5G Synchronization Aspects

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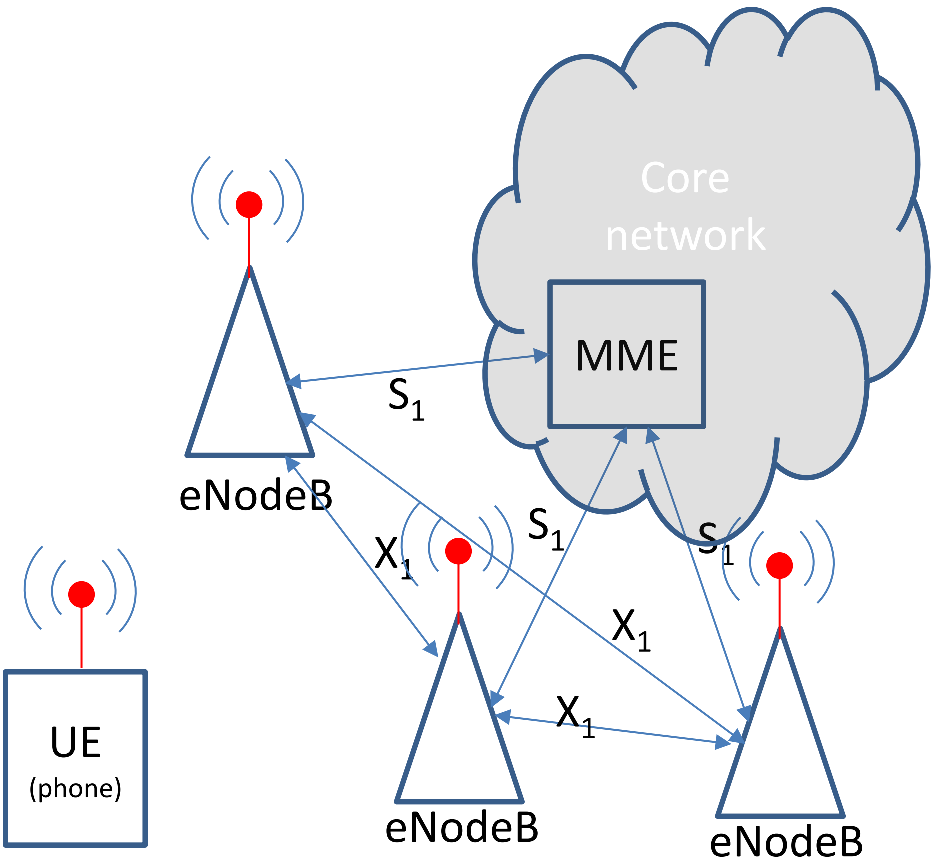
WSTS, San Jose, June 2016

Objective and outline

- Objective:
  - To provide an overview and summarize the direction being taken with 5G mobile networks, focussing on what is required in terms of synchronization
  - (what, when, how, and why)
- Outline:
  - 5G: what is it?
  - Review of modulation
  - Some architectural components
  - What may be required to time this

