TRANSPORT NETWORKS FOR MOBILE OPERATORS

RAN & BACKHAUL NETWORKS

20-21st May 2015 • Hotel Palace Berlin

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

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RAN&Backhaul Networks

Session : WHAT ARE THE FRONTHAUL STRATEGIES

21th May 2015, Berlin, Germany

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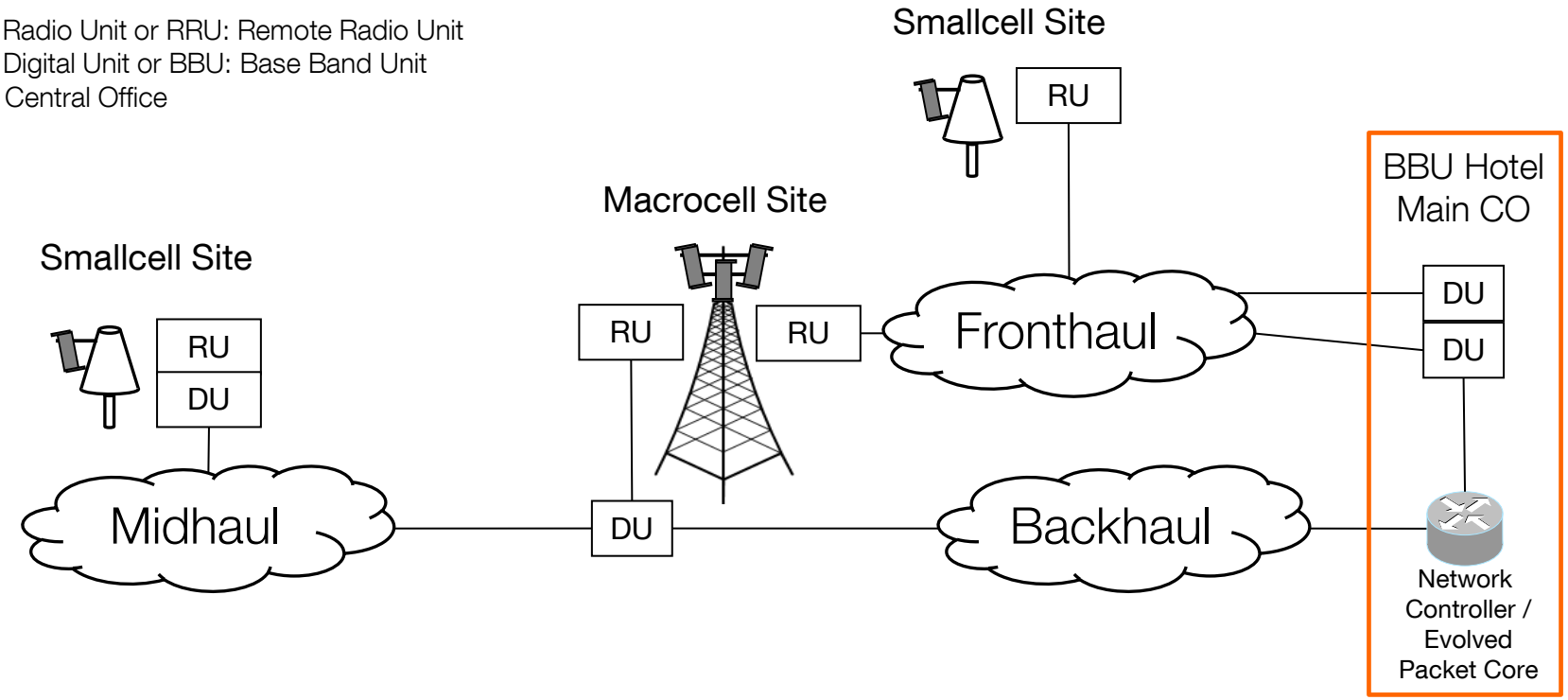
Contents

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 **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

Contents

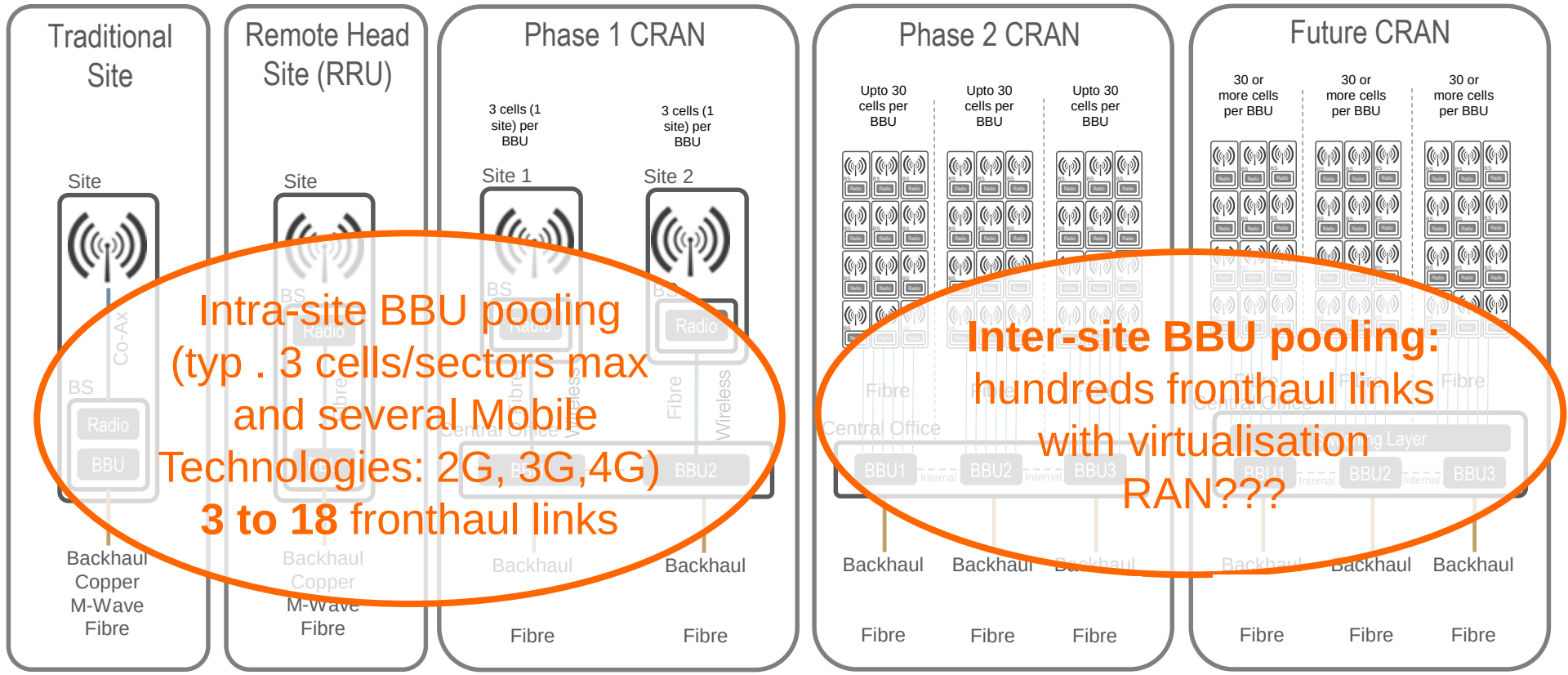
Cloud-RAN migration

Conventional Architecture

Cloud RAN Architectures

Standard BS | BBU Remoted | BBU Centralised | Intra BBU Pooling + CoMP | Inter BBU Pooling + CoMP

