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# Getting standards ready for Fiber to the Antenna

Panel about Optics in Access: Technology and Standards
Organizer: Frank Effenberger; *FutureWei Technologies, Inc., USA*
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# Agenda

section 1 Clarification : Back-, mid-, and front- haul

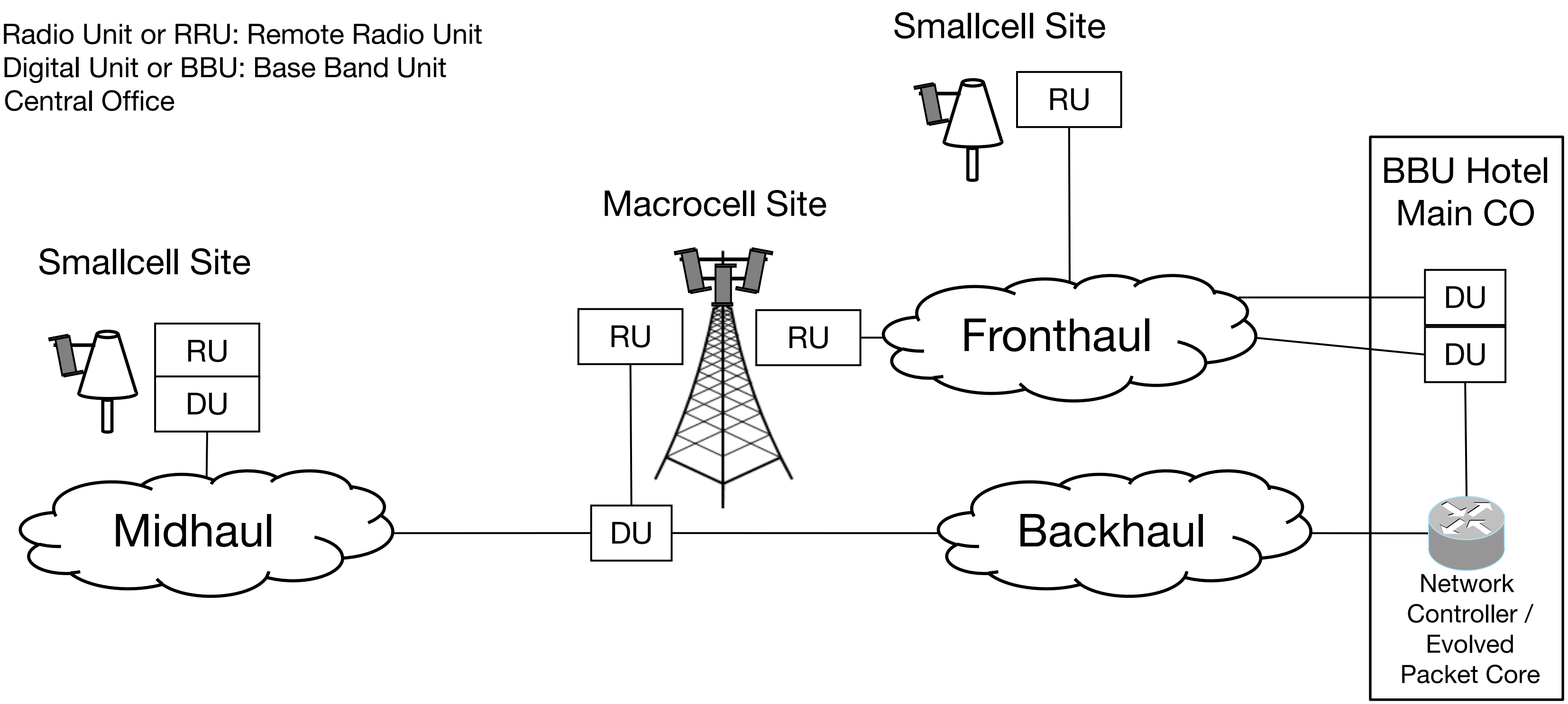
section 2 Fronthaul requirements

section 3 Recent standardization works about fronthaul transport
- Q2 G.suppl RoF & NG-PON2 TWDM & PtP WDM
- Q6 CPRI over WDM Metro
- Q11 CPRI over OTN
- IEEE 1904-3 RoE
- ETSI ORI
- NGMN

section 4 Future work in standardization (personal views)

# 1. Clarification : Back-, mid-, and front- haul

RU: Radio Unit or RRU: Remote Radio Unit
DU: Digital Unit or BBU: Base Band Unit
CO: Central Office




- 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 access interfaces:
  - G-PON, XG-PON1, and coming NG-PON2 TWDM
  - PtP interface Ethernet based

