1914 Copenhagen

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China Mobile : 5G impact on FH transport & potential NGFI scenarios

LTE RRH with:

- Partial offload of LTE L1 functions
- Proprietary protocol based on 1914.3 RoE
- Validated multiple scenarios
- NGFI split 4 variant
- More than 4-factor data reduction compared to CPRI
- ~300 Mbps for single antenna 20 MHz LTE cell
- < 10 Mbps during low load

Function repartitioning

- Packet based network
- Cell load dependent traffic
- Support for coordinated functions
- Decouple traffic from number of antennas

Different functional splits proposed

No ”one size fits all” solution

	Split 1	Split 2	Split 3	Split 4	Split 5
RRH complexity	High	High	High	Low	Lowest
FH Interface complexity	Low	High	Medium	Low	Low
Pooling gain	Small	Relatively small	Relatively small	Large	Large
Complexity of upgrading and maintenance	High	High	High	Low	Low
Delay requirement	< 100 ms	< 1 ms	< 1 ms	< 1 ms	< 1 ms

Source: ”White Paper of Next Generation Fronthaul Interface”

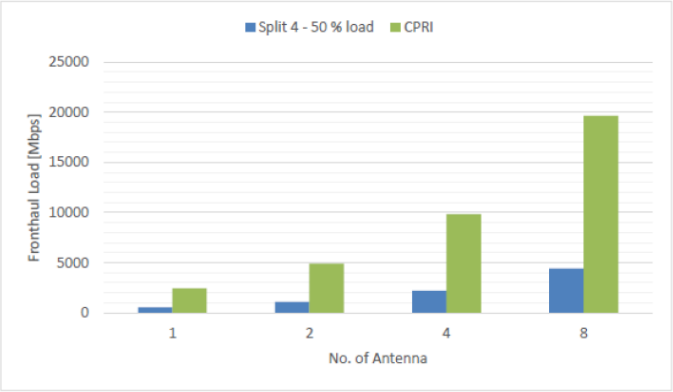
Split 4 has low implementation complexity and offers cell-load dependent fronthaul traffic

