Fronthaul scenarios and 1914 transport classes

Vincenzo Sestito, SM Optics
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IEEE 1914
Next Generation Fronthaul Interface
Jinri Huang, huangjinri@chinamobile.com

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<th>Date:</th>
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Author(s):

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Phone [optional]</th>
<th>Email [optional]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vincenzo Sestito</td>
<td>SM Optics</td>
<td></td>
<td><a href="mailto:vincenzo.sestito@sm-optics.com">vincenzo.sestito@sm-optics.com</a></td>
</tr>
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Premises
1914 - Converged RAN view and split points

Fronthaul scenarios

Multiple splits over network

Source: IEEE 1914.1 D0.2
Two levels FH network

Source: CMCC contribution to 1914 WG meeting in Beijing
Latency requirements – LTE and 5G fronthaul

**5G User plane latency [38913]** - The time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point via the radio interface in both uplink and downlink directions, where neither device nor Base Station reception is restricted by DRX (Discontinuous Reception occurring when in Idle mode for accomplishing with “paging” process).

**5G Control plane latency [38913]** - Control plane latency refers to the time to move from a battery efficient state (e.g., IDLE) to start of continuous data transfer (e.g., ACTIVE).

**LTE-A Backhaul reference [TR 36 912 V9.0.0]**

**5G Fronthaul reference [TR 38913]**

<table>
<thead>
<tr>
<th>Component</th>
<th>UE</th>
<th>RRH</th>
<th>BBU</th>
<th>UE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRC</td>
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<tr>
<td>Data</td>
<td>PDCP</td>
<td></td>
<td></td>
<td>PDCP</td>
</tr>
</tbody>
</table>

**User Plane latency [5 ms]**

**Control Plane latency [10 ms]**

**5G Fronthaul reference [TR 38913]**

<table>
<thead>
<tr>
<th>Component</th>
<th>UE</th>
<th>RRH</th>
<th>DU</th>
<th>CU</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRC</td>
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<td></td>
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<tr>
<td>Data</td>
<td>PDCP</td>
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<td>PDCP</td>
</tr>
</tbody>
</table>

**User Plane latency [eMBB=4 ms; URLLC=0.5 ms – 1 ms w/ BER<10^-5]**

**Control Plane latency [10 ms]**

Note - Latency requirements considered here refer to UE/eNb scope and do not include connectivity towards Core elements.
NGFI transport classes of service

<table>
<thead>
<tr>
<th>Class</th>
<th>Sub Class</th>
<th>Priority Level</th>
<th>Latency upper bound requirement (one way)</th>
<th>Throughput requirement (SPS)</th>
<th>Reliability</th>
<th>Reserved</th>
<th>informative</th>
</tr>
</thead>
<tbody>
<tr>
<td>control &amp; management</td>
<td>synchronization</td>
<td>TBD</td>
<td>TBD</td>
<td></td>
<td></td>
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<td></td>
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<td>$\tau_1$</td>
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<tr>
<td>data-plane</td>
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<tr>
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<td>Subclass_1</td>
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<td>$\tau_1$</td>
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<td>3GPP model Option 6,7,8</td>
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<tr>
<td></td>
<td>Subclass_2</td>
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<td>3GPP model Option 2,3,4,5</td>
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<tr>
<td></td>
<td>Subclass_3</td>
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<td>$\tau_2$</td>
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<td>Legacy backhaul</td>
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<td></td>
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<tr>
<td>Transport NW control &amp; management</td>
<td>Transport NW control-plane</td>
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<tr>
<td>Reserved</td>
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</table>

<table>
<thead>
<tr>
<th>$\tau_0$</th>
<th>$\tau_1$</th>
<th>$\tau_2$</th>
<th>$\tau_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 $\mu$s</td>
<td>100 $\mu$s</td>
<td>1 $ms$</td>
<td>10 $ms$</td>
</tr>
</tbody>
</table>

$\tau_0 \leq \tau_1 \leq \tau_2 \leq \tau_3$

Source: AT&T contribution to 1914 WG meeting in Dallas
FH scenarios and traffic classes
Legacy FH – CPRI (LTE and former services)

- In this scenario, CPRI (split option 8) is assumed to be the signal format provided by the antenna link.
- This scenario applies to LTE (and former) services and it might apply to eMBB (5G), at least, for transitory phase towards different split option/interface.
- It is unlikely that CPRI can also support remaining 5G services, mMTC and URLLC: since recently defined, it is expected that related antenna elements/ sensors provide a packet based signal.