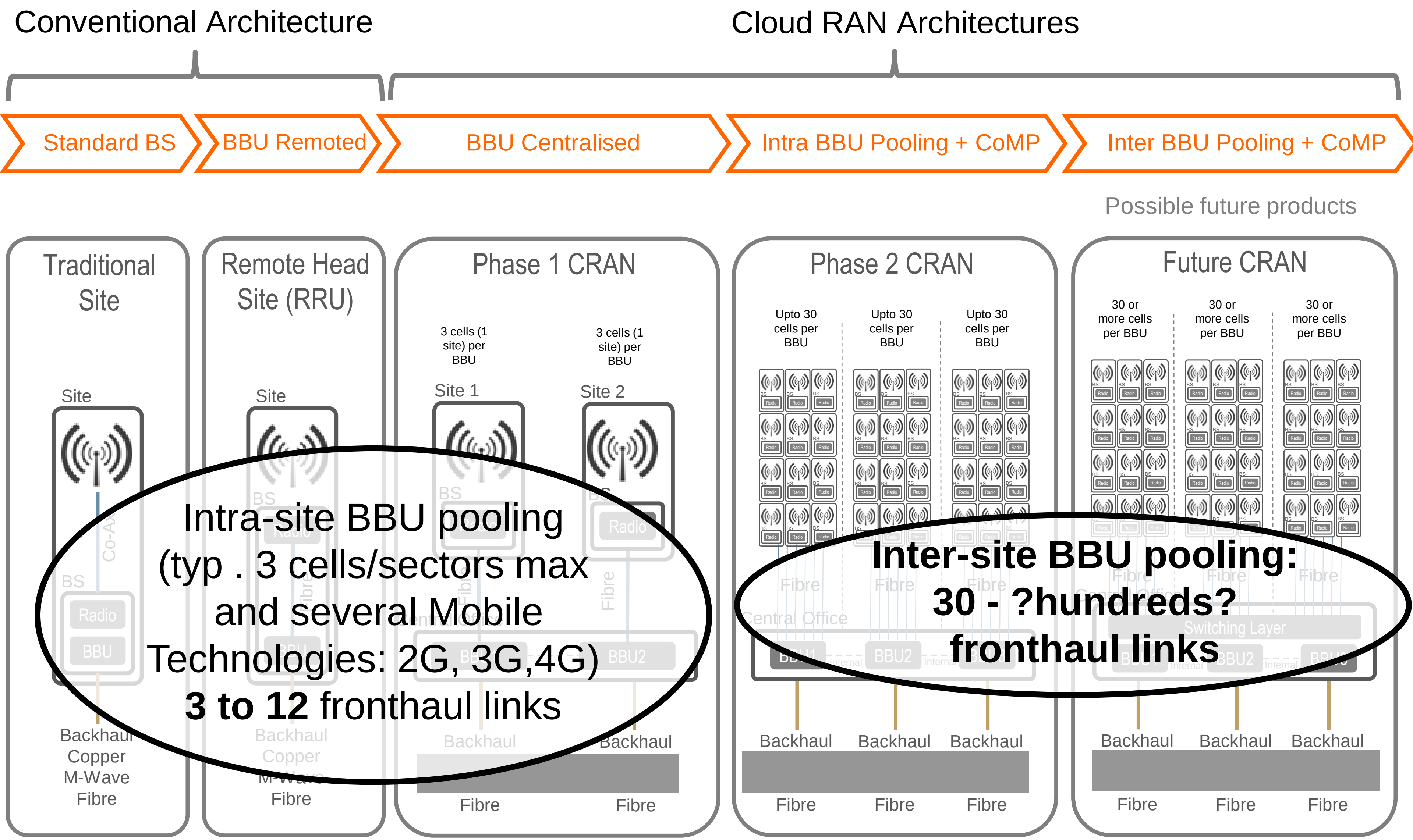
- Current dominant Fronthaul interface is based on a specification designed as a backplane extension
  - CPRI* is not a legacy interface to be carried over existing access protocols (Ethernet,…)
  - CPRI is only a MSA (Mutual Standard Agreement)

* CPRI : Common Public Radio Interface

# 2. Fronthaul requirements

- Cloud RAN scenarios
- Reference models
- Requirements

# Cloud-RAN compared to conventional RAN



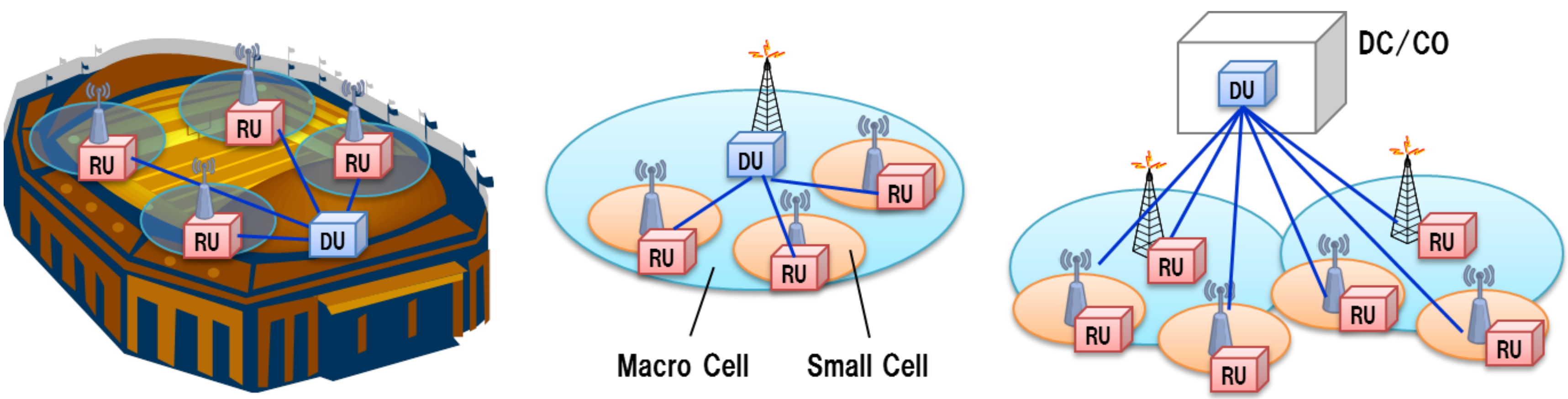

Fibre between remote BBU and Radio head known as "Fronthaul" CRAN = Cloud RAN BBU = Base Band Unit BS = Base Station RRH = Remote Radio Head

