Moving Optical Dynamicity to the Edge

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- Fronthaul: CRAN Transport requirements and technical alternatives
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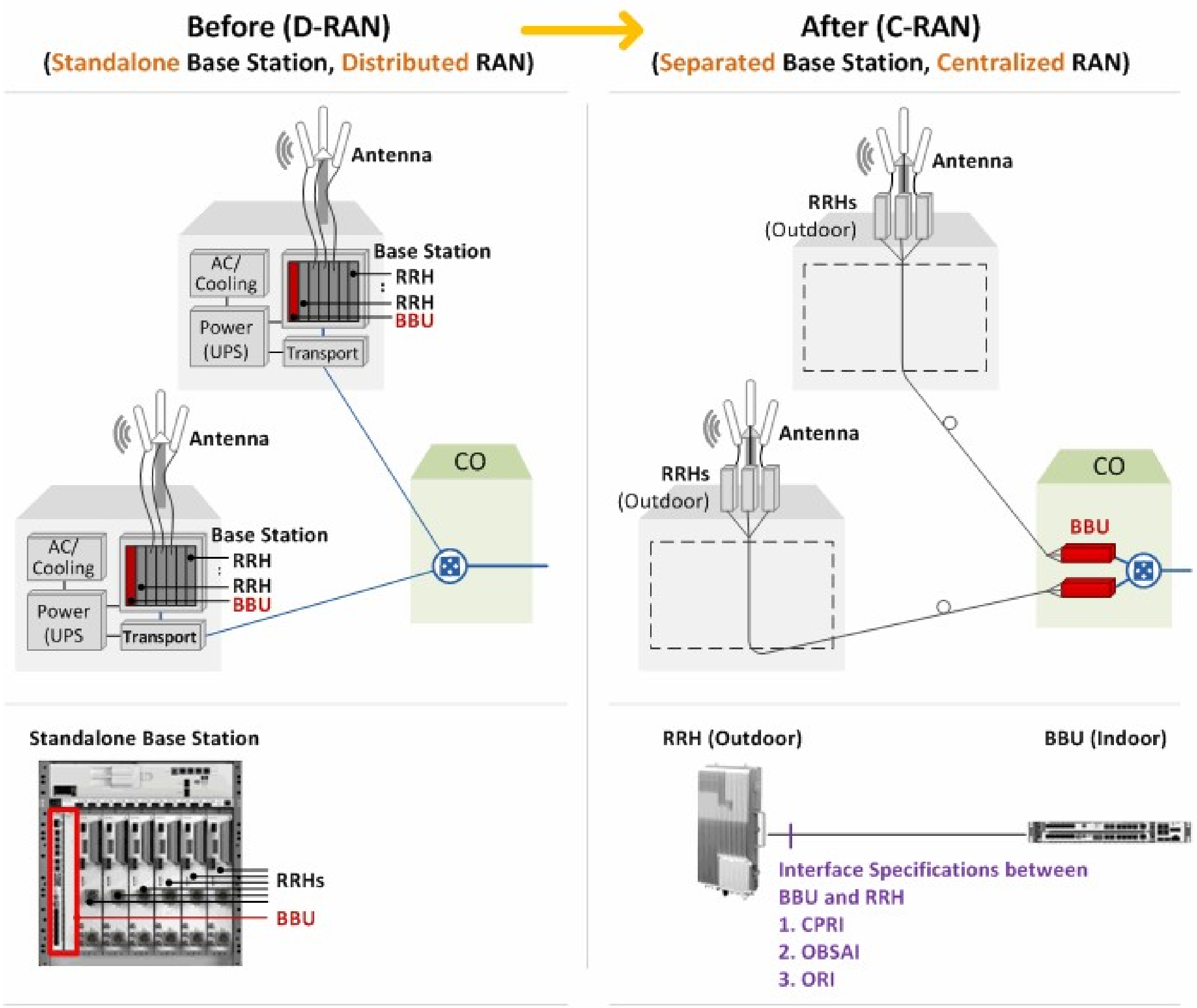
Cloud/Centralized RAN



Centralized RAN drivers

- **Faster deployment**. 2 days per RRU versus a conventional installation work 7 days (BBU + RRU).
- **Less space in remote sites** translate in savings in the installation of new cabinets, easier negotiation with owners by requiring less space and energy.
- **Lower rental costs in new places.** Simplifies model co location with other operators.
- **Maintenance BBUs** concentrated in one single place. FO network between farm and RRUS site.
- **Simplified transport architecture**. No GWT (switch or mini-router in the mobile site) in this architecture. The expansion of the backhaul network are necessary only GWD / GWC level.
- More **efficient use of energy and backups** in the BBUs farms.

