Implementation Agreement

MEF 22.2.1

Mobile Backhaul Phase 3 - Amendment 1: Time Synchronization

November, 2016

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Introduction

This amendment makes the following changes to MEF 22.2 [12]:

1. Addition of two use cases for phase and time synchronization
2. Addition of new service attributes for the first phase and time synchronization use case
3. Addition of new requirements in support of phase and time synchronization
4. Alignment of synchronization clause to distinguish between frequency and time synchronization
5. Various editorial corrections, including alignment to current MEF style

The new figures in this amendment are sequenced alphabetically. Amended figures from MEF 22.2 [12] are indicated numerically.

1. 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.

Albis Technologies

China Telecom

Comcast

Ericsson AB

Nokia Networks

2. Abstract

This is an amendment to MEF 22.2 that addresses the addition of technical content on time and phase synchronization.

3. 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.

Note: This amendment adds the following terms to section 3 as follows

Term	Definition	Reference/Source
EEC	synchronous Ethernet equipment clock	G.8264 [43]
MTIE	maximum time interval error	G.810 [53]
PRTC	primary reference time clock	G.8260 [38]
TDEV	time deviation	G.810 [53]

Table A: Terminology and Acronyms

6. Scope

Note: This amendment replaces section 6 as follows:

6.1 In Scope

The following work items 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, LTE, and LTE-A.
- Support a single CEN 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 MEF 13 [12] and MEF 20 [17].
- Provide requirements for ENNI beyond those in MEF 51 [29].
- Define requirements for Mobile Backhaul with Ethernet Services specified in MEF 6.2 [3], MEF 33 [26], and MEF 51 [29].
- Provide requirements for Link OAM, Service OAM Fault Management.
- Provide requirements for Class of Service and recommend performance objectives consistent with MEF 23.1 [20], where possible.
- Specify frequency synchronization requirements where possible for packet based synchronization methods and Synchronous Ethernet.
- Specify time and phase synchronization methods and requirements.
- Define functional requirements applicable to Generic Inter-Working Function interfaces.
- Specify resiliency related performance requirements for Mobile Backhaul.
- Include Multiple CENs based on OVC Service Definitions

6.2 Out of Scope

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

- Provide an architectural and functional description of the CEN 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 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

7. 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 [92]. All key words must be in upper case, bold text.

Items that are **REQUIRED** (contain the words **MUST** or **MUST NOT**) will be labeled as **[Rx]** or **[A-Rx]** for required. Items that are **RECOMMENDED** (contain the words **SHOULD** or **SHOULD NOT**) will be labeled as **[Dx]** or **[A-Dx]** for desirable. Items that are **OPTIONAL** (contain the words **MAY** or **OPTIONAL**) will be labeled as **[Ox]** or **[A-Ox]** for optional**.**
A paragraph preceded by **[CR*a*]<**, where *a* indicates a sequentially increasing number throughout the document, specifies a mandatory requirement that **MUST** be followed if the condition(s) following the “<” have been met. For example, “**[CR1]<[D38]**” indicates that conditional requirement 1 must be followed if desired requirement 38 has been met. A paragraph preceded by **[CD*b*]<**, where *b* indicates a sequentially increasing number throughout the document, specifies a desired requirement that **SHOULD** be followed if the condition(s) following the “<” have been met. A paragraph preceded by **[CO*c*]<**, where *c* indicates a sequentially increasing number throughout the document, specifies an optional requirement that **MAY** be followed if the condition(s) following the “<” have been met.

11. UNI Requirements

Note: This amendment replaces section 11.4 and inserts a new section 11.5 as follows:

11.4 UNI PHY for Synchronous Ethernet Service

This section specifies Synchronous Ethernet capability so that the CEN operator can offer a Synchronization Service typically with a PRC[1] traceable frequency reference towards the Mobile Operator’s RAN BS sites. The case when a Mobile Operator owns the PRC cannot be supported by MEF service (for example, transport of SyncE over OTN would be required in this case - see G.8264 [43] clause 12).

[O8] The Mobile Backhaul Ethernet Service **MAY** have a value of Enabled for Synchronous Mode Service Attribute, as specified in MEF 10.3 [7], to deliver a PRC traceable frequency reference to the RAN BS site.

[1] Note that PRS (Primary Reference Source) is the term used for the equivalent function of the PRC as defined by ANSI [105]

It is expected that the CEN Operator will enable Synchronous Ethernet with or without Ethernet Synchronization Message Channel (ESMC) (ITU-T G.8264 [43]) at specific RAN BS sites when needed. ESMC is a protocol used to indicate the quality level of the clock. There are two aspects to consider:

1. UNI PHY can operate in Synchronous mode, and,
2. UNI PHY operating in Synchronous mode with ESMC support and with or without QL indication for PRC traceability

[R18] If Synchronous Ethernet is used for frequency synchronization service at the RAN BS UNI then the requirements [R19] to [R28] **MUST** apply.

11.4.1 UNI PHY with Synchronous mode

UNI operates as Full Duplex with Synchronous or Asynchronous modes. Asynchronous mode refers to interface operating with physical layer frequency as specified in IEEE Std. 802.3™-2012 [33] e.g., transmit clock frequency of 125MHz +/-0.01% for 100BASE-SX interface. In ITU-T G.8264 [43] this is referred to as Non-synchronous operation mode (on the transmit side). Synchronous operation mode (ITU-T G.8264 [43]), on the transmit side, refers to the case when the frequency is driven from the synchronous Ethernet Equipment Clock (EEC). Such an operation mode, however, might not have the EEC locked to any external clock source.

[R19] Synchronous Mode attribute **MUST** be set to a value of Disabled or Enabled based on the mode of operation as shown in Table 2.

Administrative Action	Synchronous Mode
Disabled	Full Duplex Asynchronous mode with ESMC and QL process disabled
Enabled	Full Duplex Synchronous mode

Table 2: Synchronous Mode

11.4.2 ESMC Protocol (L2CP) on UNI PHY

The protocol uses the slow protocol address as specified in Annex 57B of IEEE Std. 802.3-2012 [33] and no more than 10 frames per second can be generated for all protocols using slow protocol address. ESMC frames are sent at 1 frame per second.

[R20] A Mobile Backhaul Ethernet Service **MUST** be as per R17 and R18 of MEF 45 [28] when Synchronous Mode attribute has a value of Enabled.

[R21] The ESMC Frame format **MUST** be as specified in ITU-T G.8264 [43].