# 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

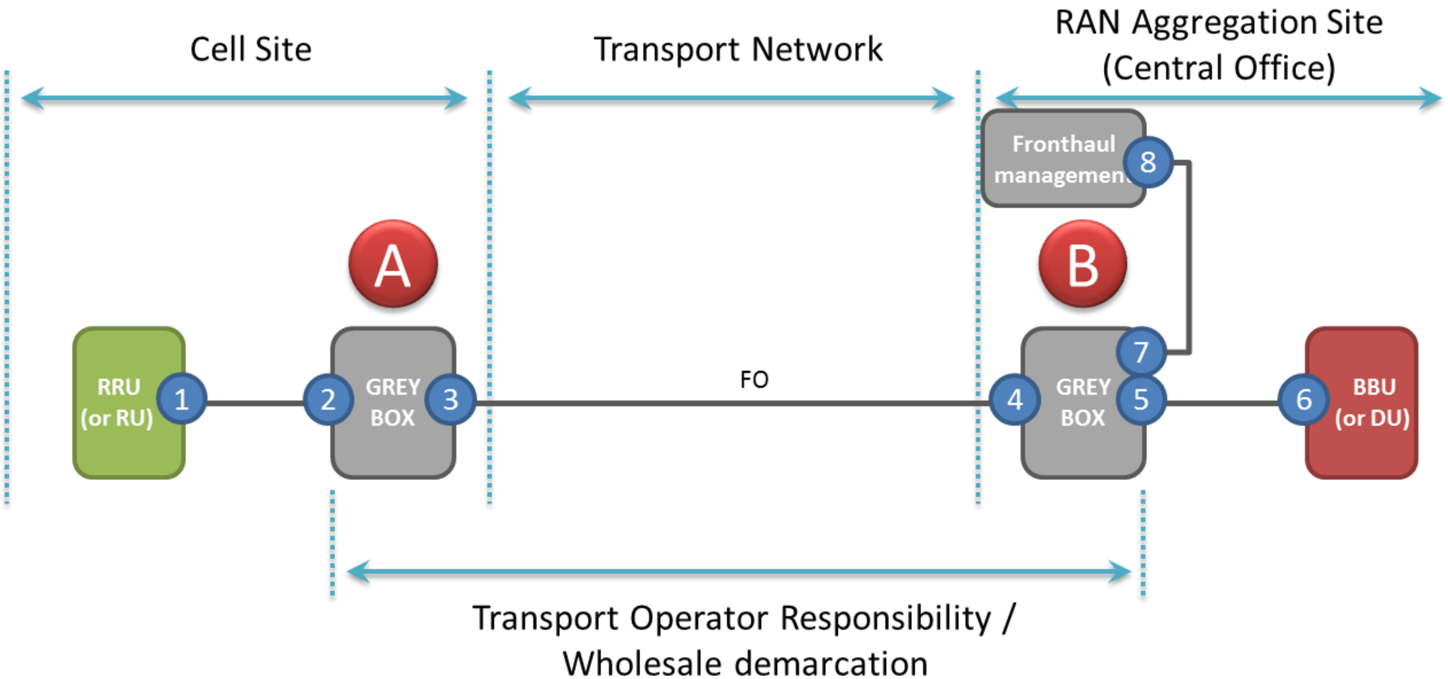



①Private C-RAN

②Local C-RAN
(Fronthaul Extension)

③Wide C-RAN
(CO-based C-RAN)