Possible future products



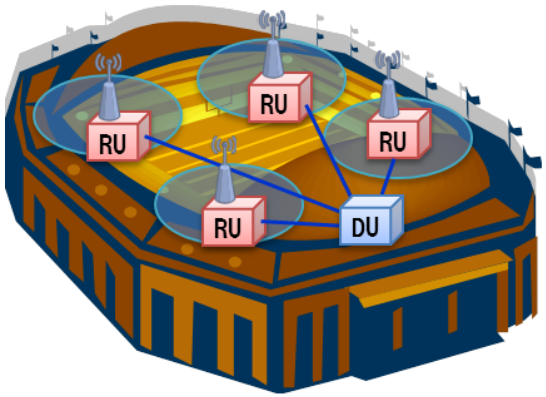
Fibre between remote BBU and Radio head known as “Fronthaul” CRAN = Cloud RAN BBU = Base Band Unit BS = Base Station RRH = Remote Radio Head

Different C-RAN architectures

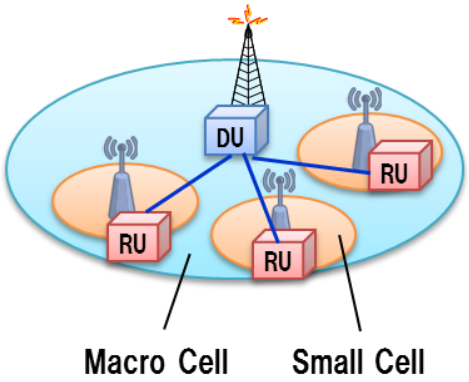
- Wide C-RAN
  - Macrocells + Hetnets

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

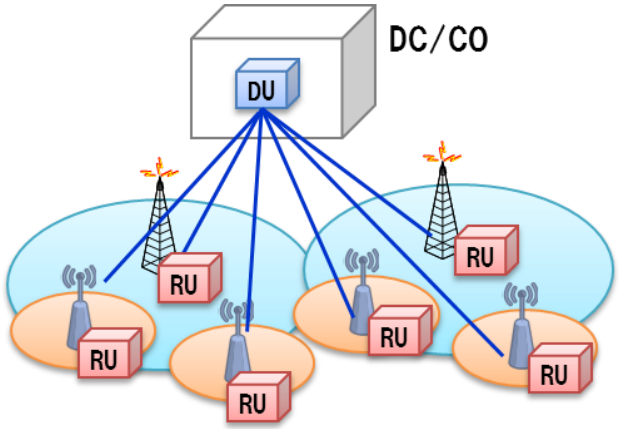
DC: Data Center
CO: Central Office



①Private C-RAN

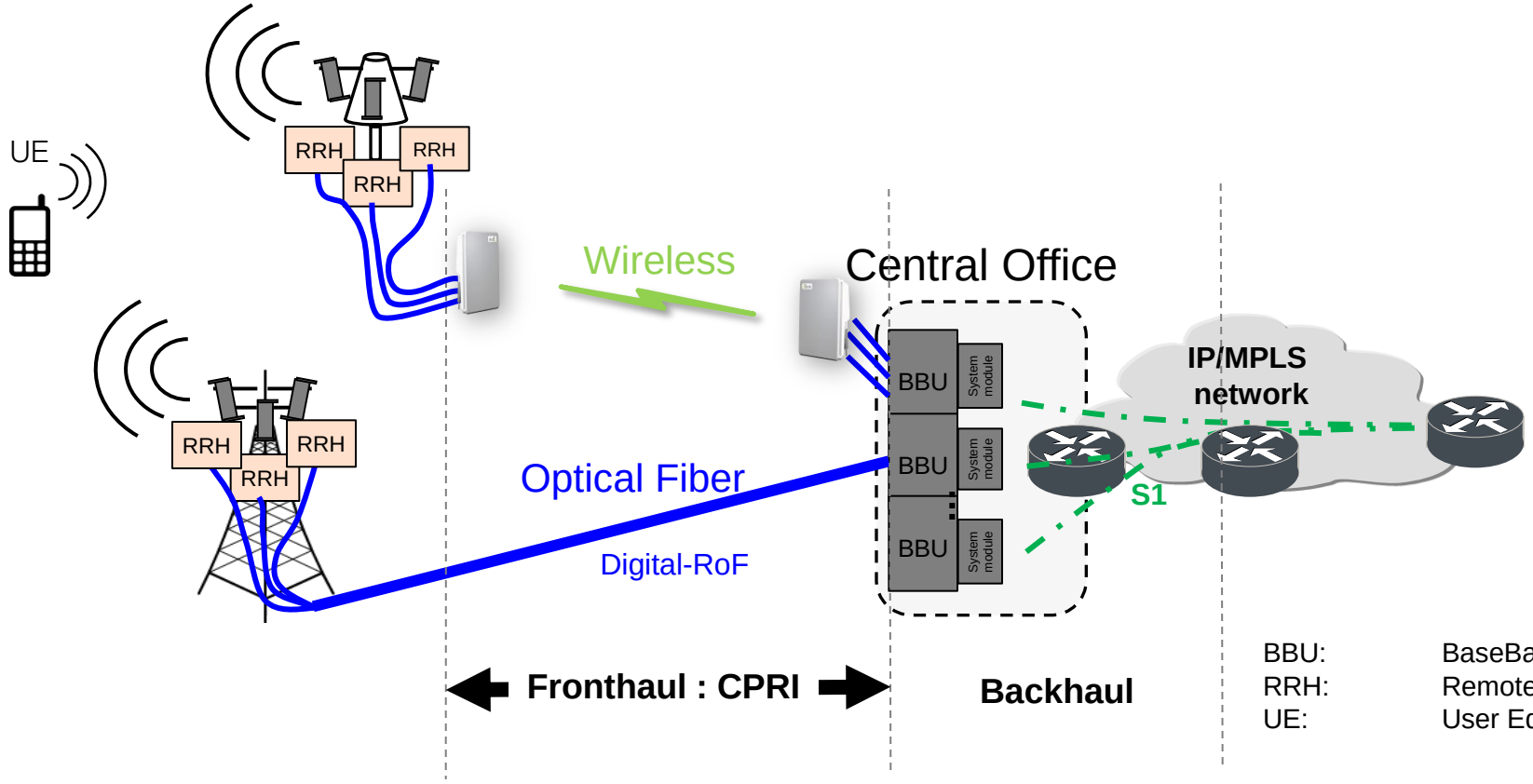


②Local C-RAN
(Fronthaul Extension)



③Wide C-RAN
(CO-based C-RAN)