Optical Fronthaul– implementation options

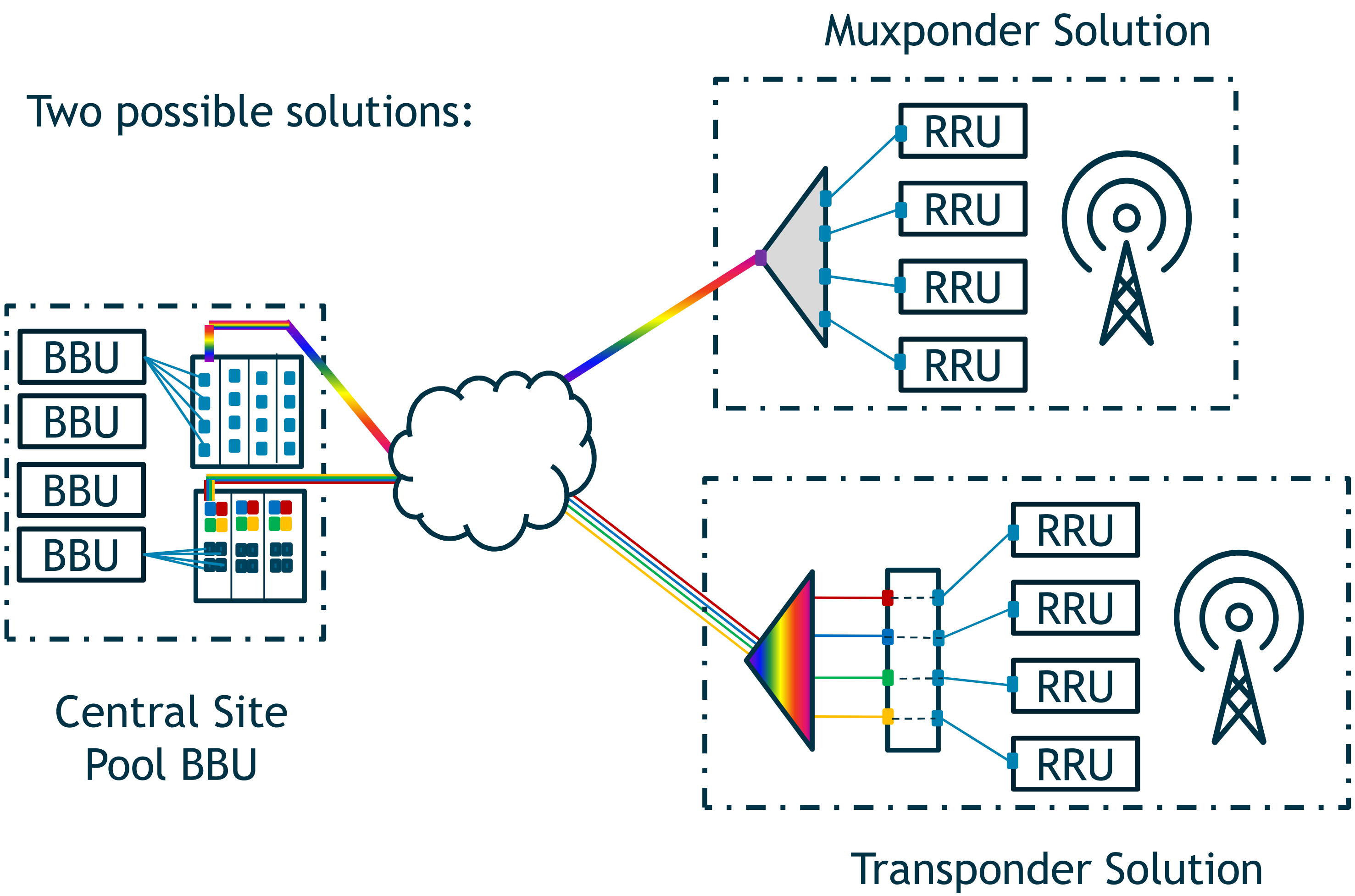
- Support of **fiber based** CPRI fronthaul can be carried out with different technological solutions, each of them with different pros and cons:

	Technology description	Pros	Cons
Dedicated fiber	Passive solution. CPRI signal is transported natively without encapsulation	No additional cost for transmission equipment; no need for power supply at radio site	Requires a lot of fiber. Each RRH requires a single fiber; multiple technologies each require own access fibers; extra equipment is required for monitoring
Passive CWDM	Uses colored SFPs (tuned to specific wavelength frequencies) at BBU and RRH locations combined with CWDM filters that channelize the fiber	Uses no active components; well suited for outdoor deployment; does not introduce latency and provides a highly reliable low-cost solution for CPRI transport	CWDM is limited to 8 or 16 wavelengths, which may not be enough in the future. Passive equipment offers no OAM capabilities
Active WDM	Uses active OTN/WDM gear to transport CPRI encapsulated in OTN frames	Provides CPRI transport over a standardized format; offers a high degree of OAM capabilities	CPRI transport requires careful consideration because the overhead processing required for OTN also adds latency and reduces reach. Since the OTN/WDM solution is active it also requires power and costs more
Passive optical networking (PON)	Passive solution to support CPRI front-haul transmission	PON is typically deployed in dense urban neighborhoods and by its nature has access to existing fiber in places where C-RAN is likely to be deployed.	If the OLT from the PON system and the BBU are not co-located, additional latency will be incurred that limits cell radius. PON is a passive solution and thus end-to-end monitoring of CPRI is an issue

- **Wireless fronthaul** is also an option, with several proprietary solutions already available
  - Based on the use of high frequency bands (e.g., E-Band or Free Space Optics)
- **Ethernet based** solutions are also being explored, e.g., IEEE P1904.3 Radio over Ethernet standard
  - This may become feasible due to the TSN developments to make Ethernet time-aware, like 802.1Qbu Preemption or 802.1Qcc Stream Reservation Protocol

Active solution

Two possible solutions:



Passive vs. Active implementations

Passive:

✓ Does not require power supply
✓ Suitable for outdoor deployments
✓ Low footprint
✓ Low cost
✓ No extra latency

X No OAM channel: no inventory, no supervision…
X Colored pluggables supported at all RRUs/BBUs??

Passive vs. Active implementations

Active:

- ✓ OAM channel: inventory, supervision…
- ✓ Simultaneous support of backhaul, fronthaul and other networks
- ✓ Simplified operation: grey interfaces at BBU/RRU, tunable muxponder/transponder

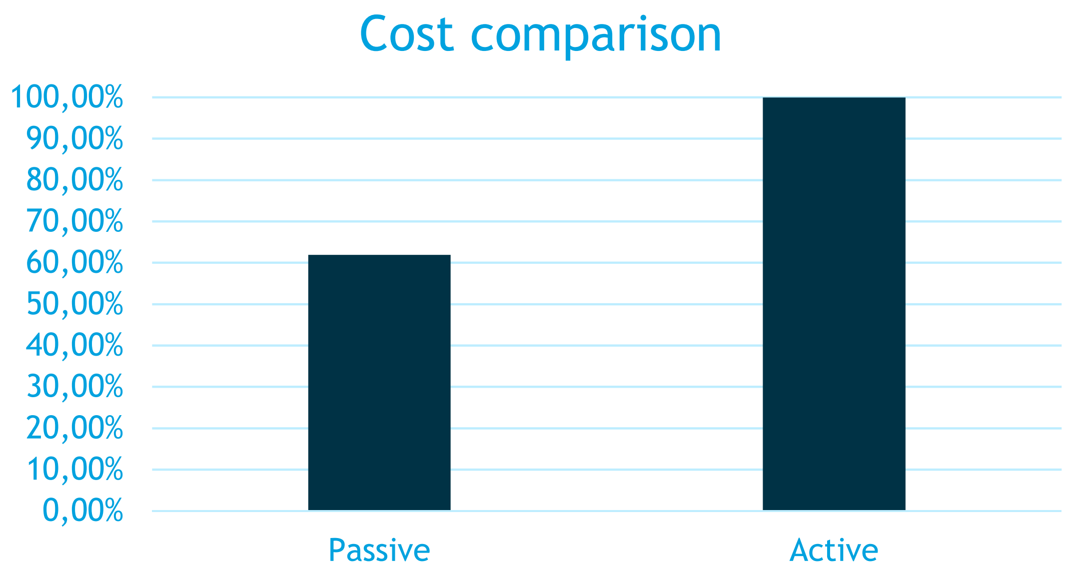
- X Extra latency insertion
- X Outdoor is not always possible
- X Requires power supply
- X Higher footprint
- X Higher cost

Passive vs. Active preliminary capex evaluation

Assuming a protected ring architecture, with 4 RS, each one generating:

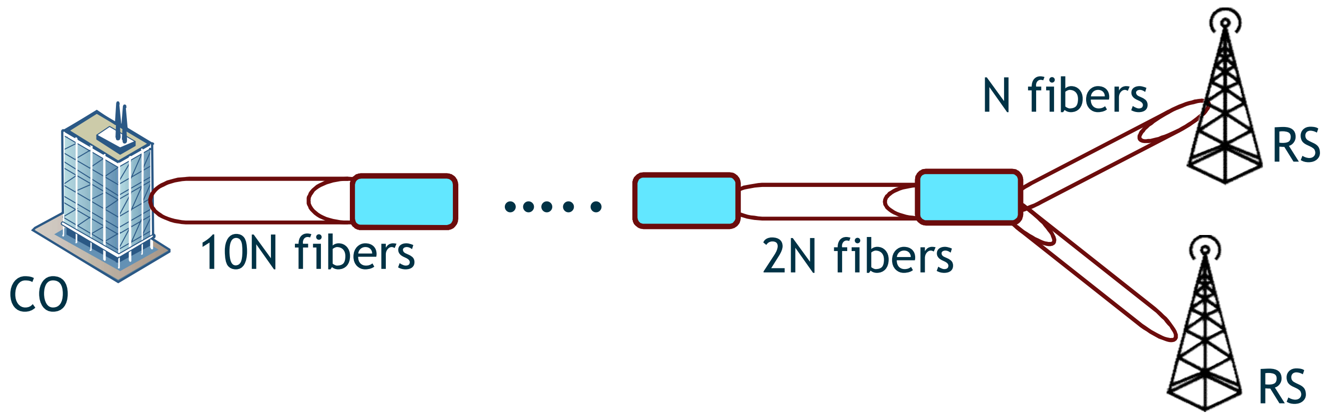
- 1 x CPRI 2 (1.229 Gbit/s)
- 7 x CPRI 3 (2.458 Gbit/s)
- 2 x CPRI 6/7 (6.144 Gbit/s – 9.830 Gbit/s)

Rough estimation (hw+sw) active and passive costs.



C-RAN (Passive & Active) vs C-RAN Dark Fiber

- Transport is interesting vs. dark fiber where cables are getting exhausted or ducts have no more room



Transport capacity is multiplied by λ (with λ=8,16,40,80)
Fiber needs transport = Fiber needs dark fiber/λ

Main technical challenges for 5G fronthaul

- The low-latency and strict synchronization requirements demanded in CPRI requires dedicated lambda per RRU.

- Existing optical fronthaul solutions provides static bandwith provisioning between BBU and RRU. This could be inefficient in dynamic 5G networks where optical fronthal bandwidth depends on the number of users connected to the cell site.

- The upcoming 5G RANs, where 100 MHz channels with massive MIMO are envisioned, may require several tens or even hundreds of gigabits per second capacity in the fronthaul

Key technologies for future 5G fronthaul

- RAN virtualization enabling an **alternative functional split between RRU and BBU** in order to enable more relaxed requirements in terms of latency and bandwidth