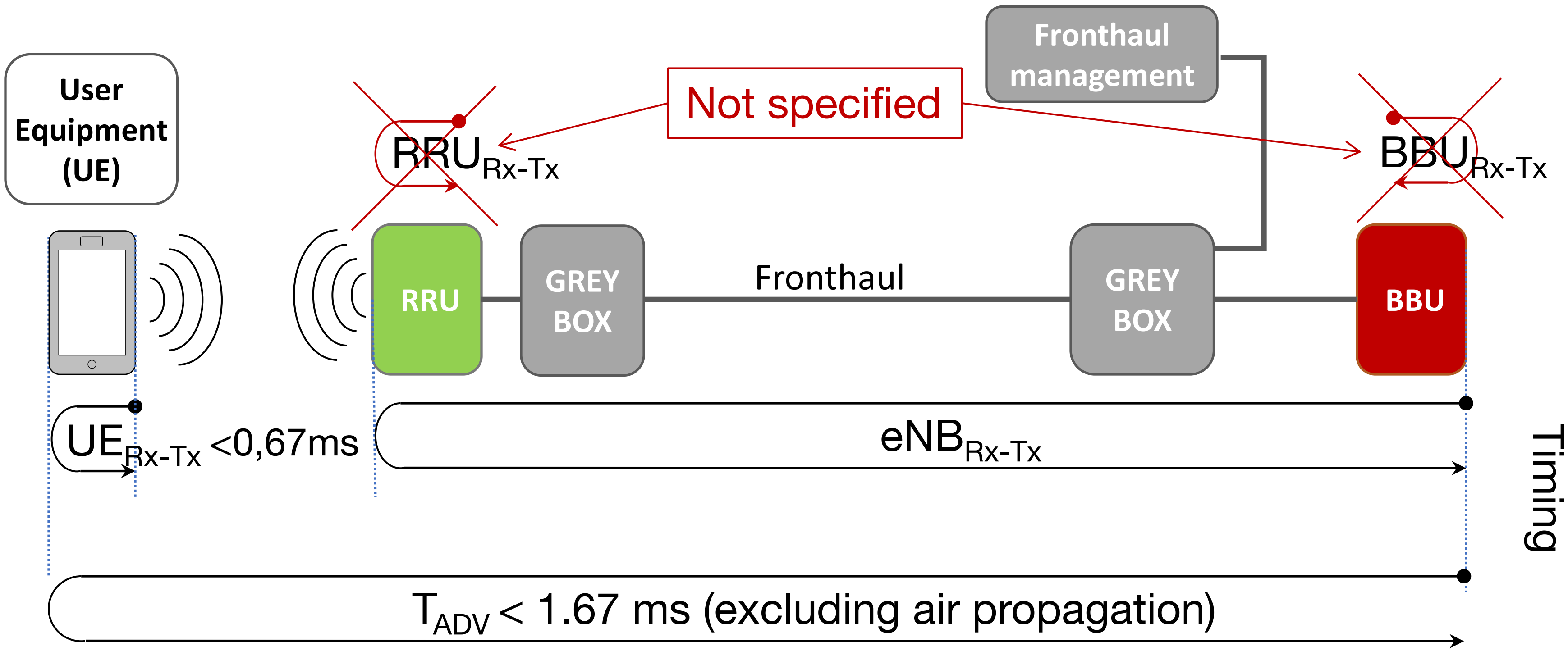
# Fronthaul reference model




1. RRU Interface (**RRUI**)
2. Site Transport Access Interface (**STAI**)
3. Site Transport Network Interface (**STNI**)
4. Aggregation Transport Network Interface (**ATNI**)
5. Aggregation Transport Access Interface (**ATAI**)
6. BBU Interface (**BBUI**)
7. Aggregation Transport Management Interface (**ATMI**)
8. Management Interface (**MI**)

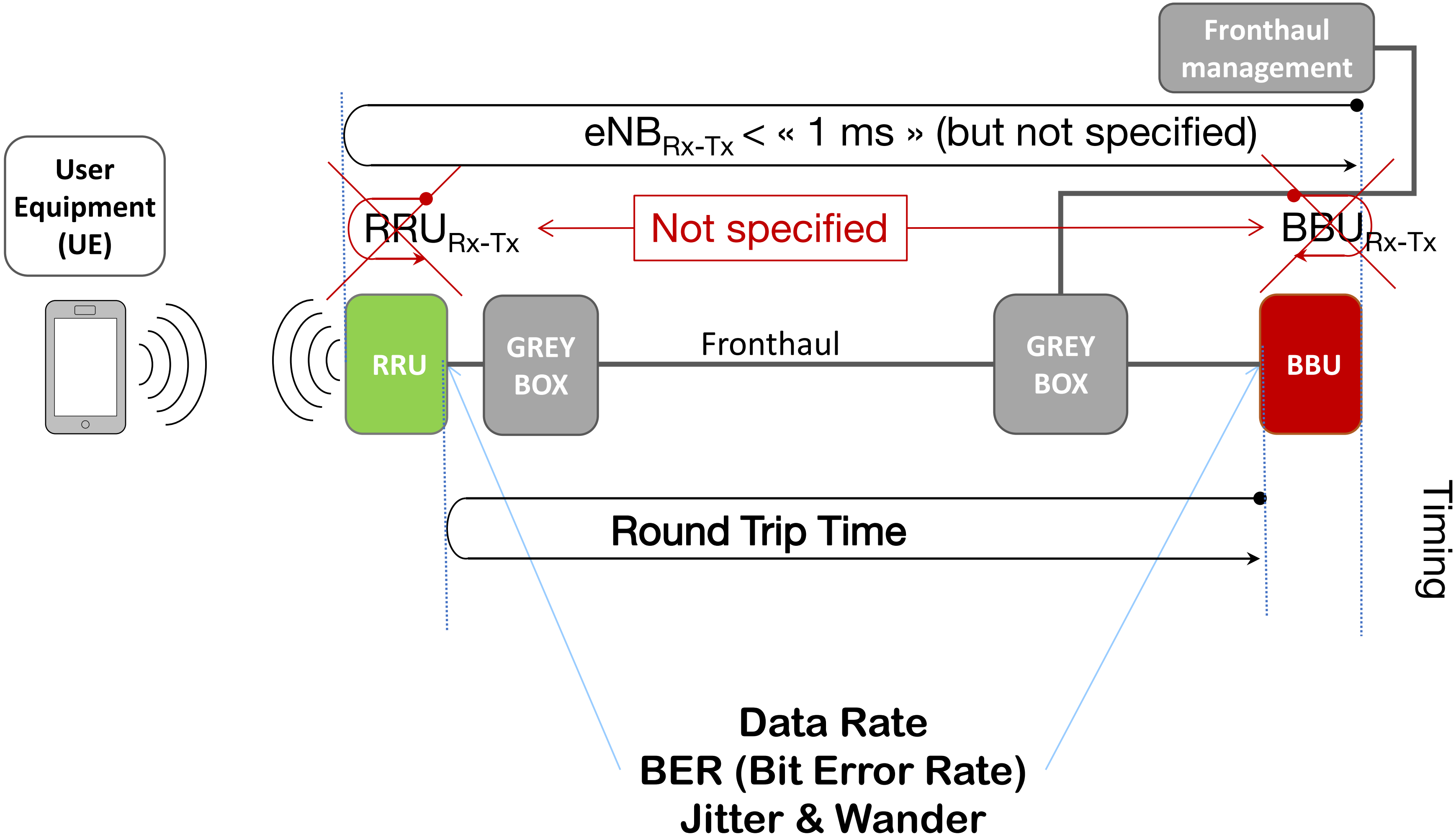
Demarcation points: A + B

# Why fronthaul network segment is not clearly specified by Mobile Standard (3GPP)?




- Mobile standards consider the BBU-RRH as a proprietary black box and implementation depends on RAN vendors and operator use cases.

