Synchronizing the RAN in 5G Wireless Networks

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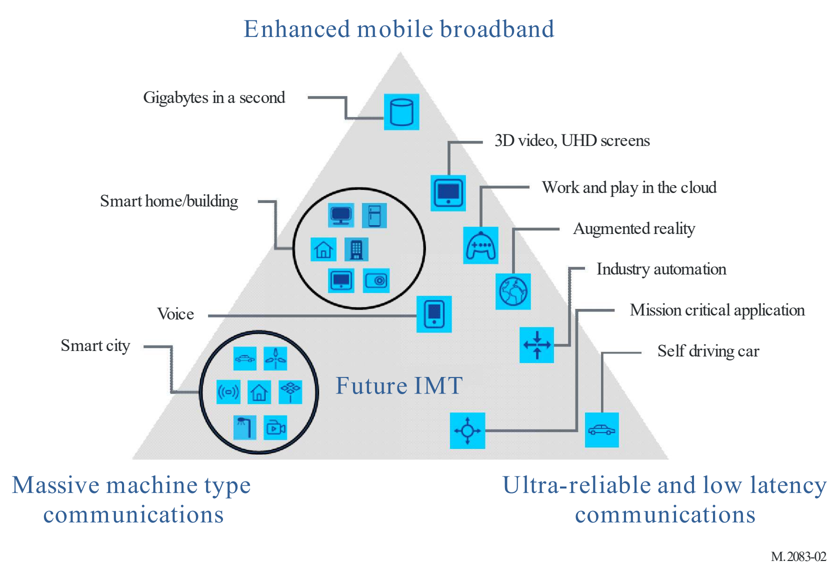
Objective and outline

- Objective:
  - To provide an overview of issues that need to be considered when synchronizing 5G RANs
- Outline:
  - 5G: applications and how achieved
  - Air interfaces for 5G
  - The evolving RAN architecture components
  - Functional splits
  - Slicing and virtualization

5G Capability summary

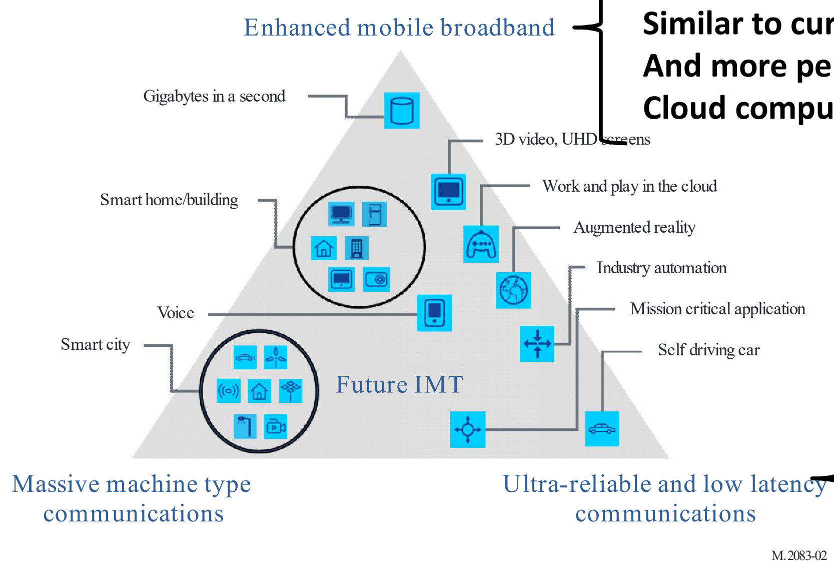


Source: ITU-R Rec.M.2083; Usage scenarios of IMT for 2020 and beyond

5G represents evolution of both services and infrastructure

5G Capability summary

SmartPhones, tablets
Similar to current LTE-A but faster
And more pervasive (video everywhere)
Cloud computing



IoT, low power,
Large numbers
Of devices

Autonomous driving,
Very low latency, reliable
Car-to-car and car-to-
Network communication
Sensor sharing

Source: ITU-R Rec.M.2083; Usage scenarios of IMT for 2020 and beyond

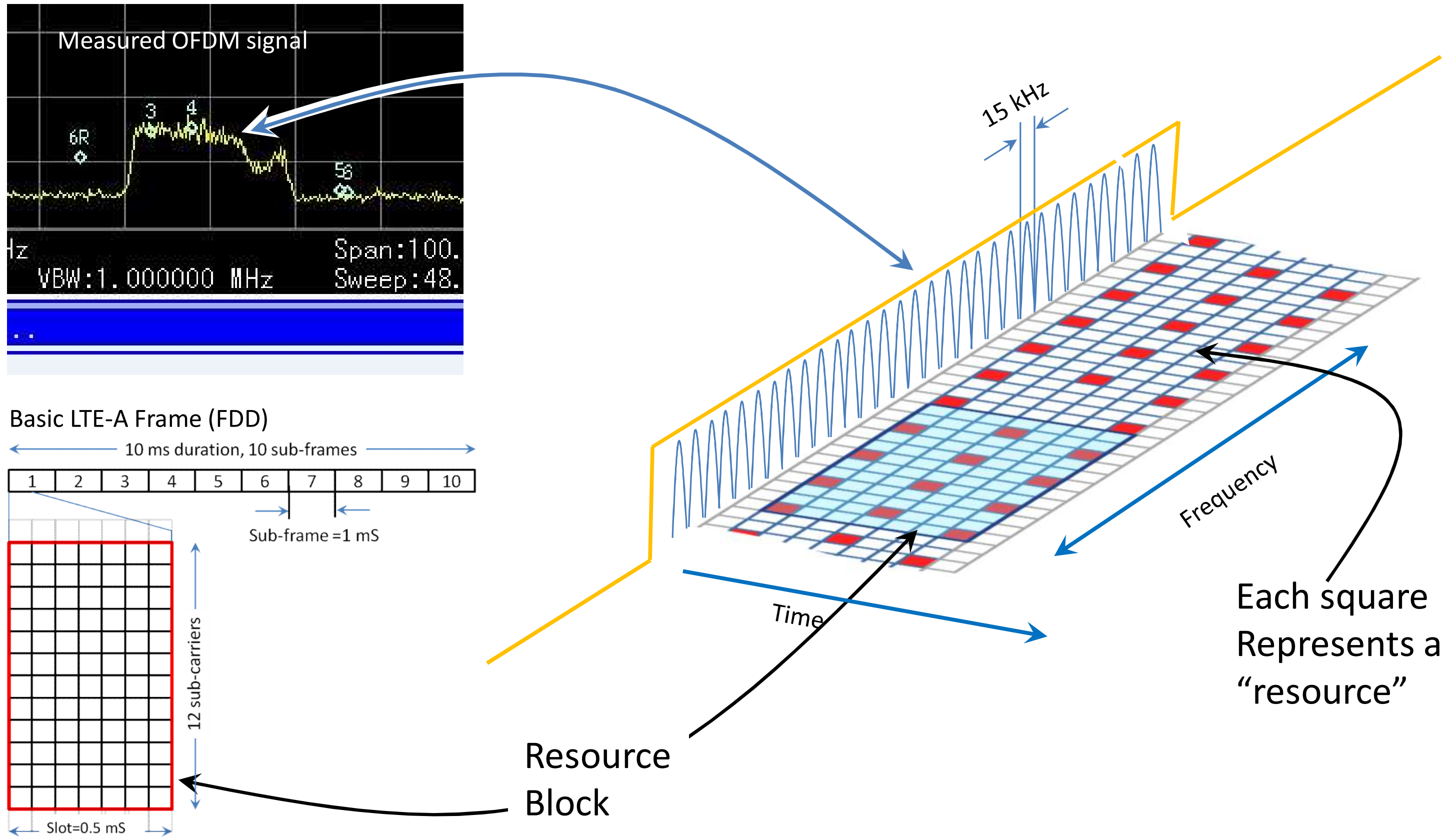
One-size-fits-all approach may be an overkill.
But what about timing?

