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Precise time. Synchronized.

Synchronization for Wireless Fronthaul and C-RAN

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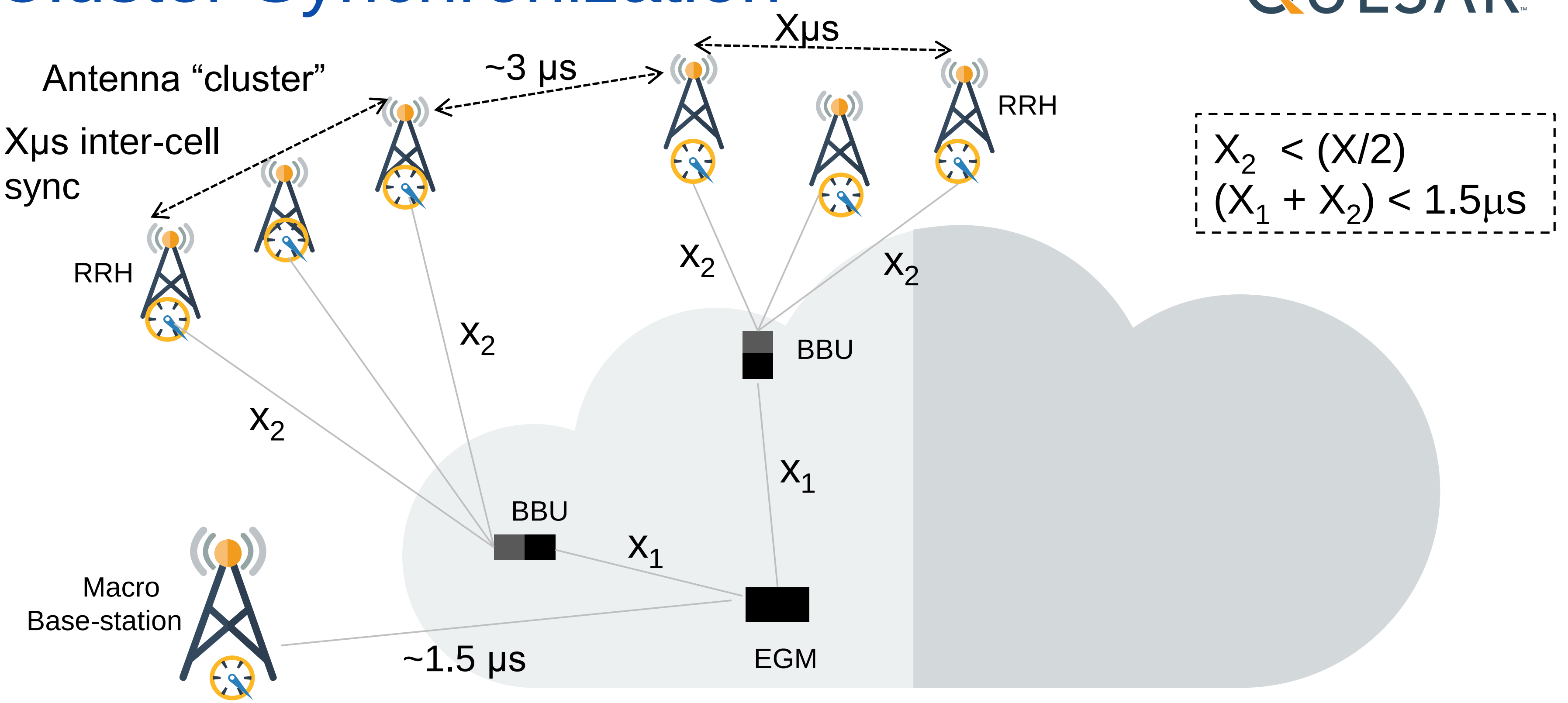
Outline of Presentation

- The underlying premise
- Evolution of a Base-Station
  - Integrated to Distributed
  - Considerations (time/frequency related)
- Evolution to a C-RAN architecture
- C-RAN and Small Cell deployments (synchronization perspective)
- Concluding Remarks

The Premise

- There will be a large number of “wireless points of presence”, namely cellular antennas.
  – Traditionally, each antenna was associated with a complete base-station
  – The DAS (Distributed Antenna System) has a base-band unit with multiple antennas
- These antennas (“base-stations”) will be deployed in clusters with coordinated actions mainly involving antennas of the same cluster.
- The antennas (“RRH”) of a cluster can all home into a common base-band unit (BBU)
- From a timing perspective:
  – The synchronization between antennas of a cluster must be stringent
  – The synchronization between antennas of different clusters can be “relaxed”

Cluster Synchronization



- BBU-RRH "fronthaul" likely to be over Ethernet
- Base-station (BBU or MacroBS) derives timing using PTP (+SyncE) (could be APTSC) from a close-in GM (EGM)
- "X" likely to be less than ~500ns, closer to ~200ns