[R22] If Synchronous Mode attribute has a value of Enabled then ESMC protocol processing **MUST** be enabled as shown in Table 3.

Administrative Action	ESMC processing
Disabled	Transmit: No generation of ESMC Frames Receive: discard ESMC Frames if any received due to misconfiguration errors, for example.
Enabled	Transmit: Generate ESMC Frames Receive: Peer ESMC Frames

Table 3: ESMC Protocol

The terms transmit and receive are used in this IA since the requirements apply to CEN and RAN CE. MEF 10.3 [7] uses ingress and egress but this is always with respect to CEN, i.e., ingress is towards CEN and egress is towards CE.

[R23] UNI with Synchronous Mode attribute value of Enabled, and with ESMC enabled as shown in Table 3, **MUST NOT** be a selectable clock source for the CEN.

While a RAN CE UNI in synchronous mode will be compliant to [R27] the requirement [R23] is to ensure that under any condition the direction of clock distribution is from CEN to a RAN BS. When ESMC is disabled the actual frequency of the UNI PHY can still be driven from the EEC if in Synchronous mode. See Section 10.2 in ITU-T G.8264 [43] for non-synchronous operation mode.

This IA has specified the option of using Link Aggregation for UNI resiliency in Section 11.3 with exactly 2 links. Both Link Aggregation and ESMC use slow protocols. However, Link Aggregation operates above any other IEEE 802.3 sublayer, (IEEE Std. 802.1AX-2008 [32]) including the ESMC. In fact the OAM sublayer presents a standard IEEE Std. 802.3 MAC service interface to the superior sublayer. Superior sub-layers include MAC client and Link Aggregation. Furthermore, a Synchronous Ethernet link and associated ESMC and QL remain independent of Link Aggregation state being in Selected/UnSelected/Standby.

When both physical links in the Link Aggregation are configured to be in Synchronous Ethernet operation mode, with ESMC enabled carrying its own ESMC channel and related QL, then the configuration needs to be consistent for both links. Further considerations on the implications of having multiple SyncE links, with or without Link Aggregation, are described in ITU-T G.8264 Amd 1[43]. It is left to the CEN operator to configure several synchronous Ethernet enabled ports or only one synchronous Ethernet enabled port of the LAG.

11.4.3 QL process support on UNI PHY in Synchronous mode

QL is used to design the synchronization network in order to properly handle fault conditions. In particular, QL can help in prevention of timing loops. In a typical deployment it is expected that the timing distribution is unidirectional (i.e., CEN to RAN BS).

[R24] The QL process, with ESMC enabled, **MUST** support states as shown in Table 4.

Administrative action	QL Indication
QL Disabled ITU-T G.781 [51]	Transmit: Set QL TLV=DNU or DUS Receive: Ignore QL TLV
QL Enabled	Transmit: Set QL TLV Receive: Process QL TLV

Table 4: QL process support in Synchronous operation mode

[R25] UNI with Synchronous Mode attribute value of Enabled, and with ESMC protocol enabled as shown in Table 3, **MUST** have QL process enabled as shown in Table 4.

[R26] The QL mode of operation at UNI **MUST** be configurable by administrative methods, i.e., using a NE's management interface.

[R27] UNI with Synchronous Mode attribute value of Enabled, and with ESMC protocol enabled as shown in Table 3, **MUST** set QL TLV=DNU or DUS per ITU-T G.781 [51] in ESMC frames transmitted towards CEN.

[R28] If QL process is disabled, with ESMC protocol enabled, at a CEN's UNI PHY for any operational reason then ESMC frames **MUST** be sent by CEN's UNI with QL-TLV=DNU or DUS (ITU-T G.8264 [43]).

In some deployments there might be UNI designs with >1 UNI to the same RAN BS site. With >1 UNI a CEN operator could provide clock distribution from multiple PRC sources so the RAN BS can use QL to select the highest traceable clock. This would be useful if for some reason a traceable reference is lost on one UNI.

Furthermore, even with 1 UNI to a RAN BS site, QL value with a DNU message can allow a RAN CE's UNI to go in to hold-over mode until such time the fault condition (absence of traceable reference) is corrected. More importantly, RAN CE's UNI will use its internal clock source and not synchronize to the holdover clock of the CEN nodes that could potentially be lower quality than its internal clock source.

However, ITU-T G.8264 [43] allows certain applications, such as in access networks, where a RAN CE's UNI might be able to recover frequency from the Synchronous Ethernet interface without needing to process ESMC or QL.

A CEN's UNI will need to be capable of generating Ethernet Synchronization Messaging Channel (ESMC) messages assuming RAN CE's UNI requires a traceable frequency reference and clock quality indication. Also, all values of QL as specified in ITU-T G.781 [51] will need to be supported. The requirements are to ensure that CEN NEs supporting UNI-N at RAN BS are capable of Synchronous Ethernet with support for QL mode of operation if a RAN CE's UNI is capable of processing the messages. Some operators might also choose to enable this only when wanting to offer traceability to a PRC with QL mode as enhanced capability to a basic Synchronous Ethernet frequency reference service. Additional Interface Limits at the UNI for Jitter and Wander are included in Section 13.3 when Synchronous Ethernet is used for Synchronous Service.

11.5 UNI for Time Synchronization Service

This section specifies Time Synchronization Ethernet capability so that the CEN operator can offer a Synchronization Service typically with a Primary Reference Time Clock (PRTC) traceable time reference towards the Mobile Operator's RAN BS sites.

The Time Synchronous Mode Service Attribute is a list with one item for each of the physical links implementing the UNI per Section 9.4. Each item in the list takes on one of two values: "Enabled" or "Disabled." When the value of an item is "Enabled", the data transmitted from the CEN to the CE on the physical link corresponding to the item can be used by the CE as a PRTC traceable time synchronization reference by means of PTP messages.

When the value of an item in the Time Synchronous Mode Service Attribute is "Enabled," the Service Provider MUST be able to provide a time synchronization service according to the applicable PTP profile and performance objectives (See section 13.4).

The case when a Mobile Operator owns the PRTC is for further study.

[A-O1] The Mobile Backhaul Ethernet Service **MAY** have a value of Enabled for Time Synchronous Mode Service Attribute, to deliver a PRTC traceable time reference to the RAN BS site.

The CEN Operator will enable Time Synchronization Ethernet according to the applicable PTP Profile. In this IA the applicable profile is based on PTP mapped over Ethernet and on multicast addressing (ITU-T G.8275.1 [46]).

