Evaluating the different fronthaul options and the technical requirements for the different scenarios

Philippe Chanclou, Orange Labs Networks
Sebastien Randazzo, Orange Technical Direction
RAN&Backhaul Networks
Session: WHAT ARE THE FRONTHAUL STRATEGIES
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1. Back-, mid- and front-haul
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1. Clarification: Back-, mid-, and front- haul

According to MEF, midhaul is backhaul from small-cell BSs to a macro BS:

- MEF definition (MEF 22.1.1, Mobile Backhaul Phase 2, Amendment 1, 2014/01/27): Backhaul extension between a small cell base station (BS) and its master macrocell BS.

- “A variant of Mobile Backhaul termed Midhaul that refers to the network between base station sites (especially when one site is a small cell site).”
1. Clarification: Back-, mid-, and front-haul

- **Back- & Mid-haul** are network segment compatible with standardized **Ethernet** access interfaces:
  - optical PtP interface
  - G-PON (FTTx - PtMP)
  - mwave ....

- Current dominant **Fronthaul** interface is based on a specification designed as a backplane extension
  - CPRI* is **not** a legacy interface to be carried over existing access protocols (Ethernet, …)
  - CPRI is only a MSA (Mutual Standard Agreement)

* CPRI: Common Public Radio Interface
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Cloud-RAN migration

Conventional Architecture

- **Standard BS**
- **BBU Remoted**
- **BBU Centralised**

Cloud RAN Architectures

- **Intra BBU Pooling + CoMP**
- **Inter BBU Pooling + CoMP**

Possible future products

**Intra-site BBU pooling**
(typ. 3 cells/sectors max and several Mobile Technologies: 2G, 3G, 4G)

3 to 18 fronthaul links

**Inter-site BBU pooling**: hundreds fronthaul links with virtualisation

RAN??

Fibre between remote BBU and Radio head known as “Fronthaul”

CRAN = Cloud RAN  BBU = Base Band Unit  BS = Base Station  RRH = Remote Radio Head
Different C-RAN architectures

- **Wide C-RAN**
  - Macrocells + Hetnets

- **Private and Local C-RAN**
  - Micro or small cells
  - Outdoor: Local C-RAN
  - Indoor: Private C-RAN

DC: Data Center
CO: Central Office
**Fronthaul: a new segment that comes with Centralised Radio Access Network**

**Fronthaul interfaces:** CPRI, OBSAI, ORI  
**Fronthaul mediums:**
- **Optical Fiber:** Single Mode Fiber with or without color flavors  
- **Wireless:** several RF bands possible with or without spectral efficiency
Fronthaul interface: at the heart of a basestation

- 2003: Common Public Radio Interface (CPRI)
  - Physical layer: copper or optical fibre based on SFP connectivity

- 2002: Open Base Station Architecture Initiative (OBSAI)

- 2010: ETSI Open Radio Interface (ORI)
  - Multi-vendor interoperability (CPRI based)
  - Allows for compression

All base stations are based on a **internal digitised radio interface** between RU and DU.
It is a **serial Constant Bit Rate** interface based on SFP connectivity for banalisation, volume and interoperability.
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Fronthaul requirements 1/2

1. Radio site configuration:
   - **Macrocells**: 3 sectors x 4-5 Radio Access Technologies/bands → **up to 15 RRH**
   - **Micro/small cells**: 1 sector x 4-5 Radio Access Technologies

2. Bit-rate requirements per antenna site (symmetrical Bit-rate):
   - 1 sector 2G → few Mbps should be required but RAN vendors propose CPRI 2.457Gbit/s
   - 1 sector 3G → few 100 Mbps should be required but RAN vendors propose CPRI 2.457Gbit/s
   - 1 sector LTE 20MHz 2x2 MIMO → CPRI 2.457Gbit/s
   - 1 sector LTE 20MHz 4x4 MIMO → CPRI 4.9Gbit/s