Speaking notes for the following slide. Included for handout.

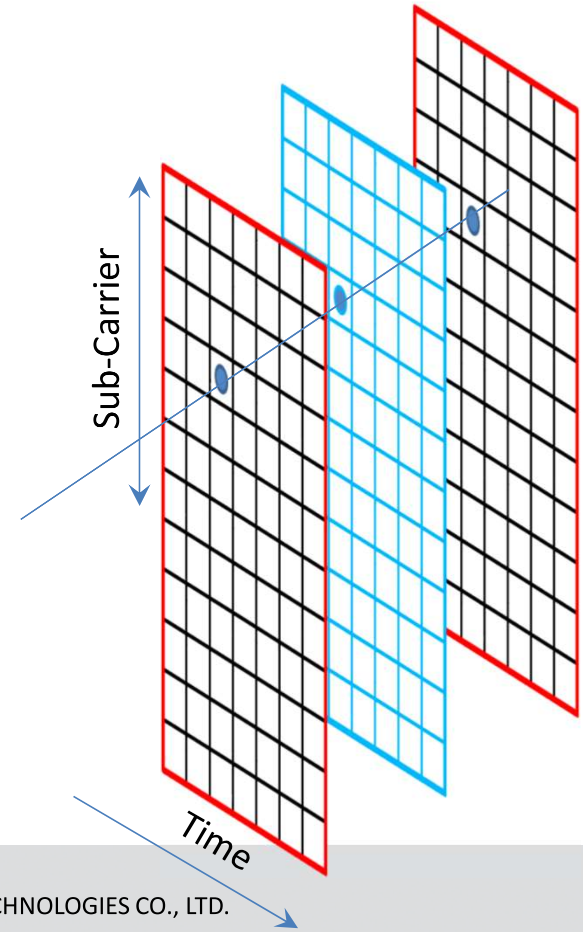
The 5G air interface

- LTE-A uses variants of Orthogonal Frequency Division Multiplexing (OFDM):
  - Downlink: Multiple access OFDMA
  - Uplink: Single Carrier FDMA
- Attraction for wireless:
  - Low symbol rate (1/15kHz) is less susceptible to ISI
  - SC-FDMA optimizes cost for UE at expense of complexity at the base-station
  - Use with QAM results in high spectral efficiency
- Synchronization?
  - A single base-station/UE pair will operate with a very poor oscillator.
  - But, advanced network features (CoMP, MiMo, eICIC, HetNets) need accurate timing to enable high performance networks
- 5G will likely use a variant of OFDM
  - Some changes to the Air PHY may be needed to enhance latency
  - So far, synchronization requirements based on LTE-A will suffice

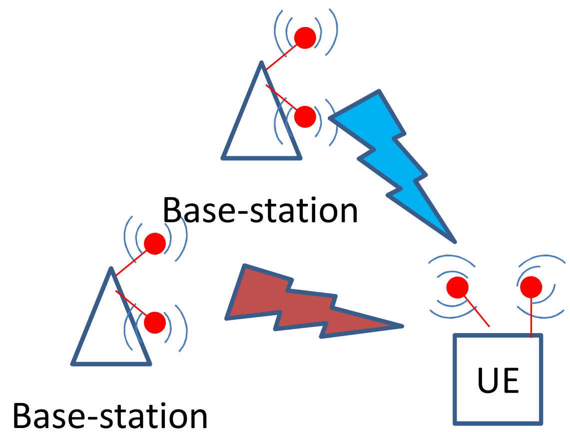
Review: OFDM signal



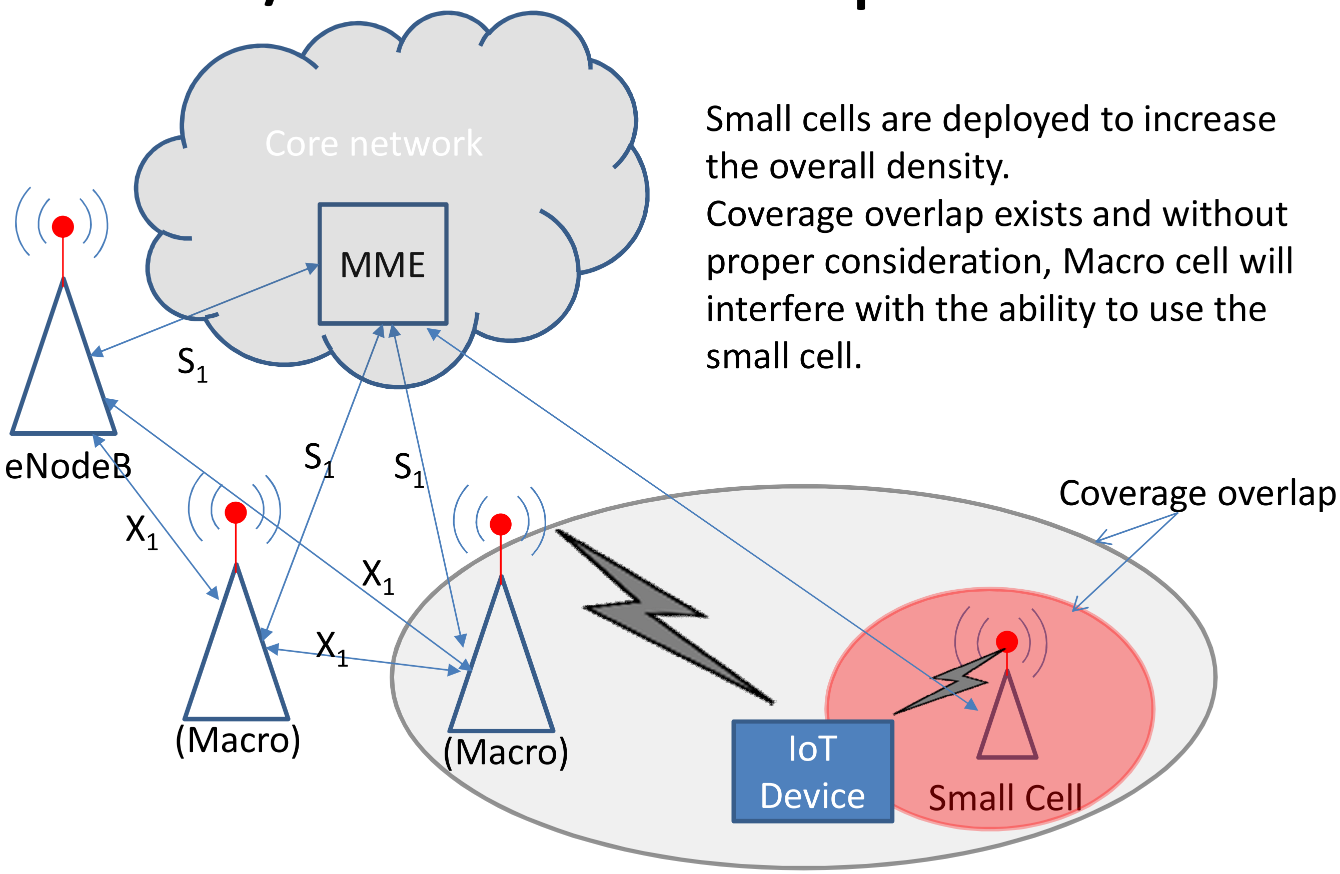
Coordinated Multipoint (CoMP)