5G: WHAT IS IT

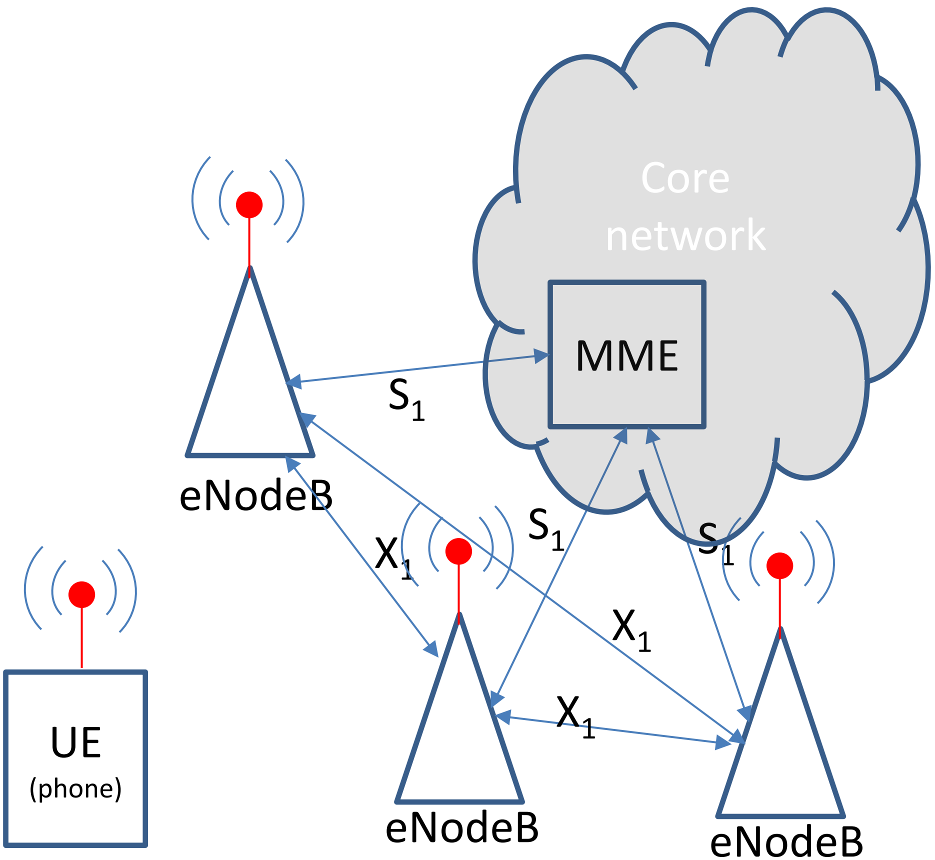
4G as the starting point



- LTE-A is the starting point
  - Also defined as IMT-Advanced
  - 5G is also known as IMT-2020
- Mobility is key, but typical "advanced" service is the Smart Phone
- Evolution of previous wireless networks to fully packet based
- Different types of cells (macro base station, pico-cell, etc.)
- User data rates in the order of 10Mbit/s to support "traditional" services (voice, web, video)