Fronthaul: a new segment that comes with Centralised Radio Access Network

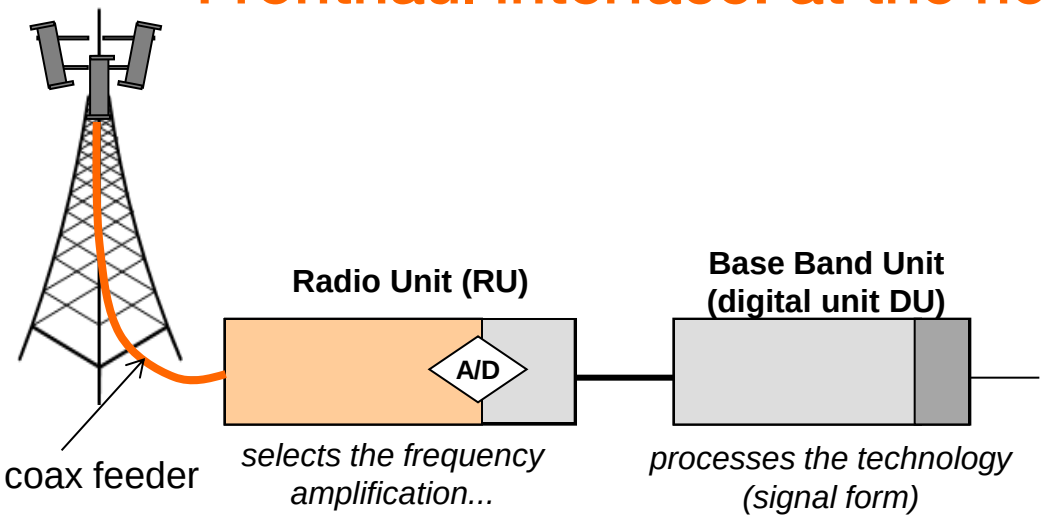


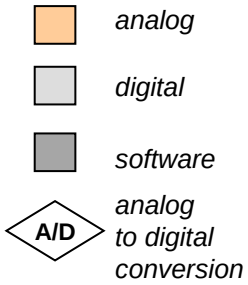
Fronthaul interfaces: CPRI, OBSAI, ORI

Fronthaul mediums:

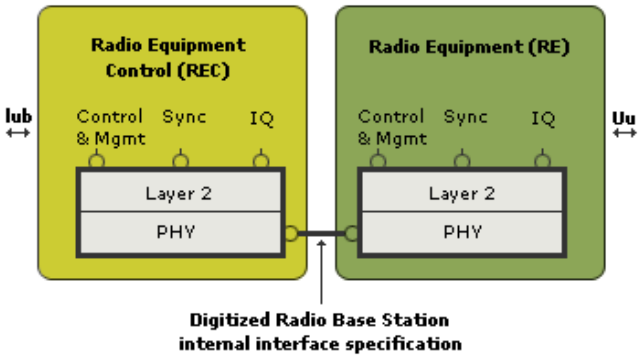
- Optical Fiber : Single Mode Fiber with or without color flavors
- Wireless : several RF bands possible with or without spectral efficiency

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

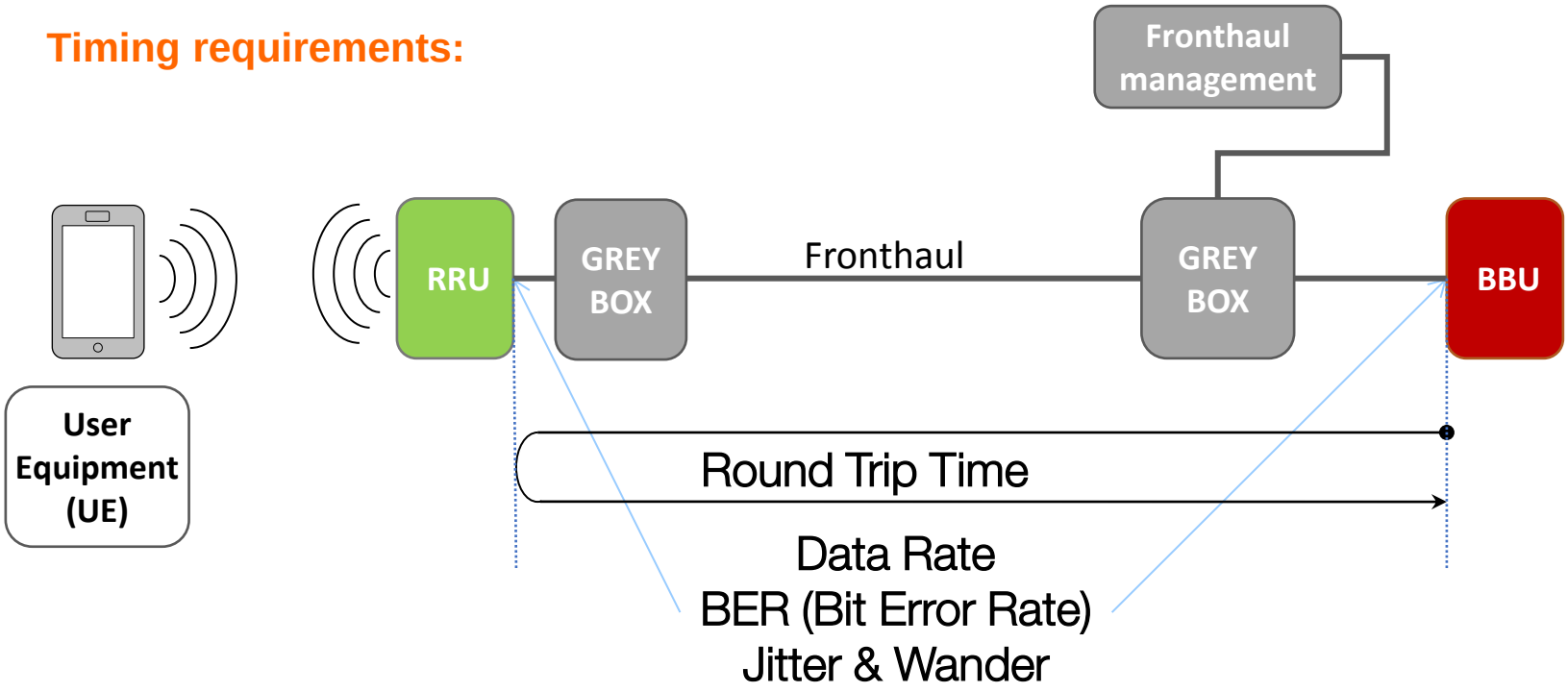


All base stations are based on **a internal digitised radio interface** between RU and DU.
It is a **serial Constant Bit Rate** interface based on SFP connectivity for banalisation, volume and interoperability.