- Coordinated Multi-point (CoMP
- Where multiple antennas share the same system clock, usually not an issue.
- For CoMP to be effective, signals need to be aligned
- Time/phase synchronization necessary



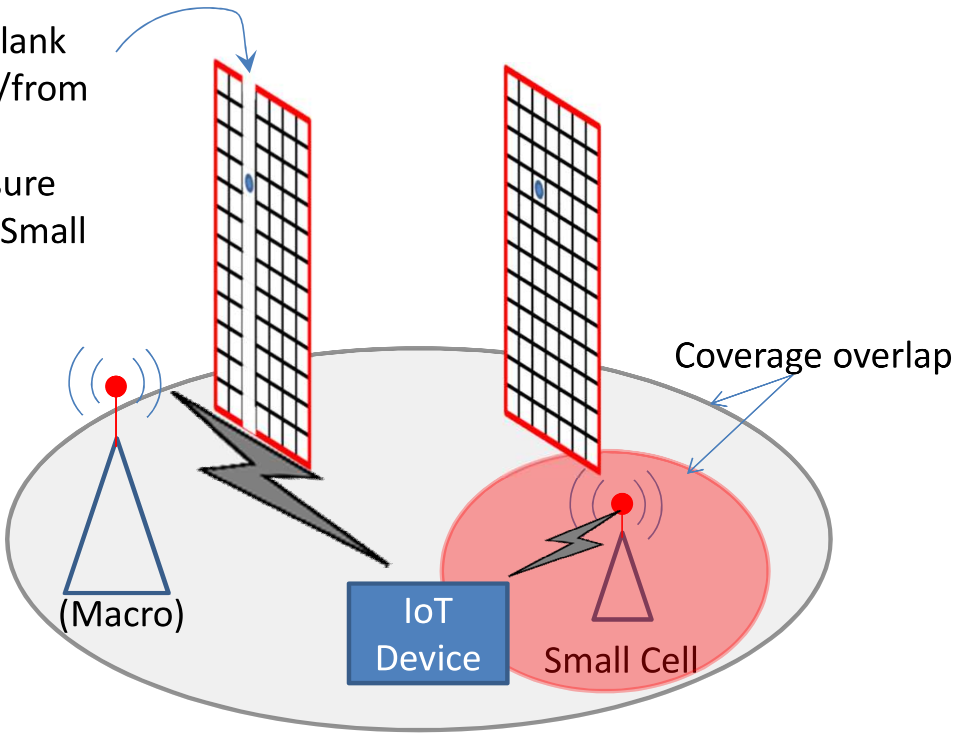
HetNets/Small Cells required for IoT



Small cells are deployed to increase the overall density.
Coverage overlap exists and without proper consideration, Macro cell will interfere with the ability to use the small cell.

Enhanced Inter-Cell Interference Coordination (eICIC)

eICIC: Enhanced Inter-cell Interference Coordination
-Macro cell transmits "Almost Blank Sub-frames" so transmission to/from small cell possible
-Synchronization needed to ensure alignment between Macro and Small Cell.