It is the most obvious choice for a Proof of Concept implementation

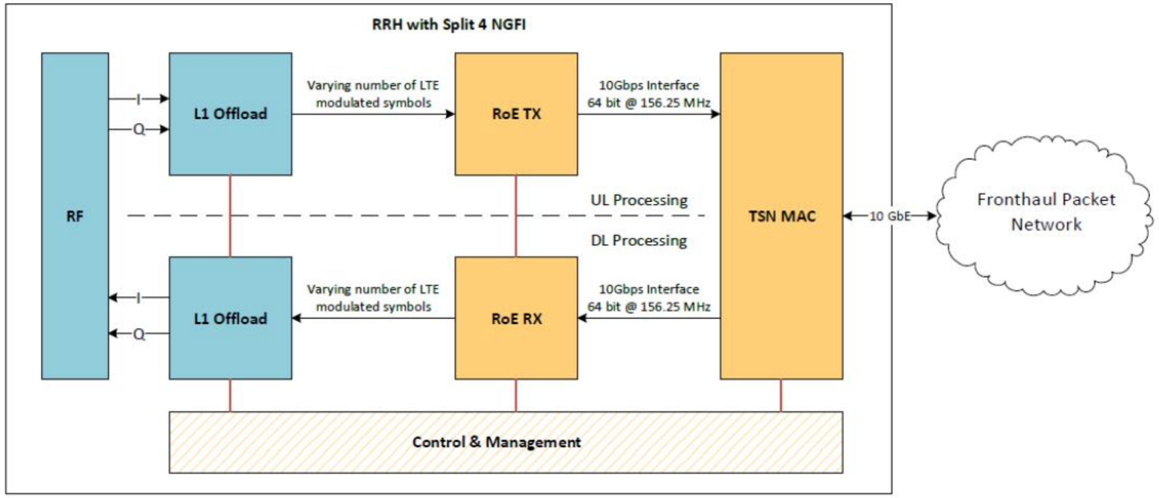
Split 4 NGFI

3-sector LTE site fronthaul load as a function of antennas

CPRI vs. Split 4 NGFI



Split 4 NGFI RRH



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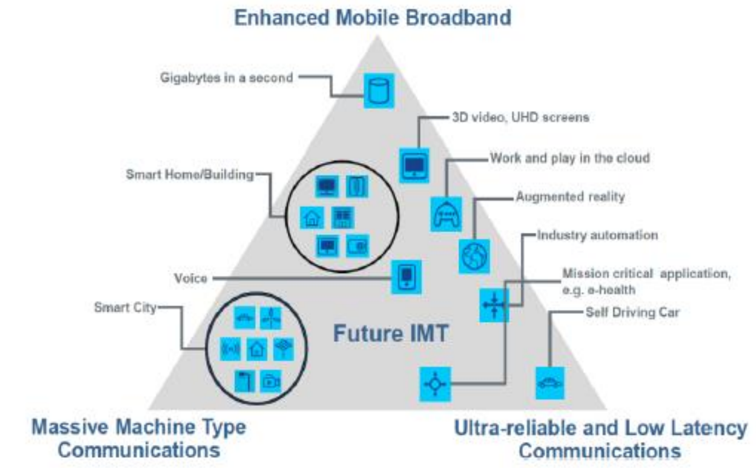
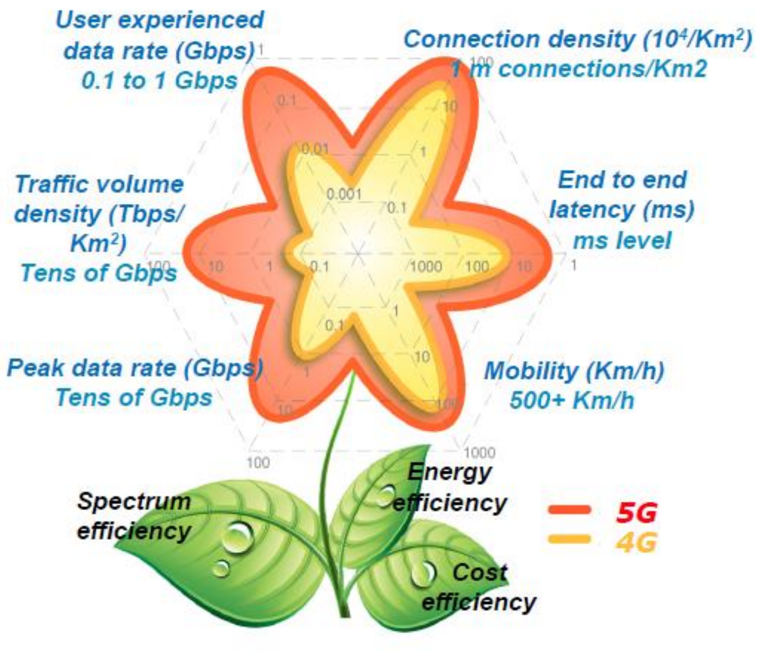
5G at a glance

Three major application scenarios

Naming:IMT-2020





"Information a finger way, Everything in Touch"

- Which scenarios may have potentially noticeable impact on FH transport?
- Which features may have potentially noticeable impact on FH transport?
- Which technologies are having potentially noticeable impact on FH transport?

Massive MIMO

mMIMO	
Typical configuration	64 Tx/Rx for sub-6GHz and 256 Tx/Rx for 30GHz, 1024 Tx/Rx for 70GHz
Key impact on FH transport	Very high FH bandwidth, e.g. on the 100G order of magnitude
Potential solution to transport	Novel function split scheme
Potential scenarios of the feature/tech.	Dense urban, outdoor-to-indoor coverage, indoor coverage
Applicable for D-RAN or C-RAN	Currently D-RAN; To support C-RAN, the FH issue MUST be addressed;
Priority	High

Joint transmission/reception (JT/JR)

JT/JR	
Typical configuration	3~7 collaborating points
Key impact on FH transport	High synchronization accuracy, low latency and jitter
Potential solution to transport	The same requirement as in CPRI
Potential scenarios of the feature/tech.	Dense urban
Applicable for D-RAN or C-RAN	Mainly C-RAN
Priority	Low or medium

China Mobile: Scenarios identified

Scenario 1: indoor hotspot E.g: office building

- High capacity, Interference not an issue
- Potential requirements on NGFI: multiplexing capability, reduced maximum bandwidth, traffic-dependent

Scenario 2-1: dense urban with 4G/5G co-located

- Dense population; outdoor; high traffic load, Interference is an issue
- Potential solutions/technologies: C-RAN-based Hetnet architecture, Interference cancellation schemes (JT/JR/CS/CB etc.), mMIMO for capacity
- Some attributes: – 1 ring ~ 6-8 MUX, 2-5km^2 coverage, – 1 DU ~ xx (e.g. 6-10) 5G RRU + 1 4G
- RRU, Distance b/w DU and 5G RRU: < 2km
- Potential requirements on NGFI: Multiplexing capability, Reduced maximum bandwidth, Flexible split options

