the same as macro only sites except in cases where the small cell radio technology requirements have been relaxed (e.g., less demanding requirements for peak rate demand, handover or service continuity) or in the case where some of the tight radio coordination features are to be used. In this tight coordination case, the performance requirements (e.g., latency, CIR/EIR and/or synchronization) might be more demanding. See section 4.1.1 for details on radio coordination.

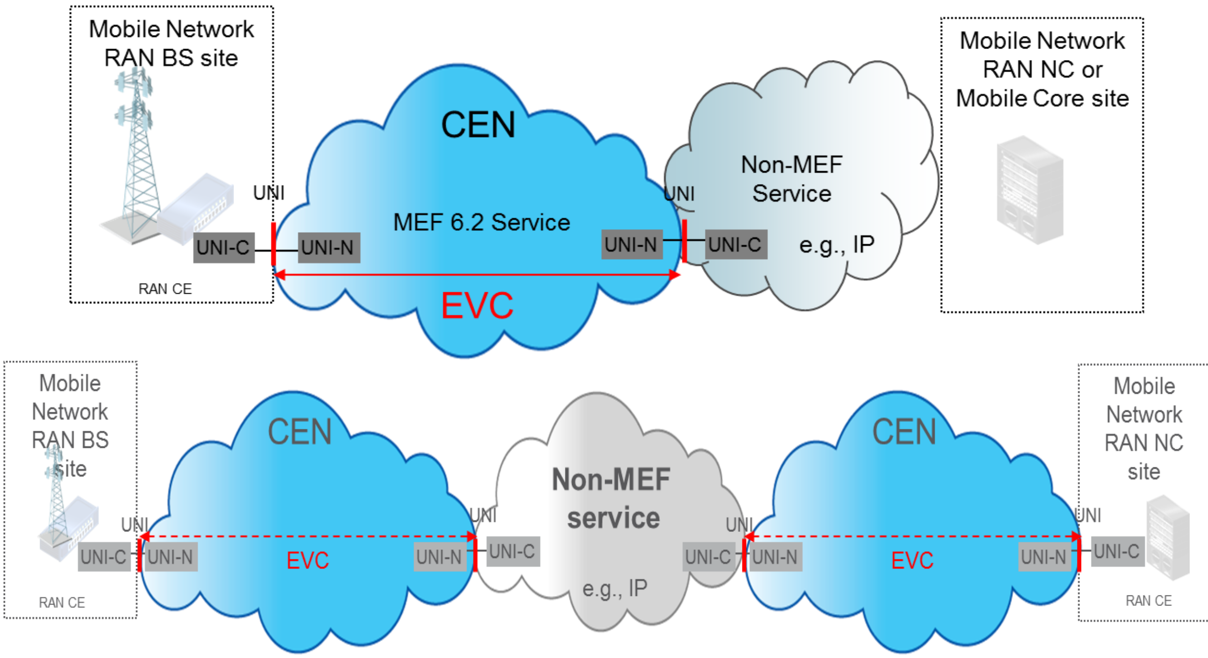

Figure G: Use case examples with CEN and non-CEN hybrid

The use case examples in Figure G shows the MEF service closest to the basestation as an extension of another non-MEF service – there may or may not be another MEF service at the RAN NC site. BBF TR-221 explains this case in more detail for the cases when the non-MEF services are MPLS. Note that this could also be deployed in the reverse case with Non-MEF closest to the basestation. The latter is expected to be prevalent in small cell deployments.

7.2.8 Use Case 3: RAN CE with Macro Backhaul Extensions to Small Cells

Use case 3 in Figure H illustrates a deployment option where extensions are made to existing backhaul connections to the macro site. In this case, the RAN CE equipment can be connected directly to the CEN with a MEF compliant UNI-C Ethernet, but there are two separate EVCs. The existing EVC(m) is shown on the right and a new EVC(sc) is shown on the left connecting the RAN CE of the macro site with the RAN CE of the small cell. Both EVCs use MEF 6.1 services and appear as entirely separate services to each CEN which may be from different CEN Operators.

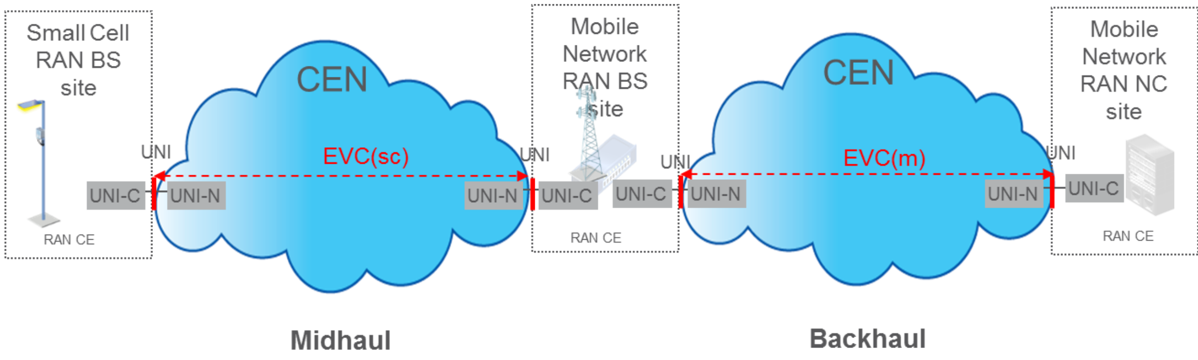

Figure H: Use Case 3: small cell extension from macro

HetNet EVC(sc) midhaul can have different requirements than EVC(m) backhaul. There are a number of options for the functions that could occur at the middle Mobile Network RAN BS site that will not be normatively specified in this IA, though several options are possible. For example, an aggregation router or a Ethernet switching device could be present which would present different relationships between single or multiple EVC(sc) with EVC (m) and might present options for implementing direct RAN BS to RAN BS traffic such as X2 for LTE (or the evolving X2+ for LTE small cells). The router or switching device would allow concentration of multiple small and macro cells onto EVC(m) for implementing traffic to the NC like S1 for LTE. The small cell RAN BS, like the macro cell RAN BS, may or may not be the device at the site with the UNI-C. If it is not, another device (router, switch or NID) would contain the UNI-C.