Timing Requirements

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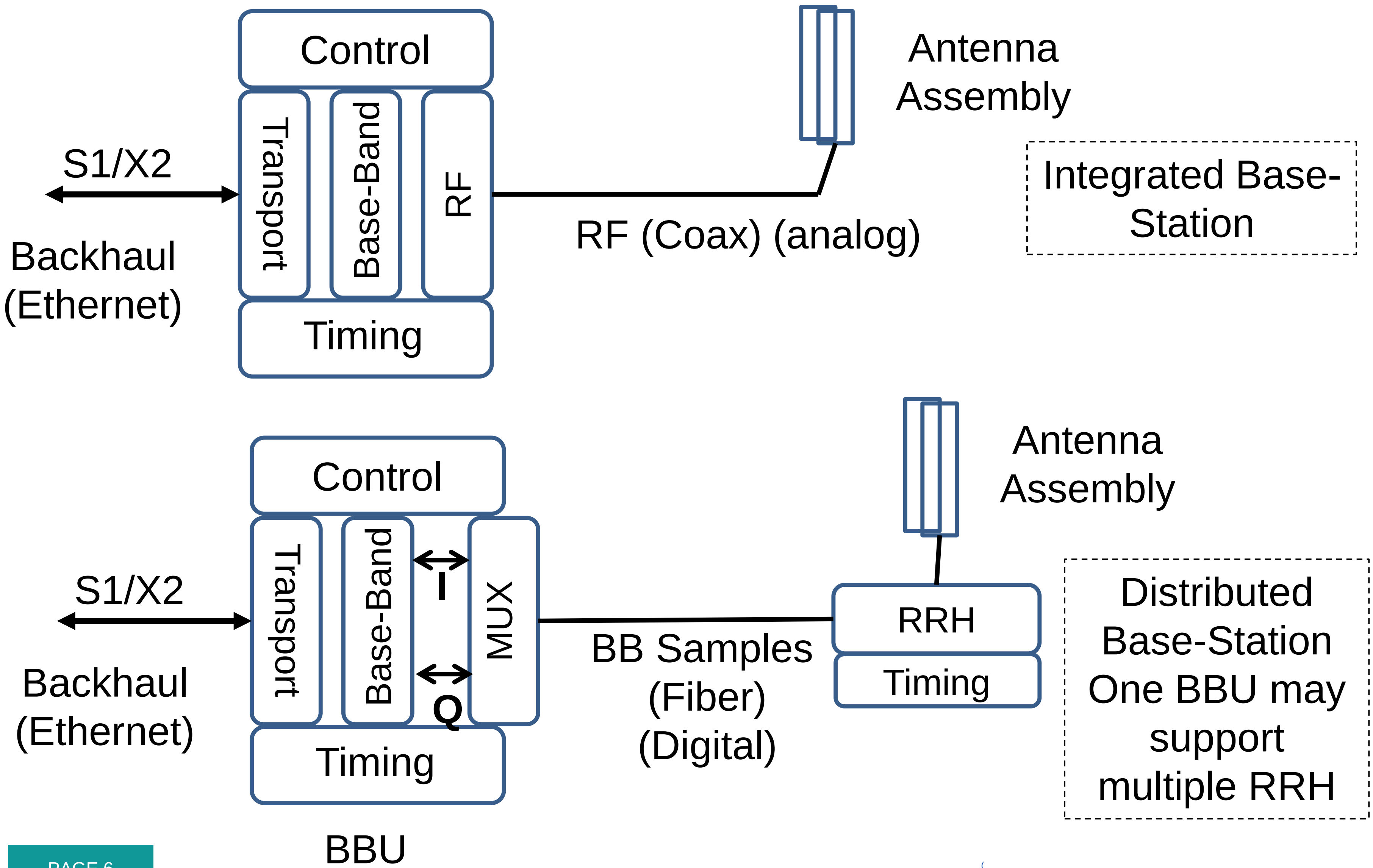
Standard	Frequency	Phase	Remarks
3G UMTS	50 ppb	Not required	
CDMA	50 ppb	10 µs	Different standard
LTE-FDD	50 ppb	None	
LTE-TDD	50 ppb	±5 µs	
+ MBMS		±10 µs	On top of either LTE- TDD / LTE-FDD
+ eICIC		±5 µs	**Tighter sync results in better performance**
+ CoMP		±1.5 – ±0.5 µs	**Tighter sync results results in better performance**

Many diverse opinions

Tighter sync performance results in higher spectral efficiencies ➔ greater traffic carrying capacity

These requirements apply at the antenna (air interface)

Evolution of a Base-Station



Important Considerations — 1

- Integrated Base-Station:
  - RF signal generated in the integrated unit and fed over coax to antenna unit
  - Cable loss, time-delay, and frequency shaping are all a function of cable length (distance between electronics and antenna)
  - Good control of D/A conversion and modulation operation because of “single” clock in device