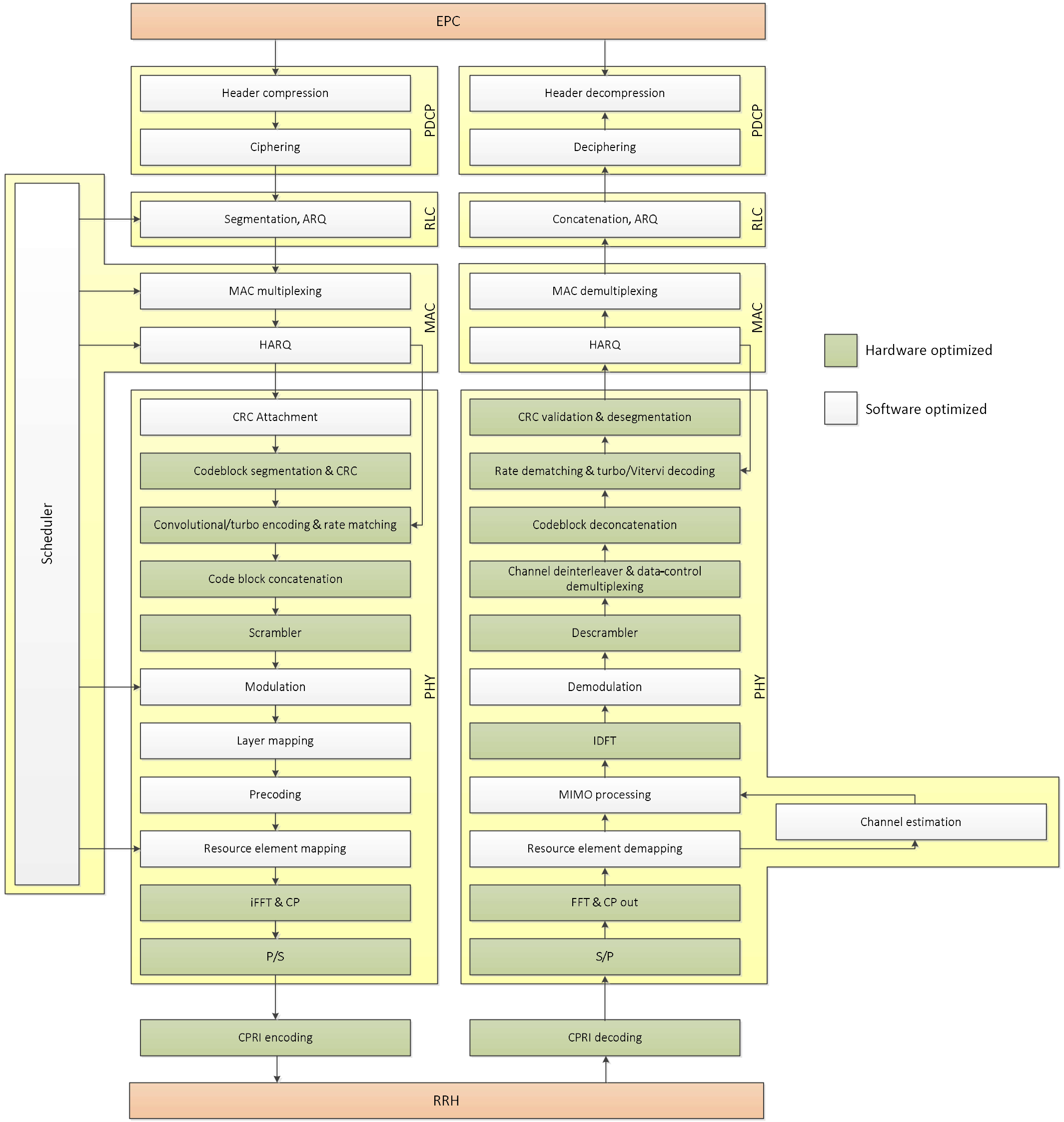
  - **IEEE 1904.3 Standard group** is exploring the possible gains of redefining the RE/REC functional split of C-RAN in the next-generation networks

- **Elastic Optical Networks** in the fronthaul enabling dynamic spectrum allocation among cell sites according to the real time traffic demands

Network virtualization and 5G

- For LTE and its evolution, virtualization is a different way of implementing an architecture that was designed not taking into account virtualization
- Core network virtualization is already a reality, with several commercial products deployed
    - E.g., virtualized EPCs have been deployed to support IoT services on LTE
- But there are good reasons to push for the extension of the virtualization to the Radio Access Network
    - To create an ecosystem of decoupled HW and SW vendors for RAN nodes, therefore reducing dependency on incumbents suppliers
    - To reduce costs, by means of sharing resources at a central site and reducing cost items at the remote locations
    - To improve network performance not compromising the cost reduction goal
    - To provide flexibility to adapt to standard evolutions and traffic demands
- In 5G, virtualization can be used to significantly change the way the network is designed
    - It is essential to implement the concept of network slice, which is expected to provide network operators a significant advantage over OTT players
    - But can also be used to change they way mobile communications are supported, e.g., moving towards a cell-less network architecture