Scenario 2-2: dense urban with 5G RRU only

- Big difference from previous one: Removal of stringent requirements via 4G RRU (i.e. CPRI requirements)

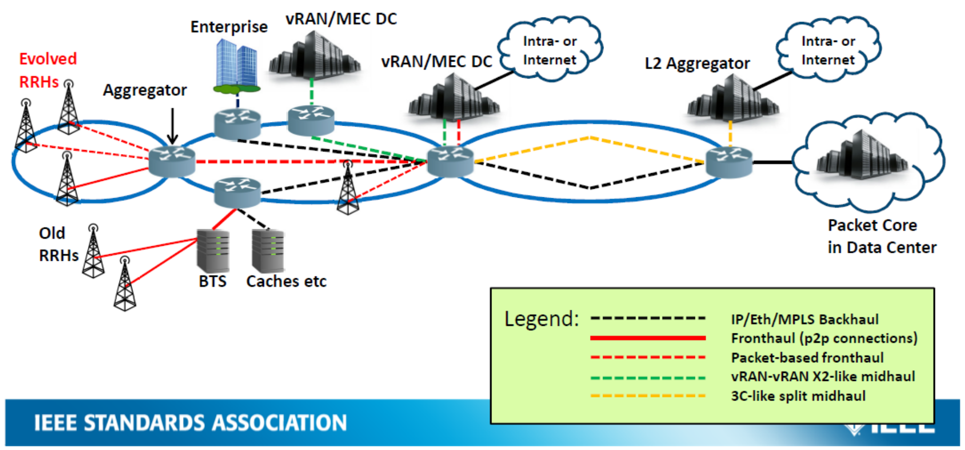
Broadcom: Practical approach to converged FH/BH network architecture and functional partitioning

- Architecture proposal for converged fronthaul and backhaul network for 4.5/5G RAN.
- Functional splits from a general purpose circuit point of view.
- Proposal NGFI **interfaces** and **functional splits**

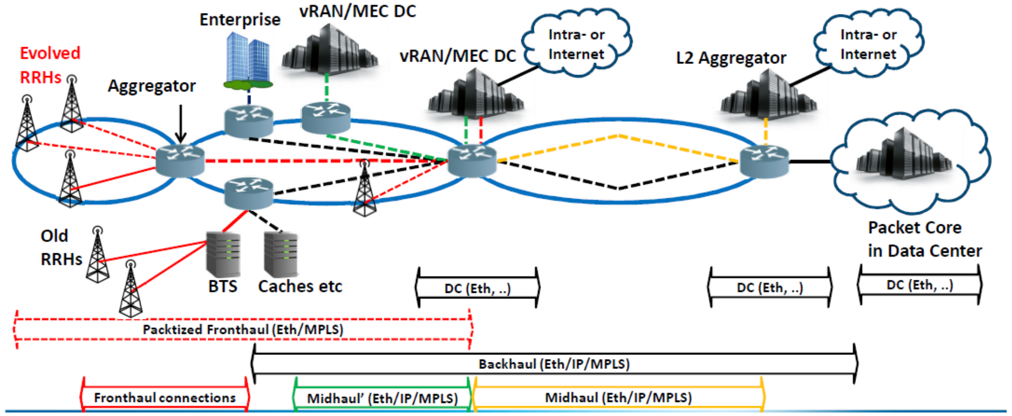
Architectural Motivations

- Relaxed backhaul bandwidth requirements, support for low latency applications and radio/proximity optimized applications.
- Converged fronthaul and backhaul with unified E2E networking infrastructure and OAM.
- Fully virtualized coordinated RAN.
- Reduced buffering in vRAN nodes and centralized higher layer radio resource/mobility management

