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Next Generation Fronthaul Interface - Use Cases & Scenarios

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Fronthaul impact by 4G/5G RAN evolution

General RAN requirement

	4G/4G+ (Rel.13)	5G
RAN technologies	LTE/LTE advanced	5G new radio (NR)
Bandwidth	100MHz and up (*)	850MHz (**)
Peak data rate requirement	1Gbps DL, 500MHz UL	20Gbps DL, 10Gbps UL
Peak spectral efficiency	30bits/Hz down, 15bits/Hz up	30bits/Hz down, 15bits/Hz up
End-end delay requirement	20ms RRT	eMBB: 4msDL+4ms UL URLCC: 0.5ms DL+0.5msUL

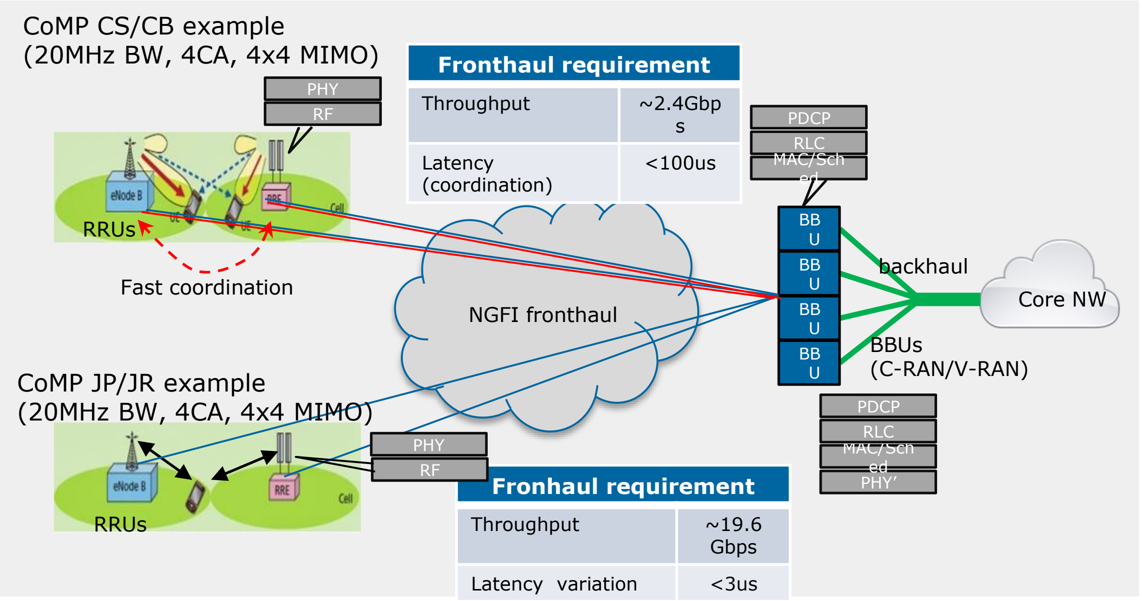
(*) BW will increase with LAA
(**) FCC 16-89

User Case: CoMP

Coordinated Multi Point	
CS/CB	Joint TX/RX (JT/JR)
• Coordinated scheduling • Coordinated beamforming • Fast coordination on TTI level	• Joint inter-site transmission for downlink • Joint inter-site reception for uplink • Improves cell edge performance • Signals from multiple sites need be combined at PHY of receiver for max benefit • eMBMS is using JT

Fronthaul requirement	

• Relax of user-plane requirement if PHY is at cell site
• Low latency signaling links needed for site coordination
• Suitable function splitting options:
  • PHY at cell site to reduce total throughput requirement
  • MAC scheduler at BBU for fast inter-site coordination
	• Low latency & high throughput data link required for signal combing in PHY
	• Suitable Function splitting options:
	  • PHY at BBU or
	  • split PHY



User Case: FD-MIMO

Full Dimension MIMO

- Practical solution of Massive-MIMO to reduce implementation complexity for cell densification
- Active array systems (AAS) to steer beams in both azimuth and elevation directions
- Simultaneous beams to support high order MU-MIMO
- Separated beamforming for CSI reference signals
- Possible RT coordination among AASs to reduce inter-site interference
- Large number of TxRUs at cell site for antenna phase control