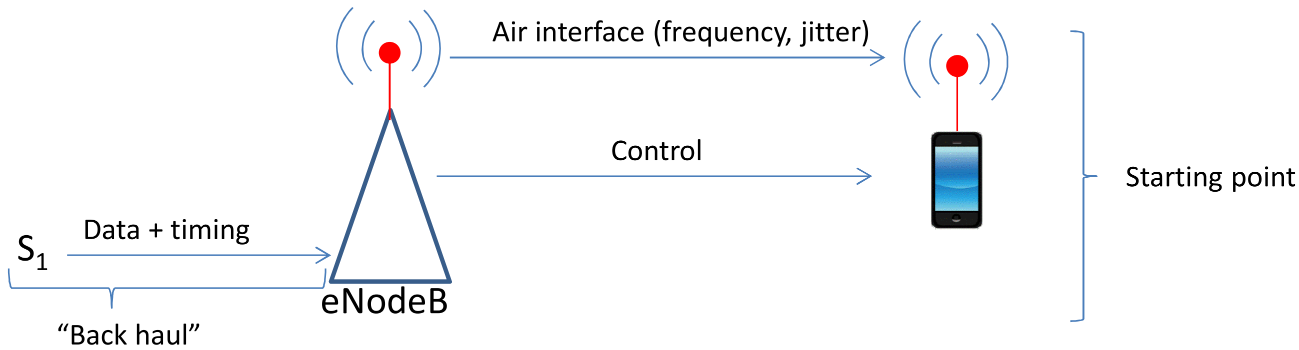
Synchronizing the RAN in 5G

NEW ARCHITECTURE CONSTRUCTS: CRAN, NETWORK SLICING AND THE START OF RAN VIRTUALIZATION

New architectural components

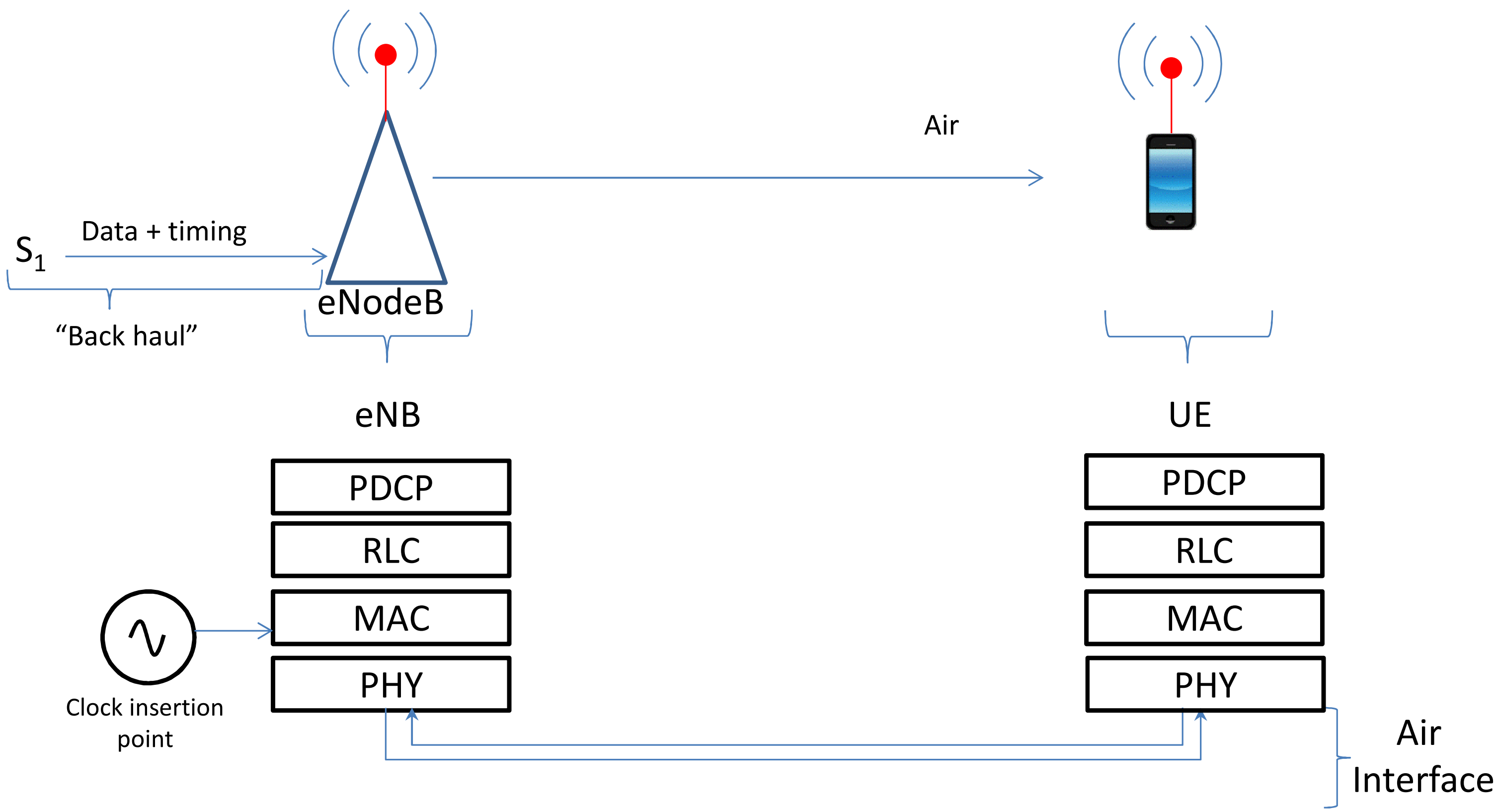
- New architectural components are key to 5G
- Architecture:
  - Front haul networks
  - C-RAN (cloud-RAN, Centralized-RAN)
    - Localizes the functions to allow sharing of resources
    - Functional split and virtualization
  - Network slicing
    - Controlling how the end-to-end network is shared between different user (groups) to achieve different network objectives
    - Involves aspects of virtualization and orchestration

Front haul: The evolving base-station model

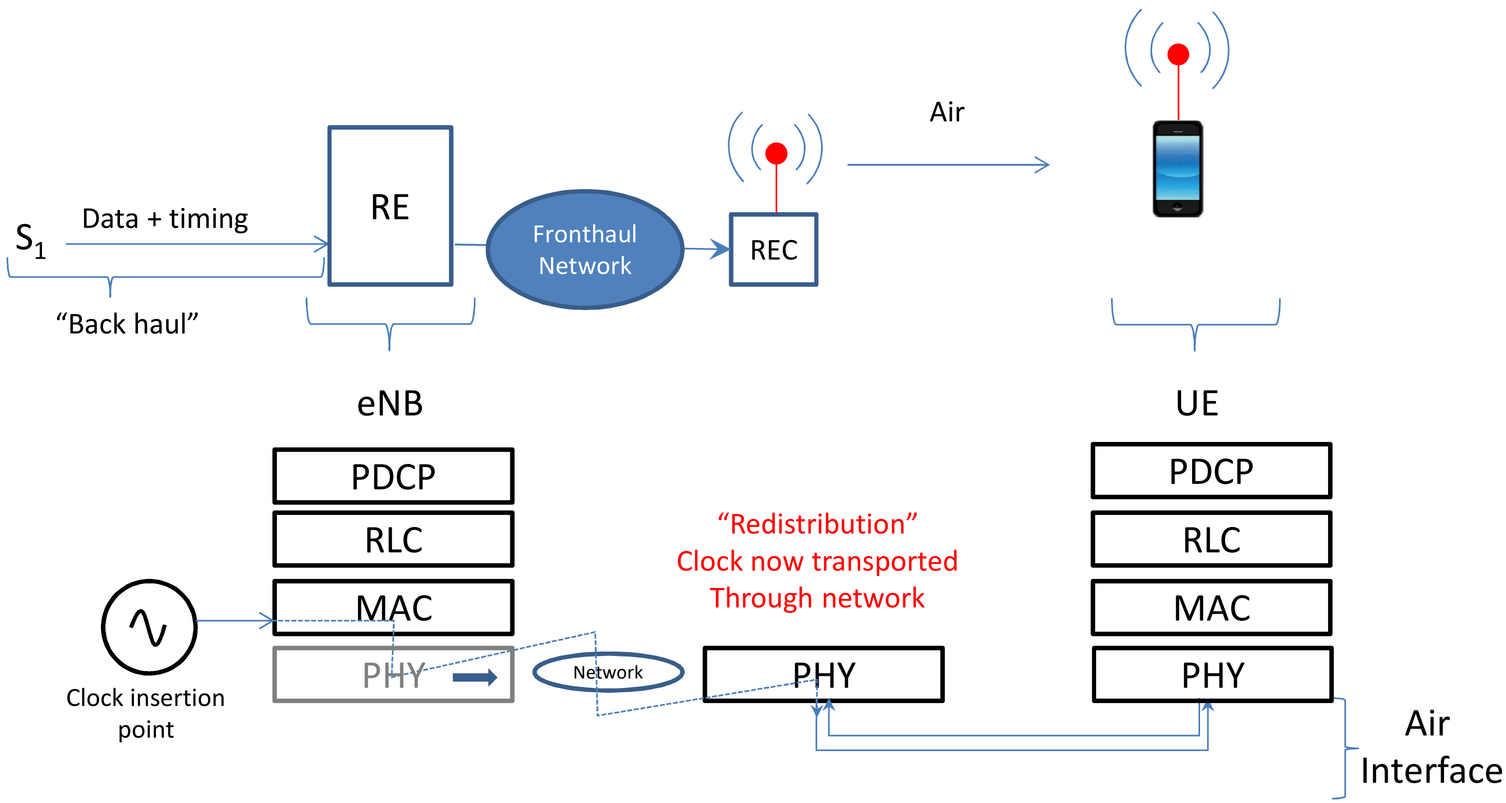


- 4G base-stations (eNodeB) are considerably complex in terms of functions
  - Implement multiple functions necessary to manage mobility and air interface
  - Timing generally from the backhaul. Any timing issues may be partly controlled by design.
- Separation of functions allows cost savings
  - First step: replace coax with fiber, allows distance between antenna and "base band" processing
  - Reduced costs, eg. no base-station hut
  - Centralization of functions and resource sharing is the next logical step (on the path to CRAN)