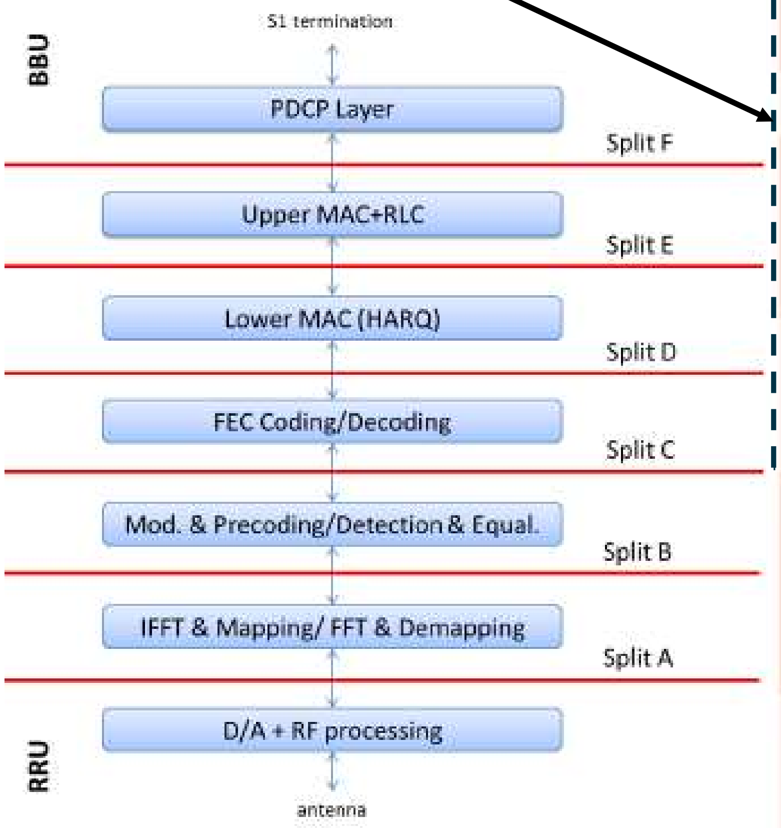
Taxonomy of the functions



- Depending on the nature of each functionality that is being supported the most adequate platform is different
  - **Layer 2 and upper layers** are better implemented in **software over GPP**
  - **Iterative operations like FFT/iFFT and encoding/decoding** are better implemented with **specialized hardware components**, like DSPs or FPGAs
- However, it may be necessary to allow for some flexibility
  - **Encoding is a much less complex operation than decoding**, and can be implemented in GPP with no significant penalty
  - **IDFT after MIMO equalization can be implemented in software**, as this would facilitate the support of advanced interference cancellation receivers

Different functional splits have different implications

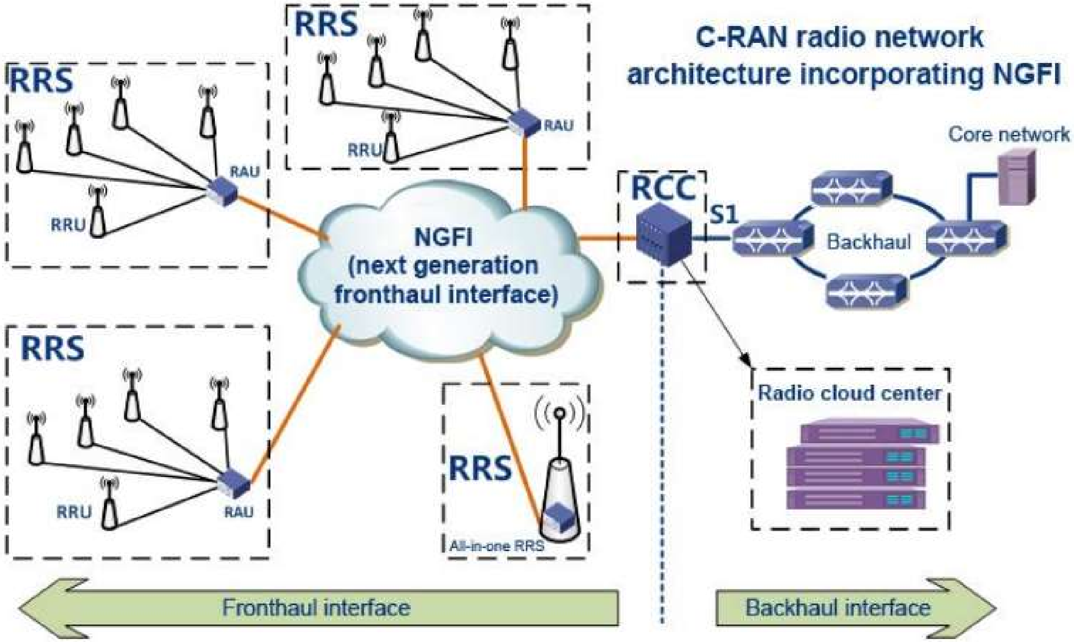
Optimum splits for dynamic Optical networks



No.	Advantages/Disadvantages
F	• Clean cut • No centralized scheduling
E	• No HARQ delay requirement for FH
D	• Data rate depends on code rate per user • Clean cut • Potentially no hardware acc. at BBU • No centralized joint decoding
C	• Data rate depends on modulation scheme, layers per user • No centralized CoMP, MU-MIMO
B	• Only utilized RB (enables stat. mux.) • No CP, GC on FH • Potentially no RS, SS on FH • Frequency domain (lower A/D res.) • Additional hardware at RRU required (FFT)
A	• CPRI • No limitation in centralized processing • Very little digital hardware at RRU • Very high, static data rate • Low latency required