3. Timing requirements:
## Fronthaul requirements 2/2

<table>
<thead>
<tr>
<th>Fronthaul requirement</th>
<th>From standards</th>
<th>From RAN providers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency : RTT (Round Trip Time)</td>
<td>Max. 500 µs (NGMN) 5µs excl. cable (CPRI)</td>
<td>500 µs possible but no more than <strong>150 µs</strong> (30km) recommended to allow CoMP implementation</td>
</tr>
<tr>
<td>Latency Up/Down unbalance</td>
<td>3GPP/ETSI</td>
<td>± 125 ns equivalent to</td>
</tr>
<tr>
<td></td>
<td>- UE positioning error (RSTD* - localization) accuracy : ± 163 ns</td>
<td>- ≈ 25m fibre</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- ≈ 20km SMF chromatic dispersion 1,3/1,55µm (B&amp;W transceiver)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- all processing time diff. ONU/OLT</td>
</tr>
<tr>
<td>Latency accuracy</td>
<td>CPRI:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Link Timing Accuracy: ± 8 ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Round Trip Delay Accuracy: ± 16 ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3GPP/ETSI:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- UE transmission timing accuracy ($T_{ADV}$): ± 130ns</td>
<td></td>
</tr>
<tr>
<td>Jitter &amp; wander</td>
<td>CPRI (guided by XAUI specifications (IEEE 802.3))</td>
<td>RMS ≈ 1.8 ps</td>
</tr>
<tr>
<td></td>
<td>- Freq. deviation : ± 2 ppb (3GPP: 50ppb)</td>
<td>Peak-To-Peak ≈ 26 ps</td>
</tr>
<tr>
<td>BER</td>
<td>$10^{-12}$</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>
**Wireless fronthaul (CPRI)**

<table>
<thead>
<tr>
<th>From Small cell or 4(^{th}) sector</th>
<th>Native wireless</th>
<th>with spectral efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 Gbps CPRI in 500MHz</td>
<td>1 x 2.5 Gb/s</td>
<td>3 x 2.5 Gb/s</td>
</tr>
<tr>
<td><strong>500 MHz</strong></td>
<td><strong>70 MHz</strong></td>
<td><strong>7.5 Gbps in 70 MHz</strong></td>
</tr>
<tr>
<td>mmwave (E-BAND)</td>
<td></td>
<td>Sub-6 ghz, mmwave, mmwave</td>
</tr>
<tr>
<td>3 x 2.5 Gbps CPRI in 500MHz</td>
<td>3 x 2.5 Gb/s</td>
<td>LPE with MIMO 8x8</td>
</tr>
<tr>
<td><strong>500 MHz</strong></td>
<td><strong>500 MHz</strong></td>
<td></td>
</tr>
<tr>
<td>mmwave (E-BAND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 x 2.5 Gbps CPRI in 4x500MHz</td>
<td>3 x 2.5 Gb/s</td>
<td>3 x 10 Gb/s</td>
</tr>
<tr>
<td><strong>10 Gbps</strong></td>
<td><strong>30 Gbps</strong></td>
<td></td>
</tr>
<tr>
<td>mmwave (E-BAND)</td>
<td></td>
<td><strong>12 x 2.5 Gb/s</strong></td>
</tr>
</tbody>
</table>

**With wireless fronthaul, turn existing macro site into local C-RAN**

Easier and faster deployment, same network architecture, better radio performance
Optical fronthaul (CPRI)

Passive

Active & Semi Active
Discussion about fronthaul transport

- **Muxponder**  
  (active)
  - High efficiency fiber sharing
  - WDM management
  - Native OAM and demarcation
  - Risk on performance (latency, synchro) needed for CPRI
  - CPRI rate dependent
  - Power supply required
  - Foot print (cooling cabinet)
  - Cost issue

- **Transponder**  
  semi-active / active
  - High efficiency fiber sharing
  - WDM management
  - Native OAM and demarcation
  - Transparent CPRI transport
  - Power supply required
  - Foot print (cooling cabinet)
  - “Cost” issue

- **Passive**  
  (CWDM)
  - Fiber sharing (18 CPRI / up to 200 Gbit/s per fiber)
  - No power supply (high reliability)
  - Suited for outdoor deployment
  - Quick qualification process
  - No introduction of transport constraint
  - Passive demarcation point
  - Low foot print
  - Low “Cost”
  - Passive demarcation point
  - OAM by RAN
  - WDM management by RAN
What is a passive fronthaul solution?

- BBU Hotel Data center area for a cells cluster
- FTTA & PTTA hybrid cable
- Low footprint cabinet Energy and passive fiber
- Passive CWDM MUX & DeMUX
- Backhaul
- Hardware sharing
- BBU hotel
  - BBU 3G
  - BBU 4G
  - Interface fronthaul
  - Interface backhaul
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What will be 5G?

