1914 Copenhagen

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China Mobile: 5G impact on FH transport & potential NGFI scenarios

**LTE RRH with:**

- Partial offload of LTE L1 functions
- Proprietary protocol based on 1914.3 RoE
- Validated multiple scenarios
- NGFI split 4 variant
- More than 4-factor data reduction compared to CPRI
- ~300 Mbps for single antenna 20 MHz LTE cell
- < 10 Mbps during low load

**Function repartitioning**

- Packet based network
- Cell load dependent traffic
- Support for coordinated functions
- Decouple traffic from number of antennas

Different functional splits proposed
No "one size fits all" solution

<table>
<thead>
<tr>
<th></th>
<th>Split 1</th>
<th>Split 2</th>
<th>Split 3</th>
<th>Split 4</th>
<th>Split 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRH complexity</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Lowest</td>
</tr>
<tr>
<td>FRH Interface complexity</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Pooling gain</td>
<td>Small</td>
<td>Relatively small</td>
<td>Relatively small</td>
<td>Large</td>
<td>Large</td>
</tr>
<tr>
<td>Complexity of upgrading and maintenance</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
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<tr>
<td>Delay requirement</td>
<td>&lt; 100 ms</td>
<td>&lt; 1 ms</td>
<td>&lt; 1 ms</td>
<td>&lt; 1 ms</td>
<td>&lt; 1 ms</td>
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Split 4 has low implementation complexity and offers cell-load dependent fronthaul traffic. It is the most obvious choice for a Proof of Concept implementation.

Split 4 NGFI

3-sector LTE site fronthaul load as a function of antennas
CPRI vs. Split 4 NGFI

Split 4 NGFI RRH
China Mobile: 5G impact on FH transport & potential NGFI scenarios

5G at a glance

Three major application scenarios

• Which scenarios may have potentially noticeable impact on FH transport?
• Which features may have potentially noticeable impact on FH transport?
• Which technologies are having potentially noticeable impact on FH transport?
# Massive MIMO

<table>
<thead>
<tr>
<th>mMIMO</th>
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<tbody>
<tr>
<td>Typical configuration</td>
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<tr>
<td>Key impact on FH transport</td>
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<tr>
<td>Potential solution to transport</td>
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<tr>
<td>Potential scenarios of the feature/tech.</td>
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<tr>
<td>Applicable for D-RAN or C-RAN</td>
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<td>Priority</td>
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# Joint transmission/reception (JT/JR)

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<td>Priority</td>
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China Mobile: Scenarios identified

**Scenario 1: indoor hotspot** E.g: office building
- High capacity, Interference not an issue
- Potential requirements on NGFI: multiplexing capability, reduced maximum bandwidth, traffic-dependent

**Scenario 2-1: dense urban with 4G/5G co-located**
- Dense population; outdoor; high traffic load, Interference is an issue
- Potential solutions/technologies: C-RAN-based Hetnet architecture, Interference cancellation schemes (JT/JR/CS/CB etc.), mMIMO for capacity
- Some attributes: – 1 ring ~ 6-8 MUX, 2-5km^2 coverage, – 1 DU ~ xx (e.g. 6-10) 5G RRU + 1 4G
- RRU, Distance b/w DU and 5G RRU: < 2km
- Potential requirements on NGFI: Multiplexing capability, Reduced maximum bandwidth, Flexible split options

**Scenario 2-2: dense urban with 5G RRU only**
- Big difference from previous one: Removal of stringent requirements via 4G RRU (i.e. CPRI requirements)
Broadcom: Practical approach to converged FH/BH network architecture and functional partitioning

- Architecture proposal for converged fronthaul and backhaul network for 4.5/5G RAN.
- Functional splits from a general purpose circuit point of view.
- Proposal NGFI interfaces and functional splits

Architectural Motivations
- Relaxed backhaul bandwidth requirements, support for low latency applications and radio/proximity optimized applications.
- Converged fronthaul and backhaul with unified E2E networking infrastructure and OAM.
- Fully virtualized coordinated RAN.
- Reduced buffering in vRAN nodes and centralized higher layer radio resource/mobility management
Summarizing..  
- Multiple functional split points – not just how it splits in the radio stack but also how it fits into network architecture.  
- Different functional splits affect latencies and synchronization requirements on specific parts of the transport network –

they **do not change** the overall system level radio synchronization requirements  
- Highly accurate Time-synchronization distribution becomes key.  
- Traffic isolation (no traffic interferes other traffic) becomes key.
Proposal

- Define requirements and functions for a small number of splits (2? 3?).
- Functional splits should aim for simplicity:
  - Identify the most common and important functions that are easy to design “5G ready”.
- Adopt the three interfaces proposed in this contribution as a baseline:
  - NGFI1 – simple split functions, high volume standard networking solutions with little software involvement.
  - NGFI2 – more complex split functions, aggregation, converged front- and backhaul, software functions are likely needed.
  - NGFI3 – “L2 splits” with full service provider functions.
HFR: NGFI State-of-the-art Overview

Architecture for the transport of mobile fronthaul traffic (e.g., Ethernet-based), including user data traffic, and management and control plane traffic.