Contents

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

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

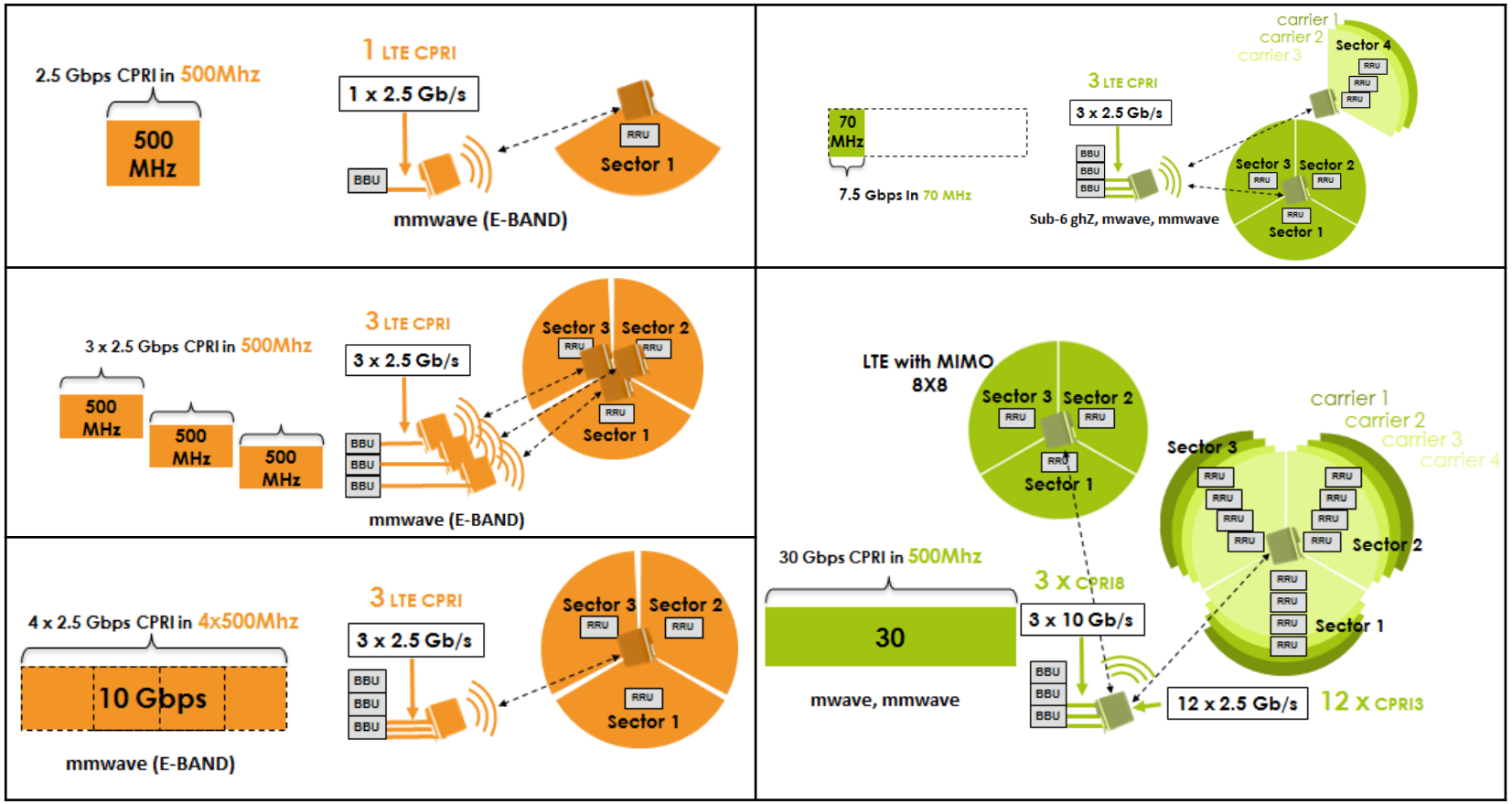
Wireless fronthaul (CPRI)

Native wireless

with spectral efficiency

From Small cell or 4th sector

to Macro cell



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

Easier and faster deployment, same network architecture, better radio performance

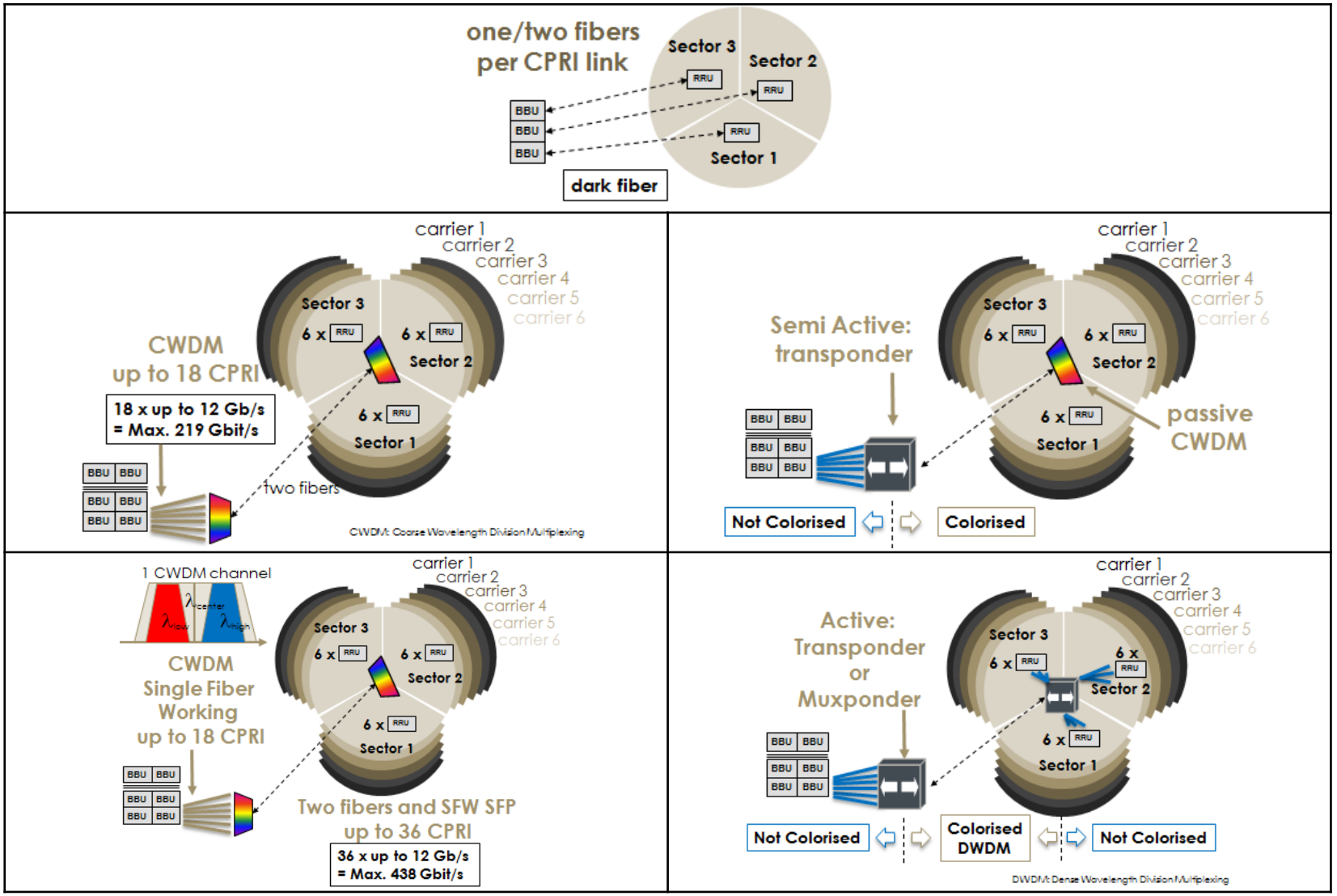
Optical fronthaul (CPRI)