If separate frequencies are used for macro and small cells or if interference risk is low, there might not be significant difference other than capacity. However, if there is a risk of interference, the EVC(sc) midhaul might have different requirements, not only on capacity, but on delay and delay variation, to maximize the utilization of the radio resources using a tighter level of radio coordination. The constrained requirements on the backhaul/midhaul will thus be dependent on the level of radio coordination. This is addressed in section 11.5.2. However, it is important to note that this small cell extension use case can realize several different RAN interconnection topologies for the LTE small cell. As shown in the Figures below, these are:

1. S1 only (Figure I)
   The midhaul EVC for the LTE small cell carries only LTE S1 traffic. This is transited at the macro basestation site and is transported with the macro LTE S1 traffic over the backhaul EVC. The constraints are the same as for backhaul (e.g., PT1 per 11.5.2).
2. S1 and X2 (Figure J)
   The midhaul EVC for the LTE small cell carries LTE S1 and X2 traffic. The S1 traffic is transisted as above, but the X2 traffic is only between cell sites. Radio coordination is supported and tight radio coordination will add constraints to the midhaul (e.g., constrained PT1 per 11.5.3)
3. Xn (Figure K)
   The midhaul EVC for the LTE small cell carries only LTE Xn traffic. This evolving 3GPP Release 12 feature [22] involves a split bearer such that the small cell is directly connected to its master basestation. The constraints on this type of midhaul are the same as backhaul (e.g., PT1 or PT2 per 11.5.4).

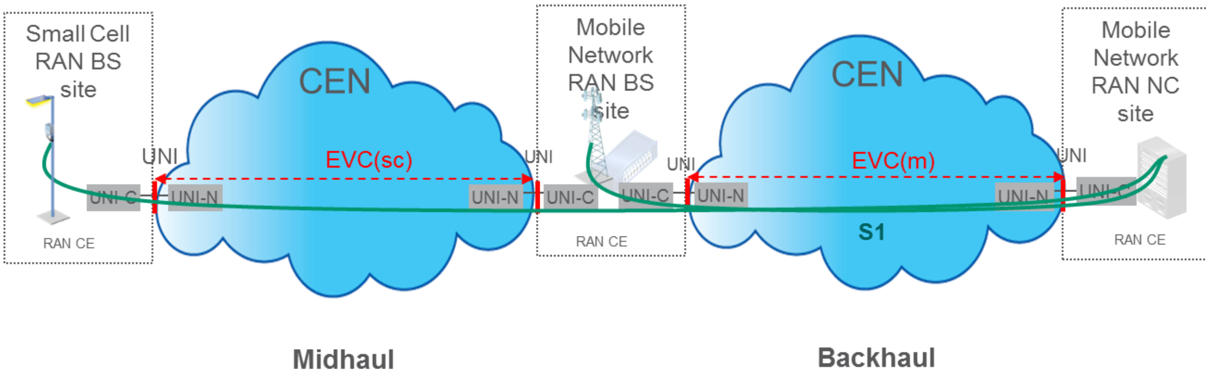

Figure I: Use case 3a: Small cell extension for LTE S1 only

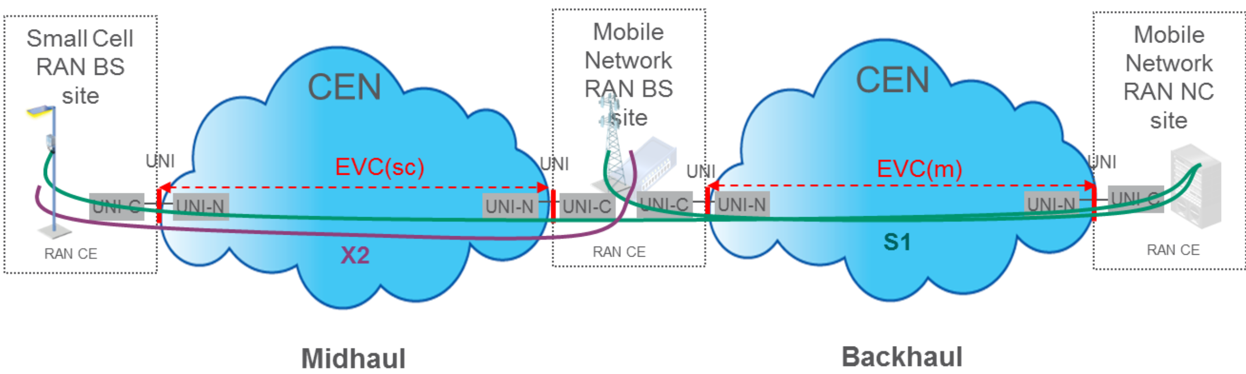

Figure J: Use case 3b: Small cell extension for LTE S1 and X2 (radio coordination possible) only