Visualizing the split relative to LTE-A protocol stack

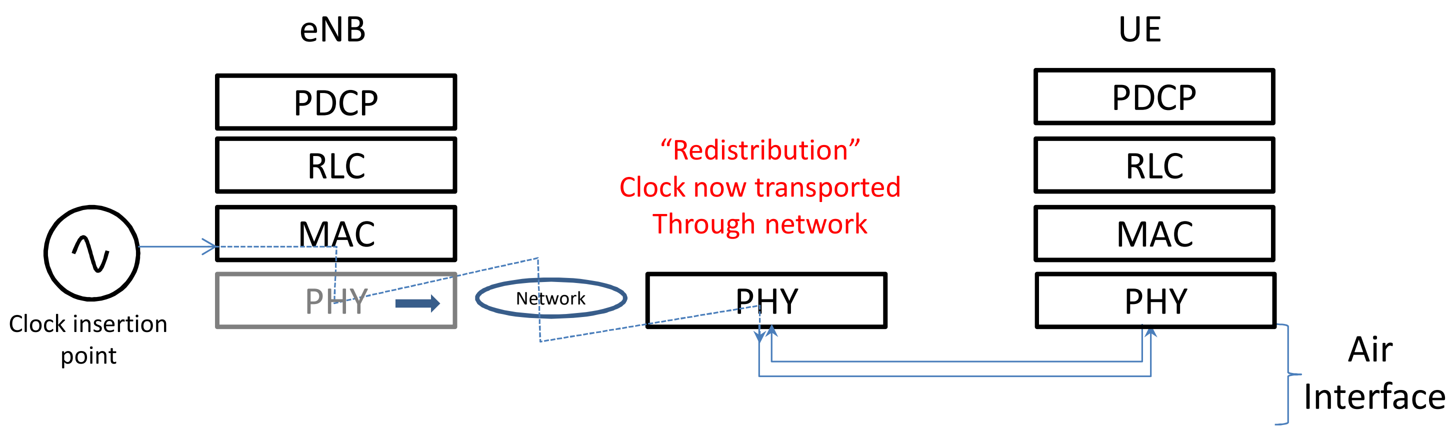


Visualizing the split relative to LTE-A protocol stack

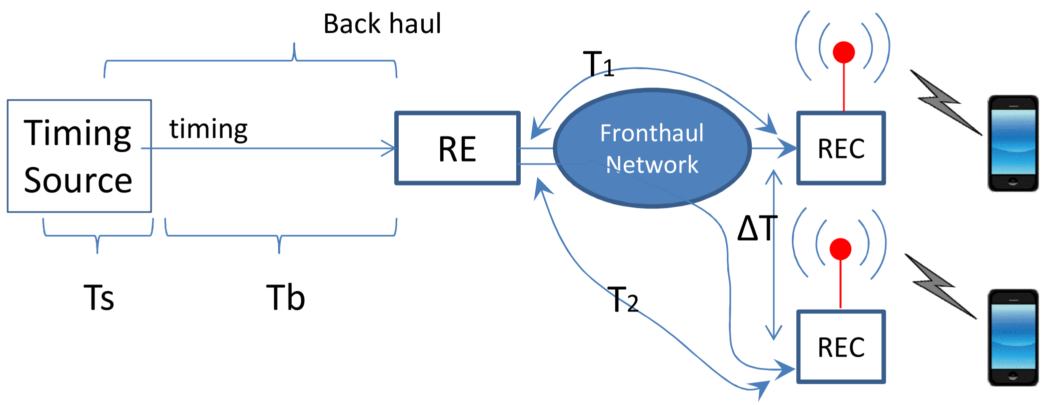


Visualizing the split relative to LTE-A protocol stack

- Simply adding a network is not simple.
  - Some PHY level functions (e.g. HARQ) are actually implemented in the MAC layer.
  - May have unintended consequences

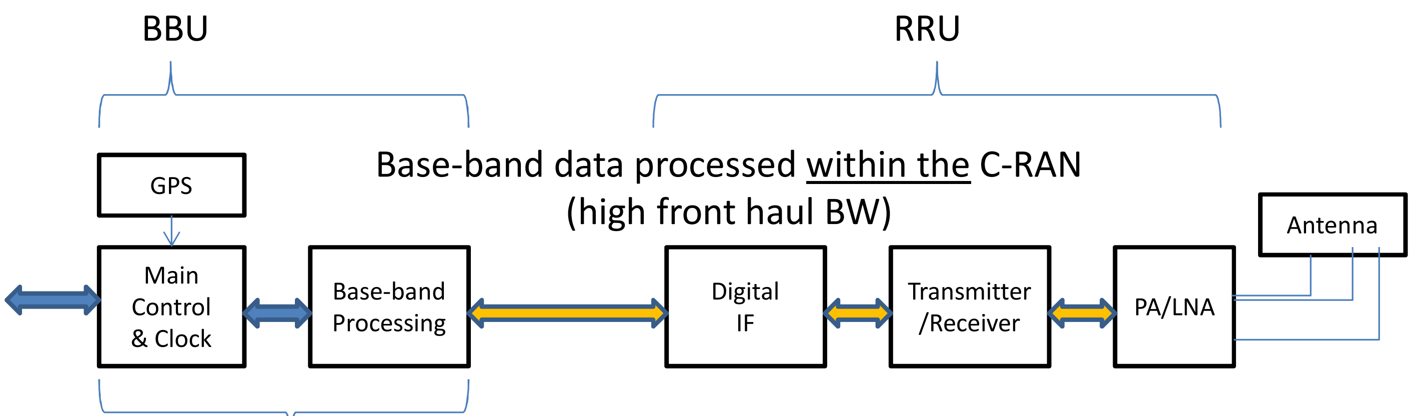


Base-station evolution



- Adding a front haul network has benefits, but base station architecture is not standardized
  - What is the front haul?
  - Where should the functions be split?
  - What synchronization issues exist?