Synchronization is typically supplied from the core over the S1 interface

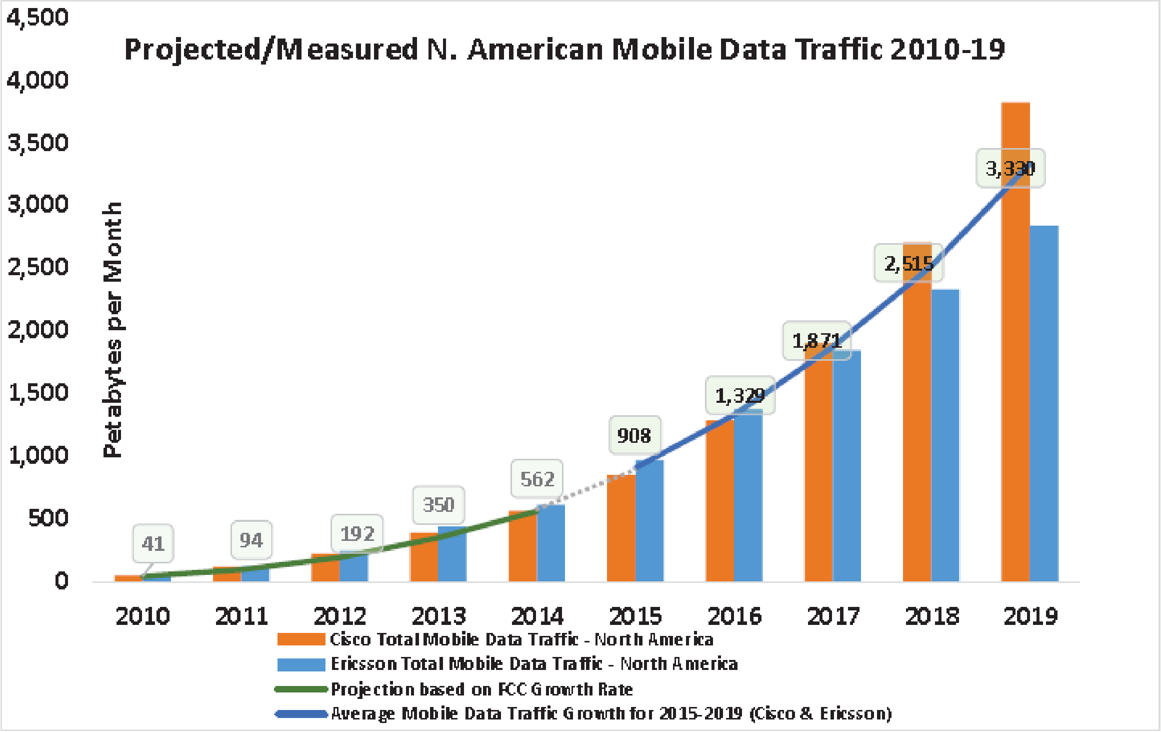
LTE features



- LTE-A technology also includes
  - MIMO
  - Carrier aggregation
  - HetNets
  - Home Base station
- All increase performance to the end user.
- End user is typically using a smart phone.

How can this architecture be further developed to address evolving services?

5G drivers: need anything else be said?



Type of characteristics of network devices are also changing , phone and tablet Still dominate (61% as of Q1/15), but growth in M2M(24%) and Car (15%)

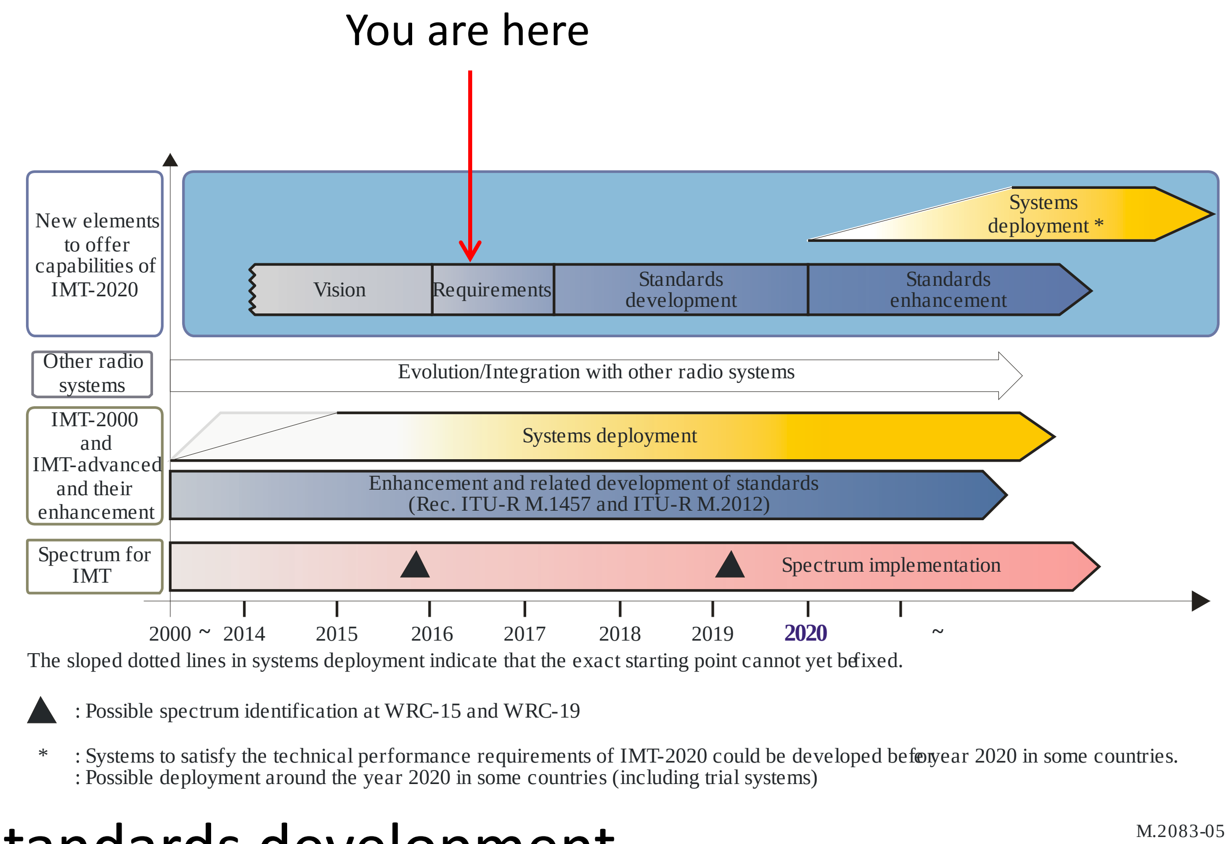
Source: MOBILE DATA DEMAND: GROWTH FORECASTS MET
Significant Growth Projections Continue to Drive the Need for More Spectrum, CTIA,