# 2. Fronthaul requirements 1/3



# 2. Fronthaul requirements 2/3

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

# 2. Fronthaul requirements 3/3

- CPRI bit rate for one BBU-RRH link

| CPRI option | Line bit rate [Mbit/s] | Line coding | Notes |
|---|---|---|---|
| 1 | 614.4 | 8B/10B | 1 x 491.52 x 10/8 Mbit/s |
| 2 | 1228.8 | 8B/10B | 2 x 491.52 x 10/8 Mbit/s |
| 3 | 2457.6 | 8B/10B | 4 x 491.52 x 10/8 Mbit/s |
| 4 | 3072.0 | 8B/10B | 5 x 491.52 x 10/8 Mbit/s |
| 5 | 4915.2 | 8B/10B | 8 x 491.52 x 10/8 Mbit/s |
| 6 | 6144.0 | 8B/10B | 10 x 491.52 x 10/8 Mbit/s |
| 7 | 9830.4 | 8B/10B | 16 x 491.52 x 10/8 Mbit/s |
| 8 | 10137.6 | 64B/66B | 20 x 491.52 x 66/64 Mbit/s |

# 3. Recent standardization works about interfaces supporting CPRI

- Q2 G.suppl RoF & NG-PON2 TWDM & PtP WDM
- Q6 CPRI over WDM Metro
- Q11 CPRI over OTN
- IEEE 1904-3 RoE
- ETSI ORI
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# ITU-T current actions

- **SG15 - Q2**
  - **G-Suppl. RoF : Radio-over-fiber (RoF) technologies and their applications**

    This Supplement describes the radio-over-fiber (RoF) technology types and their applications in optical access networks for Analog and Digital RoF.
- **SG 15 – Q2**
  - **NG PON2 : G.989.x**

    NG-PON2 systems with TWDM and PtP WDM flavors have to support the high speed transport (e.g. CPRI) between BBU and RRUs.
    *TWDM and PtP WDM interfaces are considered.*
- **SG 15 – Q6**

  Transport of CPRI interfaces over G.Metro WDM links (including colorless issue)
- **SG15 – Q11**

  Transport of CPRI interfaces over OTN mapping G.798 (G.709)

# IEEE current actions

- **IEEE 1904.3 Task Force : RoE**

**Standard for Radio Over Ethernet Encapsulations and Mappings**

This standard will specify:

- The encapsulation of digitized radio In-phase Quadrature (IQ) payload, possible vendor specific and control data channels/flows into an encapsulating Ethernet frame payload field.
- The header format for both structure-aware and structure-agnostic encapsulation of existing digitized radio transport formats. The structure-aware encapsulation has detailed knowledge of the encapsulated digitized radio transport format content. The structure-agnostic encapsulation is only a container for the encapsulated digitized radio transport frames.
- A structure-aware mapper for Common Public Radio Interface (CPRI) frames and payloads to/from Ethernet encapsulated frames. The structure-agnostic encapsulation is not restricted to CPRI.

# NGMN current actions

- **NGMN 5G White paper has identified technology building blocks.**

- **One enabler is "Enhanced fronthauling"**

The expected benefits are:

- Improved cost-efficiency and system performance, while retaining the multi-technology and future-proofing advantages of existing interfaces

# ETSI ISG (Industry Specification Group) ORI (Open Radio Interface) current actions

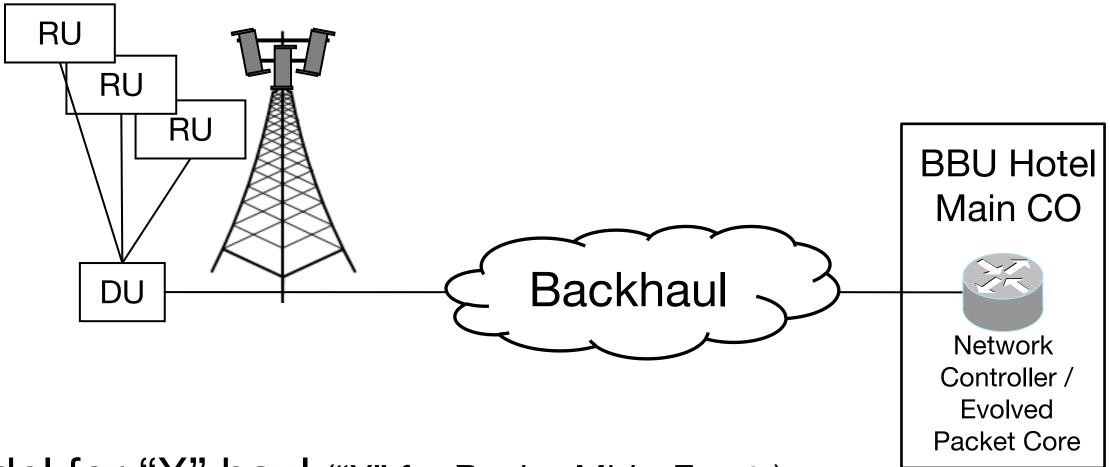
- An open interface enables operators to source the RU and DU from different vendors, helping to avoid “lock-in” to a specific supplier and permitting a more rapid response to operational demands and market opportunities.
- The interface defined by the ORI ISG is built on top of the interface defined by the CPRI group. However, options are removed and functions are added with the objective of making the interface fully interoperable, which is the main goal of this group. Recently, ETSI ORI group completed specification work on Digital I/Q Compression to cater for the centralized RAN deployment scenario, and supports different deployment topologies (including chain/tree/ring).

- Compression
  - ORI proposes CPRI compression by a factor of 2.
  - Investigation is in progress to acheive a compression factor up to 3.

- Successful Trial of Open Radio Equipment Interface by Vodafone, Fujitsu, and Kathrein confirm LTE network operated to ETSI ORI Release 1 standard.