Front haul split:
Fully centralized C-RAN



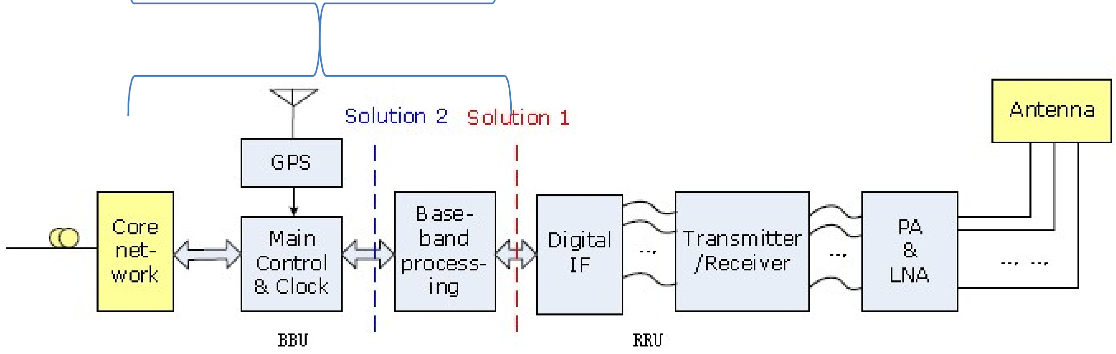


Fig. 3-1 Different Separation Method of BTS Functions

Front haul split: Distributed C-RAN

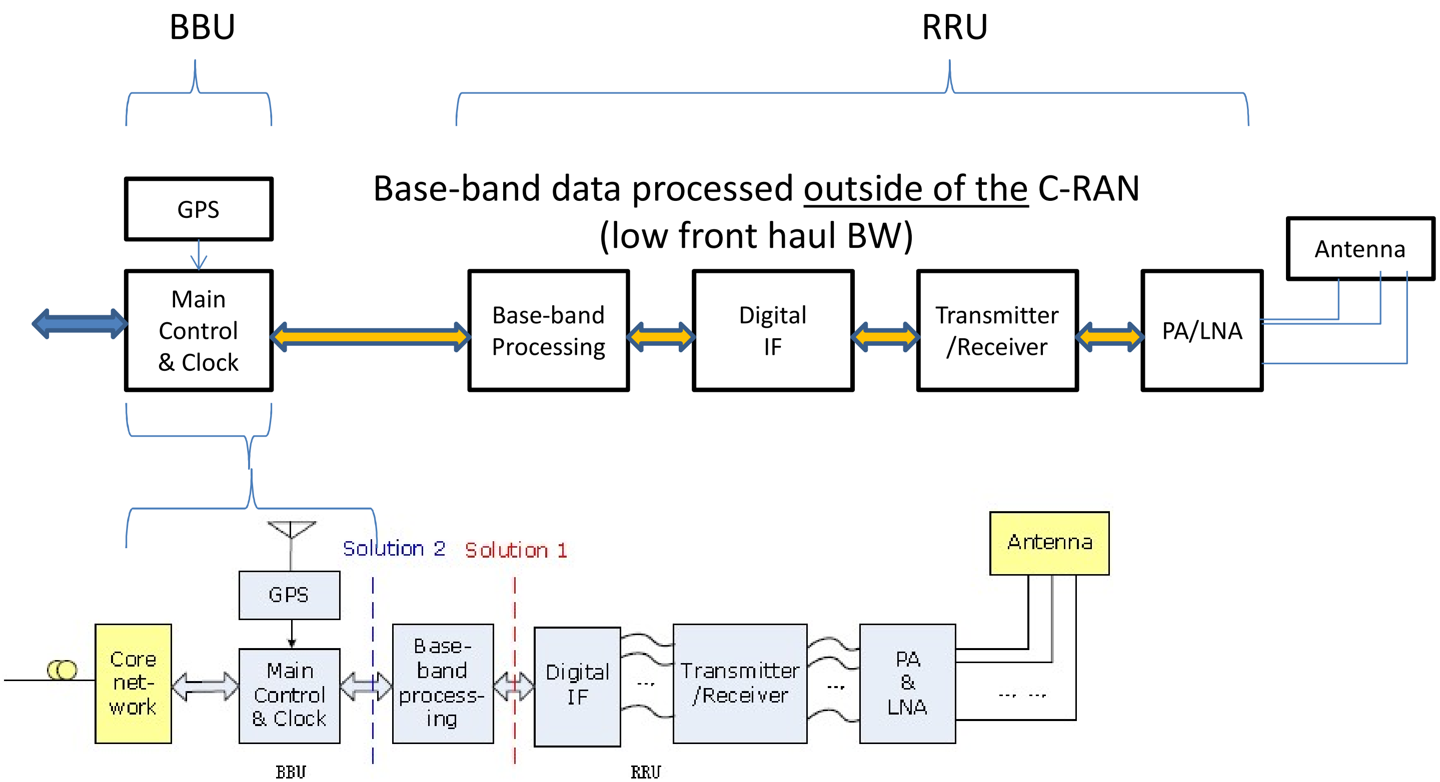
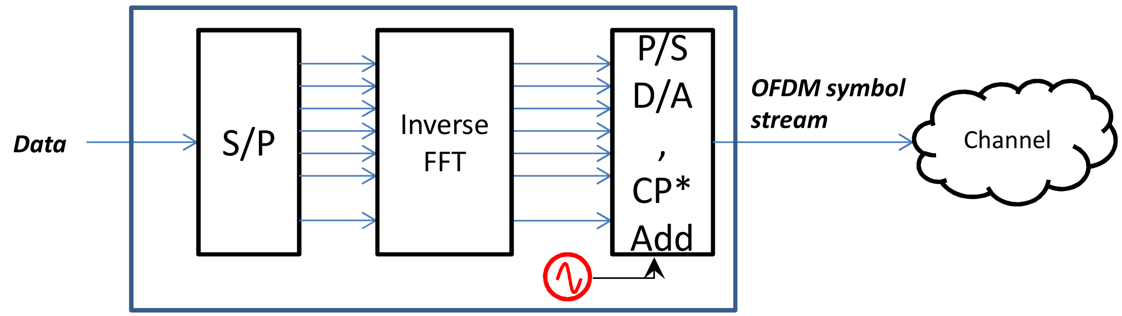


Fig. 3-1 Different Separation Method of BTS Functions

Effect of different splits



Centralized

- IFFT located at REC
- I/Q over front haul mapped synchronously via CPRI
- Line timed RE