Note: the relevant PTP parameters are distributed by the PTP messages (e.g. sourcePortIdentity, Domain number(s), GM Identities, clockQuality).

Depending on the actual deployment (see section 13.4), the same interface may also carry a Synchronous Ethernet Service as per 11.4.

According to G.8275.1 the PTP profile supports both the non-forwardable multicast address 01-80-C2-00-00-0E and forwardable multicast address 01-1B-19-00-00-00. The default Ethernet multicast address to be used at the UNI depends on the operator policy; further considerations are provided in G.8275.1 Appendix III.

When the service attribute is TRUE, optionally the applicable multicast MAC address may be selected by the Mobile Operator.

[A-O2] The Mobile Backhaul Ethernet Service **MAY** define a default value for Multicast address at the UNI, if Time Synchronous Mode Service Attribute is enabled.

[A-R1] If PTP is used for time synchronization service at the RAN BS UNI then the requirements [A-R2] and [A-R4] to [A-R6] MUST apply.

13. Synchronization

Note: This amendment replaces section 13 as follows:

Synchronization is a generic concept of distributing common time and frequency references to all nodes in a network to align their time and frequency scales. In this IA timing is used as a single term to refer to either time or frequency. Synchronization is a key component in mobile technologies and different mobile technologies have different synchronization requirements. This phase of the IA addresses both frequency synchronization, as well as time and phase synchronization.

Synchronization is used to support mobile application and system requirements to minimize radio interference, facilitate handover between base stations, and to fulfill regulatory requirements. Various mobile technologies stipulate that the radio signal must be generated in strict compliance with frequency, phase and time accuracy requirements, as illustrated in Table 5.

Technology	Frequency (ppb)	Phase (µs)	Time (µs)	Reference Document
CDMA	±50		±3 (Traceable & Synchronous to UTC)	TIA/EIA-95-B [63]
CDMA2000	±50		±10 (>8hrs) when external timing source disconnected ±3 (Traceable & Synchronous to UTC)	3GPP2 C.S0002-E v2.0 [64] C.S0010-C v2.0 [66]
GSM	±50 ±100 (pico BS)			ETSI TS 145.010 [64]
UMTS-FDD (WCDMA)	±50 (Wide area BS) ±100 (Medium range BS) ±100 (Local area BS) ±250 (Home BS)	12.8 (MBSFN-3GPP Release 7/8)		3GPP Frequency: TS 25.104 [75] MBSFN:TS 25.346 [77]
UMTS-TDD (WCDMA)	±50 (Wide area) ±100 (Local area) ±250 (Home eNB)	±2.5 ±1 (between Macro eNB and Home eNB)		3GPP Frequency: TS 25.105 [76] Phase: TS 25.402 [78] Home eNB: TR 25.866 [80]
TD-SCDMA	±50	±3		3GPP TS 25.123[74]
LTE (FDD)	±50 (Wide area) ±100 (Local area) ±250 (Home eNB)	CDMA handover and Synchronized E-UTRAN GPS time ±10 (> 8hours) when external timing source disconnected		3GPP Frequency: TS 36.104 [83] Time: TS 36.133 [84]

Technology	Frequency (ppb)	Phase (µs)	Time (µs)	Reference Document
LTE (TDD)	±50	≤ ±3 (small cell) ≤ ±10 (large cell)		3GPP Frequency: TR36.922 [88] Phase & Time: TS36.133 [84]
		CDMA handover and Synchronized E-UTRAN GPS time ±10 (> 8hours) when external timing source disconnected		
Mobile WiMAX	±2000 (i.e., 2ppm)	≤ ±1		IEEE Std. 802.16-2009 [34] WMF-T23-001-R015v01 [100]

Table 5: Mobile Technology Synchronization Requirements

There are four main methods related to timing distribution from a PRC, i.e., timing source, to slave clocks at a RAN BS site:

1. Using GPS at RAN BS sites
2. Using a legacy TDM network with a TDM demarcation to RAN BS;
3. Using a CEN with Ethernet physical layer (Synchronous Ethernet) for links.
4. Using a CEN with packet based methods and protocols such as PTP [35] or NTP [92], and ACR[98]/RTP [97].

At the RAN BS site, in case the Synchronous Ethernet is terminated by a co-located transport equipment, the timing can be delivered from this transport equipment to the Radio Base Station via any other suitable standard interface (e.g. 2048 kHz according to G.703 [50])

At the RAN BS site, in case the timing, carried by the packet based method, is recovered by a co-located equipment the physical interface that can be used to distribute the timing to the Radio Base Station can be Synchronous Ethernet or any other suitable standard interface (e.g. 2048 kHz according to G.703 [50]).

Some of the above methods can provide only frequency synchronization (e.g. Synchronous Ethernet, legacy TDM network, ACR/RTP). Method 1 and 2 are outside of the scope of this IA. Method 3 and 4 for frequency synchronization are examined in the scope of this IA. Method 4 using PTP has been defined in ITU-T for frequency synchronization but use for phase or time synchronization is yet to be specified. Method 4 for time and phase synchronization is out of scope for this revision of this IA. Method 4 using PTP has been defined in ITU-T for frequency synchronization and time synchronization – both are examined in the scope of this IA.
Packet based methods are addressed in Sections 13.2. Synchronous Ethernet is addressed in Sections 13.3 and 11.4.

13.1 Performance of frequency synchronization architecture

The performance of Frequency Synchronization distribution architecture of a SP is measured by compliance to jitter and wander limits, over certain time intervals, at the network interface offering the Synchronization service to a customer's equipment. Both the choice of architecture, the level of performance impairments (i.e., FDR) and whether the synchronization service is directly terminated at the 'End Equipment', i.e., RAN BS, impact the jitter and wander limits at the network interface. In the context of this document the 'End Equipment' is the single base station at RAN BS. Also, when the UNI-C is not on the RAN BS then the frequency reference is delivered to a 'Connected Equipment', which might be a GIWF or other equipment in the RAN BS site, owned by the Mobile Operator.