Important Considerations — 2

- Distributed Base-Station:
  - Base-Band Unit (BBU) generates the baseband version of transmit signal (In-phase and Quadrature signals) in digital format (typically 30.72MHz sampling rate, 15-bits/sample, per signal);
  - RF Signal attenuation and frequency shaping are not a function of cable distance between BBU and Remote Radio Head (RRH)
  - Need to transfer timing information from BBU to RRH
  - Time and frequency effects are still an important issue
    - Cable length introduces delay due to propagation
    - Clock regeneration adds wander/jitter

Important Considerations — 3

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- Base-Band Signal: $\overline{x(nT_s)} = x_I(nT_s) + jx_Q(nT_s)$
- RF Signal:

$$w(t) = \hat{x}_I(t-\delta)\cdot cos\big(\omega_C t + \varphi_I(t)\big) + \hat{x}_Q(t-\delta)\cdot sin\big(\omega_C t + \varphi_Q(t)\big)$$

- Deleterious impact of delay (δ) (uncertainty):
  - In TDD mode this delay uncertainty necessitates greater inter-burst gap and therefore reduces bandwidth utilization
  - Some LTE features have reduced performance with increasing time error including: eICIC, CoMP, MBMS, etc.
- Deleterious impact of jitter and wander (φ): not well documented but known to have negative impact on carrier as well as D/A conversion (affects SNR, BER, etc.)

Evolution to a C-RAN Architecture

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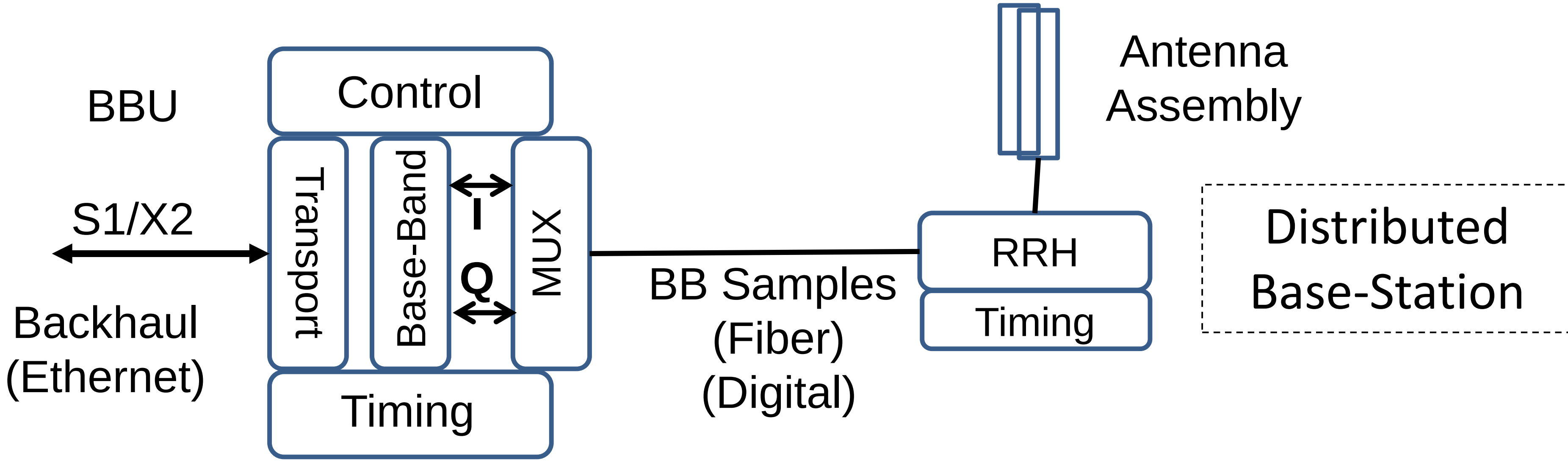
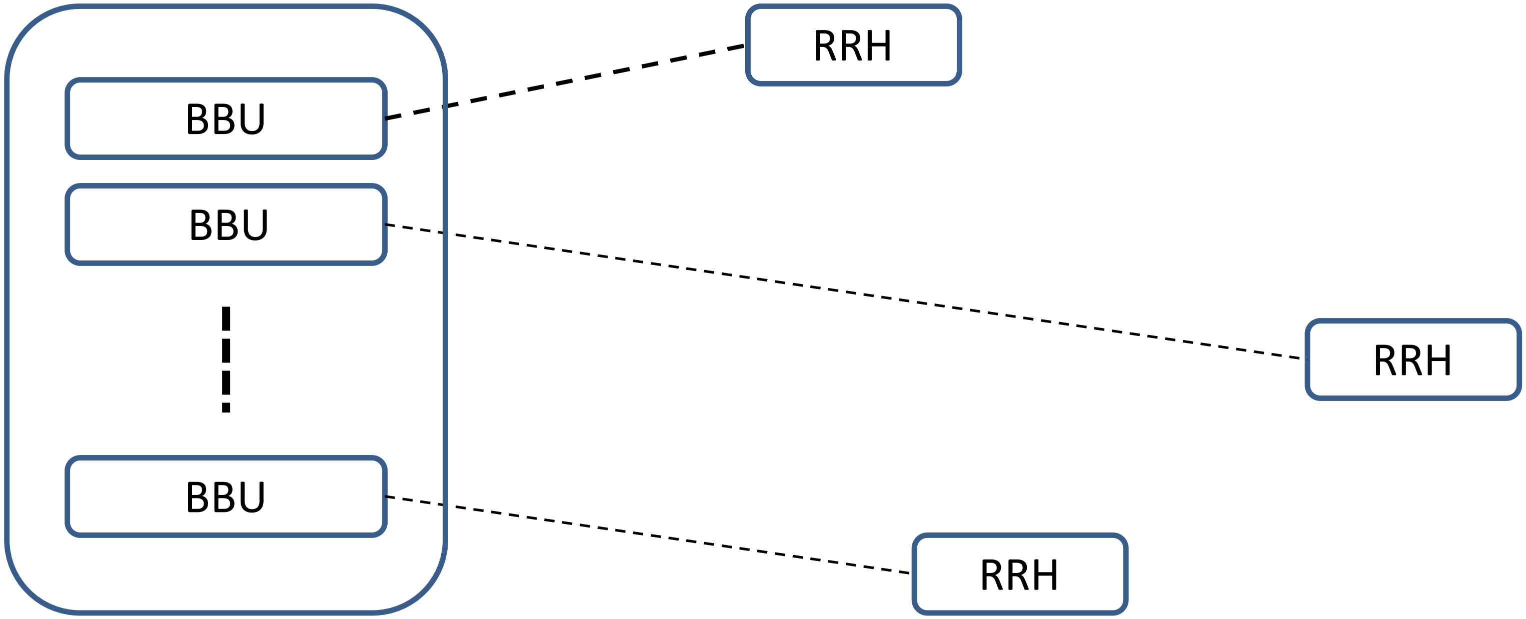


