Cloud RAN fronthaul

Options, benefits and challenges.

iJOIN Winter School "5G Cloud Technologies: Benefits and Challenges,"
Bremen, 2015-02-23

Aleksandra Checko,
Industrial PhD student
Aleksandra.Checko@mtigroup.com

www.fp7-harp.eu
Outline of today’s presentation

- Base station architecture evolution towards C-RAN
  - Traditional base station (past)
  - With RRH (present)
  - Cloud RAN (C-RAN) (present/future)
- Fronthaul network
  - Bitrate, delay and sync requirements
  - Transport medium
  - Transport solutions
- Fronthaul evolution
Base station evolution

Traditional base station

Base station with RRH

Telecom Italia Demo
Through base station with Remote Radio Head

- Currently deployed
- Power efficient
- Easy cooling
- For different standards
- Interface:
  - Open Base Station Architecture Initiative (OBSAI)
  - Common Public Radio Interface (CPRI) (some parts are vendor-specific)
  - Open Radio Equipment Interface (ETSI-ORI)
- Fiber up to 20-40 km, usually p2p
- Baseband Unit (BBU) a.k.a. Data Unit
To C-RAN architecture

- Proposed by IBM in 2010
- Cloud, Centralized processing, Cooperative radio, Clean

![C-RAN architecture diagram](image-url)
Cloud RAN

Remote sites - RRH

Data center – BBU Pool

Source: http://www.mti-mobile.com/

Source: http://krnet.or.kr/
Fronthaul transport network
- “link” between RRH and BBU

- P2P link for base station with RRH ➔
- Fronthaul network based on
  - WDM
  - Ethernet
  - OTN
Requirements on bitrate & timing

- 20 MHz LTE, 2x2 antennas (MIMO) – 150 Mbps for users, 2.5 Gbps on fronthaul link (CPRI)

- Delay < 3 ms RRH-BBU-RRH (HARQ) ≈ 0.1-0.2 ms on fronthaul (CMCC)
- Jitter < 65 ns (MIMO, 36.104)
- Frequency error < 50 ppb (Macro BS, 36.104)
- BER < 10e-12 (CPRI, for specific application)
### Which medium to choose?

<table>
<thead>
<tr>
<th>Medium</th>
<th>Bit rate</th>
<th>Distance</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>100Gbps +</td>
<td>Tens km</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>10 Gbps</td>
<td>100 m</td>
<td></td>
</tr>
<tr>
<td>Microwave</td>
<td>1 Gbps (80GHz)</td>
<td>1.5 km</td>
<td>LoS required</td>
</tr>
</tbody>
</table>

- Why to consider microwave, not fiber everywhere?

#### Mobile Backhaul Connections by Medium

![Mobile Backhaul Connections by Medium](image)

*Source: Infonetics Research, March 2012*
(Yes, people are working on compression)

- **Majority of algorithms**
  - *Remove redundancies in spectral domain,*
  - *Perform block scaling,*
  - *Use non-uniform quantizer*
  - *Up to 33% (3:1) compression ratio for 8% EVM*
  - *ALU, IDT*

- **University of Texas at Austin**
  - *rescaling,*
  - *non-uniform quantization,*
  - *noise-shaping error feedback*
  - *Resampling*
  - *5:1 ratio*

- **One algorithm detects user activity – up to 7%! (14:1)**
  - *Telefonica I+D*
Transport solution

Technology is ready (capacity not necessarily)
Ethernet enables to maximize multiplexing gains

- Among others to reduce cost of BBU pool


Timing in fronthaul

- Timing is really important
  - *Frequency of transmission*
  - *Handover, coding*

- Requirements
  - *Phase error LTE-A with eICIC/CoMP:*
    - $\pm 1.5 - 5 \, \mu s$, *MIMO: 65 ns*
  - *Frequency error LTE – A TDD/FDD:*
    - $\pm 50 \, \text{ppb}$

- Solution: timing distribution
  - *GPS*
  - *PHY layer clock – SyncEth*
  - *Packet-based timing*
    - *IEEE 1588v2 (PTP)*
  - *Multiple*
Shared Ethernet is even better for cost-saving

- Switching
- Multiplexing
- Widely deployed (reuse!)

- Fronthaul cost savings vs problems with delays
- Synchronous CPRI vs asynchronous Ethernet

![Diagram showing fronthaul and backhaul networks with CPRI and OBSAI interfaces.](image-url)
HARP optimization

- Looking when to use C-RAN
- Combining fiber and microwave
- Optimizing cell-BBU assignment
Deploying C-RANs

- Trade off
  - Fiber length
  - Cells in the C-RAN
  - Multiplexing gain
- TCO vs. capacity

Optimization model

- To maximize multiplexing gain and minimize fiber cost
- In multi C-RANs scenario
Partial C-RANs

- **Partial C-RAN**
  - *Some sites are excluded from the C-RAN and are backhauled to the nearest C-RAN site by MWR*

Updates from industry

- No more CPRI?!
- 4G towards 5G
It is time to rethink fronthaul towards 5G

- New functional split between BBU and RRH
  - To reduce fronthaul data rate
  - Decoupling user-processing and cell-processing

- No more CPRI? Need for interface supporting:
  - Variable bit rate (traffic dependent to enjoy multiplexing gain)
    - To increase scalability
  - Packet-based
    - Synchronization is a challenge
  - Multipoint to multipoint
  - Fully standardized
Timely topic

- IEEE 1904.3 - encapsulation and mapping of IQ data over Ethernet
- IEEE 802.1 – CPRI fronthaul discussion with Time Sensitive Networking task force
- CPRI → CPRI2?
- 3GPP - proposal on a study item on variable rate multi-point to multi-point packet-based fronthaul interface supporting load balancing
Wrap Up
Costs vs savings

- **Costs**
  - 2x2 MIMO, 20 MHz LTE, 15+1 CPRI → 2.5 Gbps
  - 3 sectors? → 7.5 Gbps
  - Tens of BS over long distance? → 100s Gbps

- **Savings**
  - Equipment
  - Energy

Fever BBU's?  
Re-define fronthaul
Base station architecture evolution

a) Traditional Macro BS

b) BS with RRH

c) C-RAN with RRHs

d?) Possibly C-RAN with new function split between BBU and RRH

Fiber – Digital BaseBand
Coax cable – RF
Deployment scenarios

A. Checko, et al. „Cloud RAN for Mobile Networks - a Technology Overview“, IEEE Communications Surveys & Tutorials
Take away points

- Fronthaul network capacity is a deal breaker for introducing C-RAN
- Fronthaul solutions so far rely on legacy deployments
- Industry is working on “redefining” fronthaul – towards switchable, multipoint-to-multipoint connections, with a strong focus on Ethernet-based solutions

Thank you for your attention

www.fp7-harp.eu