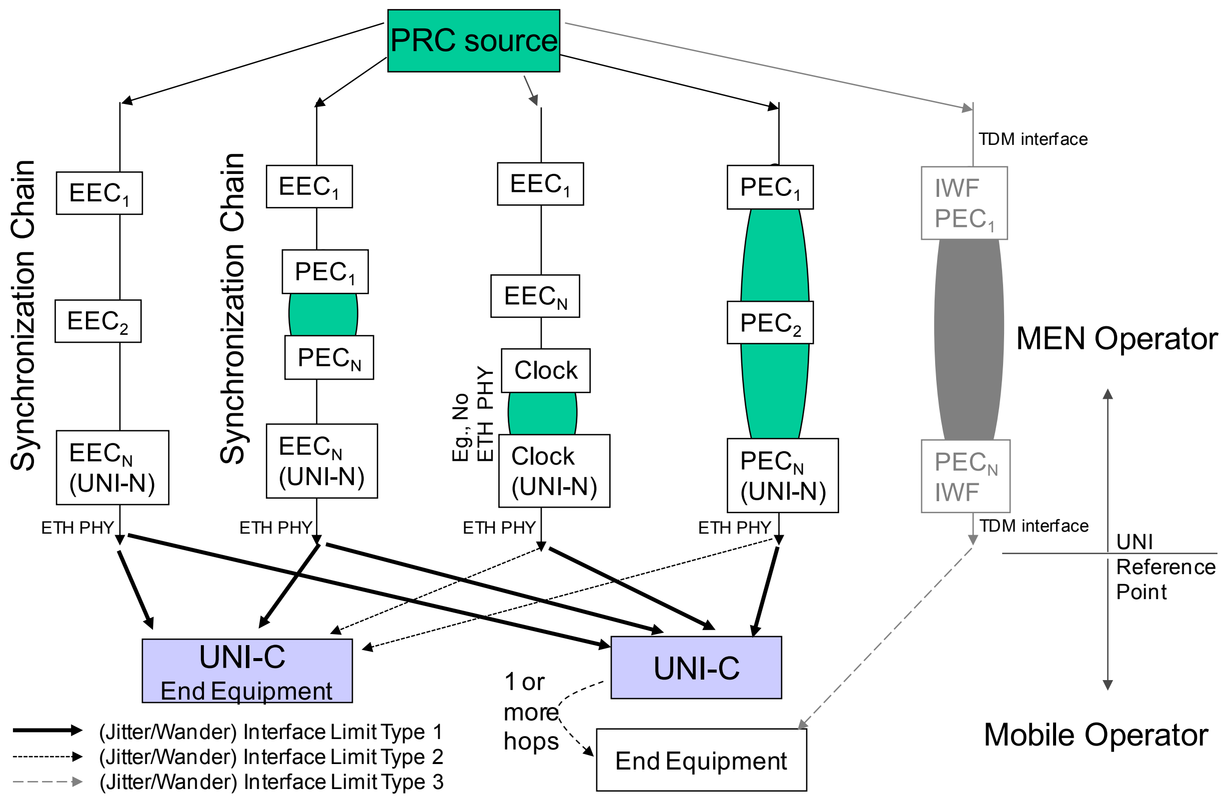

Figure 1: Synchronization Distribution Models from PRC source to RAN BS UNI

Figure 1 describes different scenarios in terms of frequency synchronization distribution. The distribution chain can be entirely synchronous Ethernet Equipment Clocks (EECs) or a mix of Packet based Equipment Clocks (PECs) and EECs or other clocks. This IA is not specifying the choice of the Synchronization architecture but is specifying interface limits for jitter and wander as follows:

1. Interface Limit Type 1: in this case, limits are described in Sections 13.2.1 and 13.3.1
2. Interface Limit Type 2: in this case limits are described in Sections13.2.2 and 13.3.2;
3. Interface Limit Type 3: in this case limits are described in Section 13.2.3.

13.2 Packet Based Methods for frequency synchronization

A master-slave hierarchy, similar to model described for SDH in ITU-T G.803 [52], is used for packet based methods with Packet Equipment Clocks. The source clock is distributed from a Primary Reference Clock (PRC).

For the UNI, there are two main use cases for frequency synchronization as shown in Figure 2:

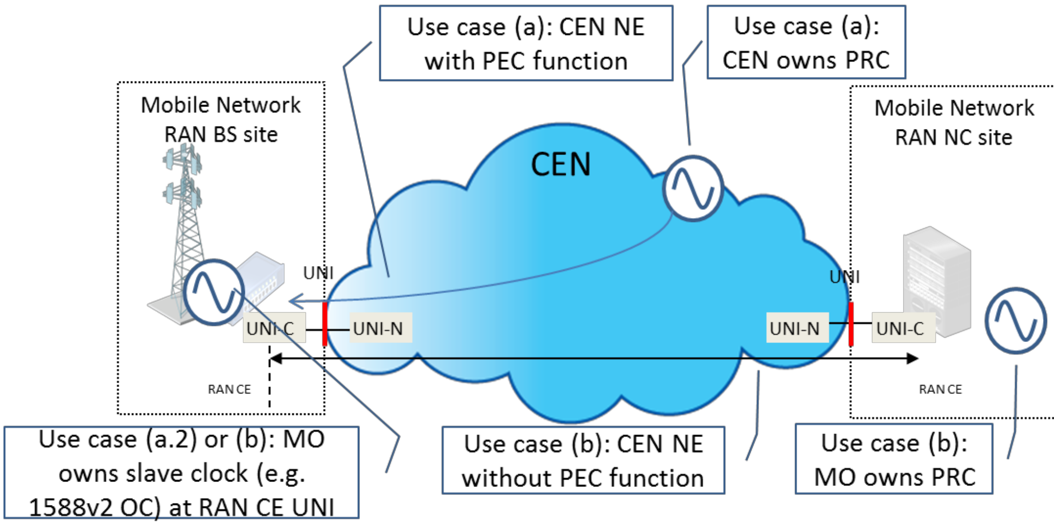

Figure 2: UNI use cases for packet method to distribute reference timing

(a) CEN NE with PEC function: This functionality can be at the NEs with UNIs to RAN BSs or can also be present at other NEs within the CEN. Also, CEN provides the source clock (PRC) for the synchronization service. PEC in support of packet method (for non CES application) will be defined by ITU-T.
   - (a.1.) Slave clock at the CEN's UNI: The timing (frequency) information can be directly recovered from the frame arrival times, e.g., ACR, such as when CES (MEF 3 [1]) is the backhaul service to RAN BS with TDM interfaces. PEC functions, as shown in Figure 1, are used to translate the frame arrival rate in to a physical layer frequency over the Interface. Performance at the network interface is specified in Sections 13.2.1 and 13.2.2 with Ethernet demarcation as well as Section 13.2.3 with TDM demarcation using GIWF.
   - (a.2.) Slave clock in RAN BS: The CEN's PEC function at the UNIs, or any NE in CEN, participates in the protocol to provide additional information such as accumulated delay. This use case is for further study.