5G networks

- 5G networks will:
- Support of new services:
  - IoT, Sensor Networks, tactile internet
- With higher performance:
  - Higher bit rates, higher speed mobility handoff, lower latency
- Networks deployed with:
  - Higher connection densities, new spectrum allocation, use of unlicensed spectrum

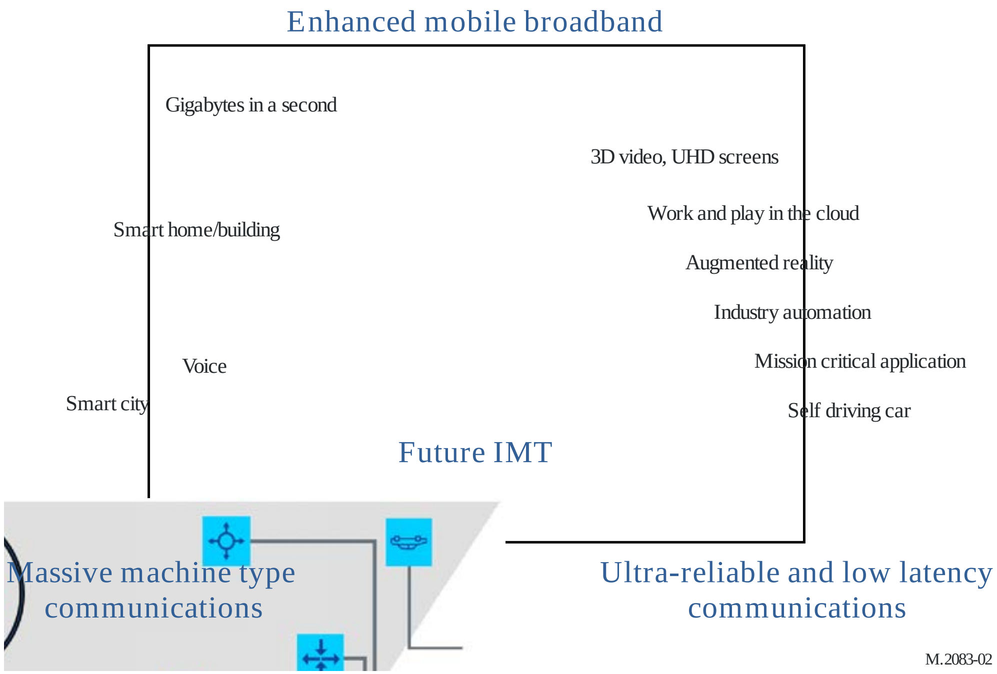
There is a need to look at the synchronization requirements