- Antenna system (RRH) can be disjoint from the BBU
- Given that the BBU-to-RRH link is suitably implemented, there is no stringent geographic linkage between BBU and RRH
- It is possible to co-locate multiple BBUs independently of the deployment of the (RF) antenna assembly
- C-RAN: antennas (RRH) located where the mobiles are; BBUs are located where building space (power, ground, air-conditioning, etc.) is available

Provided that the timing constraints (time/frequency) are satisfied

C-RAN Architecture



- Base-Band units (BBUs) are co-located and each BBU has a link to an RRH carrying the base-band signal samples
- RRH units are deployed according to cellular traffic needs
- BBU and RRH have to be (mutually) synchronized
- Functional split between BBU and RRH is a design choice
  - Latency and sync requirements depend on the functional split

C-RAN Synchronization

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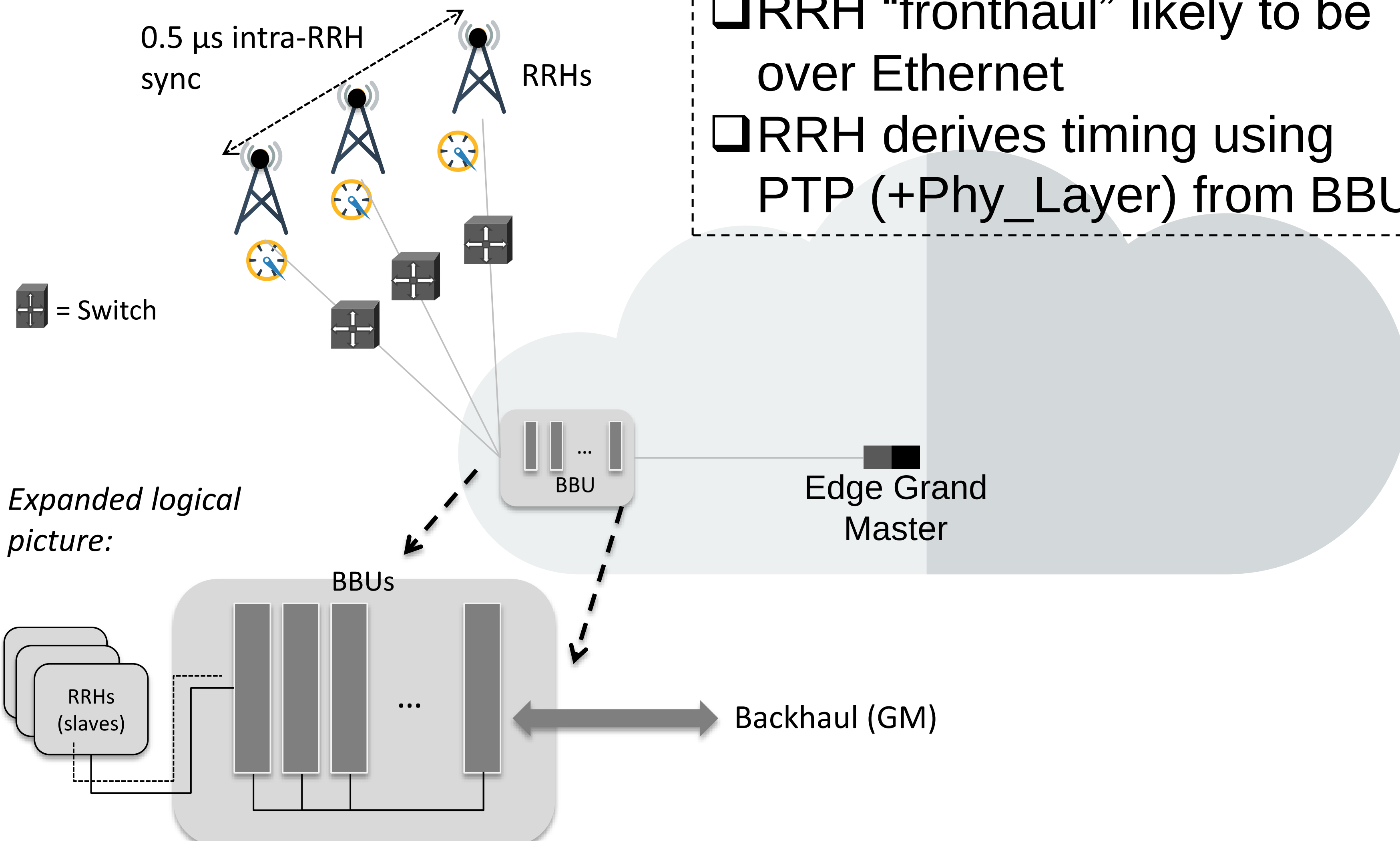