(b) CEN NE without PEC function: Mobile Operator owns timing source at RAN NC site(s) and slave clocks at RAN BSs as defined in ITU-T G.8265 [44] and, in case of PTP, with a IEEE Std. 1588 PTP profile for frequency distribution as defined in ITU-T G.8265.1 [45]. The CEN provides EVC with performance objectives in support of the synchronization traffic class. See Section 8.2 for EVC Types and Section 12 for EVC, CoS as well as CPO for the CoS Name used to support packet based synchronization traffic class. The slave clock at RAN BSs can implement the PEC function to recover timing based on frame arrival rates or timestamps.

The UNI can be in Asynchronous Full Duplex Mode, i.e., Synchronous Ethernet mode of operation is disabled, when the CEN Operator is offering a Mobile Backhaul service to support the synchronization traffic class.

For the ENNI, there are also two main use cases as shown in Figure 3 - ENNI use cases for packet method to distribute reference timing

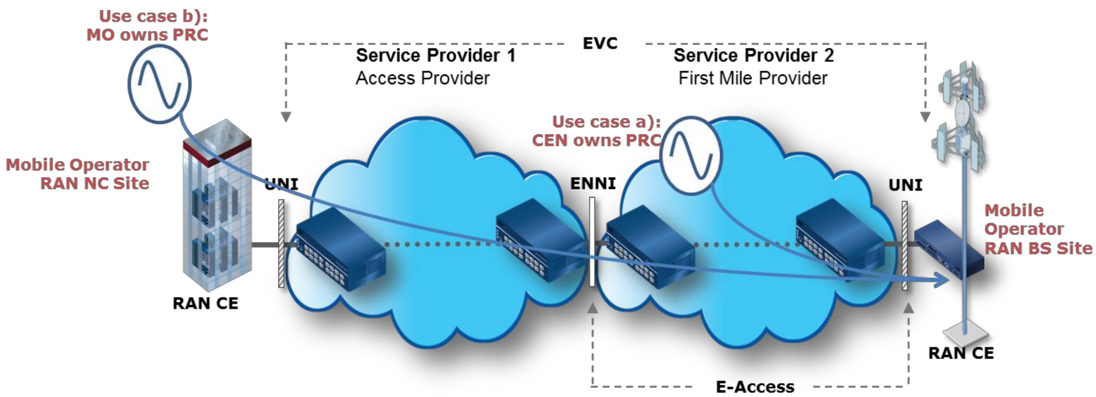

Figure 3 - ENNI use cases for packet method to distribute reference timing

(a) CEN NE with PEC function: This functionality is the same as in the UNI case shown in Figure 2.
(b) CEN NE without PEC function: As in the UNI case, the Mobile Operator owns timing source at RAN NC site(s) and slave clocks at RAN BSs as defined in ITU-T G.8265 [44] and, in case of PTP, with a IEEE Std. 1588 PTP profile for frequency distribution as defined in ITU-T G.8265.1 [45]. The CEN provides EVC with performance objectives in support of the synchronization traffic class. However, there is no guidance provided in this IA on how to distribute the performance objective budget of the EVC between the two CEN operators.

13.2.1 Network (UNI-N) Interface Limits for Packet based Methods

When a packet based frequency synchronization service is provided to a UNI-C not on 'End Equipment' at RAN BS site, then Interface Limit Type 1 applies as shown in Figure 1. The requirement in terms of tolerance and level of accuracy for the recovered timing signal are as defined for deployment case 1 in ITU-T G.8261 (see clause 9.2.2.1) [39].

[R33] If UNI-C is not on 'End Equipment' at RAN BS site (i.e., RAN BS) then the Interface Limits for Jitter and Wander at the UNI-N **MUST** meet clause 9.2.2.1 EEC network limits as defined in ITU-T G.8261 for deployment case 1 [39]

13.2.2 Network (UNI-N) Interface Limits for Packet based Methods – Special Case

When a packet based synchronization service is provided to a UNI-C on 'End Equipment' at RAN BS site, then Interface Limit Type 2 applies as shown in Figure 1. The requirement in terms of tolerance and level of accuracy for the recovered timing signal are as defined for deployment case 2 in ITU-T G.8261 Recommendation (see clause 9.2.2.1) [39].

Typically, Base Stations are designed to tolerate wander as per G.823 / G.824 traffic masks of T1/E1 interfaces, Section 4.2.1 and Reference 16 in 3GPP TS 25.411 [74].

[O15] If UNI-C is on 'End Equipment' at RAN BS site (i.e., RAN BS), as defined in deployment case 2 of ITU-T G.8261 (see clause 9.2.2.1) [39], then the Interface Limits for Jitter and Wander at the UNI-N **MAY** be as defined by ITU-T G.823 clause 5 [57] or ITU-T G.824 clause 5 [58]

It is important to note that the looser criteria might be justified as long as the tolerance of the 'End Equipment' at BS site is met.

13.2.3 Network (UNI-N) Interface Limits for Packet based Methods, use case b

When a packet based synchronization service is provided to a UNI-C without PEC function in the CEN NE, the requirement in terms of maximum permissible levels of packet delay variation of the packet timing signal are as defined in clause 8 of G.8261.1 [40].

13.2.4 CES timing requirements

Use case 1a and 1b in Section 8.1.1 has a SP delivering Mobile Backhaul service at a TDM demarcation using a GIWF with TDM interface to the RAN CEs. The internal implementation details of the GIWF are out of the scope for this IA.

13.2.4.1 Network (TDM Interface) Interface Limits at Output of GIWF

Interface Limit Type 3, as shown in Figure 1, applies for the synchronization performance at the TDM demarcation.

[R34] The synchronization distribution **MUST** be such that jitter and wander measured at the output of the GIWF TDM interface meets the traffic interface requirements specified in ITU-T G.823 [57] for E1 and E3 circuits, and ITU-T G.824 [58] for DS1 and DS3 circuits and, in case of SDH signals, that meet the network limits for the maximum output jitter and wander at the relevant STM-N hierarchical interface as specified by ITU-T G.825 [59].