# 4. Future work in standardization (personal views)

- Preamble:
  - Network model : Backhaul network design is based on **one fiber link** and **one ONU** to collect all RAN generations traffic




- Expected network model for "X" haul ("X" for Back-, Mid-, Front-)
  - Saving fibre infrastructure
  - Ressource allocation
  - Ethernet Network supporting fronthaul

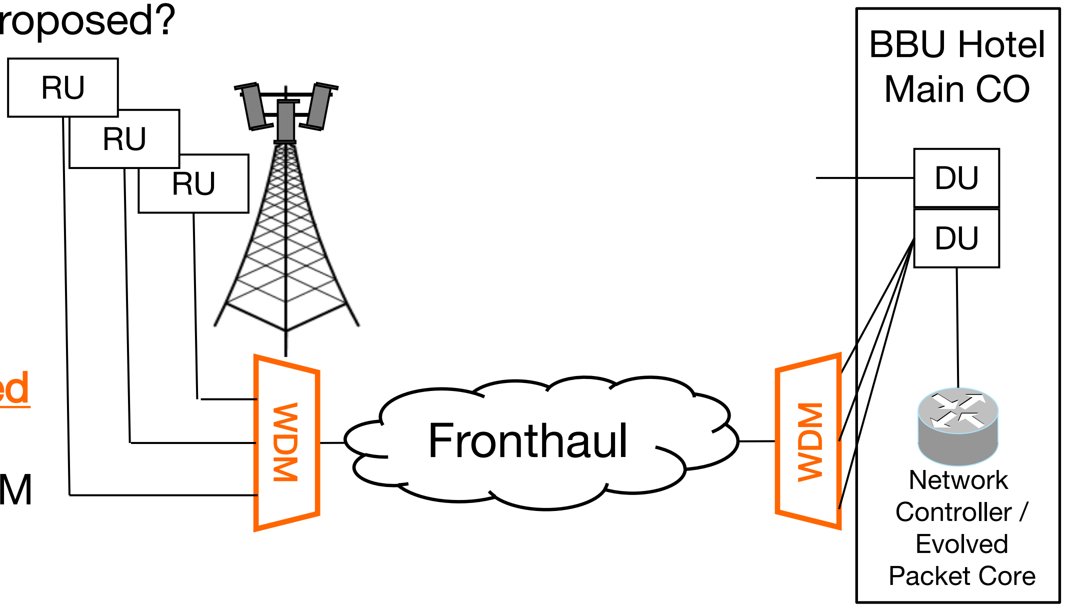
# 4. Future work in standardization (personal views)

- Fiber saving:

Antenna site : 2G, 3G, 4G with 1 or 2 carriers for 3 sectors = 15 to 18 CPRI links (18 x 2.5 Gbit/s = 45 Gbit/s symetrical) and certainly more with 5G

- by Compression (50% by ORI):
  - new compression factor could be proposed?

- by WDM
  - Passive (without encapsulation)
    - CWDM
    - CWDM bidirectional (SFW*)
      - New standard is requested
    - DWDM compatible outdoor
      - colorless / Out of Band OAM
  - Active (with encapsulation)
    - NG-PON2 PtP WDM with enough wavelength channel pairs
    - Radio over Ethernet with WDM flavor