Passive

Active & Semi Active

Fiber-rich network

to shared fiber



Discussion about fronthaul transport

	PRO	CONS
▪ 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

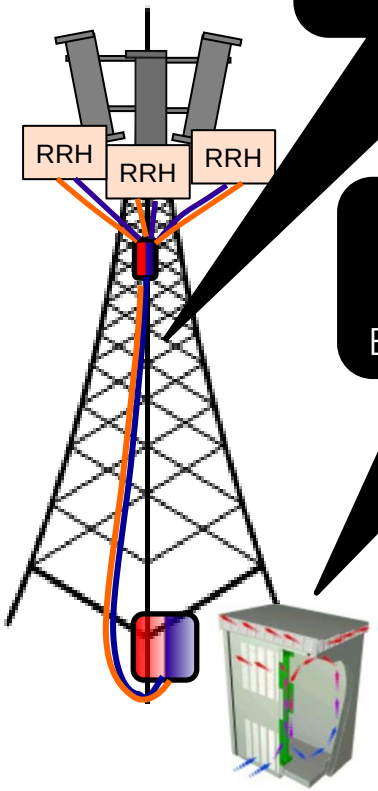
What is a passive fronthaul solution?

FTTA & PTTA
hybrid cable

BBU Hotel
Data center area
for a cells cluster

Backhaul

Hardware sharing



Low foot print
cabinet
Energy and passive fiber

Passive CWDM
MUX & DeMUX

optical fiber

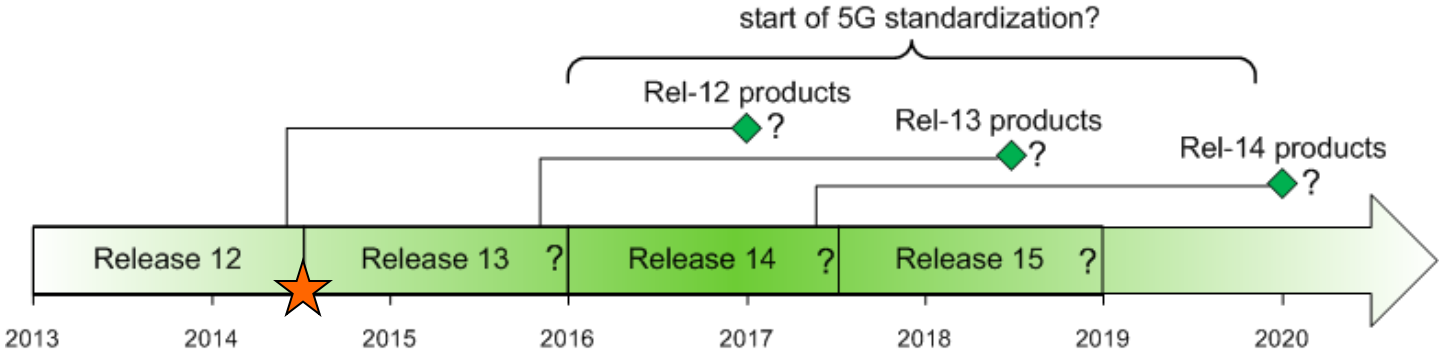
BBU hotel

BBU 3G
BBU 4G
interface fronthaul
interface backhaul

Contents

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

10x performance

10x spectrum

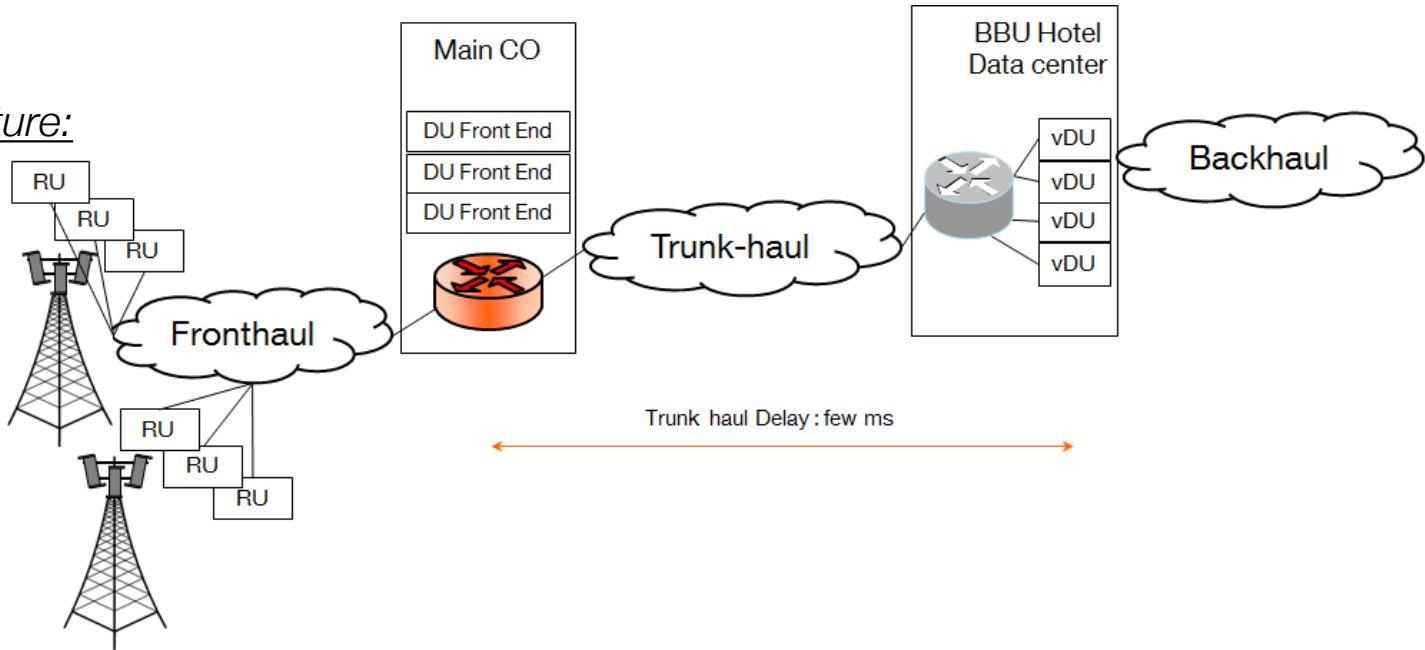
10x base stations

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?