High level architecture – proposal



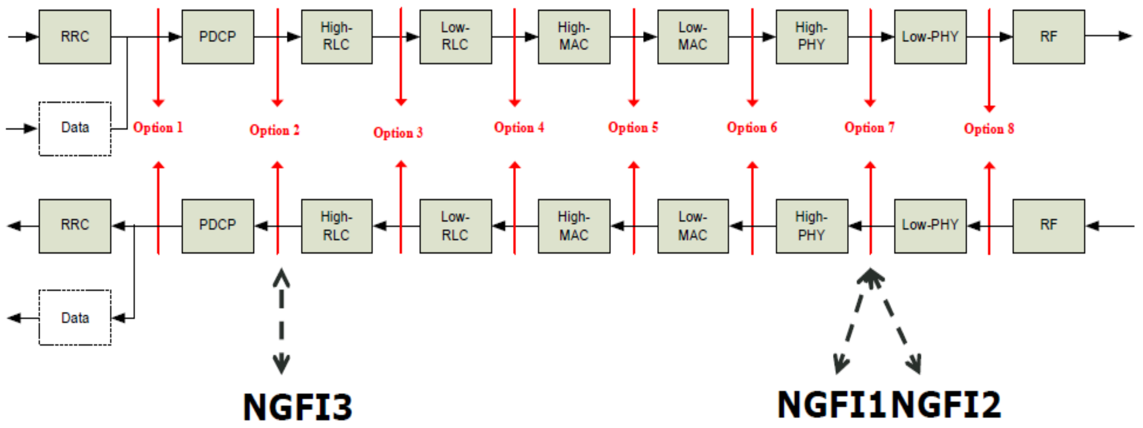
Transport view



Summarizing..

- Multiple functional split points – not just how it splits in the radio stack but also how it fits into network architecture.
- Different functional splits affect latencies and synchronization requirements on specific parts of the transport network – they **do not change** the overall system level radio synchronization requirements
- Highly accurate Time-synchronization distribution becomes key.
- Traffic isolation (no traffic interferes other traffic) becomes key.

3GPP TR38.801 functional split view



Each "interface" has different set of requirements to the networking.

Proposal

- Define requirements and functions for a small number of splits (2? 3?).
- Functional splits should aim for simplicity:
- Identify the most common and important functions that are easy to design "5G ready".

- **Adopt** the three interfaces proposed in this contribution as a baseline:
- NGFI1 – simple split functions, high volume standard networking solutions with little software involvement.
- NGFI2 – more complex split functions, aggregation, converged front- and backhaul, software functions are likely needed.
- NGFI3 – "L2 splits" with full service provider functions.

Requirements based on interfaces

NGFI1

Split functions:
- (I)FFT and CP insert/remove.

Transport latency/jitter:
- Few tens of μs – based e.g., on the FFT block size.

Time-synchronization:
- **~1ns** timestamping accuracy (radio still has 65ns TA & 50ppb freq. accuracy or strickter..)
- 1588 + SyncE.
- OC/TC support.

Transport functions:
- Ethernet, MPLS (PW).

NGFI2

Split functions:
- NGFI1 + **mappers**.
- ..possibly upper PHY, PRACH handling, etc.

Transport latency/jitter :
- Around NGFI1..

Time-synchronization:
- NGFI1 + BC support.

Transport functions:
- NGFI1 + some service provider features.
- **Strict isolation & protection** (FH vs BH vs MH).