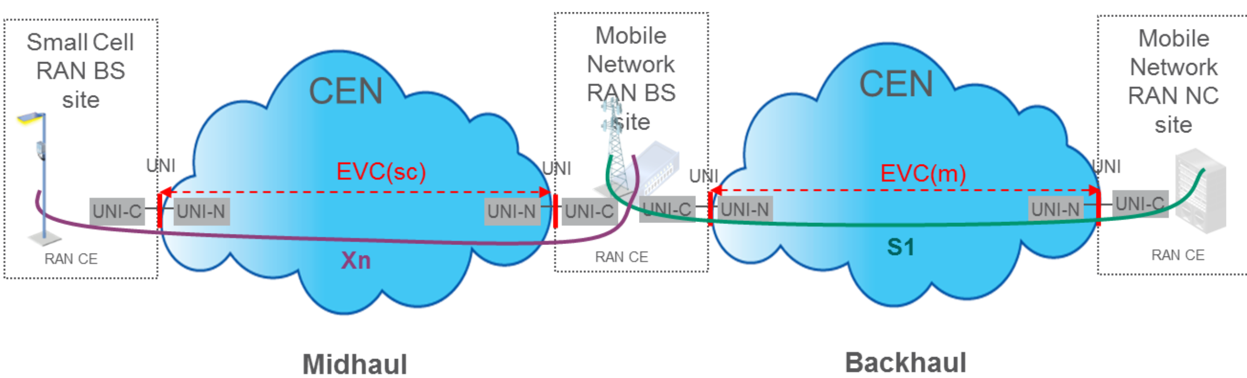

Figure K: Use case 3c: Small cell extension for LTE Xn only

It should be noted that unless they are mapped unto different EVCs, the LTE interfaces (S1, X2, Xn) will not be distinguishable to the CEN. The use cases highlight the varying CoS requirements. In some cases, the Mobile Operator is likely to provide the midhaul EVC(sc) themselves - depending on service availability – however, modeling the interconnection as an MEF service would still be useful (e.g., for planning or certification). These relatively short mobile backhaul needs would generally be prior to the CEN Operator's first office or switching location and therefore dedicated transport is likely to be most common. Example cases include the Mobile Operator utilizing microwave Ethernet transport to provide this short midhaul, or the Mobile Operator acquiring wireline physical assets like dark fiber. Topologies that involve the transport of the frames to a central office switch and back to the Macro RAN BS site might not be cost or performance suitable.

11. EVC Requirements

Note: This amendment adds subsection 11.5.3 and 11.5.4

11.5.3 CoS Performance Objectives (CPOs) for Small Cells With Tight Radio Coordination

In 3G and 4G Mobile Networks the midhaul transport for small cell use case 3 (section 7.2.8) will be between the macro RAN BS and the small cell RAN BS within a relatively small distance (e.g. resulting in EVCs of <10km). Across this midhaul interface there can be logical interfaces between the RAN BS sites (e.g., X2 for LTE) and/or it might contain a portion of logical interfaces for the RAN NC (e.g., S1) (per use cases 3a and 3b).

A macro-based mobile broadband network optimized for maximum performance, in capacity and coverage, will be complemented with small cells that for maximum performance may need to be tightly coordinated with the macro cells and potentially with other small cells. For maximum performance of radio features there are additional constraints that can be placed on the midhaul transport between the macro RAN BS and the small cell RAN BS. In such a case, assuming MEF services are used, those services may need to provide additionally constrained CoS performance objectives (CPOs) for small cells as shown in Figure L:

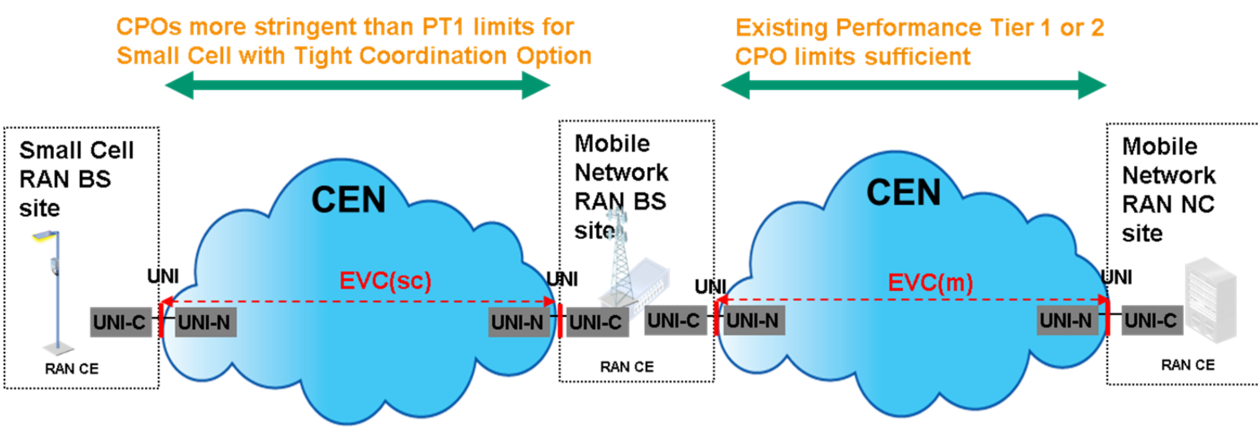

Figure L: Two CPOs for Use Case 3

This IA recommends use of CPOs that are generally more stringent than the most stringent Performance Tier currently specified by MEF (PT1). These "tight-coordination" CPOs are used when tight radio coordination is implemented between the small cell and its neighboring cells, such as when certain LTE-Advanced features including Coordinated Multi-point (CoMP) are used.

[D1] A MEF compliant Mobile Backhaul with EVC(sc) for X2 or R8 that supports HetNet tight radio coordination **SHOULD** use the CPOs in Table B which are compliant with but more stringent than PT1 as defined in MEF 23.1 [12].

[O1] A MEF compliant Mobile Backhaul with EVC(sc) for X2 or R8 that supports HetNet moderate or no radio coordination service **MAY** use PT1 or PT2 [12].

For example, a small cell backhaul/midhaul use case with relaxed radio requirements and no radio coordination may use PT2 CoS Performance Objectives.

The existing requirements for macro backhaul will continue to apply for EVC (m). See {11.5.x].

Table B in this IA specifies the one way CPOs for Point-to-Point Mobile Backhaul service with 1 or more CoS Labels: H, M, L. This is based on tight radio coordination requirements for small cells for Mobile Backhaul across all mobile technologies (2G to 4G) and thus will support any of the service combinations (e.g. MEF 3, MEF 6.1) across the same CEN. It should be noted that mapping of radio coordination "signaling" to CoS labels is shown in Table 7.