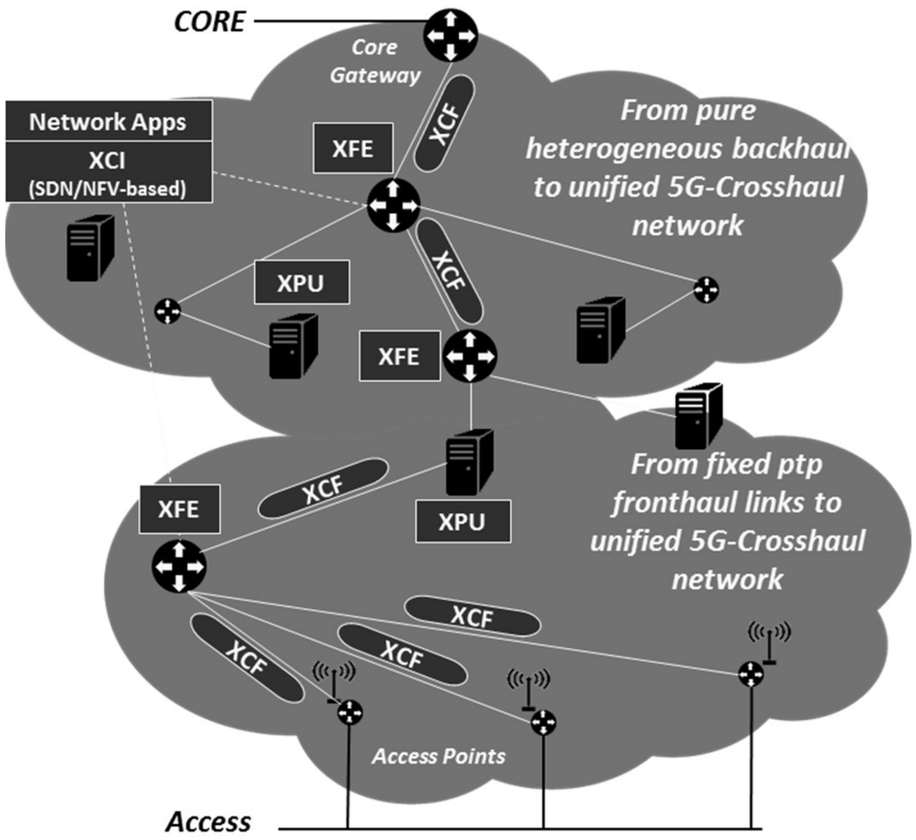
Next Generation Fronthaul Interface (NGFI)

- NGFI is an open interface possessing at least two key properties:
  - First, it redefines the functions of baseband units (BBUs) and remote radio units (RRUs), so some baseband processing functions are shifted to the RRU, which leads to a change in BBU and RRU architecture
    - As a result, the BBU is redefined as the Radio Cloud Center (RCC), and the RRU becomes the Radio Remote System (RRS)
  - Second, the fronthaul changes from a point-to-point connection into a multiple-to-multiple fronthaul network, using packet switch protocols.



5GXCrosshaul
the integrated fronthaul/backhaul

A high capacity low latency transport solution that lowers costs and guarantees flexibility and scalability



A holistic approach for converged Fronthaul and Backhaul under common SDN/NFV-based control, capable of supporting new 5G RAN architectures (V-RAN) and performance requirements

Main building blocks

- **XCF - Common Frame** capable of transporting the mixture of various Fronthaul and backhaul traffic
- **XFE - Forwarding Element** for forwarding the Crosshaul traffic in the XCF format under the XCI control
- **XPU - Processing Unit** for executing virtualized network functions and/or centralized access protocol functions (V-RAN)
- **XCI - Control Infrastructure** that is SDN-based and NFV-enabled for executing the orchestrator's resource allocation decisions
- **Novel network apps** on top to achieve certain KPIs or services