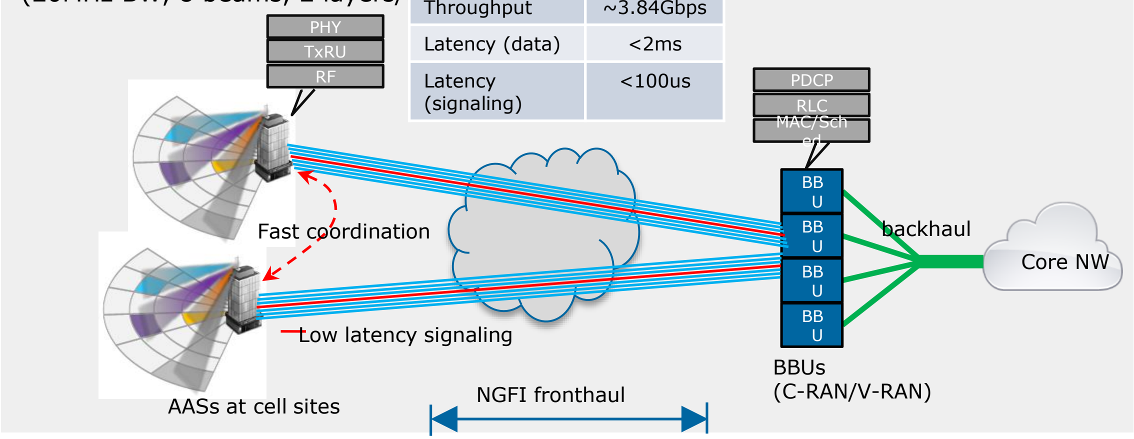
Fronthaul requirement

- Massive connections to each cell site (per each TxRU, up to 64 of them)
- Suitable function splitting options:
  - PHY at cell site to reduce total throughput requirement
  - MAC scheduler at BBU for fast inter-site coordination

FD-MIMO example
(20MHz BW, 8 beams, 2 layers/

Fronthaul requirement

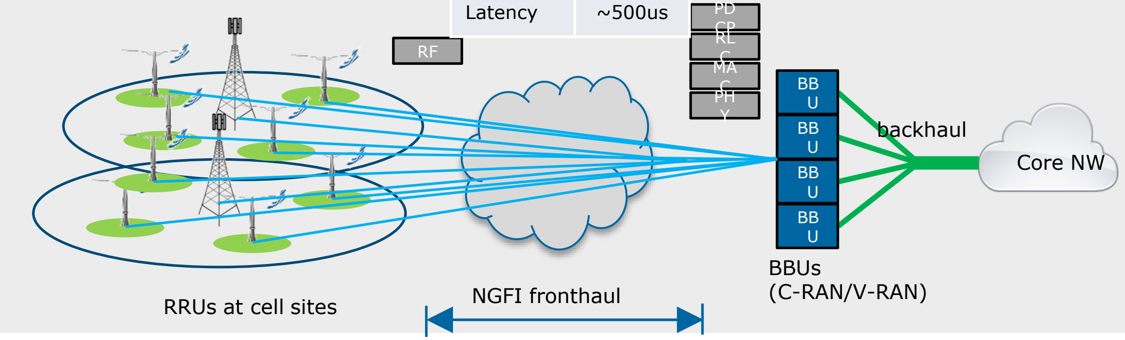
Throughput	~3.84Gbps
Latency (data)	<2ms
Latency (signaling)	<100us



User case: IOT

IOT use case categories
Non-critical apps

- Massive numbers
- Low cost/low power
- Low mobility
- Small data packets
- Infrequent transmission
- Non-time critical



Fronthaul requirement	
Throughput	76.8Mbps
Latency	~500us

Current 3GPP IOT air interface technologies

	R13 Cat-M1	R13 NB-IOT
Max BW	1.4MHz	200kHz
Peak data rate	1Mbps	70kbps
RF Sample frequency	1.92MHz	480kHz
Modulation order	Max: 16QAM	QPSK
Num of UE RX antenna	1	1
Operation mode	Standalone	Standalone Guard-band In-band
Coverage extension	15dB	20dB
Software PHY		Yes

- Low bandwidth
- Low data rate
- Low sample rate
- Low modulation

→ **Low Fronthaul throughput requirement**

→ **More suitable for Fronthaul over Ethernet & all processing functions centralized at BBU**