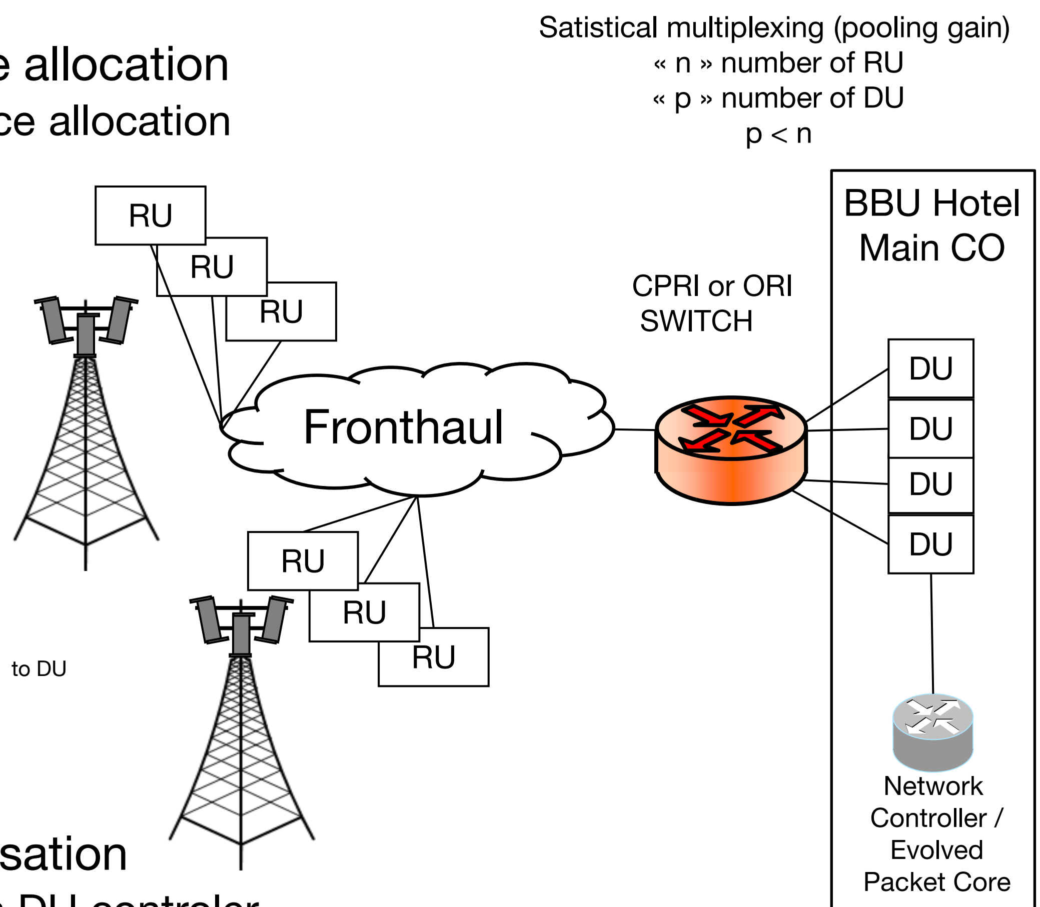

- by TDM [TWDM]
  - In progress by ITU SG15 Q2 & Q11

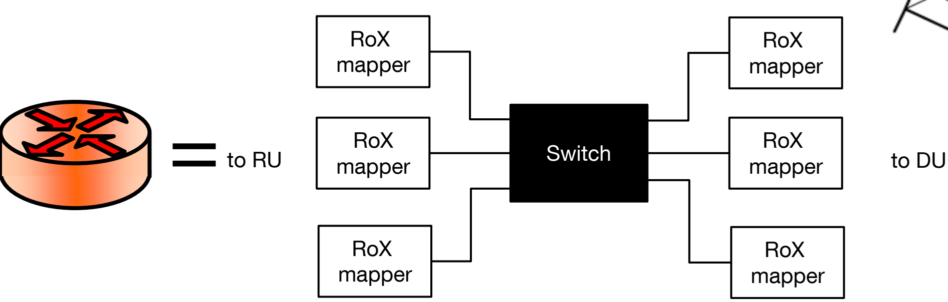
*SFW: Single Fiber Working

# 4. Future work in standardization (personal views)

- Ressource allocation: CPRI/ORI switch

- Switching function: dynamic ressource allocation
  - Reuse existing algorithme of ressource allocation
    - coming from Ethernet (switch)
    - coming from PON
    - other…
- Interface of the switch
  - ORI/CPRI mapper definition




- Control & Management and Synchronisation
  - radio ressource policy comming from DU controler
  - configuration of optical access ressource
  - power saving policy for optical and radio layers

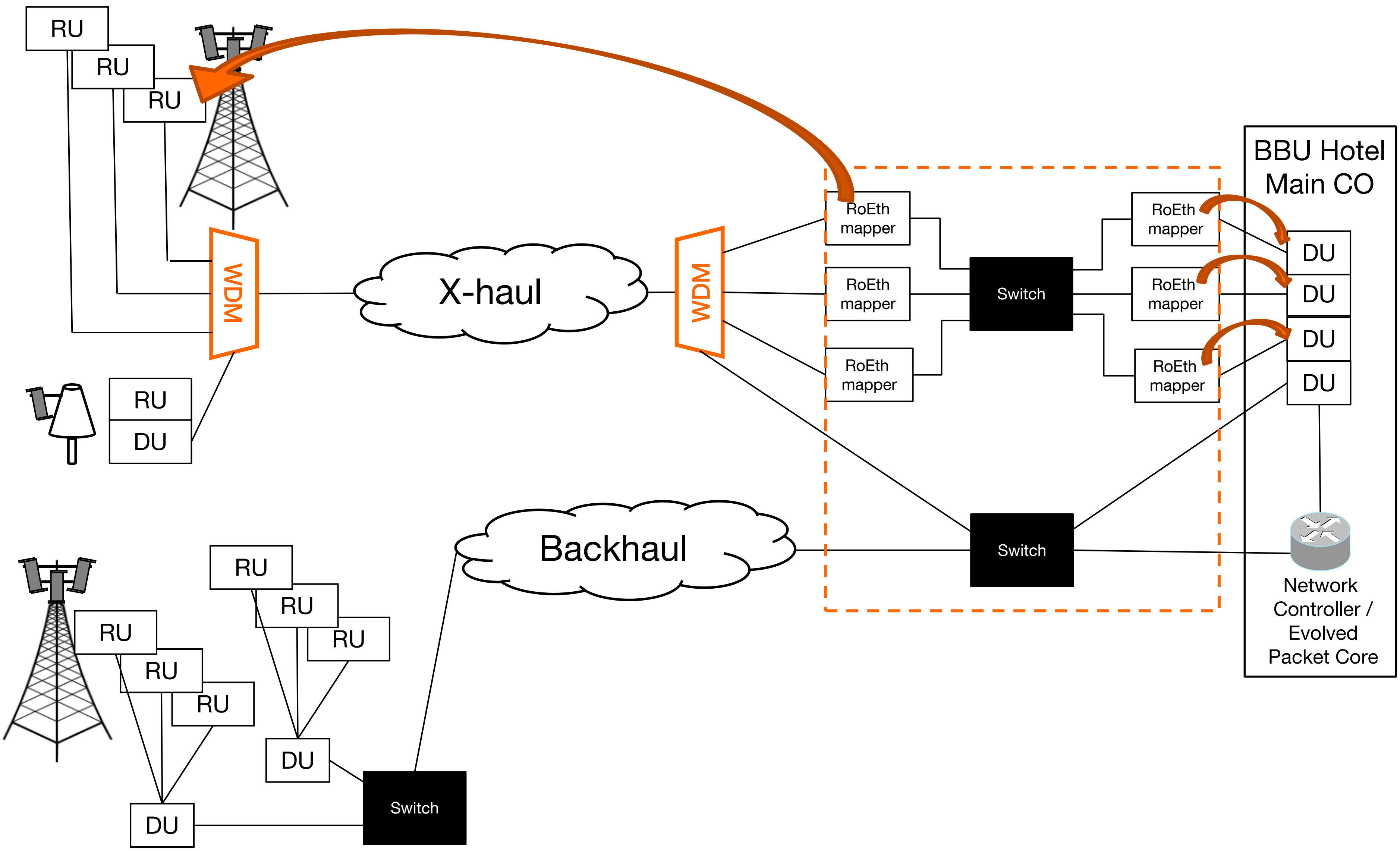
# 4. Future work in standardization (personal views)

What is this “Ethernet network” for fronthaul?