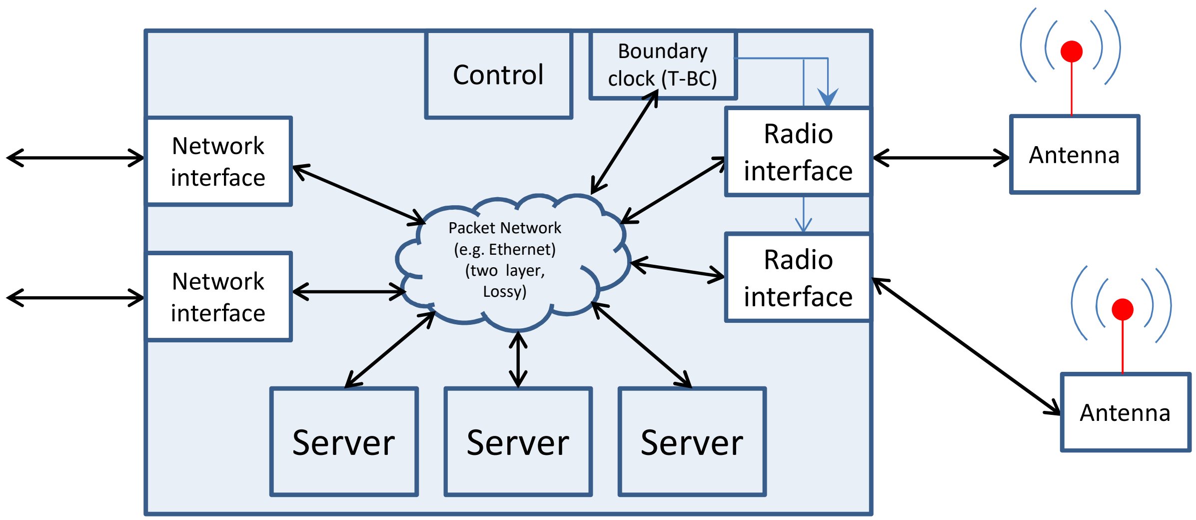
Distributed

- IFFT at RE
- Lower data capacity
- Timing potentially more complex
- Standardization of eCPRI underway to address some issues

Front haul technology

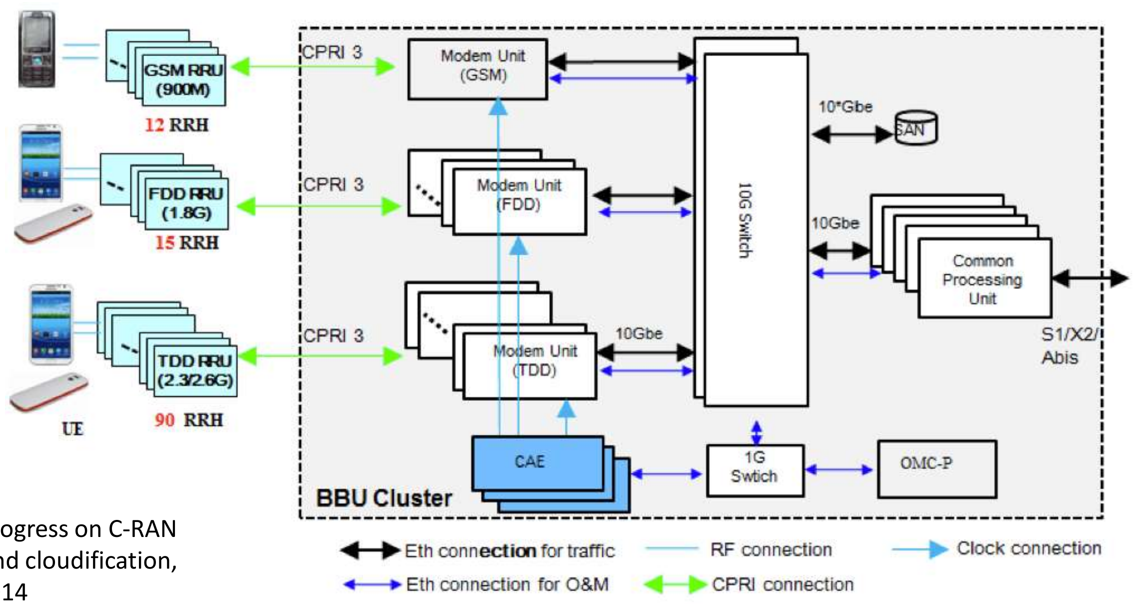
- Front haul is the interface between the REC and the RE
- Technologies:
  - CPRI
  - eCPRI (under development)
  - CPRI/OTN
  - Microwave
  - Switched Ethernet (e.g. IEEE 802.1CM, P1904.3)
  - mmWave (Small cell sync)

C-RAN



- C-RAN:
  - Localize functions associated with radio base Station control with the goal of achieving statistical gains.
  - Data centre model
  - Allows tighter control of latency and synchronization in the case of distributed MIMO, or CA, where normally separate base-stations would have been deployed
  - Above example shows timing distribution via boundary clocks, but other possibilities exist.
  - Synchronization impact: consistent with existing HRM for time/phase/frequency (Sync provided to radio interface, not necessarily via line interface)

Specific C-RAN example (supporting three slices)



From: Recent progress on C-RAN centralization and cloudification, Chih-lin et al, 2014

Network slicing

- 5G networks will aggregate multiple services on possibly separate radio access technologies
  - Spectrum may be shared and needs control and coordination
  - Network slice represents the portion of all network resources that may be allocated to a service or user.
  - Allows the network to be optimized to meet the requirements of a service group.
  - Provides isolation and separation over a “one-size-fits-all network. For example:
    - Self-driving car slice: not impacted by someone watching YouTube on a smartphone!
  - Allows tailoring
    - IoT, M2M: massive numbers of devices with moderate bandwidth requirements, scheduled downloads, non-mobile, mmwave etc.

Synchronization impact: Carriers may need to consider the most stringent requirements

Slices have different characteristics

-High bandwidth (CA, MIMO required),
-High mobility and roaming
-may be tolerant to latency

-Moderate/High bandwidth (CA, MIMO required),
-High mobility and roaming
-Low latency required
-device/device (e.g. car-to-car) communication may be required.

-Low/medium bandwidth
-Fixed without roaming
-may be tolerant to latency
-may use with unlicensed spectrum, or mmwave