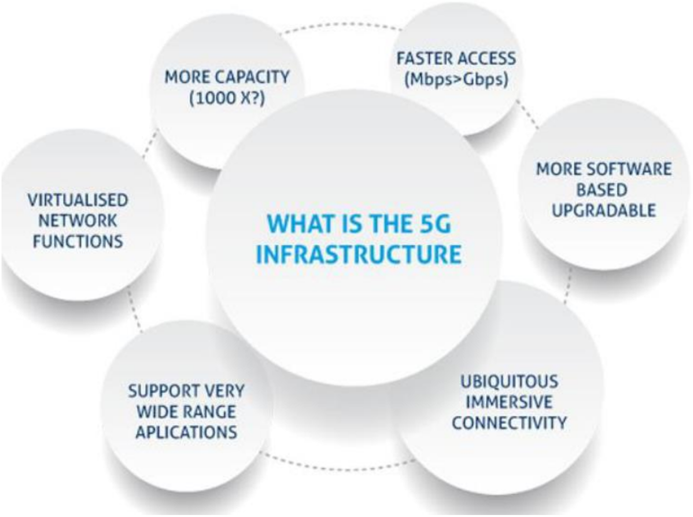
NGFI3

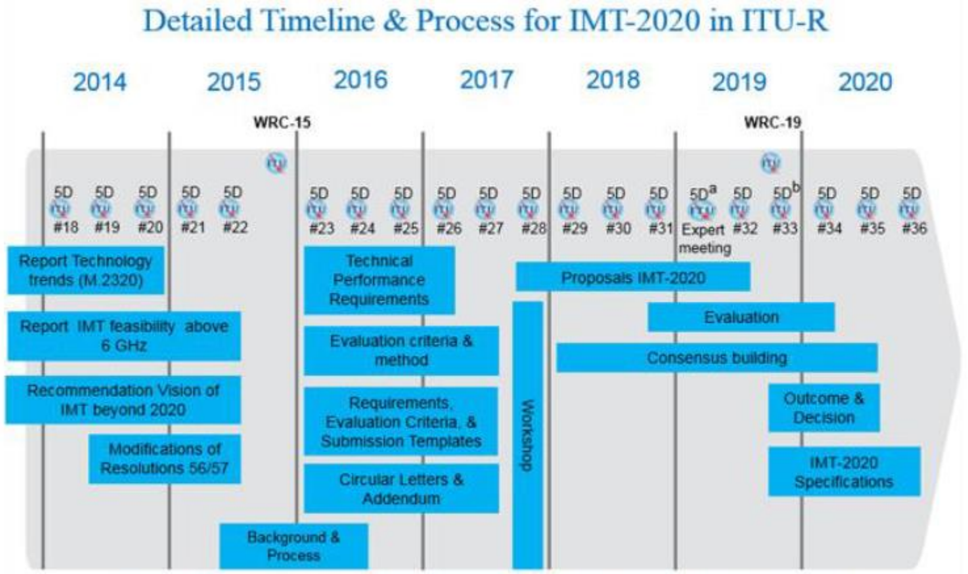
Split functions:
- 3GPP 3C-like (Dual Connectivity)..

Latency and Time-synchronization:
- Existing ITU-T and MEF specified for BH and MH.
- NGFI2 support.

Transport functions:
- Typical service provider features.

HFR: NGFI State-of-the-art Overview





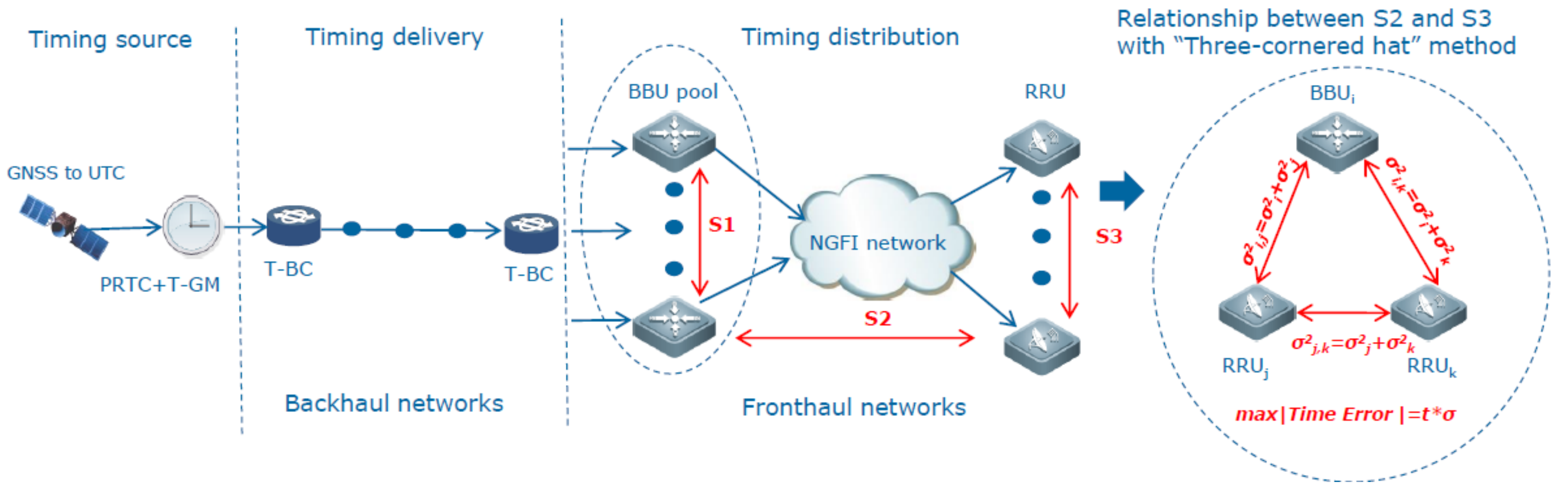
Architecture for the transport of mobile fronthaul traffic (e.g., Ethernet-based), including user data traffic, and management and control plane traffic.

Requirements and definitions for the fronthaul networks, including data rates, timing and synchronization, and quality of service.

The standard also analyzes functional partitioning between RRUs and BBUs that improve fronthaul link efficiency and interoperability on the transport level, and that facilitate realization of cooperative radio functions, MIMO operational modes, CoMP.

CAICT: Considerations on synchronization in next generation CRAN fronthaul architecture

- Data are transmitted Statistical multiplexing with Ethernet;
- Nodes are synchronized over Ethernet to take advantage of idle period to make power consumption earth-friendly;
- Under packet switching network Synchronization performance may suffer from PDV(Packet Delay Variance) and will be more challenging;
- Initial discussion on how to support synchronization for NGFI in ITU-T.

