Towards Bandwidth-Efficient Ethernet-Based 5G Mobile Fronthaul Networks

Group Meeting Presentation

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Mobile Fronthaul Recap

- Mobile fronthaul refers to the connection between BBU and RRU.

Two Challenges

- Traditional C-RAN architecture relies on CPRI/OBSAI to carry sampled radio signal and synchronization data between BBU and RRU. This imposes very high bandwidth requirements on the mobile fronthaul network.
- Circuit-switched dedicated fiber connections for fronthaul are expensive.

Bandwidth Requirement Too High?

Potential solutions:

- **No functional split:**
  - CPRI data compression.
  - Useless traffic classification and sifting.

- **Functional split:**
  - Next Generation Fronthaul Interface (NGFI).
**CPRI Data Compression**

- **CPRI basic frame**
  - Each frame has 16 words.
  - First word is Control Word (CW).
  - Next 15 words contains sampled I/Q data from receiving antennas.

- **CPRI I/Q data compression**
  - Use high-level digital modulation to modulate I/Q data.
  - Other possibilities – converting I/Q data series to frequency domain and encoding the frequency signal.
Useless Traffic Classification and Sifting

\[ \begin{array}{c|c|c|c|c|c|c|c|c|c|c|c} \hline \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_1 & \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_1 \cdots & \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_1 \mathcal{C}_{\text{PRI}} \hline \end{array} \]

\( M \) I/Q samples for \( \mathcal{G}_i \), \( i = 0, 1 \)

Feature Selection (dimension reduction)
\( x_i \) features for \( \mathcal{G}_i \), \( x_i \leq M \)

Feed \( x_i \) features to pre-trained ML classifier
Classification result \( U_{i}^{f} \)

\[ \begin{array}{c|c|c|c|c|c|c|c|c|c|c} \hline \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_1 & \mathcal{G}_0 & \mathcal{G}_0 & \mathcal{G}_1 \cdots & \mathcal{G}_1 & \mathcal{G}_0 & \mathcal{G}_1 \mathcal{C}_{\text{PRI}} \hline \end{array} \]

Mark \( U_{i}^{f} \) to the ctrl word of the last CPRI BF

I/Q data power scheme

Sample distribution scheme
NGFI redefines the baseband processing split between BBU and RRU, hence redefining the positioning of eNB stack components between BBU/RRU.

BBU is redefined as Radio Cloud Center (RCC) and RRU becomes Radio Remote System (RRS).

NGFI architecture from China mobile envisions point-to-multipoint architecture from RCC-RRU, hence there is another element Radio Aggregation Unit (RAU) which interfaces with RCC and carries transport for several RRUs.

In NGFI, various fronthaul functional splits are being defined to provide different tradeoffs among RRU complexity, system performance, and fronthaul bandwidth efficiency.
Next Generation Fronthaul Interface (NGFI)

Architecture

Next Generation Fronthaul Interface (NGFI)

Functional split

Layer 1
- Resource Mapping & FFT
- Layer Mapping & Precoding
- Modulation
- Bit-level Processing

Layer 2
- Low MAC
- RLC
- Dual Connection

Layer 3 and above
- PDMP
- S1 Termination

Interface delay

Maximum interface bandwidth

Next Generation Fronthaul Interface (NGFI)

Example 1:

Example 1:

Next Generation Fronthaul Interface (NGFI)

Example 1:

Next Generation Fronthaul Interface (NGFI)

Example 2:

<table>
<thead>
<tr>
<th>Subframe 0</th>
<th>Subframe 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slot 0</td>
<td>Slot 0</td>
</tr>
<tr>
<td>Slot 1</td>
<td>Slot 1</td>
</tr>
<tr>
<td>0 Sym 6</td>
<td>0 Sym 6</td>
</tr>
<tr>
<td>0 Sym 6</td>
<td>0 Sym 6</td>
</tr>
</tbody>
</table>

PRB 5

PRB 4

PRB 3

PRB 2

PRB 1

PRB 0

Color Legend

- PDCCH
- PBCH
- PSS
- SSS
- PDSCH
- Reserved
- Ref-Signal
- PCFICH
- PHICH
- TDD Uplink
- Guard Period

Downlink shared-channel for user data

Example 2:

Low load in a 10 MHz cell

Peak load in a 10 MHz cell

Dedicated Connections Too Expensive?

- Potential solutions:
  - Reduce fronthaul line rate and take advantage of time-domain multiplexing
    - TDM-PON
  - From circuit switching to packet switching
    - Ethernet -- IEEE 802.1CM Time-Sensitive Networking (TSN) in fronthaul
Ethernet

- **Motivation for Ethernet Based Fronthaul**
  - New fronthaul interface technologies are required to reduce fronthaul transmission costs.
  - Fronthaul architecture is migrating from traditional RAN where single BBU connects to single/few RRUs to architectures where multiple centralized BBUs connect to multiple RRUs making a packet switched technology ideal.
  - Ethernet is a widely adopted and nearly ubiquitous standard technology.
IEEE 802.1CM Time-Sensitive Networking (TSN) in fronthaul

- Separate fronthaul flows
- Separate synchronisation provided other means

Radio Domain

Packet Domain

- IEEE 802.1CM Fronthaul Profiles
  - Meet fronthaul requirements
- Synchronization may be provided by packet network, e.g., Sync as a Service (SaaS)

IEEE 802.1CM

IEEE 802.1/802.3 Ethernet encapsulation

std IEEE 802.1/802.3 Ethernet frames via edge ports

IEEE 802.1CM Time-Sensitive Networking (TSN) in fronthaul

Two profiles for both Classes

- **Profile A:**
  - I/Q data: high-priority traffic class.
  - C&M data: lower-priority traffic class.
  - Max Ethernet frame size for all traffic: 2000 octets.

- **Profile B:**
  - Fronthaul traffic: high-priority traffic class.
  - Non-fronthaul traffic: lower-priority traffic class with preemption.
  - Max Ethernet frame size for fronthaul traffic: 2000 octets.
  - Flexible frame size for non-fronthaul traffic.
Thank you!