5G/IMT-2020 Timeline



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

Capability summary



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

Capability delta

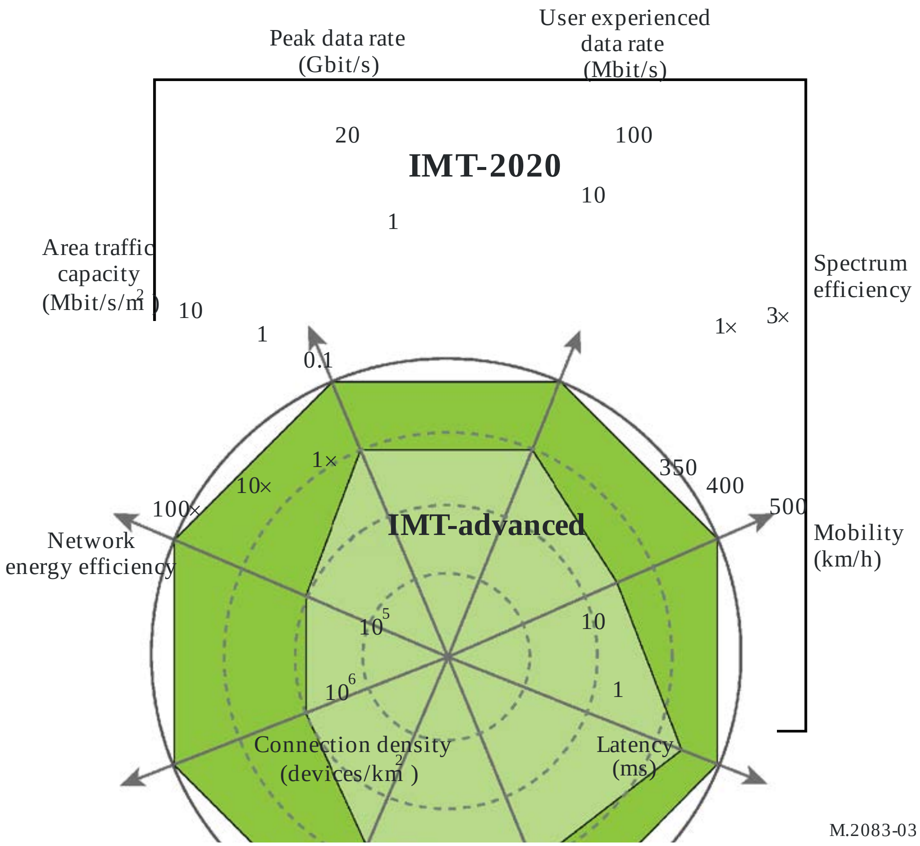


Figure: ITU-R M.2083

5G realized by:

- Peak data rate
  - New spectrum allocation
- User data rate
  - CoMP, MIMO
- Spectrum efficiency
  - Modulation
- Mobility
  - Faster hand-off capability (CRAN)
- Latency
  - Movement of service data bases
- Connection density
  - CRAN architecture
- Network energy
  - CRAN architecture
- Area traffic capacity
  - CRAN/CoMP/MIMO

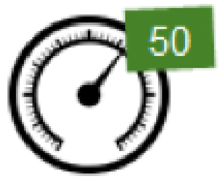
5G use case families and related examples (NGMN)

Broadband access in dense areas

PERVASIVE VIDEO

Broadband access everywhere

50+ MBPS EVERYWHERE



Higher user mobility

HIGH SPEED TRAIN

Massive Internet of Things

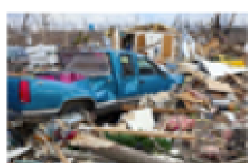
SENSOR NETWORKS

Extreme real-time communications

TACTILE INTERNET

Lifeline communications

NATURAL DISASTER

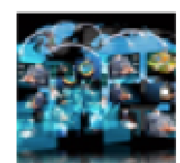


Ultra-reliable communications

E-HEALTH SERVICES

Broadcast-like services

BROADCAST SERVICES



Synchronization requirements?

- Synchronization requirements will be based on two aspects: the needs of the service and the needs of the infrastructure
  - Service:
    - M2M, IoT may require accurate synchronization, which may or may not be provided by the network.
  - Infrastructure needs
    - New air interfaces may be defined
    - New capabilities related to time-sensitive networks may be needed and may require synchronization support from the network