CoS Name	Ingress Bandwidth Profile**	One Way CPO for Mobile Backhaul Service with Tight Radio Coordination – constrained PT1 {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	See MEF 23.1 Table 6 PT1 [12]	TBD $\geq A_{Avail}$	TBD $\leq A_{HLI}$	TBD $\leq A_{CHLI}$
Medium *(M)*	*CIR>0 EIR≥0*	≤ 2.9 ms	≤2 ms	≤0.9 ms or N/S	≤1 ms or N/S	See MEF 23.1 Table 6 PT1 [12]	TBD $\geq A_{Avail}$	TBD $\leq A_{HLI}$	TBD $\leq A_{CHLI}$
Low *(L)*	*CIR≥0 EIR≥0**	≤10 ms	≤8 ms	≤2.8 ms or N/S	≤2.9 ms or N/S	See MEF 23.1 Table 6 PT1 [12]	TBD $\geq A_{Avail}$	TBD $\leq A_{HLI}$	TBD $\leq A_{CHLI}$

Notes:

- *H+ is not further constrained by this Amendment, so is not shown. Impact of feature driven Time and Phase Synchronization is out of scope for this Amendment and is not included. In addition, no additional constraints are required for frequency synchronization.*
- *More stringent PT1 CPOs shown above may be utilized on a per CoS Name basis, e.g., radio default bearer on CoS Label L may not use tight radio coordination and thus may utilize PT1 CPOs rather than those shown for L above.*
- *(*) both CIR = 0 and EIR = 0 is not allowed as this results in no conformant Service Frames. CIR=0 and EIR>0 results in non-specified objectives.*
- *(**) Ingress Bandwidth Profile for CoS Labels (H, M and L) are from Table 2 of MEF 23.1[12] .*
- *CBS, EBS≥ MTU per MEF 23.1[12]*

Table B: One way CPOs for "tight radio coordination" for Point-to-Point Mobile Backhaul case when Synchronization is not provided on the Backhaul[1]

CPOs for "tight radio coordination" for Point-to-Point Mobile Backhaul case when time/phase synchronization is provided on the Backhaul are for a future deliverable in MBH Phase 3.

3GPP TR23.203 [21] suggests that the typical average delay[2] for S1u traffic is 20ms. The constrained PT1 for small cells in the figure above allow for S1 traffic carried in a multi-CoS environment to be within reach of this average, and certainly within the 10ms to 50ms range. Figure M below shows the component contribution to the end-to-end latency as contributed to by node delays (assumed to be 1ms) and the constrained PT1 value of FD for EVC(sc) with CoS Name M (5ms) and the PT1 value of FD for EVC(m) with CoS Name M (20ms). This concatenation is shown as guidance so that operators can appropriately provision their backhaul networks. This figure does not imply any restriction on CoS levels on the EVC(sc) and EVC(m) segments (e.g., it could be CoS M in EVC(sc) and at CoS H at EVC(m)) to meet the 3GPP typical average delay.

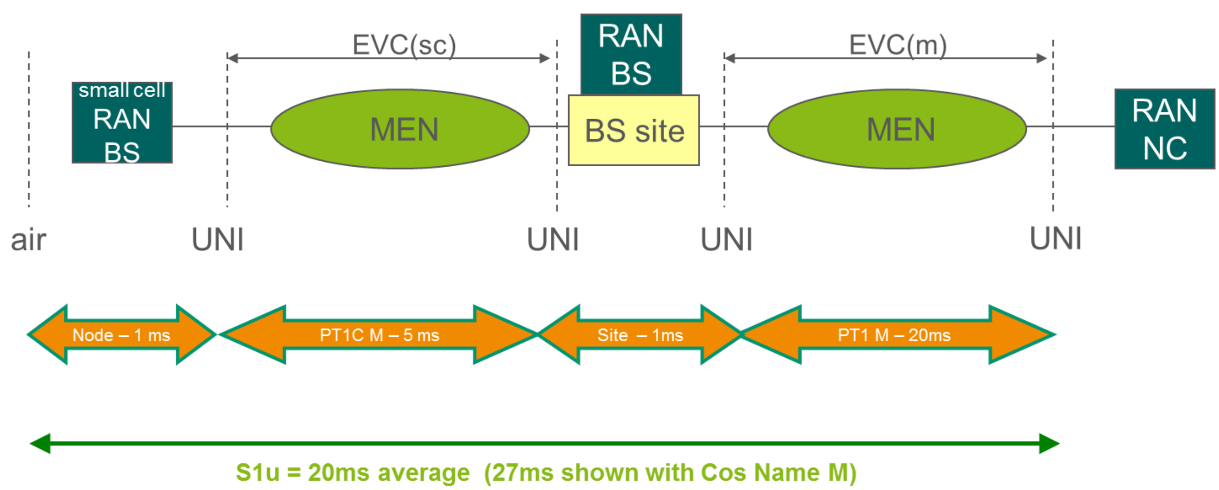

Figure M: S1u FD budget for small cell use case

11.5.4 CoS Performance Objectives (CPOs) for Small Cells With Split Bearer

3GPP TS 36.842 [22] introduces bearer splitting for LTE in support of dual connectivity. There are 3 main options described, but recommended option 3C highlights the midhaul architecture shown in Figure K. The small cell becomes a secondary eNB (SeNB) and is only connected to its master eNB (MeNB). This interconnection is an X2 interface (labeled Xn) carrying both user and control plane traffic, while supporting a slightly higher latency (see Appendix D). The

[1] MEF 23.1 is being updated with the CoS Phase 3 project. This project will add a PT0.5 that is similar or equivalent to the constrained PT1 defined here. A future revision of MEF 22 will align with MEF 23.