Requirement on scalability of aggregated small data packets

Fronthaul Impact by current & future RAN technologies

Evolution To 5G

Current RAN technologies		Fronthaul impact	
		Capacity	Latency
CoMP CS/CB/ JT	Real time intra/inter-site coordination	Proportional to user data rate	Fast control/signaling link to ensure multiple site synchronization at sub-frame level
CoMP JR	Real time intra/inter-site Signal combining	Proportional to BW & number of TX antennas. Significant larger than user data rate	Very tight synchronization requirement to ensure signal alignment (< few of μs)
FD-MIMO	Large number of antennas at cell site. High order MU-MIMO	Proportional to user data rate x order of MU-MIMO users.	Fast control/signaling link to ensure site synchronization, if inter-site coordinated
LTE-M /NB-IOT	Large number of devices, small packets	Low capacity requirement. Aggregation & Scalability requirement	Low latency requirement

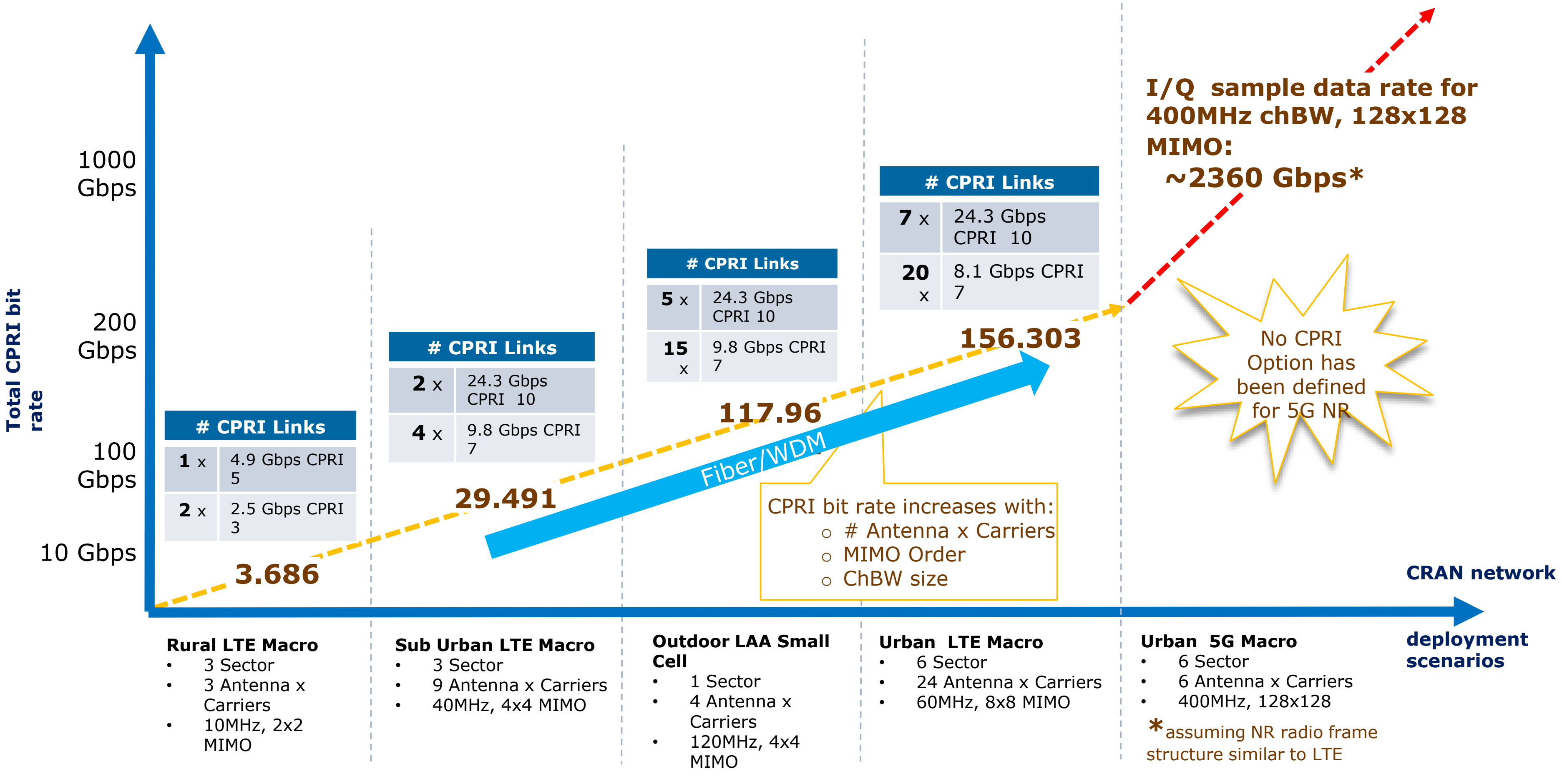
Future RAN technologies		Fronthaul impact	
		Capacity	Latency
Massive MIMO (eMBB)	Massive number of antennas + cross-site BF/MIMO among small cells	Astronomical increase of capacity requirement due to the vast increase of user data rate, i.e. 20xLTE-A and ≥ x10 MIMO order	Tighter end-to-end RAN delay requirement (by a factor of roughly 2.5) will lead to much shorter sub-frame length, CP, and HARQ loop time in PHY design, which in turn will place even more rigorous fronthaul requirement in terms of latency
Massive IOT (mMTC)	Massive number of devices	Low capacity requirement. Aggregation & Scalability requirement	Less challenge for non-critical IOTs (critical IOT use cases should follow URLLC category)
URLLC	Ultra low delay Ultra reliable	Depends on the application, i.e. VR with RT Video dramatically impacts capacity	1ms RTT in 5G NR RAN. Extremely challenging, i.e. ~1/20 of LTE RAN, 1/8 of eMBB 5G NR