- RRH "fronthaul" likely to be over Ethernet
- RRH derives timing using PTP (+Phy_Layer) from BBU

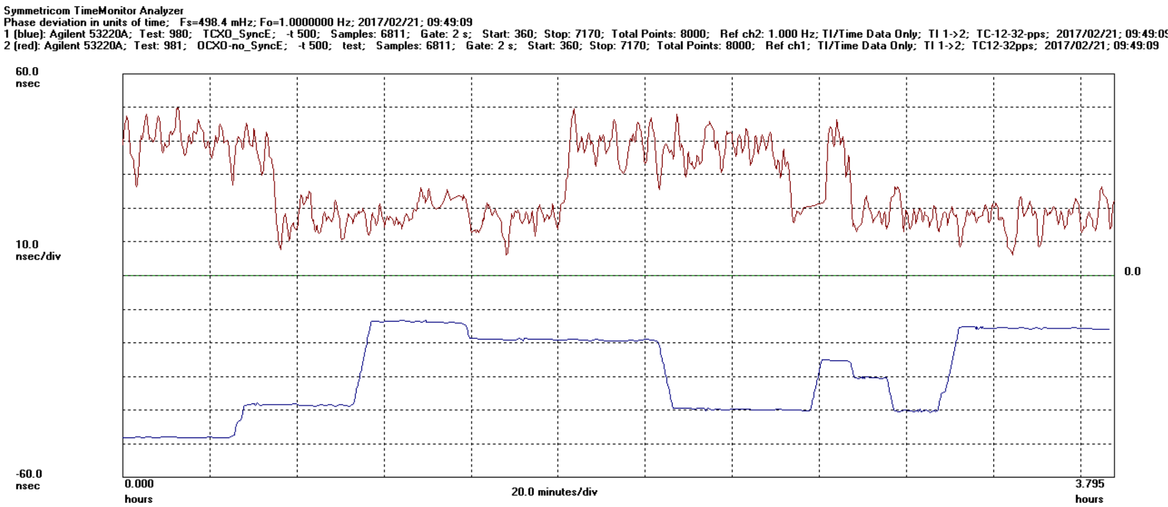


C-RAN (Small Cell) Synchronization

- Similar issues for synchronization in Small Cell and C-RAN deployment scenarios
- Boundary clocks in every BBU; Limited number of hops between master-slave
- Hold-over oscillators deployed in BBU / Edge Grand Master
  - End-points need to be inexpensive
- Synchronization requirement is stringent between RRHs in cluster; “regular” LTE requirements between clusters
- Recommend BBU to RRH link switches support at least Phy_layer sync & T-BC/T-TC if practical

Supporting Test Results

Time Error



- Network between BBU and RRH emulated as 10-switch network (based on G.8261) with TC12 traffic loading (80%)
- Case 1 (blue) : using a TCXO with physical layer assist (SyncE)
- Case 2 (red) : using an OCXO without physical layer assist
- Both cases: 32 packets/sec (*sync* and *delay_request*)
- Asymmetry “added” to offset graphs