[2] The average delay of 20 ms is between a PCEF and a radio base station. It is the delay attributed to backhaul and should be subtracted from a given Packet Delay Budget (PDB) to derive the actual PDB that applies to the radio interface The PDB defines an upper bound for the time that a packet may be delayed between the UE and the PCEF. The PDB shall be interpreted as a maximum delay with a confidence level of 98 percent.

midhaul transport required for small cell use case 3c (section 7.1.4) will be between the macro RAN BS and the small cell RAN BS within a relatively small distance (e.g. resulting in EVCs of <10km). However, this midhaul interface will only support the Xn logical interfaces between the RAN BS sites

In such a case, assuming MEF services are used, those services need less constrained CoS performance objectives (CPOs) for small cells. That is, the CPO requirements in 11.5.2 would apply.

12. Synchronization

Note: Phase and time synchronization, for example in support of radio coordination, will be in a future deliverable of MBH IA Phase 3

13. References

MEF Specifications

[1] MEF 3, “Circuit Emulation Service Definitions, Framework and Requirements in Metro Ethernet Networks”
[2] MEF 4, “Metro Ethernet Network Architecture Framework Part 1: Generic Framework”
[3] MEF 6.1, “Ethernet Services Definitions - Phase 2”
[4] MEF 10.2, “Ethernet Services Attributes - Phase 2”
[5] MEF 10.2.1, Amendment to MEF 10.2
[6] MEF 11, “User Network Interface (UNI) Requirements and Framework”
[7] MEF 12.1, “Metro Ethernet Network Architecture Framework Part 2: Ethernet Services Layer”
[8] MEF 13, “User Network Interface (UNI) Type 1 Implementation Agreement”
[9] MEF 17, “Service OAM Requirements & Framework”
[10] MEF 20, “User Network Interface (UNI) Type 2 Implementation Agreement”
[11] MEF 22.1, “Mobile Backhaul Phase 2 Implementation Agreement”
[12] MEF 23.1, “Class of Service Phase 2 Implementation Agreement”

IEEE Standards

[13] IEEE 802.1Q-2011, “Virtual Bridged Local Area Networks”
[14] IEEE 1588-2008, “Standard for A Precision Clock Synchronization Protocol for Network Measurement and Control Systems”

ITU-T Recommendations

[15] ITU-T G.8260, “Definitions and terminology for synchronization in packet networks”, August 2010
[16] ITU-T G.705, “Characteristics of plesiochronous digital hierarchy (PDH) equipment functional blocks”, October 2005

GSM, CDMA, WCDMA & LTE
[17] GSM 01.04 v8, “Abbreviations and Acronyms”, May 2000
[18] TIA IS-2000.1-A, “Physical Layer Standard for cdma2000 Spread Spectrum Systems”, March 2000
[19] 3GPP TS 21.905V12.0.0 (2013-06), “Vocabulary for 3GPP Specifications”
[20] 3GPP TS 36.300V12.1.0 (2014-03),“Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2”
[21] 3GPP TS 23.203V12.1.0 (2014-03), “Technical Specification Group Services and System Aspects;Policy and charging control architecture”
[22] 3GPP TR 36.842 V12.0.0 (2013-12), “Technical Specification Group Radio Access Networks; Study on Small cell enhancements for E-UTRA and E-UTRAN”

BBF
[23] TR-221 , "Technical Specifications for MPLS in Mobile Backhaul Networks" (October 2011)

IETF
[24] RFC 791, “Internet Protocol”
[25] RFC 2119, “Key words for use in RFCs to Indicate Requirement Levels”
[26] RFC 2460, “Internet Protocol, Version 6 (IPv6) Specification”

Wimax Forum Specifications
[27] WMF-T32-001-R016v01,“WiMAX Forum Network Architecture - Architecture Tenets, Reference Model and Reference Points Base SpecificationStage 2. 2010-11-30”

NGMN Alliance
[28] NGMN Alliance, “NGMN Optimized Backhaul Requirements”, August 2008(http://www.ngmn.org/uploads/media/NGMN_Optimised_Backhaul_Requirements.pdf)

Small Cell Forum
[29] Small Cell Forum 102.02.01, “Release two – Enterprise: Overview”, December 2013

CPRI
[30] CPRI, “Common Public Radio Interface (CPRI); Interface Specification V6.0”, August 2013

Appendix A. Generic Interworking Function (Informative)

Note: This amendment adds Appendix A.1 as follows

A.1 Aggregation Node

This Appendix provides an informative definition of the Aggregation Node.

BS aggregation nodes are a type of RAN CE, however they exist on the customer side of the UNI-C. In many cases, this aggregation node (e.g., a cell site gateway or router) is connected to the UNI-C. It may shape traffic, assign VLANs, assign CoS labels and so forth. However, it is not visible to the UNI-C and has no direct relation to the MEF service attributes.