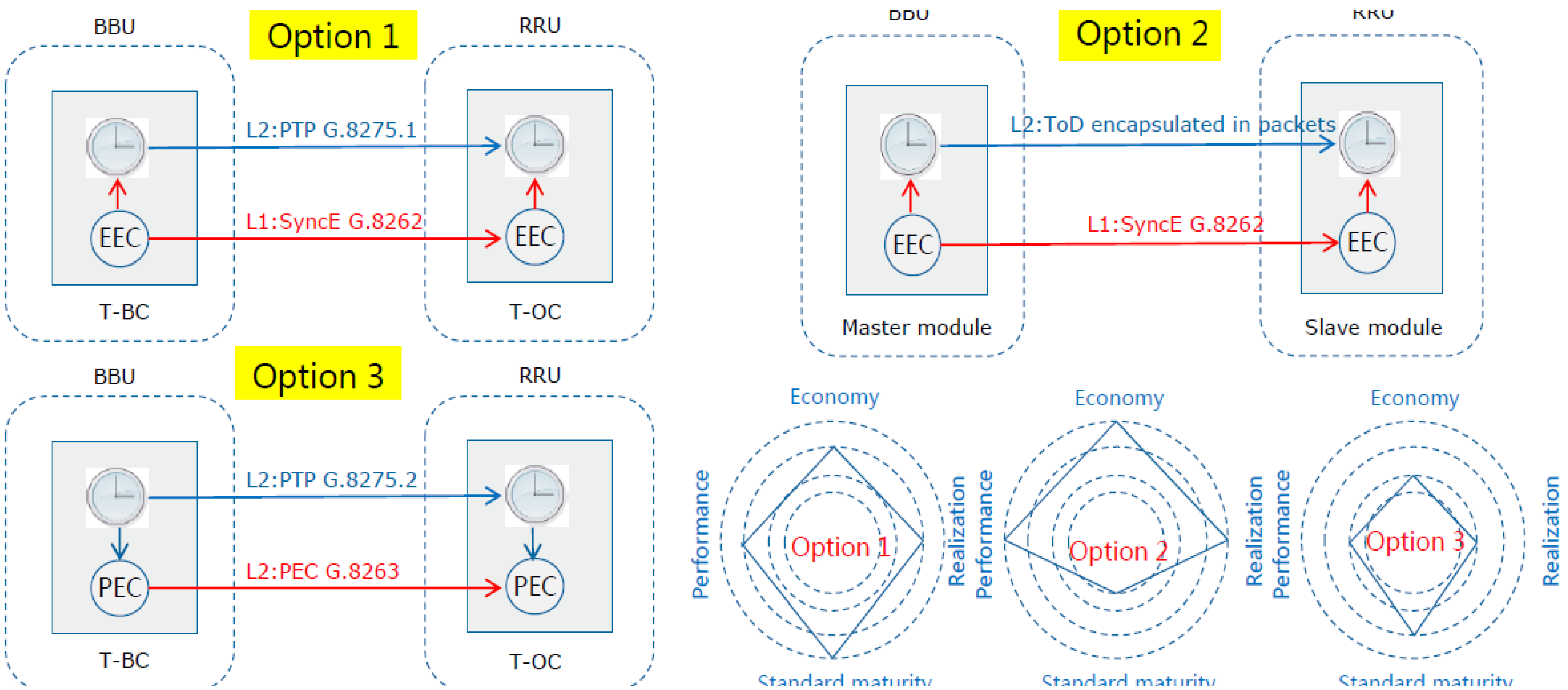


S1(BBU to BBU)is distributed in backhaul architecture solved in ITU-T G.8271.1 HRM

S2(BBU to RRU)is suggested as key issue to be discussed in CRAN fronthaul architecture

S3(RRU to RRU)is so complex and difficult to be controlled but can be converted to S2(illustrated in "Three-cornered hat" method).

CAICT: 3 proposed solutions



Option 1: T-BC and T-OC are located in BBU and RRU respectively with G.826x and G.827x series standards supporting compatible with packet networks

Option2:Master and slave module are located in something called "remote PTP-head" technology, noted that ToD format and mechanism of link delay compensation should be specified in NGFI standard for further study;

Option 3:EEC clocks are replaced by PEC clock in T-BC and T-OC, with the advantage of partial supporting for timing in PTP/syncE unaware networks(e.gthrough switch/router),however this option may be great challenge against PDV and complexity of algorithm for packet filtering, so it is recommended in low priority comparing to option 1 and option 2.