Supporting Test Results

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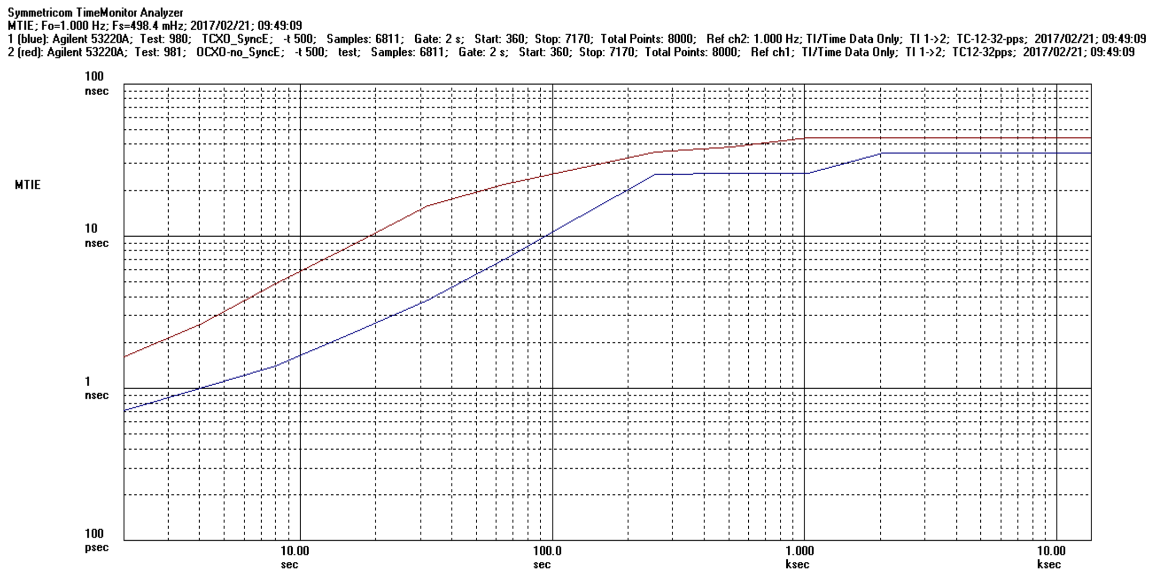
MTIE



- Network between BBU and RRH emulated as 10-switch network (based on G.8261) with TC12 traffic loading (80%)
- Case 1 (blue) : using a TCXO with physical layer assist (SyncE)
  - Peak-to-Peak time error (limiting MTIE): ~35ns
- Case 2 (red) : using an OCXO without physical layer assist
  - Peak-to-Peak time error (limiting MTIE): ~45ns

Concluding Remarks

- C-RAN architecture is a logical extension of a distributed base-station
- In a C-RAN situation there is likely to be a switched Ethernet *Fronthaul* network
- Timing distribution architectures for C-RAN must support tight (of the order of 100ns or less) between BBU and RRH
- These tight synchronization requirements can be achieved (cost-effectively) by ensuring the Fronthaul supports physical layer timing; Full-on-path support is helpful.

Questions?