- Legacy FH, CPRI based, relies commonly on a single split: an aggregator of RRH’s signals is placed at cell site and remaining blocks of BBU are placed in a single CU site. However, a double split may apply, provided to include at least MAC layer (devoted to HARQ handling) on the first available edge of fronthaul network (CU_A in the following example, but, in principle also DU may have this role) and to locate higher layer blocks in a farer CU stage. DU may be dedicated per cell site (then, co-located) or shared among more sites (then, located in different place).
- Both in single/double split scenario, fronthaul network is expected to cope with 1914 subclass 1, up to the edge where MAC layer is implemented (i.e., FH_I and FH_II, in the following example).
- In case of double split, the further stage of fronthaul network (FH_III, in the example) may comply to subclasses 2 or 3 depending on the actual layer implemented at CU_A and CU_B.
Legacy FH – CPRI – (LTE and former services)

No actual DU deployed in this scenario just aggregation elements

Macro Small

RRH

CPRI

FH_I

DU

FH_II

CPRI

CU_A

FH_III

RoE TBC/std ETH??

CU_B

BKH

EPC/NGC

CPRI aggregator

Transport connection (server layer)

Sub-class 1 [100 µs]

Sub-class 2 [1 ms]

Sub-class 3 [10 ms]

ETH aggregator

BS/eNB blocks

L1 client aggregation blocks

L2 client aggregation blocks

Transport connection (Lx-server layer, x=0, 1, 2)
NG_FH – CPRIoETH (LTE and 5G enabling)

• In this scenario, legacy CPRI sourced by RRH’s is encapsulated in RoE packet: DU realizes, in this case the mapping procedure/RRH’s signal aggregation and possibly the functional split toward CU.
• As for legacy CPRY scenario, DU may or may not be co-located with RRH’s, depending on the network application.
• In case of mapping over ETH (RoE) performed close to cell sites, the network scheme recalls the legacy CPRI splits possibilities: CU_A may include all of the functional blocks; so as, in alternative, it may just hosts PHY+MAC layers (at least, for HARQ termination) leaving the remaining blocks at CU_B.
• In case of higher layers at DU, including MAC block (option 5), would result in keeping tight latency requirements just in the scope of FH_I connectivity Note.

  Note - TR38913 suggests ISD= 5 Km for rural applications, thus FH_I scope <10 Km.
This implies that CU_A centralizes either fully or partially remaining processing blocks. In this last case, a further CU_B stage may be considered: sub-class 2 characterizes the transport network FH_II; while sub-class 3 may be applied to FH_III transport connectivity.
• It has to be noticed that just PHY block (options 7, 6) might be included in DU processing resulting in sub-class 1 requirement to be applied up to FH_II. FH_III would then rely on sub-classes 2, 3.
NG_FH – CPRIoETH (LTE and 5G enabling)

DU deployed in CASE 2 only

CASE 1
Possible CPRI aggregator
RoE mapper & aggregator

Sub-class 1 [100 µs]

CASE 2

Sub-class 1 [100 µs]
Sub-class 2 [1 ms]
Sub-class 3 [10 ms]

BS/eNB blocks
L1 client aggregation blocks
L2 client aggregation blocks
Transport connection (Lx-server layer, x=0, 1, 2)
**NG_FH – RoE (eMBB and mMTC)**

- In this scenario, RoE (or eCPRI) is assumed to be the signal format provided by the antenna link: this implies that PHY block is partially or, in principle, totally integrated into RRH, with different flavours possibly compliant to split options 7 and 6.

  Note – 1914 currently supports option 8 and I/Q native mapping - eCPRI is likely positioned somewhere in PHY block, so option 7 compliant.

- This scenario applies to 5G services, due to the assumed transmission of antenna signals in packet format.

- In case of no split performed close to cell sites, blocks higher than PHY (or PHY’) are integrated into CU. An ETH aggregator grooms signals coming from cell site(s): transport solution sub-class 1 applies to the network between RRH’s and CU, where HARQ (or equivalent 5G protocol) is terminated.