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

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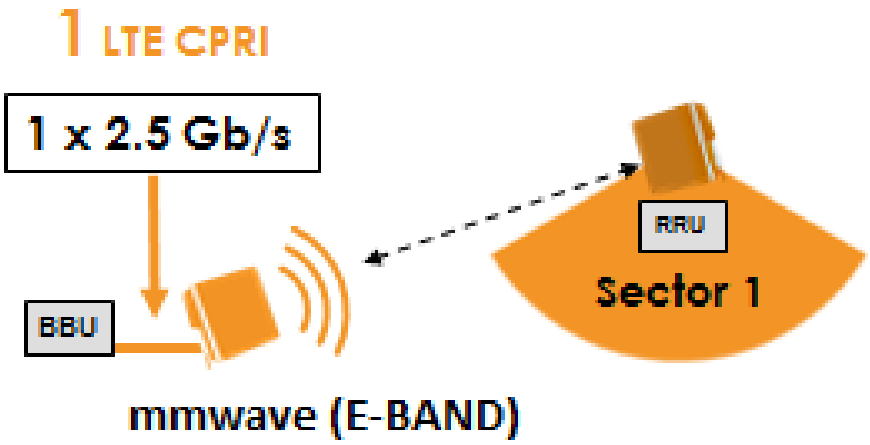
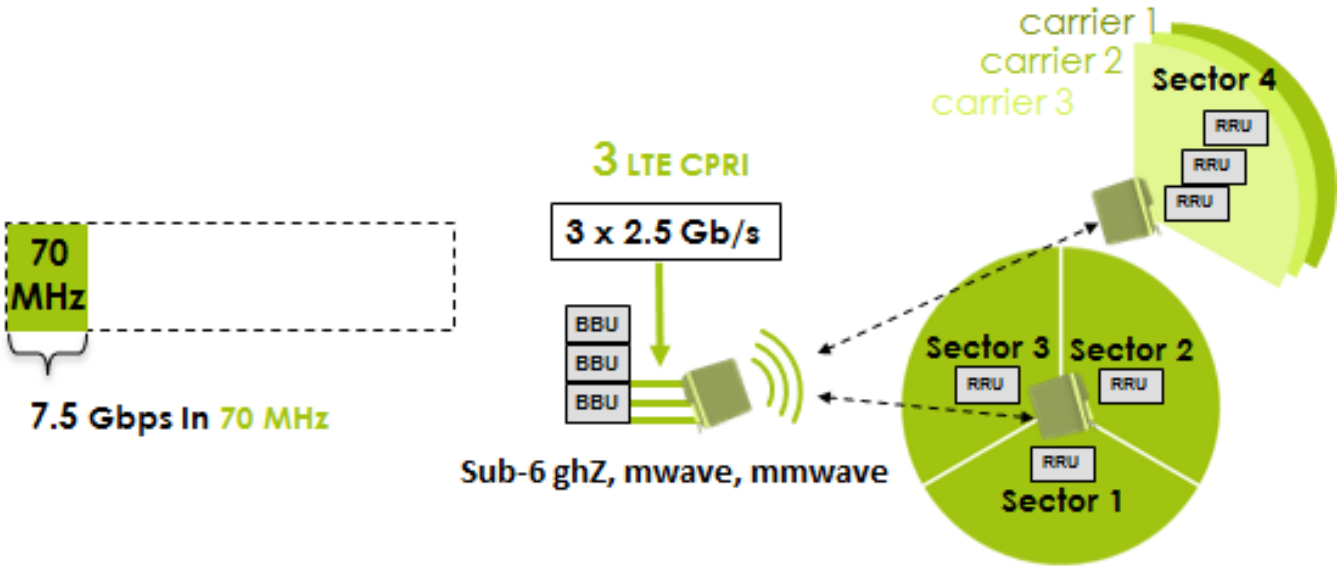
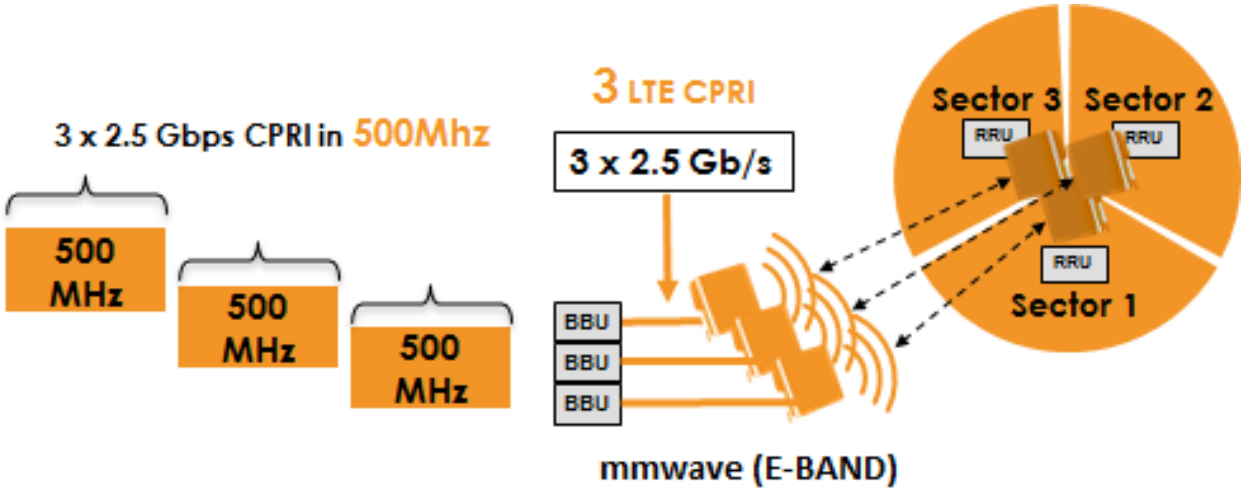
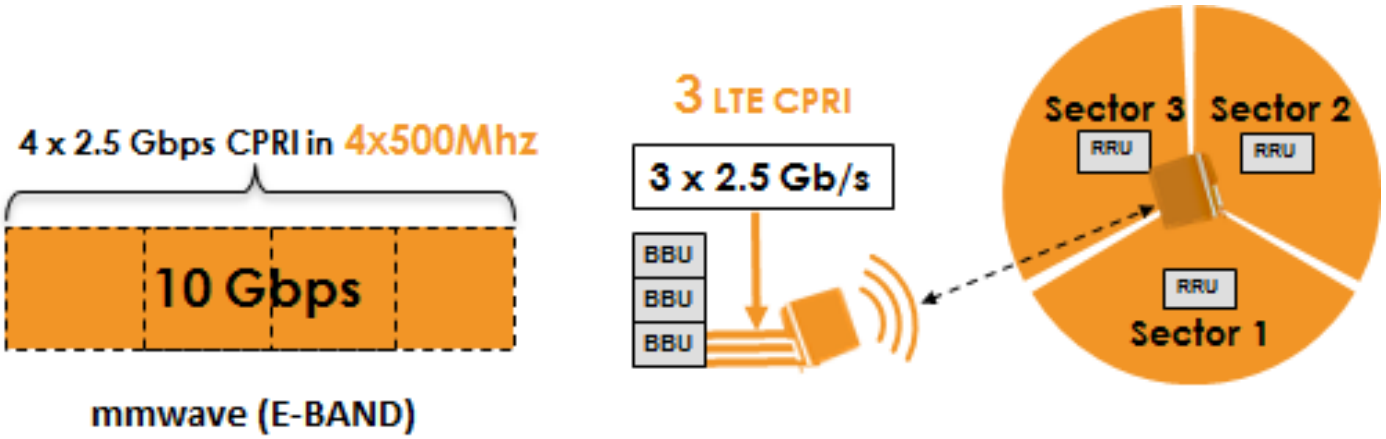
2.5 Gbps CPRI in 500Mhz