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Back-up Slides

Use case architectures: BBU – RRH split

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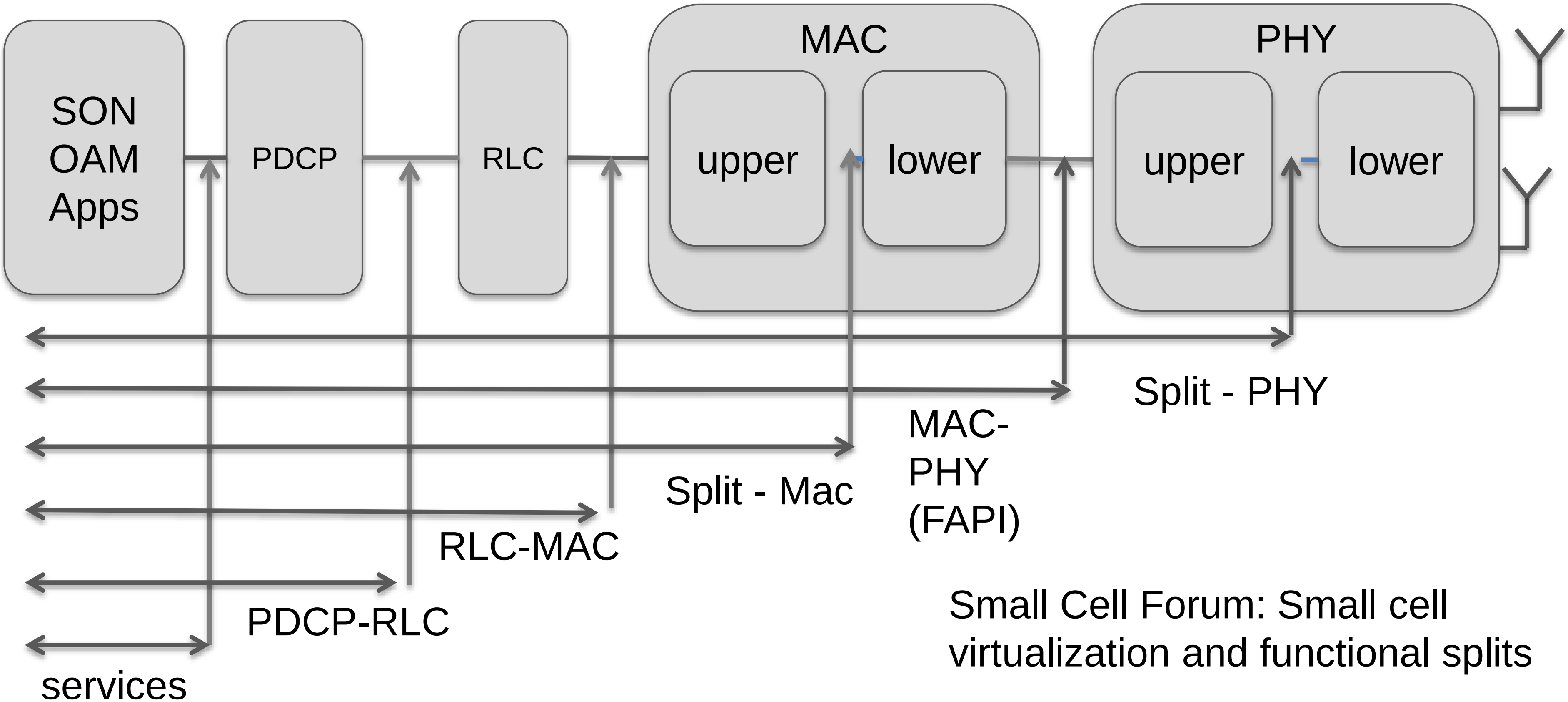

Small Cell Forum: Small cell virtualization and functional splits

Virtualized services on the BBU

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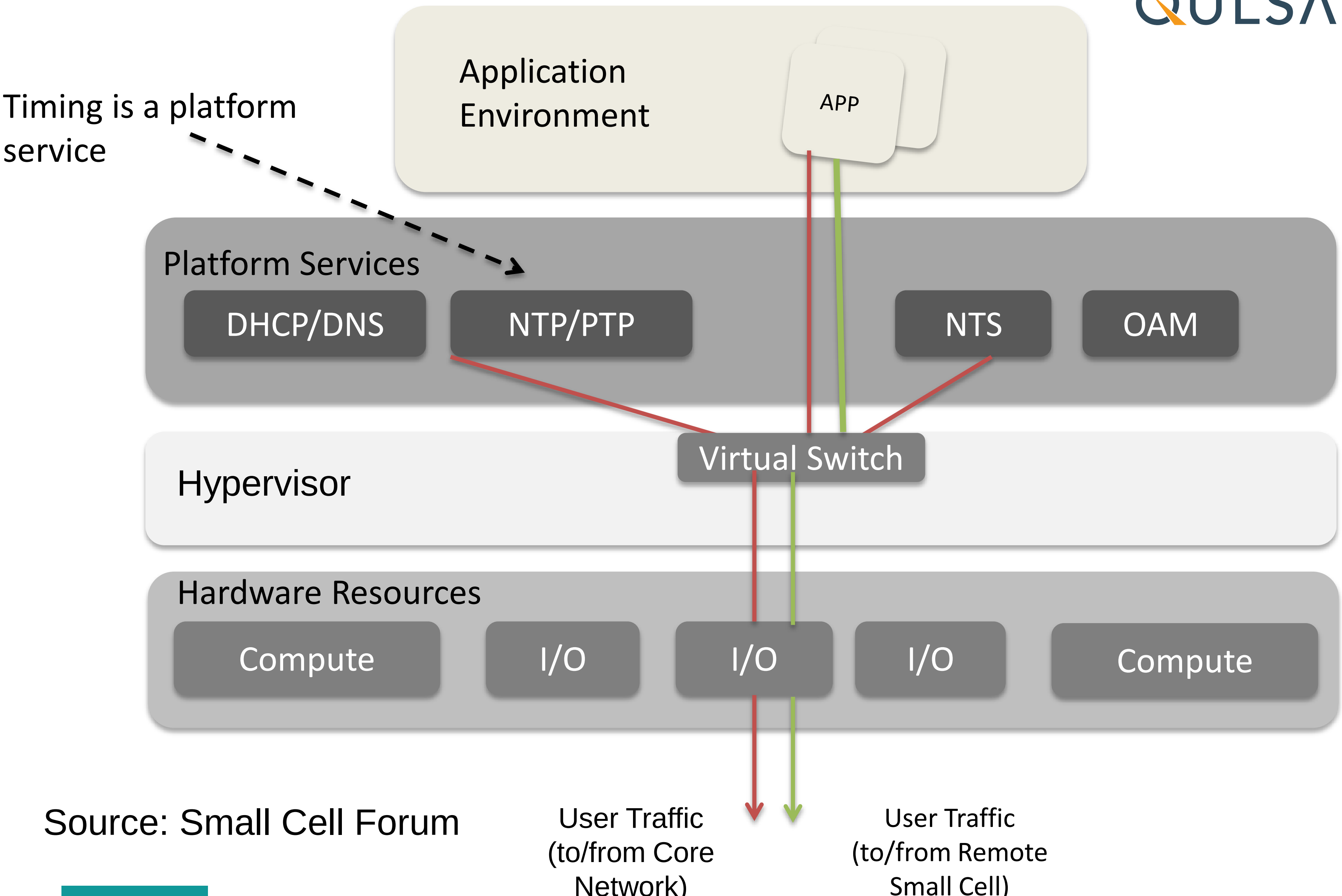