Function split option summary

BBU - - - - - RRU	PDCP RLC MAC/Scheduler PHY - - - - - RF	PDCP RLC MAC/Scheduler PHY' - - - - - PHY RF	PDCP RLC MAC/Scheduler - - - - - PHY RF	PDCP RLC - - - - - MAC/Scheduler PHY RF	PDCP - - - - - RLC MAC/Scheduler PHY RF
	Option 1	Option 2	Option 3	Option 4	Option 5
	All processing functions centralized at BBU	PHY split	PHY&MAC split	MAC&RLC split	RLC&PDCP split
Rough estimate of Throughput (T) (bi-direction)	~60*Ntx*BW T1	8*L*MSC*BW T2~=0.8*T1	~2*R T3~=T1/8	~2*R T4<T3	~2*R T5<T4
Latency requirement	micro sec range	micro sec range	mili sec range	mili sec range	mili sec range
CoMP performance	Combining gain & Coronation gain	Combining gain & Coordination gain	Coordination gain	Diversity gain only	Diversity gain only
Data types	I/Q samples	OFDM symbols Control/signaling	MAC PDUs Control/signaling	RLC PDUs Control/signaling	PDCP PDUs Control/signaling
Notes	Current CPRI solution	HARQ combining& FEC centralized or IRC also centralized			
Ntx: number of TX antennas, BW: bandwidth, R: peak data rate, MCS: modulation order, L: number of MIMO layers					
Challenge: If different vendor devices deployed at two sides of the splitting point, are they interoperable?					

C/V-RAN Fronthaul Challenges

Fronthaul CPRI capacity requirements for various network deployment scenarios



Fronthaul Transport and C/V-RAN

Fronthaul Challenges when deploying C/V-RAN

- Today CPRI is the preferred transport protocol to implement the RAN functional split between Radio (I/Q) and Baseband, however
  - CPRI bit rate linearly increases with
    - Channel bandwidth
    - MIMO order
    - Number of sectors
  - Cloud/Virtual RAN deployment over CPRI demands fiber <u>and</u> WDM, however
    - fiber is not everywhere available and costly to deploy
    - CPRI/WDM does not support
      - switching
      - CoS and manageability
    - Strict Latency requirements when CoMP is considered
  - CPRI does not scale well with the continuous increase of Peak User throughput and Cell Site capacity
  - Need a more agile transport mechanism for wide deployment of Cloud RAN, where Operators should be able to choose the access medium (i.e. copper, fiber, mW) and protocol (i.e. GPON, metro Ethernet) based on network economics and technology trends.

Next Generation Fronthaul Transport and C/V-RAN

Next Generation Fronthaul Interface (NGFI)

- Should support:
  - Legacy C-RAN deployment
    - Include CPRI to ensure fronthaul transport continuity for legacy RRUs/BBUs
    - Migration from CPRI/WDM architecture to CPRI/packet/WDM architecture
    - Consider latency requirements for inter-BBU pool co-ordination
    - Further optimize CPRI bit rate → compression
  - Support LTE HW protocol split evolution
    - All possible protocol split architectures, so operators can chose the split architecture based on medium (copper, fiber, MW), distance (BBU-RRU, BBU-BBU) and spectrum efficiency
  - Support New Radio (5G) air interface
    - Massive MIMO and URLCC pose great challenges for Fronthaul capacity and latency
    - All possible functional split options for 5G RAN

→ NGFI should be defined with both current (LTE) and future (5G) RAN technologies in mind

Q&A Discussion