Verizon: Transport Requirements for a 5G Broadband Use Case

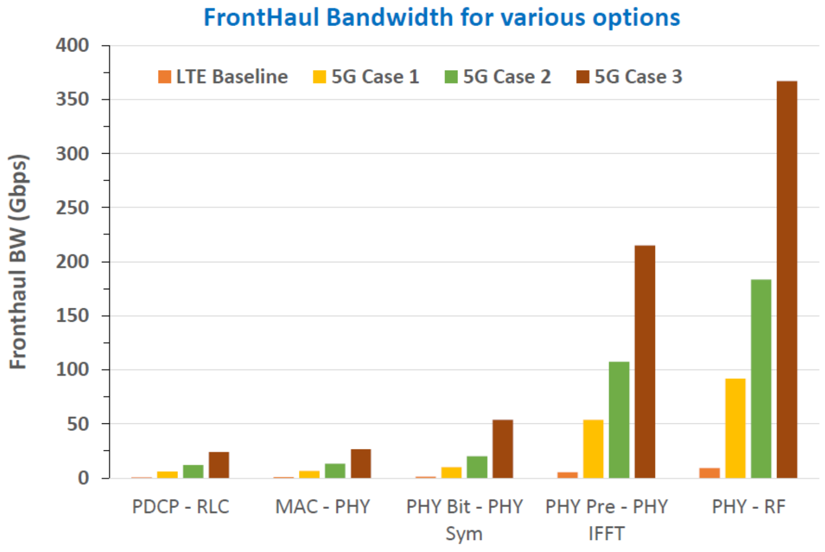
RAN Split Benefits/Drivers

Resource Pooling	• Pool resources across multiple eNBs • L2/L3 resources dimensioned on aggregate traffic / connections • L1 resources dimensioned on RF BW & antennas
Cooperative Processing	• Centralized Scheduling and Interference management • UL/DL CoMP schemes
Increased Virtualization	• Enable SDN/NFV with general purpose compute hardware • Efficient scalable RAN
Easier Upgrades and Self Healing	• Reduce hardware/software upgrade & provisioning time • Grow user capacity / connections / features as needed • Virtual machine switchover on failure
Edge Applications	• Faster deployment of new services and features (M2M handling, Edge Analytics (User/Application), Video Optimization etc) • Decouple applications from dedicated physical elements
Energy Savings	• Efficient pooling of compute to lower overall energy consumption • Power down resources during lighter traffic to save energy
Reduce CAPEX/OPEX	• Large scale centralized processing on general purpose hardware • Cost effective Fronthaul transport - some PHY functions at edge • Easier hardware, software and vendor switching