Source: Small Cell Forum

C-RAN survey results

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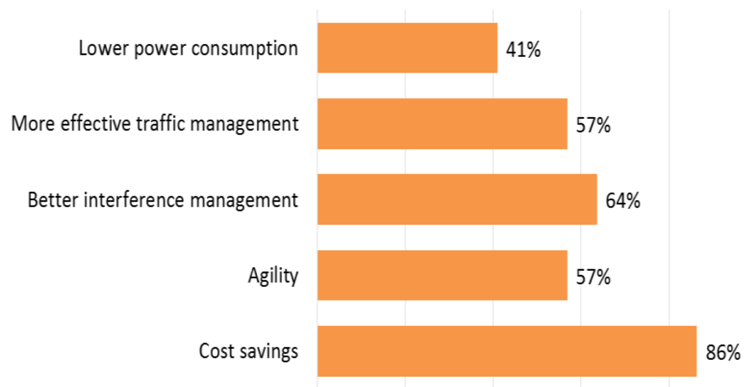
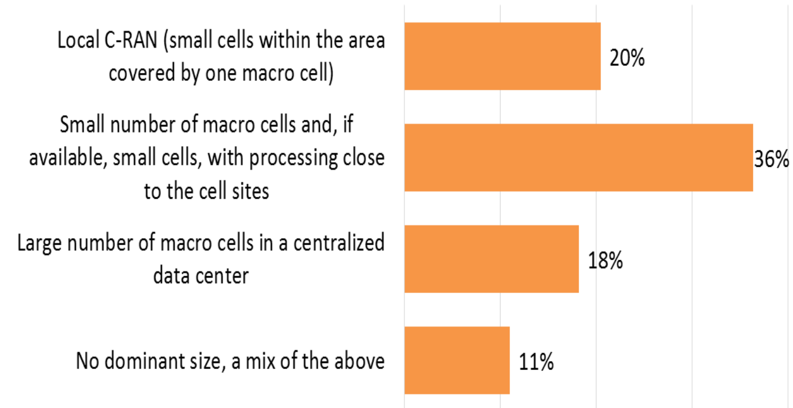
What motivates mobile operators to adopt C-RAN?



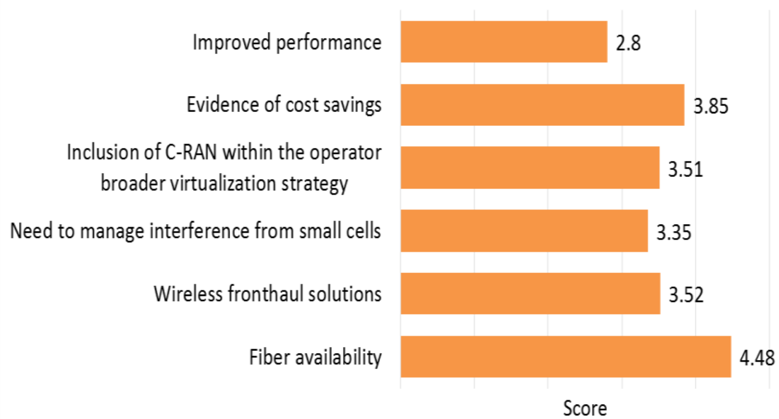
Cost savings are major motivation for C-RAN adoption
But yet difficult to assess cost savings in the long term

What type of size of C-RAN do you think will dominate?



C-RAN and small cells strengthen each other value proposition

What may slow down or accelerate C-RAN deployments?



Fiber availability is still perceived as the major obstacle to C-RAN adoption

Courtesy: CRAN Webinar Sept 9'2015
Senza Fili Consulting LLC 2015