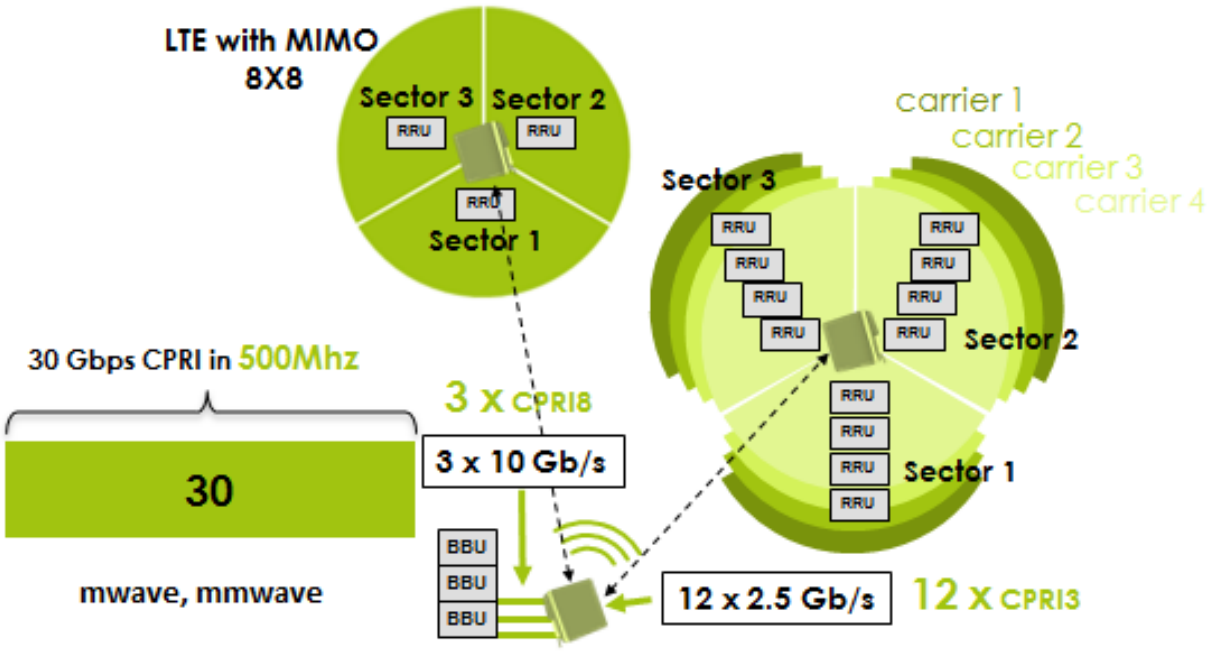
500 MHz



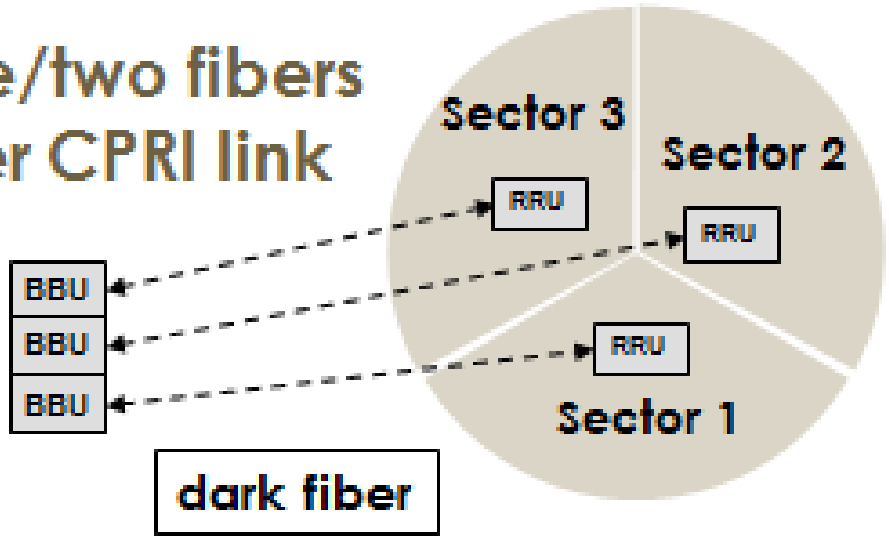


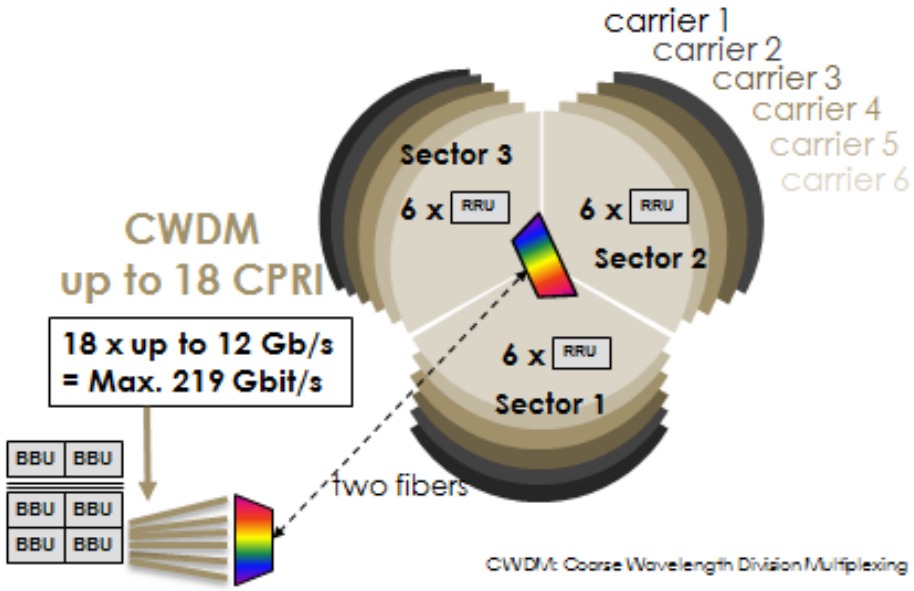

3 x 2.5 Gbps CPRI in 500Mhz
500 MHz
500 MHz
500 MHz
3 LTE CPRI
3 x 2.5 Gb/s
BBU
BBU
BBU
Sector 3
Sector 2
Sector 1
RRU
RRU
RRU
mmwave (E-BAND)