- In case of split at DU, as per «CPRIoETH» scenario, the integration of MAC (or layer terminating equivalent HARQ protocol) would keep the latency constraint between RRH and DU. While sub-classes 2 or 3 may apply to FH_I and FH_III depending on the actual split operated at CU_A and CU_B.
**NG_FH – RoE (eMBB and mMTC)**

CASE 1

- **PHY**
- **ETH aggregator**
- **Sub-class 1 [100 µs]**
- **DU**
- **FH_I**
- **RoE/eCPRI**
- **FH_II**
- **RoE/eCPRI**
- **CU_A**
- **RH**
- **Small**
- **Macro**

CASE 2

- **PHY**
- **Sub-class 1 [100 µs]**
- **PHY'**
- **MAC**
- **Sub-class 2 [1 ms]**
- **DU deployed in CASE 2 only**
- **CU_A**
- **FH_II**
- **RoE/eCPRI**
- **FH_III**
- **RoE TBC / eCPRI, Std ETH ??**
- **CU_B**
- **BKH**
- **EPC / NGC**

Transport connection (Lx-server layer, x=0, 1, 2)

- BS/eNB blocks
- L2 client aggregation blocks

Sub-class 1 [100 µs]  Sub-class 2 [1 ms]  Sub-class 3 [10 ms]
NG_FH – RoE (URLLC, mMTC)

- **Most critical services** for latency requirement (URLLC and mMTC) need very likely a Controller location closer to the radio elements, than the one for eMBB or mMTC (relaxed performance): this implies the usage of different CU’s.

- User Plane latency requirement derived from 3GPP (0.5/1 ms for URLLC) results in sub-class 0 application.

- In case of no split close to cell site, keeping all the BBU blocks devoted to critical services at CU should give more chances for resource sharing.

- Possible split at DU may apply, depending on the actual termination of time sensitive protocols (HARQ-like). This may give more margin to the network span DU-CU (FH_II), with respect to the total 50 µs latency budget. However, no «multiple split» is likely in this scenario due to the tight UP latency requirement.
NG_FH – RoE (URLLC, mMTC)

Macro Small Sensors

DU deployed in CASE 2 only

CASE 1

ETH aggr.

CASE 2

User Plane latency [URLLC=0.5 ms – 1 ms w/ BER<10^-5]

Sub-class 0 [50 µs]

BS/eNB blocks

L2 client aggregation blocks

Transport connection (Lx-server layer, x=0, 1, 2)
Transport connection

Macro
Small
Sensors

RRH

FH_I
CPRI
RoE
eCPRI

DU

Sub-class 0 [50 µs]

CU_C

FH_II
URLLC
eMTCoM

Sub-class 1 [100 µs]

Sub-class 2 [1 ms]
Sub-class 3 [10 ms]

Sub-class 3 [10 ms]

FH_III

CU_A

FH_III

Sub-class 2 [1 ms]
Sub-class 3 [10 ms]

Sub-class 3 [10 ms]

CU_B

BKH

EPC / NGC

Very low latency transport
Low latency transport
Mid latency transport
Transport connection

- **Fulfilment of sub-class 0** implies the application of a single split across the FH network, and, very limited (or no) switching elements in the connection RRH-CU, depending also on the the actual optical links length. Due to the tight requirement in latency (and jitter), it also drives to the extensive application of the lowest layer technology available (L0).

- **Fulfilment of sub-class 1** may allow multiple split across the network, provided to keep the layer handling time sensitive protocols (e.g. HARQ) as close as possible to the cell site.

The requirements (latency/jitter) are expected to be compatible with both L1 and L2 mapping and networking (e.g., ETH RoE, ETH TSN/CM, OTN) where a controlled engineering of the network (geographical scope, span length, amount of switching nodes) is realized.

Additional deployment of L0 technologies (e.g., WDM) may occur for optimizing the usage of transmission resources.

- **Fulfilment of sub-classes 2 and 3**, implies more relaxed latency/jitter requirements, meaning higher span length length and more switching elements across the network.

The requirements allows for both L1 and L2 mapping and networking.

Additional deployment of L0 technologies (e.g., WDM) may occur for optimizing the usage of transmission resources.
Further steps proposed

Consolidating previous assumptions by providing a view on path latency performances (RRH-CU) associated to different transport options and realistic mix of traffic over the network:

• ROE (CPRI/IQ) over ETH TSN/CM (& WDM)
• ROE (CPRI/IQ) over OTN (& WDM)
• ROE (CPRI/IQ) over radio

....other options??????
THANK YOU!