- **LTE**: Max DL 300Mbit/s
- **LTE-A**: Max DL 1Gbit/s
  - improvements based on carrier aggregation, MIMO, enhanced interference coordination and coordinated MultiPoint

- **5G** should support:
  - **1000 times** higher mobile data volume per area
  - 10 – 100 times higher number of connected devices
  - 10 -100 times higher typical user data rate
  - 10 times longer battery life
  - 5 times reduced End-to-End latency
5G impact on fronthaul

- **CPRI link-rate explosion:**
  - LTE-A 20MHz 8x8 MIMO → CPRI 9.8Gbit/s
  - 5G 100MHz → CPRI 25Gbit/s or more
    - >> 100MHz at mm-waves → CPRI rate?
    - Massive MIMO

  → Compression? new functional split between RU and DU?

- **Fronthaul and backhaul coexistence?**
- Adaptable fronthaul for **dynamic network load**?
- CRAN load balancer: **CPRI switch**?
- 5G End-to-End **Latency**: 5 times reduced?

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Potential 5G architecture:
Fronthaul over Ethernet: the promise, but with some challenges

- **IEEE 1904.3 Task Force (RoE) in progress**
  Standard for Radio Over Ethernet Encapsulations and Mappings

- A lot of work ongoing on fronthaul over Ethernet:
  - possibility to **reuse Ethernet connectivity inside the RAN but not on transport network**
  - Ethernet includes **natively OAM**
  - Linked with compression & functional split work

- However some challenges:
  - CPRI: constant bit rate interface transporting also synchronization to RRH
  - **Packetization → delay** and utilization of Eth packets
  - Frequency and time/phase **synchronization**.
  - Switchs and gateways must be « transparent » and CPRI dedicated?
  - To address an antenna site, several CPRI over Eth. links must be carried
    - **WDM is the must-have for fronthaul network for either native CPRI or CPRIoEth.**

- **Re-used Ethernet backhaul equipment/network for RoEthernet is not trivial**
  - number of ports (one RRH = one RoE, one antenna site = several 1GEth RoE)
  - switching policy and capacity (transparent mode)
  - synchronisation
  - scalability
## Conclusions and next steps

### C-RAN drivers and global perspective
- Radio Site engineering solution & hardware sharing
- Radio performance improvements and future proof for LTE-A
- Hybrid Fronthaul/Backhaul solution needed to address **HetNets**
- C-RAN to co-exist with regular RAN architecture

### Wireless Fronthaul
- Wireless fronthaul **commercially available today** for network densification and **local C-RAN**
- Use of millimetric bands in future for **massive small cells**

### Fiber Fronthaul
- **CWDM ready**: simple, passive, cost effective and future proof
- **CWDM single fiber working**: increase fiber sharing and operational simplification – in the roadmap
- **Transponder** if wavelength management is an issue
- Supervision and OAN of fronthaul by RAN

### Fronthaul
- RAN OSS to support fronthaul link (Fiber and wireless)

### CPRI redefinition if needed
- CPRI transport: include natively the OAM of the medium
- New functional split interface to reduce bandwidth?
- Packetized fronthaul?
- Reference configuration including demarcation point
- Sleep mode for energy efficiency?
Thank you
Merci
Danke
Grazie
Tack
谢谢
감사합니다
ありがとうございました
2.5 Gbps CPRI in 500Mhz

70 MHz
7.5 Gbps in 70 MHz

1 LTE CPRI
1 x 2.5 Gb/s

mmwave (E-BAND)

3 LTE CPRI
3 x 2.5 Gb/s

Sub-6 ghZ, mwave, mmwave
3 x 2.5 Gbps CPRI in 500Mhz

4 x 2.5 Gbps CPRI in 4x500Mhz

LTE CPRI

3 x 2.5 Gb/s

mmwave (E-BAND)
LTE with MIMO 8x8

30 Gbps CPRI in 500Mhz

30 mwave, mmwave

3 x CPRI 8

3 x 10 Gb/s

BBU
BBU
BBU

12 x CPRI 3

12 x 2.5 Gb/s

carrier 1
carrier 2
carrier 3
carrier 4

Sector 3
Sector 2
Sector 1

Sector 3
Sector 2
Sector 1
one/two fibers per CPRI link