[D23] The synchronization distribution **SHOULD** be such that the wander budget allocated to the CEN and the GIWF as measured at the output of the GIWF TDM interface meets the traffic interface requirements of ITU-T G.8261, Deployment Case 2 [39].

13.2.4.2 Network (TDM Interface) Interface Limits at Input of GIWF

[R35] Jitter and wander that can be tolerated at the GIWF TDM input **MUST** meet the traffic interface requirements specified in ITU-T G.823 [57] for E1 and E3 circuits, and ITU-T G.824 [58] for DS1 and DS3 circuits and in case of SDH signals, the GIWF TDM **MUST** meet the jitter and wander tolerance for STM-N input ports as specified by ITU-T G.825 [59].

13.3 Synchronous Ethernet Methods for frequency synchronization

The IEEE Std. 802.3-2012 standard [33] specifies that transmit clocks can operate with a frequency accuracy of up to +/-100 ppm. The Synchronous Ethernet (SyncE) approach provides a mechanism to deliver a network traceable physical layer clock over IEEE Std. 802.3 PHYs with EEC as specified in ITU-T G.8262 [41]. The SyncE model follows the same approach as was adopted for traditional TDM (PDH/SDH) synchronization i.e., utilizing the physical layer line signals, and implemented with similar engineering rules and principles. Synchronous Ethernet has also been designed specifically to inter-work with the existing SONET/SDH synchronization infrastructure. Note that Synchronous Ethernet is used to deliver frequency, but not phase or time of day.

The architectural aspects of Synchronous Ethernet are defined in ITU-T G.8261 [39]. SyncE provides the capability to provide an Ethernet clock that is traceable to a primary reference clock (PRC) as defined in ITU-T G.811 [54]. The details of the clock aspects of Synchronous Ethernet equipment can be found in the ITU-T G.8262 [41]. The latter specification defines the requirements for clock accuracy, noise transfer, holdover performance, noise tolerance and noise generation.

The frequency reference, delivered to the UNI-C at RAN BS site, is traceable to the CEN (Service Provider) PRC, as shown in Figure 4 below. The Mobile Operator can specify the required performance in terms of Network Interface Limit for Jitter and Wander at the UNI-N.

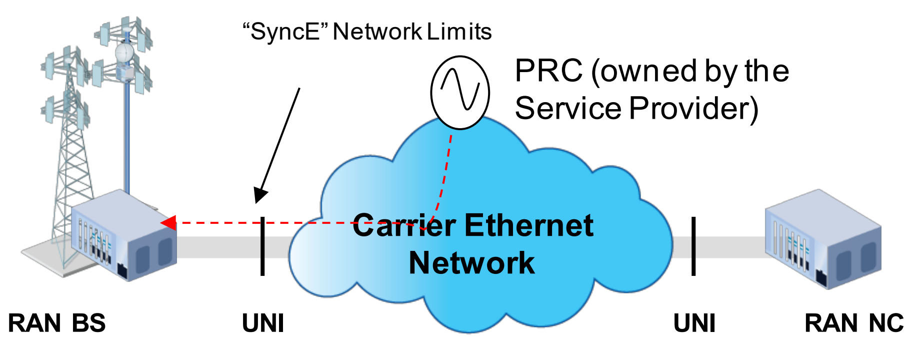

Figure 4: Example of Synchronization Service using Synchronous Ethernet

Further considerations on the use of Synchronous Ethernet in a multi-operator context can be found in ITU-T G.8264 Amendment 1 [43] for when Mobile Operator owns the PRC and CEN Operator is responsible for distribution of frequency reference to RAN BS sites.

13.3.1 Network (UNI-N) Interface Limits for Synchronous Ethernet Methods

When the Synchronization distribution across the CEN is a chain of EECs then Interface Limit Type 1 applies as shown in Figure 1. Two options are specified for Synchronous Ethernet equipment clocks (EECs). The first option, called EEC option 1, has been defined for networks using the 2048 kbps Synchronization hierarchy as defined in ITU-T G.813 option 1 for SDH networks [56] The second option, called EEC option 2, applies to Synchronous Ethernet equipment that are designed to interwork with networks optimized for 1544 kbps synchronization hierarchy and has defined based on ITU-T G.813 option 2 [56] and G.812 Type IV [55].

[R36] At the output of the UNI-N at a RAN BS site, when Synchronous Ethernet service is provided to the UNI-C at RAN BS, the interface **MUST** meet clause 9.2.1 EEC network limits from ITU-T G.8261 [39]:

The interface limits in [R36] are defined assuming the CEN implements a Synchronous reference chain as described in clause 9.2.1 of ITU-T G.8261 [39] . Synchronization chains based on Synchronous Ethernet are according to ITU-T G.823 [57], ITU-T G.803 [52] and ITU-T G.824 [58] models. [R36] is also required when there are intermediate nodes between the UNI-N and the Base Station that are part of an EEC chain.

13.3.2 Network (UNI-N) Interface Limits - Special Cases

As mentioned in clause 9.2.1 in ITU-T G.8261 [39] it is noted that the limits defined in ITU-T G.823 [57], ITU-T G.824 [58] and ITU-T G.825 [59] are generally applicable at all points in the Synchronization network. In some applications the CEN might not implement the Synchronization reference chain as described in clause 9.2.1 of ITU-T G.8261 [39]. These are defined as the limits for traffic carrying signals as opposed to synchronization signals. In some cases, a SP might decide that these less stringent limits are more appropriate for their network due to the types of links and equipment in the reference chain. Often these limits are used in conjunction with CES implementations.

In access networks, it might be possible to recover frequency reference from an Ethernet signal that is generating jitter and wander according to the tolerance characteristics of the ‘Connected Equipment’. Across the CEN either there is no chain of EECs/SECs/ or it is a Synchronization distribution network where timing is not carried on every link by an Ethernet PHY. The frequency reference is, however, delivered with an Ethernet UNI to BS sites. In these cases it might not be appropriate to require the UNI to meet Synchronous Ethernet interface limits and Interface Limit Type 2 applies as shown in Figure 1. Typically, Base Stations are designed to tolerate wander as per ITU-T G.823 [57] and ITU-T G.824 [58] traffic masks of T1/E1 interfaces, Section 4.2.1 and Reference 16 in 3GPP TS 25.411 [74]

[O16] If the CEN does not implement the synchronization reference chain according to clause 9.2.1 of ITU-T G.8261 [39] then Network limit at the UNI **MAY** be as defined by ITU-T G.823 clause 5 [57] or ITU-T G.824 clause 5 [58]

It is important to note that the looser criteria might be justified when the SP determines that the 'End Equipment' at the BS site can tolerate the traffic limits as specified in [O16].