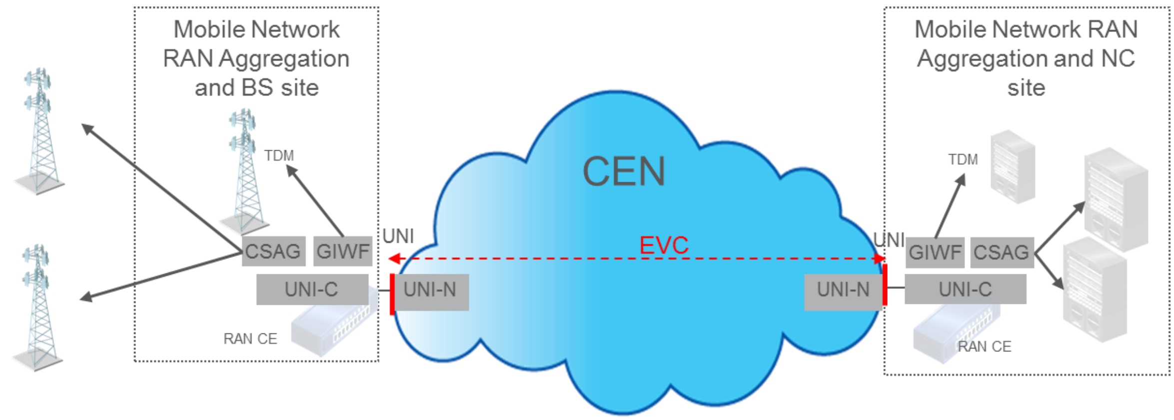

Figure N: Aggregation node CE in RAN BS and/or RAN NC site

In Figure N, the RAN CE is further decomposed and described for the case when a RAN BS and/or RAN NC include aggregation node CE functionality. At a BS the Aggregation node CE (CSAG) can aggregate various radio and RAN technologies and/or aggregate nearby BSs into a hub site for MBH. This can include a GIWF. The AGG function in Figure N denotes an aggregation function which can include aggregating multiple Ethernet interfaces, GIWF interfaces, and may include other functions such as IP. This is described in more detail by BBF in TR-221 where the CSG performs the aggregation functions described here. At the RAN NC site the aggregation function can similarly aggregate RAN technologies and may aggregate onto non-MEF service backhaul (e.g., IP) to a different RAN NC or Mobile Core site. This creates a hybrid backhaul arrangement. These aggregation nodes may perform other functions as well, including but not limited to resiliency (e.g., selecting among diverse EVC pair), GIWF (CES) and traffic management (e.g., CoS).The Aggregation CE can appear in variations of the previous use cases 1 and 2. Figure N is just a generic example. Variations of any of use case 1 or 2 may include Aggregation node CE as part of the Mobile Operator CE.

Appendix C. Mobile Backhaul Services (Informative)

C.6 Configuration alternatives for Management plane

Note: This amendment replaces Figure 30 of Appendix C.6 (to correct an error) with the following

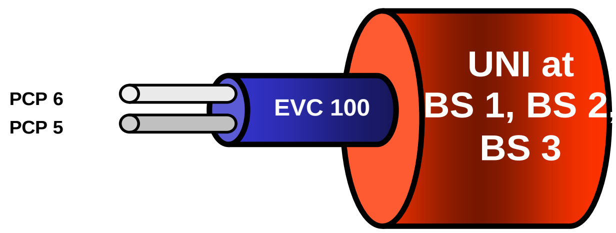

Figure 30: Multiple CoS IDs on the EVC reserved for Management traffic

Appendix D. Radio Coordination (Informative)

Note: This amendment adds a new Appendix D

Standardization continues in 3GPP on LTE-Advanced features that reduce interference in the radio domain and thus increase the uplink and/or downlink speeds for the mobile handset. Any feature that reduces interference will improve the quality of experience for the end user.

Several of these features are worth understanding as they have additional timing or latency requirements for backhaul or midhaul – examples of these are summarized in 3. Note support for time synchronization over the backhaul is not supported in this amendment (though it will be part of a future deliverable of MEF MBH Phase 3), so the values are shown for information. Time synchronization would need to be provided by other means (e.g., GNSS).

Coordination	LTE / LTE-A feature	**Time synch** *common reference accuracy*	Latency	Bandwidth
Moderate	Range expansion	None	None	Low
Moderate	Adaptive resource partitioning	None	None	Low
Moderate	Inter-Cell Interference Coordination (ICIC)	None	None	Low
Moderate	eICIC	+/- 1.5us +/- 5 us	None	Low
Moderate	Dual Connectivity	TBD[3]	5-30ms[3]	TBD[3]
Tight	CoMP - UL Coordinated Scheduling	+/- 5 us	1-10 ms[1]	Low
Tight	CoMP - UL Coordinated link adaptation	None	1-10 ms[1]	Low
Tight	CoMP - DL Coordinated Scheduling	+/- 5 us	1-10 ms[1]	Low
Tight	CoMP - DL Coordinated link adaptation	None	1-10 ms[1]	Low
Very Tight[2]	CoMP - DL Coordinated beamforming	+/- 1.5 us	< 1 ms	2.5-10 Gbps
Very Tight[2]	CoMP - DL non-coherent joint transmission	+/- 5 us	< 1 ms	< 150 Mbps
Very Tight[2]	CoMP - UL Joint processing	+/- 1.5 us	< 1 ms	2.5-10 Gbps
Very Tight[2]	CoMP -UL Selection combining	+/- 5 us	< 1 ms	< 150 Mbps

Notes:

3GPP Standardization is ongoing in this area, as such this table is a snapshot of the anticipated requriements. See [21]

"None" - no other requirements than the FDD or TDD system requires, and can be supported with MEF 22.1

[1] No strict requirement, performance benefit reduces with higher latency

[2] Very Tight coordination case is out of scope for this phase

[3] Backhaul characteristics to be determined depending on 3GPP release 12 conclusions 3GPP Standardization is ongoing. See [22]

Table D: Time and Phase Synchronization and Delay for Radio Coordination

Several 3GPP defined coordination and interference cancellation techniques are described below, with emphasis on the impact on the backhaul:

1. Range Expansion
2. Adaptive resource partitioning
3. ICIC
4. eICIC / FeICIC
5. CoMP Coordinated Scheduling (or Dynamic Point Selection)
6. CoMP Beamforming
7. CoMP non coherent joint transmission
8. CoMP joint processing (transmission/reception)
9. Dual connectivity

Range Expansion

With the deployment of multiple small cells within the macro coverage area, more "cell-edge" is created. Conventionally, the LTE handset (UE) associates with a base station with best downlink (DL) signal-to-interference-plus-noise-ratio (SINR). However, a handset with larger macro SINR may have lower path loss to the nearby small cell base station. The result is significant UL interference at the small cells.