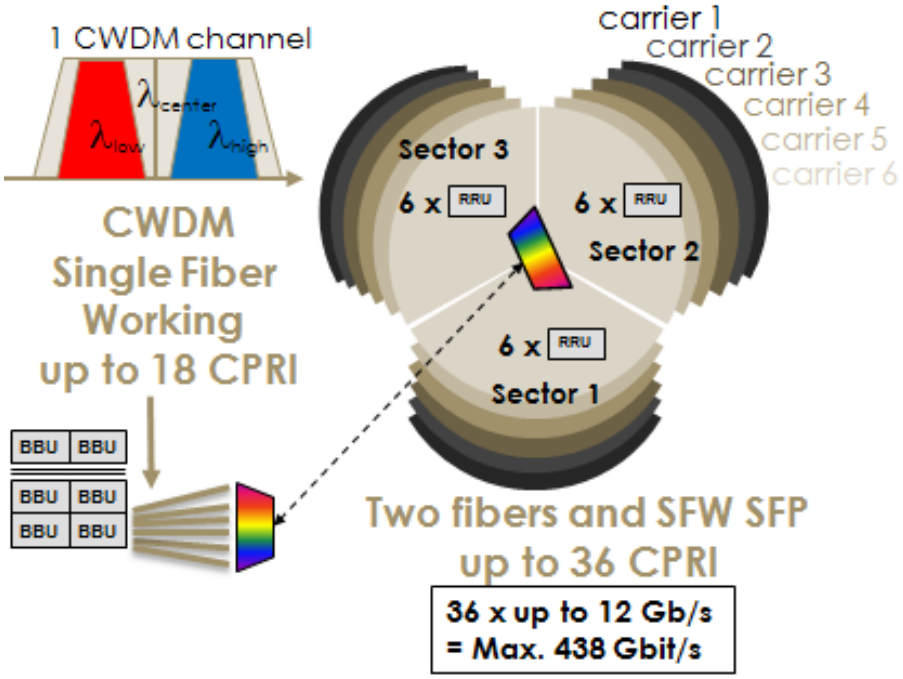

4 x 2.5 Gbps CPRI in 4x500Mhz
10 Gbps
mmwave (E-BAND)
3 LTE CPRI
3 x 2.5 Gb/s
BBU
BBU
BBU
Sector 3
Sector 2
Sector 1
RRU
RRU
RRU

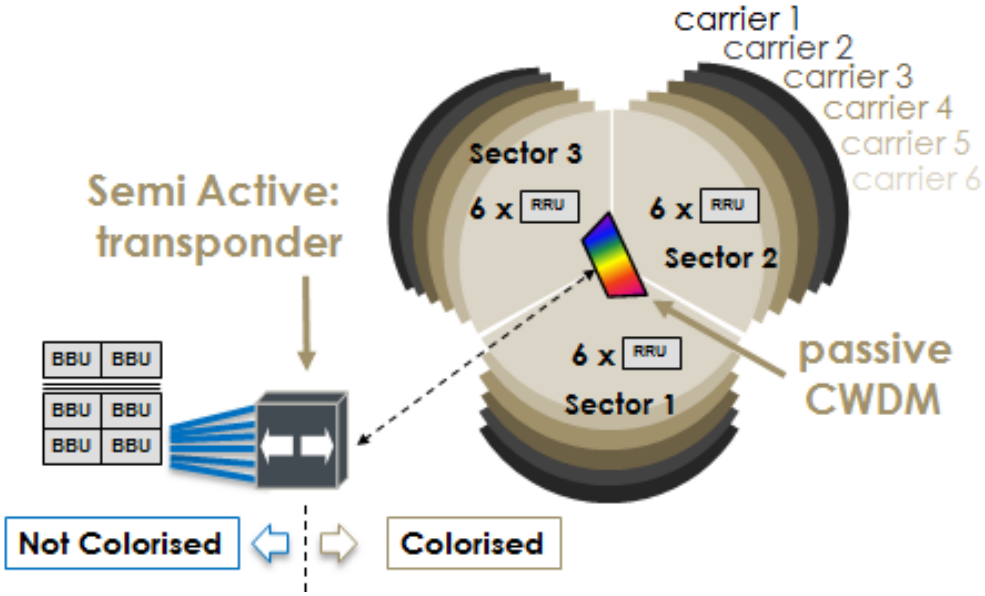

LTE with MIMO
8X8
Sector 3
Sector 2
Sector 1
RRU
carrier 1
carrier 2
carrier 3
carrier 4
30 Gbps CPRI in 500Mhz
30
mwave, mmwave
3 X CPRI8
3 x 10 Gb/s
BBU
12 x 2.5 Gb/s
12 X CPRI3

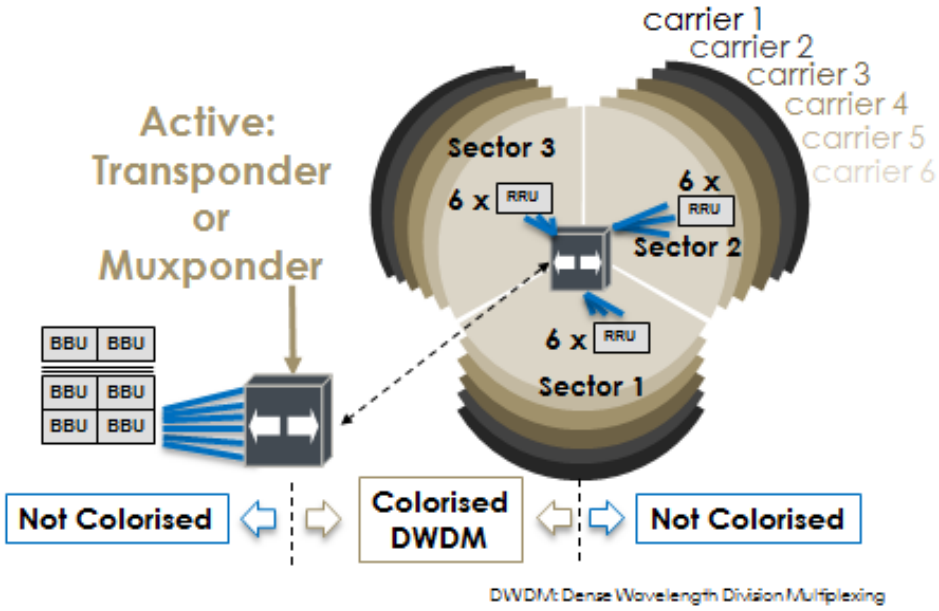
one/two fibers per CPRI link




carrier 1
carrier 2
carrier 3
carrier 4
carrier 5
carrier 6
Sector 3
6 x RRU
6 x RRU
Sector 2
6 x RRU
Sector 1
CWDM
up to 18 CPRI
18 x up to 12 Gb/s
= Max. 219 Gbit/s
BBU BBU
BBU BBU
BBU BBU
two fibers
CWDM: Coarse Wavelength Division Multiplexing


1 CWDM channel
λ_{center}
λ_{low}
λ_{high}
CWDM
Single Fiber
Working
up to 18 CPRI
carrier 1
carrier 2
carrier 3
carrier 4
carrier 5
carrier 6
Sector 3
6 x RRU
6 x RRU
Sector 2
6 x RRU
Sector 1
BBU BBU
BBU BBU
BBU BBU
Two fibers and SFW SFP
up to 36 CPRI
36 x up to 12 Gb/s
= Max. 438 Gbit/s





DWDM: Dense Wavelength Division Multiplexing