[1] http://www.5g-crosshaul.eu/

The 5G-Crosshaul Control Plane

5G Crosshaul
the integrated fronthaul/backhaul

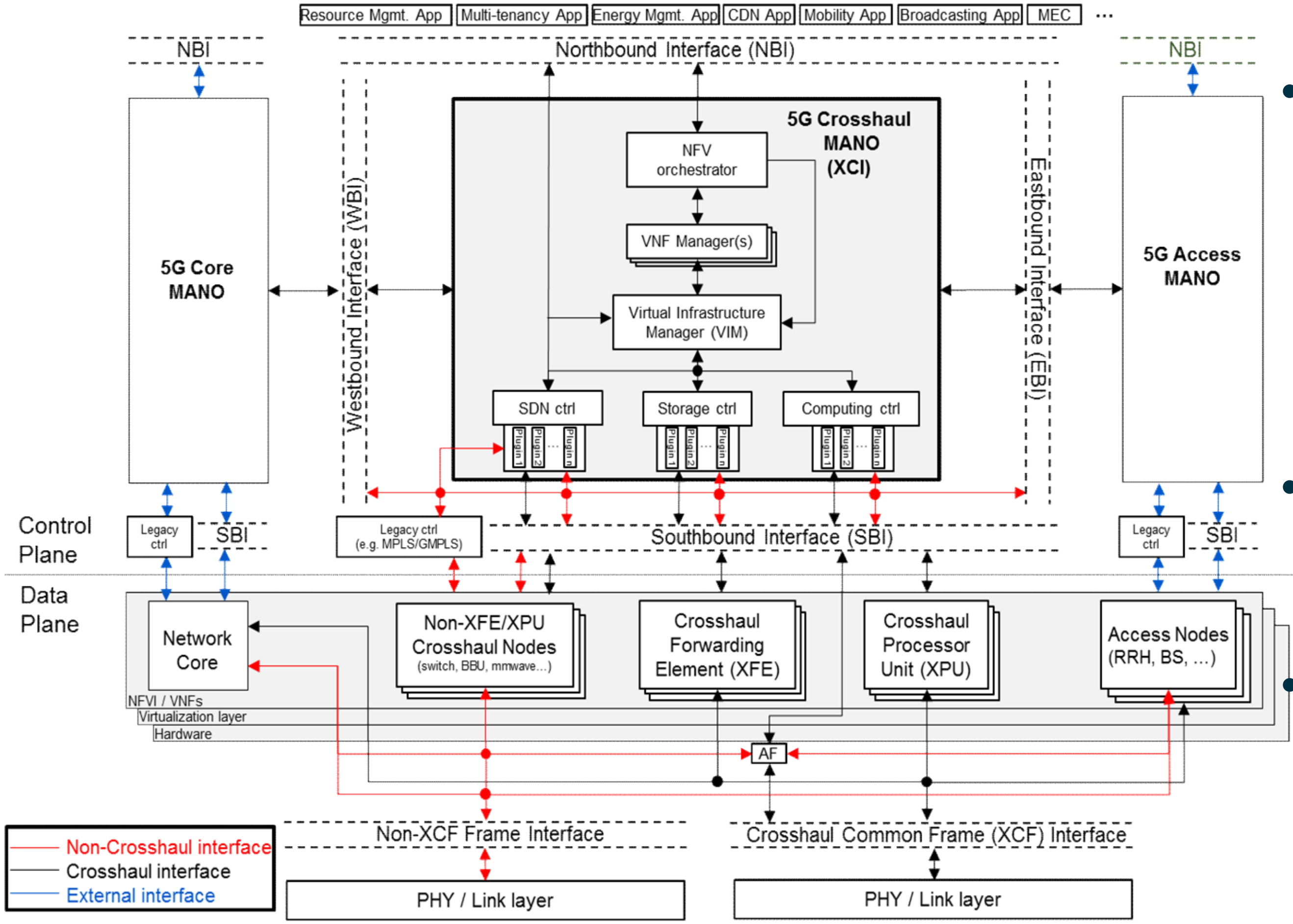


Figure 1: 5G-Crosshaul Architecture Illustration

- Unified control plane for the integrated fronthaul/backhaul transport network
- Leverages SDN/NFV technologies
- Specifically designed for multi-tenancy

5G fronthaul: Static CPRI vs dynamic optical frontahul

	STATIC HIGH CAPACITY CPRI	Dynamic Optical fronthaul
KEY TECNOLOGIES	Tunable SFPs up to 100Gbps and beyond	New Functional Split Low costs S-BVT up to 1 Tbps and BVT at 10Gbps and beyond Performance monitoring, big data analysis and dynamic SDN control
STRENGTHS	Simple architecture (no control plane)	Flexible BBU location (centralized or distributed) Lower capacity at RRU side is needed SBVT dimensioning at BBU side according to traffic patterns
WEAKNESSES	Distributed BBUs (20KM approx. between BBU and RRU) High capacity SFPs at both BBU and RRU sides No pooling at aggregation switches	Complex SDN control and SBVT and BVT designs

Conclusions

- Existing CRAN solutions impose strict transport requirements in terms of capacity and latency
- Future 5G networks will require new optical fronthaul solutions
- Two alternatives are foreseen:
  - Static CPRI
  - Dynamic optical networks
- We do not discard none but Telefonica research work is currently focused on the last one

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