13.4 Performance of time synchronization architecture

A master-slave hierarchy, is also used for packet based methods of time synchronization. The source clock is distributed from Primary Reference Time Clock (PRTC). The focus of this clause is on time synchronization. While various time synchronization architectures may be defined, in the case of this IA, the following main use cases have been identified:

1) **Use case 1:** PRTC in the CEN – G.8275.1 Boundary Clock chain (see figure A);

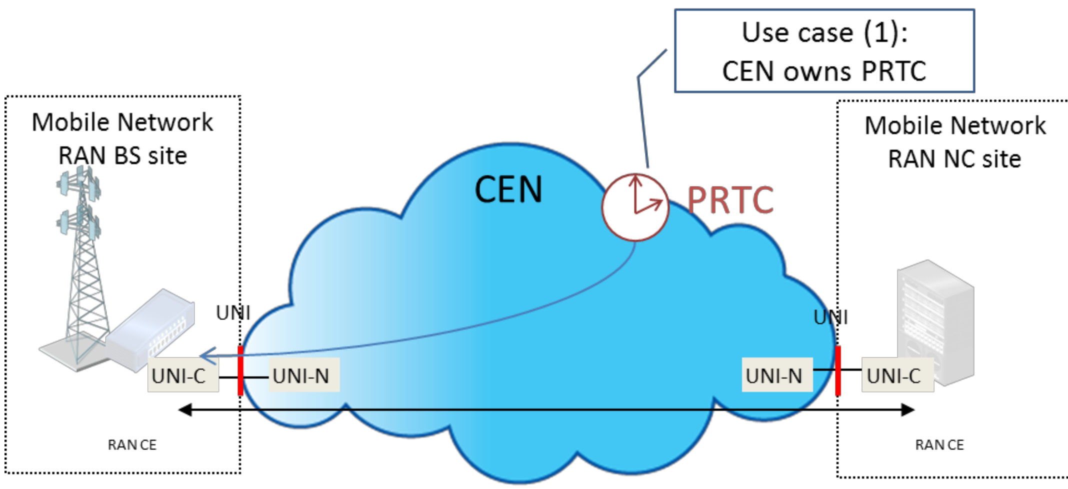

Figure A: Example of Time Synchronization Service with PRTC in the CEN – G.8275.1 Boundary Clock chain

This case with the PRTC owned by the CEN, resulting in time synchronization transported cross the UNI, has been standardized by ITU-T G.8275.1 and related performance objectives are provided in 13.4.1.

Note: the use of G.8275.2 profile in this case could also be considered. The applicable requirements are for further study.

[A-R2] In the case when the PRTC is owned by the CEN, PTP profile for time synchronization at the UNI MUST be as specified in ITU-T G.8275.1 [46]

2) **Use case 2:** PRTC in the MO network and Transparent transport as per G.8275.2 (see figure B) ;

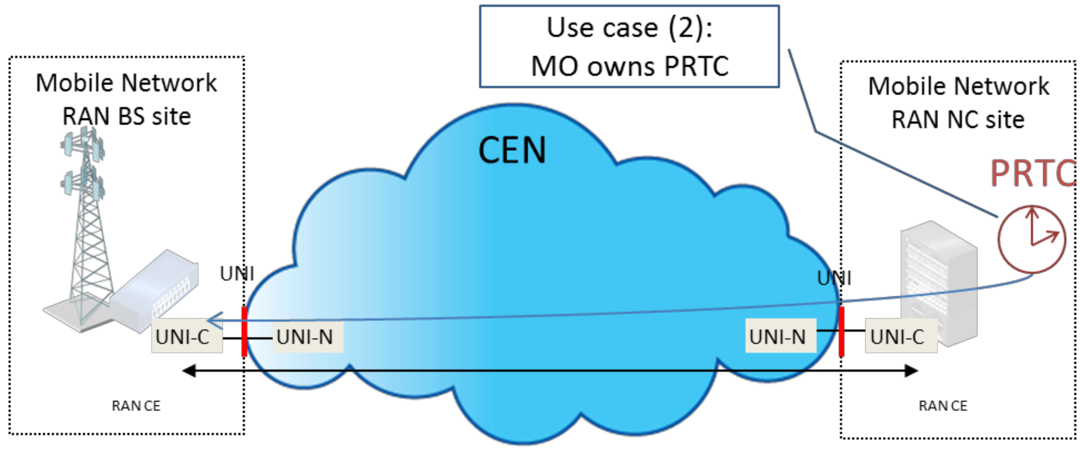

Figure B: Example of Synchronization Service with PRTC in the MO network and Transparent transport as per G.8275.2

This case with the PRTC owned by the Mobile Operator, resulting in time synchronization transparently transported cross the CEN, has been standardized by ITU-T G.8275.2 and related performance objectives are provided in 13.4.2.

[A-R3] In the case when the PRTC is owned by the Mobile Operator, PTP profile for time synchronization at the UNI MUST be as specified in ITU-T G.8275.2 [47]

Note: time synchronization transported cross a CEN using a transparent clock chain could also be considered for this use case. The relevance of this use case is still under study.

13.4.1 Network (UNI-N) Interface Limits for Packet based Methods: PRTC in the CEN

The performance objectives for G.8275.1 based service have been defined in G.8271.1 in terms of various parameters with the main target to allow the end application to meet +/-1.5 us accuracy at its output (e.g., radio interface of a radio base station).

The network limits defined by G.8271.1 are expressed in terms of two quantities:

- the maximum absolute time error: max |TE|, which includes all the noise components, i.e., the constant time error and the low frequency components of the dynamic time error-
a suitable metric applied to the dynamic time error component (in particular, MTIE and TDEV are used for measuring noise components with frequency lower than 0.1 Hz, and peak-to-peak TE is used for measuring noise components with frequency higher than 0.1 Hz)

The basic assumption in defining the network limits in G.8271.1 is that the End Node is directly connected at the interface meeting these requirements. This is shown in Figure C below

The related network limits are indicated as Type I.