- Is it possible to re-used the existing Ethernet backhaul network for fronthaul?
  - NO due to the fact that
    - Ethernet network is asynchronous
    - Ethernet network is best effort and design with aggregation policy
    - Existing Router/Switch must be replace to support:
      - highest number of ports (number of RRH >> backhaul interface)
      - to support new traffic forwarding in coexistence with regular traffic routing
    - Compatibility with multi-hop architecture
    - Latency consumed by mapper and compression

- “Ethernet network” for “X-haul” is
  - The best of each technology
    - For Ethernet
      - mature and low cost ressource allocation switch
      - low cost PHY interface (SFP / SPP+)
      - the frame include natively the OAM of the optical link
    - For WDM (without encapsulation)
      - high level multiplexing (fiber sharing)
      - existing low cost WDM technology : CWDM
      - no latency
      - no power consumption

# 4. Future work in standardization (personal views)



# Conclusion

- Clarification of Back-, Mid and Front-Haul
- Discussion about Fronthaul requirements coming from RAN suppliers and standardisation
  - Work with Mobile standardisation group is essential
- Recent standardization works about fronthaul transport
- Discussed future directions for optical standards with high light
  - a lack of standard about CWDM Single Fiber Working (duplex)
  - combination of WDM, switch and CPRI mapper (Ethernet)

Thank you

Merci

Danke

Grazie

Tack

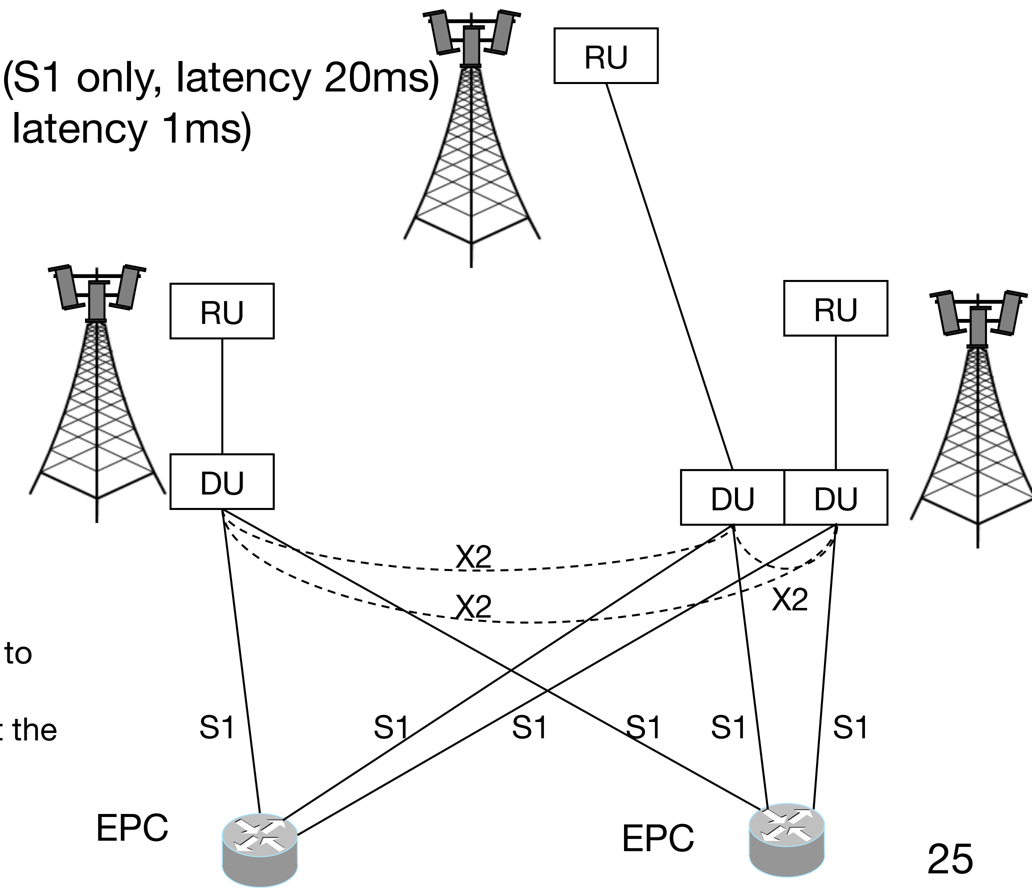
谢谢

감사합니다

ありがとうございました

- The term midhaul has been defined by MEF as the carrier Ethernet network between radio Base Station sites (especially when one site is a small cell site). The MEF reference scenario midhaul is considered as a backhaul extension between a small cell Base Station and its master macrocell Base Station. Two other scenarios are also considered:
  - i) the midhaul between two BBU (Base Band Unit) pools
  - ii) the midhaul between two BBU pools through a network controller.

- All midhaul scenarios are Ethernet based network with different options with additional requirements such as :
  - same as backhaul defined by MEF [9] (S1 only, latency 20ms)
  - support tight coordination (S1 and X2, latency 1ms)
  - support X2+ (latency 50ms)




- S1 interface shall support the exchange of signaling information between the DU and Ethernet packet core
- X2 interface shall support the exchange of signaling information between two DU, in addition the interface shall support the forwarding of protocol data units to the respective tunnel endpoints
- X2+: 3GPP rel. 12 feature involving a split bearer such that the small cell is directly connected to its master DU

# LTE Timing Advance