Range expansion (see Figure P), which has been possible since 3GPP Release 8, can be used to expand coverage area for the small cell. Instead of SINR, the UE association can also be determined by minimal path loss. A handover bias is set to indicate the handover trigger between the macro and small cell. Intelligent association achieves better spectrum efficiency and network capacity, lower interference per bit and a spatial reuse efficiency similar to cell splitting.

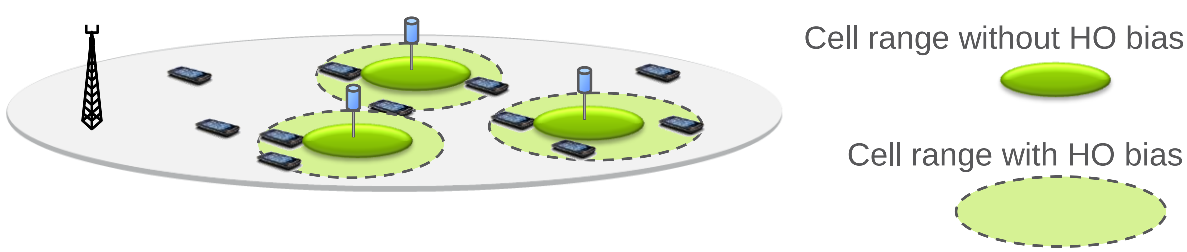

Figure P: Range expansion shown with handover (HO) bias.

Adaptive resource partitioning

The basic radio resource for OFDM transmission can be described as a two-dimensional time-frequency grid that corresponds to a set of OFDM symbols and subcarriers in the time and frequency domains. In LTE, the basic unit for data transmission is a pair of resource blocks that correspond to a 180kHz bandwidth during a 1ms subframe. Therefore, by aggregating frequency resources and by adjusting transmission parameters, such as modulation order and channel code rate, one can flexibly support a wide range of data rates.

Resource partitioning should adapt to network loading, backhaul availability, topology, SINR conditions at UE/base station, mobility, QoS, traffic patterns, etc. Distributed, adaptive resource partitioning schemes are essential to manage interference and optimize throughput performance in heterogeneous networks

The nodes in the network negotiate their resource reservation by sending messages to each other. These resource request/grant messages can be sent over backhaul connections or OTA. The slow adaptive resource negotiation algorithm is based on node load status and feedback from active UEs and updates every few hundred ms. Dynamically adaptive resource negotiation algorithm is better with bursty traffic (temporarily loaning resources between nodes) but requires OTA signaling.

- Latency: no special requirement

Scheduling

In general, scheduling refers to the process of dividing and allocating resources between users who have data to transfer. In LTE, dynamic scheduling (1ms) is applied both to the uplink and downlink. Scheduling should result in a balance between perceived end-user quality and overall system performance. Channel-dependent scheduling is used to achieve high cell throughput. Transmissions can be carried out with higher data rates by transmitting on time or frequency resources with relatively good channel conditions. The OFDM time-frequency grid facilitates the selection of resources in the time and frequency domains -- LTE supports persistent scheduling and dynamic scheduling.

ICIC - frequency domain partitioning

In some cases, the macro and small cell can use separate carriers to avoid strong interference. In this case, carrier aggregation gives flexibility in managing the interference. Essentially, the macro cell transmits at full power on its primary carrier frequency and lower power on the second carrier frequency. The small cell then uses the second carrier frequency as its primary carrier.

While this does not require time synchronization, it also offers less granular resource allocation as partitioning is limited by the number of carriers. As a result, this does not scale beyond a few small cells per macro cell.

- Latency: no special requirement

eICIC / FeICIC – time domain partitioning

Enhanced ICIC, is essentially time domain partitioning of resources in such a way to minimize the interference between the macro cell and the small cell in a large range expansion (also called handover bias) operation. That is, when the UE is intentionally locked onto a weak DL small cell.

With a range expansion of *RE* dB, a user connected to a small cell can be hit by one or more interfering downlink signals from macro cells that are *RE* dB stronger than the desired signal – plus the handover margin. With a moderate value of *RE*, that is, a moderate cell selection offset, the radio interface is robust enough to handle this situation. For larger values of cell selection offset, the macro cells can be muted or made to use reduced power. This may be done in a static or traffic adaptive pattern. Care must be taken not to mute the macro too often, which might lead to worse performance since the (overloaded) macro cell becomes even more loaded during its active periods.

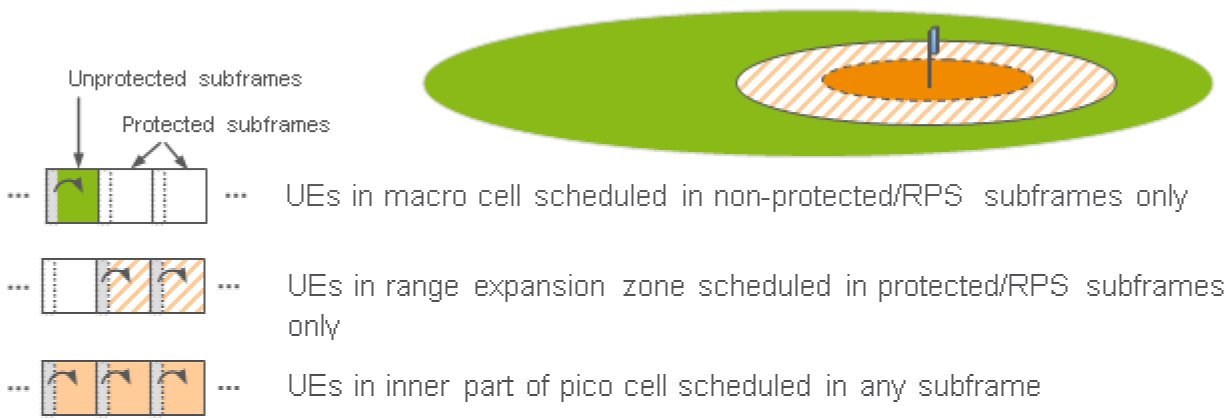

Figure Q: enhanced Inter Cell Interference Coordination (eICIC)