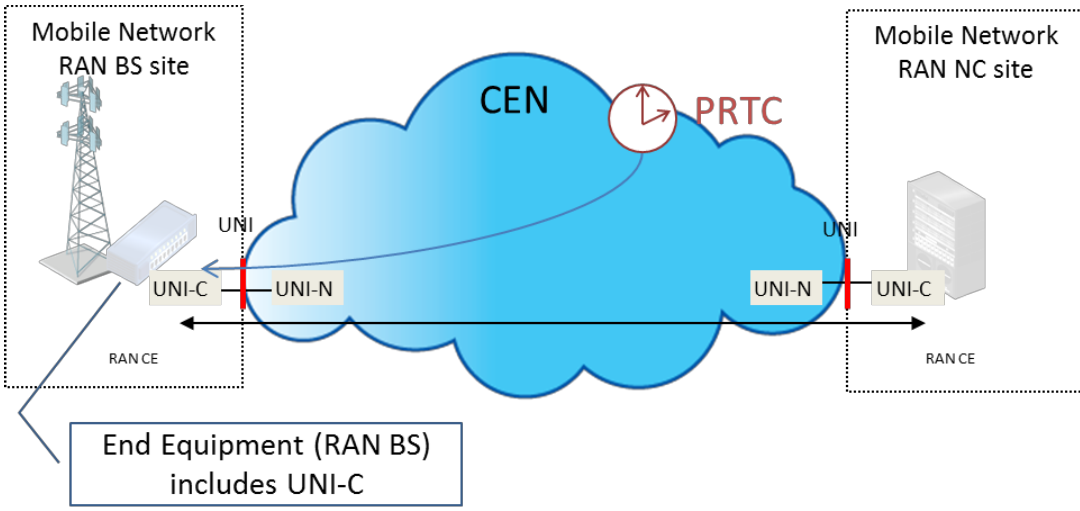

Figure C: Type I Network Limits

Additional cases may be of interest, the most notable being when there are additional hops between the UNI-C and the End Equipment (e.g., within the RAN BS site, or a few microwave hops to another RAN BS site). This is shown in Figure D. The related network limits are indicated as Type II.

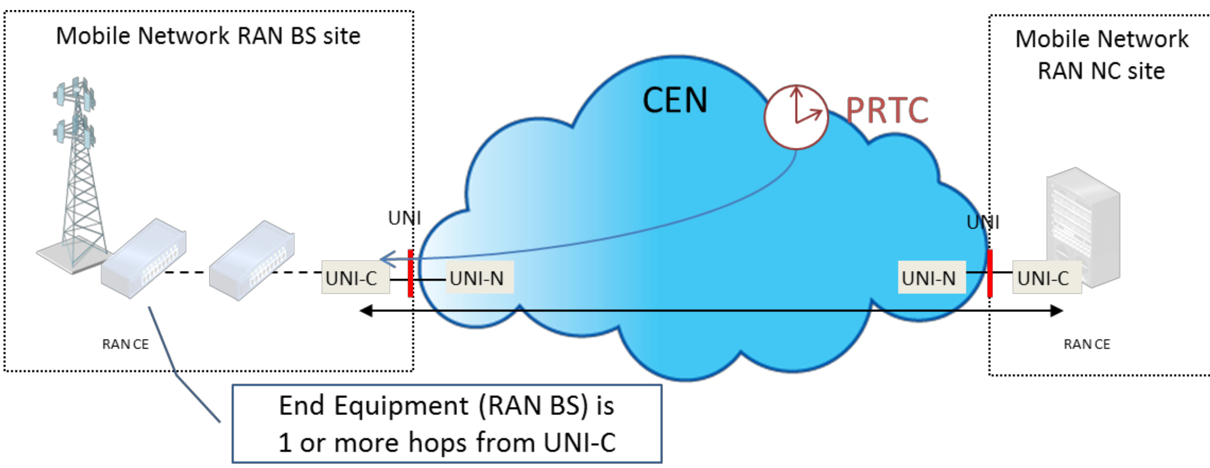

Figure D: Type II Network Limits

Finally, there may be cases when target different from 1.5 us could be of interest (either more or less stringent). For these cases different network limits would apply.

[A-R4] At the output of the UNI-N at a RAN BS site, when Time Synchronization service is provided to the UNI-C at RAN BS for any network limit Type, the interface MUST meet the specification for the dynamic time error in terms of peak-to-peak TE amplitude as defined in clause 7.3 from ITU-T G.8271.1 [39]

[A-R5] At the output of the UNI-N at a RAN BS site, when Time Synchronization service is provided to the UNI-C at RAN BS for Type I network limits, the interface MUST meet the specification for the dynamic time error in terms of MTIE as defined in clause 7.3 from ITU-T G.8271.1 [39]

The specification in terms of MTIE for other network limits type (e.g. Type II) in general depends on the characteristics of the network segment between the UNI-C and the End Equipment. This requires further studies. For small networks (e.g. 1 or 2 hops) the same specification as per [R35] could be assumed.

[A-R6] At the output of the UNI-N at a RAN BS site, when Time Synchronization service is provided to the UNI-C at RAN BS for Type I network limits, the interface **MUST** meet the specification for Maximum absolute time error network limits defined in clause7.3 from ITU-T G.8271.1 [48].

The specification in terms of max |TE| for other network limits type (e.g. Type II) may be based on the analysis provided by Appendix V in G.8271.1. This analysis allocates a certain budget that depends on the length of the chain between UNI-C and the End Equipment, or alternatively based on the target requirement at the output of the End Equipment. This is for further study.

The specification in terms of max |TE| for other network limits type (e.g. Type II) may be based on the analysis provided by Appendix V in G.8271.1. This analysis allocates a certain budget that depends on the length of the chain between UNI-C and the End Equipment, or alternatively based on the target requirement at the output of the End Equipment. This is for further study.

The time synchronization service generally implies that a Synchronous Ethernet service is also provided. In this case, the requirements as per section 13.3.1 apply. This may depend on the actual deployment, which is currently mandatory in the case of Type II network limits, and optional in case of Type I network limits.

[A-R7] In case of Type II network limits, the interface **MUST** also support Synchronous Ethernet service with requirements as per section 13.3.1.

[A-D1] In case of Type I network limits, the interface **SHOULD** also support Synchronous Ethernet service with requirements as per section 13.3.1.

13.4.2 Network (UNI-N) Interface Limits for Packet based Methods: PRTC in the MO network

Performance aspects related to this use case are currently under study in ITU-T. In particular the network limits are planned to be covered by ITU-T Rec. G.8271.2 and clock specification by G.8273.4.

14. References

Note: This amendment replaces section 14 as follows

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