Requirements and definitions for the fronthaul networks, including data rates, timing and synchronization, and quality of service.

The standard also analyzes functional partitioning between RRUs and BBUs that improve fronthaul link efficiency and interoperability on the transport level, and that facilitate realization of cooperative radio functions, MIMO operational modes, CoMP.
CAICT: Considerations on synchronization in next generation CRAN fronthaul architecture

- Data are transmitted Statistical multiplexing with Ethernet;
- Nodes are synchronized over Ethernet to take advantage of idle period to make power consumption earth-friendly;
- Under packet switching network Synchronization performance may suffer from PDV(Packet Delay Variance) and will be more challenging;
- Initial discussion on how to support synchronization for NGFI in ITU-T.

S1(BBU to BBU) is distributed in backhaul architecture solved in ITU-T G.8271.1 HRM

S2(BBU to RRU) is suggested as key issue to be discussed in CRAN fronthaul architecture

S3(RRU to RRU) is so complex and difficult to be controlled but can be converted to S2(illustrated in “Three-cornered hat” method).
CAICT: 3 proposed solutions

Option 1: T-BC and T-OC are located in BBU and RRU respectively with G.826x and G.827x series standards supporting compatible with packet networks.

Option 2: Master and slave module are located in something called “remote PTP-head” technology, noted that ToD format and mechanism of link delay compensation should be specified in NGFI standard for further study.

Option 3: EEC clocks are replaced by PEC clock in T-BC and T-OC, with the advantage of partial supporting for timing in PTP/syncE unaware networks (e.g. through switch/router), however this option may be a great challenge against PDV and complexity of algorithm for packet filtering, so it is recommended in low priority comparing to option 1 and option 2.
Verizon: Transport Requirements for a 5G Broadband Use Case

RAN Split Benefits/Drivers

- **Resource Pooling**
  - Pool resources across multiple eNBs
  - L2/L3 resources dimensioned on aggregate traffic/connections
  - L1 resources dimensioned on RF BW & antennas

- **Cooperative Processing**
  - Centralized Scheduling and Interference management
  - UL/DL CoMP schemes

- **Increased Virtualization**
  - Enable SDN/NFV with general purpose compute hardware
  - Efficient scalable RAN

- **Easier Upgrades and Self Healing**
  - Reduce hardware/software upgrade & provisioning time
  - Grow user capacity/connections/features as needed
  - Virtual machine switchover on failure

- **Edge Applications**
  - Faster deployment of new services and features (M2M handling, Edge Analytics (User/Application), Video Optimization etc)
  - Decouple applications from dedicated physical elements

- **Energy Savings**
  - Efficient pooling of compute to lower overall energy consumption
  - Power down resources during lighter traffic to save energy

- **Reduce CAPEX/OPEX**
  - Large scale centralized processing on general purpose hardware
  - Cost effective Fronthaul transport - some PHY functions at edge
  - Easier hardware, software and vendor switching

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RAN Split Options: Comparison

<table>
<thead>
<tr>
<th>Split Option</th>
<th>Front Haul Requirement</th>
<th>Performance/Operations</th>
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<tbody>
<tr>
<td></td>
<td>BW</td>
<td>Latency</td>
</tr>
<tr>
<td>Op 1</td>
<td>PDCP – RLC</td>
<td>Low</td>
</tr>
<tr>
<td>Op 2</td>
<td>RLC – MAC</td>
<td>Low</td>
</tr>
<tr>
<td>Op 3</td>
<td>MAC Hi – MAC Lo</td>
<td>Lower</td>
</tr>
<tr>
<td>Op 4</td>
<td>MAC – PHY</td>
<td>Lower</td>
</tr>
<tr>
<td>Op 5</td>
<td>PHY Bit – PHY Sym</td>
<td>Lower</td>
</tr>
<tr>
<td>Op 6</td>
<td>PHY Pre – PHY IFFT</td>
<td>High</td>
</tr>
<tr>
<td>Op 7</td>
<td>PHY – RF</td>
<td>Always High</td>
</tr>
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FH BW Comparison – RAN Split Options

4G/5G Fronthaul/Backhaul Architecture Options

Future Mobile/Access Network
Unified front-haul, mid-haul and backhaul

- Move away from CPRI (technical and ecosystem limitations)
- Ethernet could be the unifier
- Enable fronthaul resilience

Optimized RAN Split: Desired Features

- Reduced FH Bandwidth
- Low complexity interface
- Low cost off-the shelf Remote Units
- Centralization gains
- At least one high and one lower layer split

Challenges

- Tradeoffs: Timeline-Flexibility, Cent. Gains–Bandwidth
- Standardized Interfaces: Vendor Interoperability
- Ecosystem: Partners needed for equipment, compute, networking, and end-to-end testbeds/PoC