This is supported in LTE by static and adaptive Almost Blank Sub-frames (ABS) and Reduced Power Sub-frames (RPS). To support large cell selection offsets, almost blank subframes (ABS) were introduced in LTE release 10. One drawback of this approach is that when the data channel in the macro base station is completely switched off, there is a degradation in performance for users connected to the macro base station. The reduced transmission time leads directly to lower data rates, which leads indirectly to increased load (higher resource utilization) for the same amount of carried traffic. This effect can be mitigated by not completely switching off the macro data channel in the ABS, but instead reducing the power to a level that the small cell users can support. This concept is referred to as reduced power subframes (RPS). Capacity gains of up to 100 percent have been seen in 3GPP-defined scenarios

Using the LTE eICIC concept, the macro base stations schedule RPSs in a periodically repeated pattern. The pattern is signaled to neighbor base stations to enable them to schedule users in the imbalance zone when the macro power is reduced. The fraction of RPSs in the pattern can be adapted to the traffic situation. This is known as adaptive RPS. RPS is preferred over ABS as it more efficiently utilizes resources in all sub-frames.

.

eICIC consists of three design principles

1.Time domain interference management (Rel-10)

Severe interference limits the association of terminals to small cells

2.Cell range expansion (Rel-10/11)
Time domain resource partitioning enables load balancing between macro and small cells. Resource partitioning needs to adapt to traffic load
3. Interference cancellation receiver in the terminal (Rel-11/12)
Ensures that weak cells can be detected and interference removed.
Inter cell interference cancellation for control and data channels

The latter principle is sometimes refered to as a further enhanced ICIC (FeICIC).

› Time alignment: +/-1.5us -- +/-5us required between macro and small cell
› Latency: no special requirement (>20ms)

Coordinated Multipoint (CoMP)

Coordinated Multipoint is effectively a network MIMO utilizing multiple antenans at different cell sites, all of which have visibility to the handset (UE).

For Downlink (DL) CoMP, this is explicitly supported from 3GPP Rel-11 amd mostly relies on UE feedback. This results in a medium performance benefit.

Uplink (UL) CoMP currently has little 3GPP specification impact as it is mainly implementation and inter-node communication. That is, it is similar to soft/softer handover. However, this can result in a large performance benefit. There are several CoMP methods that have been defined in Rel 11 and that will be further enhanced in Rel 12.

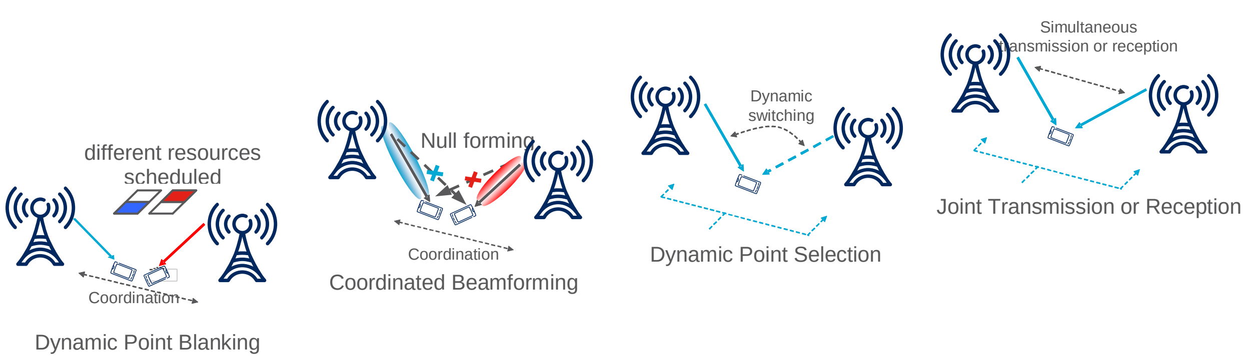

Figure R: Several options of CoMP (Coordinated Multipoint)

Coordinated Scheduling / Dynamic Point Blanking

Coordinated scheduling is a CoMP method in which a joint scheduling decision is taken across a set of cells, rather than letting each cell's scheduler operate independently. As an example, using coordinated scheduling a macro base station might be silent or use reduced power, only when a nearby small cell base station schedules a user that would have been heavily interfered by the macro base station, such as a user in the imbalance zone. Coordinated scheduling is also known as 'dynamic point blanking' and corresponds to fully dynamic ABS/RPS.

Essentially, the UE receives data from single TX point. Scheduling of time/frequency resources is coordinated among points. This exchange of coordination information between points, is on a per TTI (transmission time interval) level (i.e., every 1ms).

- Time alignment: +/-1.5us required between macro and small cell
- Latency: 1..10ms – the lower the latency, the better the cell edge gain

Joint Reception

CoMP joint reception is a UL CoMP method that involves precise scheduling of UE on the uplink. The CoMP base stations receive the transmitted data from the UE. One basestation is the master as they share received data and jointly process it. A communication between the UE and master basestion (ACK/NACK) as well as to the other basestation is required.

- Time alignment: +/-1.5us required between macro and small cell
- Latency: <0.5ms

Dual Connectivity

Dual connectivity (3GPP Rel 12 [22]) involves a UE consuming radio resources from at least two different base stations connected with midhaul or backhaul (both called “non-ideal backhaul” in 3GPP). This results in a UL/DL split between the basestations that increases throughput and decreasing HO signalling. In the case where this is deployed with an Xn interface between the master eNB and a secondary eNB the requirements on this midhaul connection can be relaxed and support latency of up to 30ms and have sufficient bandwidth.

- Latency: 5-30ms