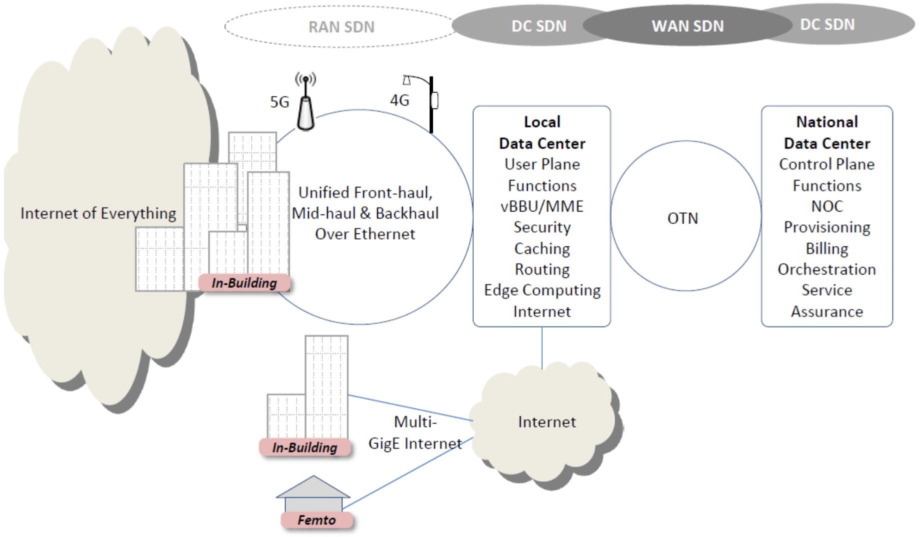
RAN Split Options: Comparison

	Split Option		Front Haul Requirement		Performance/Operations			
			BW	Latency	Central Sched. & Int. Mgmt.	Cent. Gains	Interface Complexity	FH Cost
High	Op 1	PDCP – RLC CU: RRC, PDCP RU: RLC, MAC, PHY, RF	Low	More Relaxed	No	Low	Moderate	Cheaper
High	Op 2	RLC – MAC CU: RRC, PDCP, RLC RU: MAC, PHY, RF	Low	More Relaxed	No	Better	Moderate	Cheaper
Mid	Op 3	MAC Hi – MAC Lo CU: RRC, PDCP, RLC, MAC Hi RU: MAC Lo, PHY, RF	Lower	Relaxed	Yes	High	High	Cheaper
Mid	Op 4	MAC – PHY CU: RRC, PDCP, RLC, MAC RU: PHY, RF	Lower	Strict	Yes	High	High	Cheaper
Low	Op 5	PHY Bit – PHY Sym CU: RRC, PDCP, RLC, MAC, PHYx RU: PHYy, RF	Lower	Strict	Yes	High	High	Cheaper
Low	Op 6	PHY Pre – PHY IFFT CU: RRC, PDCP, RLC, MAC, PHYx RU: PHYy, RF	High	Strict	Yes	Very High	Low + IFFT	Expensive
Low	Op 7	PHY – RF CU: RRC, PDCP, RLC, MAC, PHY RU: RF	Always High	Strict	Yes	Very High	Low Off Shelf H/W	Very Expensive

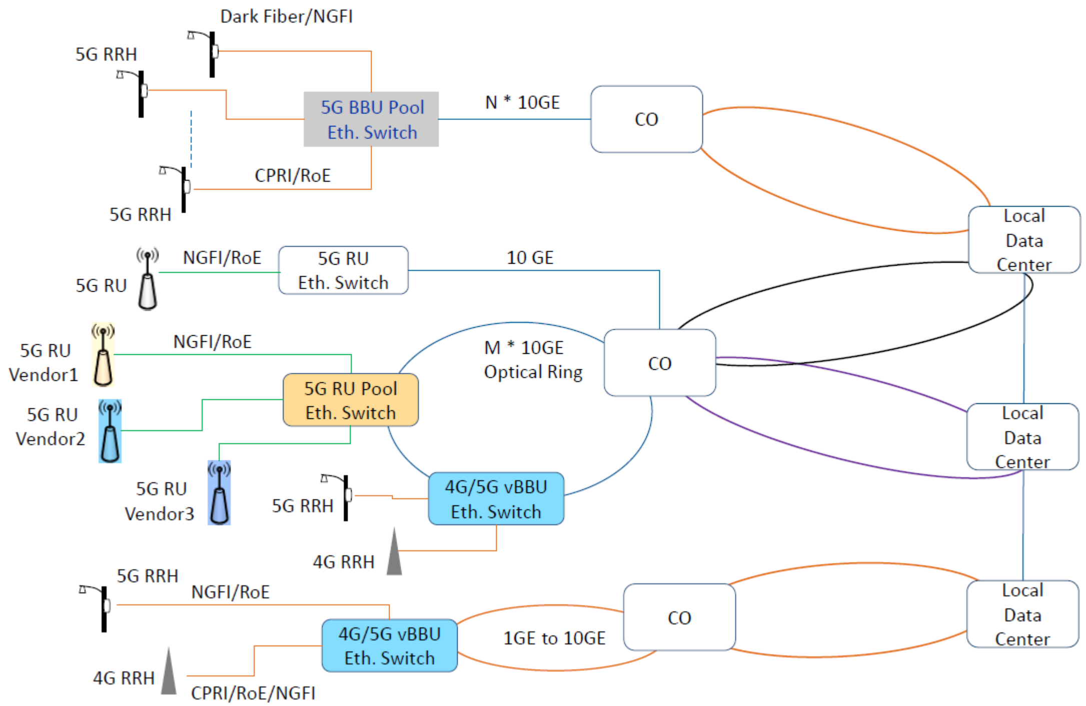
FH BW Comparison – RAN Split Options



Future Mobile/Access Network



4G/5G Fronthaul/Backhaul Architecture Options



Verizon

Unified front-haul, mid-haul and backhaul

- Move away from CPRI (technical and ecosystem limitations)
- Ethernet could be the unifier
- Enable fronthaul resilience

Optimized RAN Split: Desired Features

- Reduced FH Bandwidth
- Low complexity interface
- Low cost off-the shelf Remote Units
- Centralization gains
- At least one high and one lower layer split

Challenges

- Tradeoffs: Timeline-Flexibility, Cent. Gains–Bandwidth
- Standardized Interfaces: Vendor Interoperability
- Ecosystem: Partners needed for equipment, compute, networking, and end-to-end testbeds/PoC