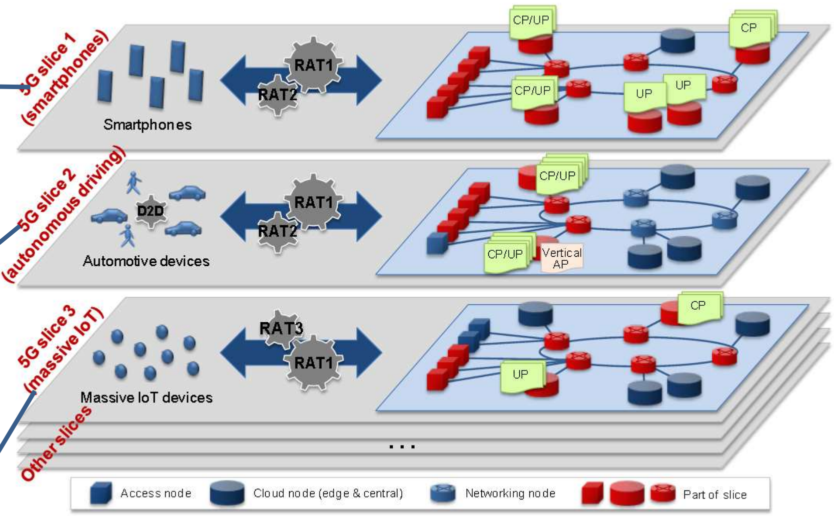
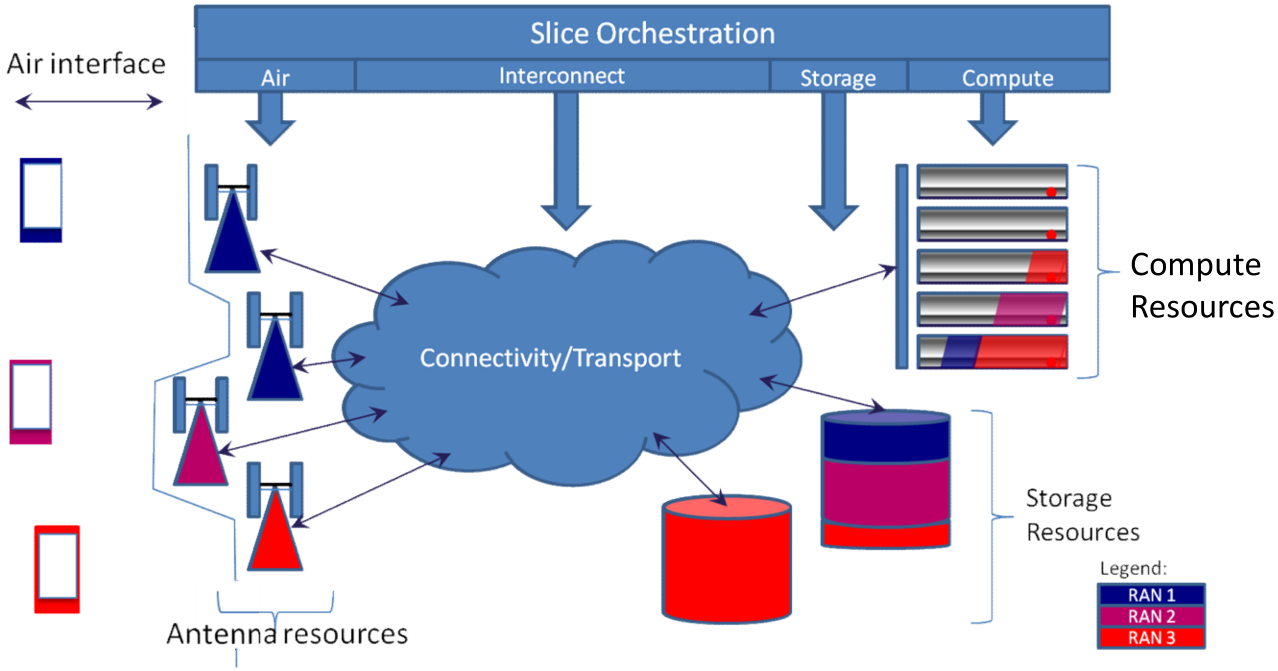


Figure 9: 5G network slices implemented on the same infrastructure

Synchronization impact:
Slice management may need to understand application sync requirements to ensure that resources are applied

Slicing: Allocate/connect resources



Synchronization impact: Orchestrators associated with virtualization need to understand PHY level implications

Thank you

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BACKUP

Some guidance on synchronizing 5G

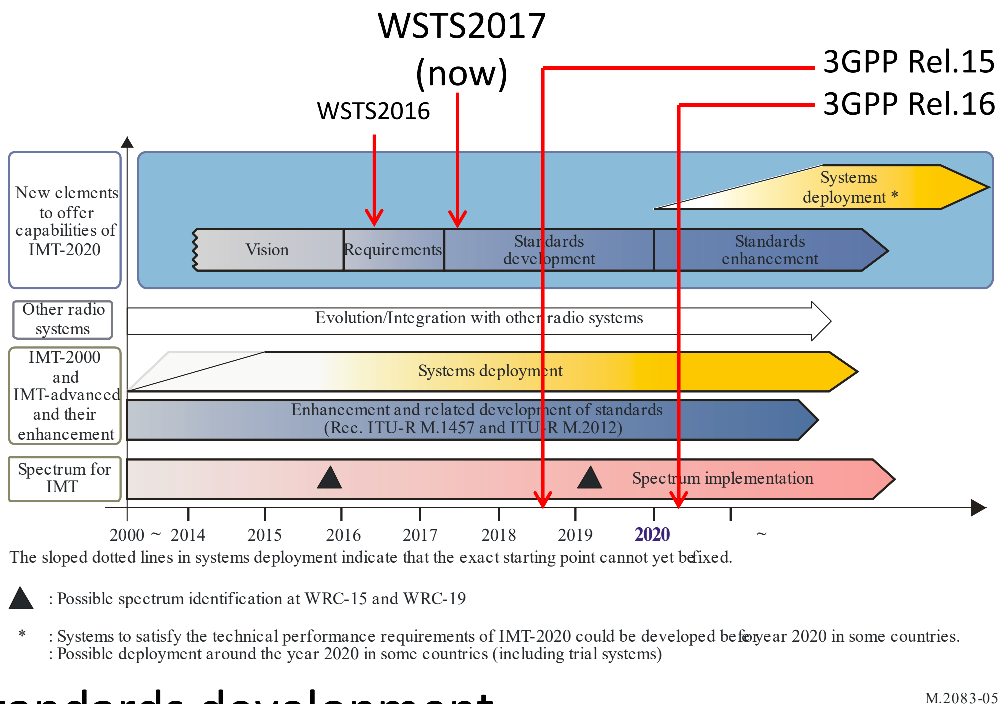
- 5G will make use of advanced features such as MIMI, CA and CoMP to achieve high speed, high density, and high performance networks
- Achieving performance targets requires stringent time/phase delivery.
- Performance is defined by the needs of the service, but delivery of timing is based on a hypothetical reference model (HRM) covering a wide number of cases
  - The HRM is a budget
  - As a budget, it can be used as an engineering tool to tailor the network to the application
- Some general guidance for synchronization
  - High density environments require the highest consideration of accuracy
  - Make use of SyncE for holdover protection at the edge (existing sync network can be used here)
  - If GPS/GNSS used, consider impacts of timing loss/jamming and plan for use of PTP as a wireline alternative. For high density networks consider GPS as a single point of failure.
  - Where lower density, some relaxation in the timing requirements may be tolerated.
  - For both fronthaul and backhaul, understand how much path asymmetry may exist. It will impact accuracy. Aim to minimize if possible. Also understand if DCMs are used.

Tools available for 5G

- SyncE clocks
  - EEC1, EEC2
  - eEEC
- SyncE network equipment fuctions
  - ESMC
  - Extended ESMC
- PTP Profiles
  - Frequency only, frequency/phase/time, Profile for assisted partial timing support
- PTP clocks
  - Frequency: slave only ordinary clock (SOOC)
  - PRTC (Packet Reference Time Clock)
  - ePRTC
  - T-GM (Telecom Grand Master
  - T-BC (Telecom Boundary Clock)
  - T-TSC (Telecom Slave clock

Red text represents recently standardized functionality

5G Standards timeline: critical points



- Sync standards development
  - Network backhaul: ITU-T SG-15
  - Radio: 3GPP

Thank you

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