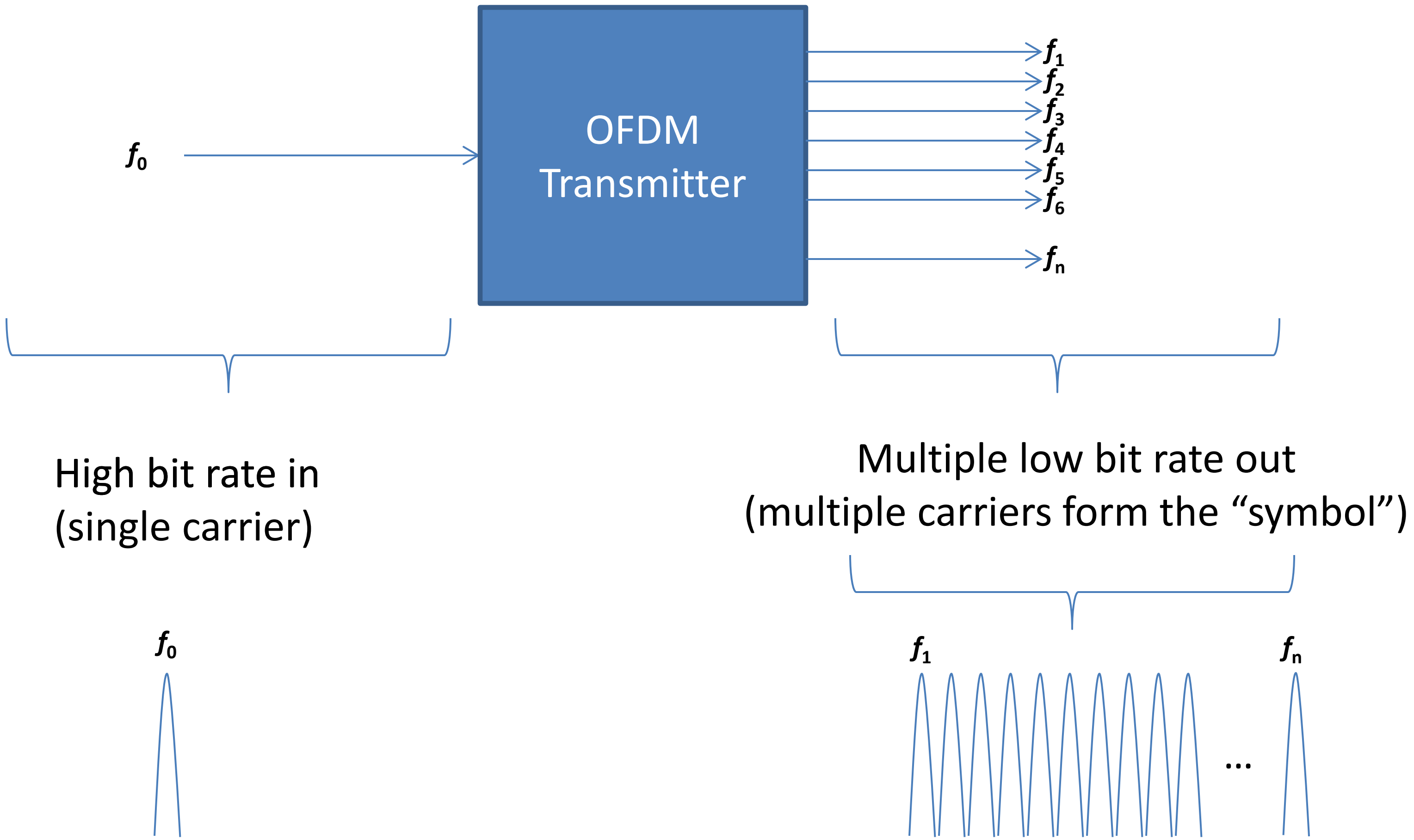
OFDM transmission and reception

Key to understanding the air interface sync requirement

Review of modulation

- Modulation gets the bits on/off the air
- Wireless modulation is generally one form of Orthgonal Frequency Division Multiplexing (OFDM)
- Splits (multiplexes) high data rate bit streams onto multiple sub-carriers, each with narrow bandwidth
  - Used in:
    - LTE-A:
    - WIMAX
- Attraction for wireless:
  - Low symbol rate (1/15kHz) is less susceptible to ISI
  - Subcarrier equalization simpler due to narrow subcarrier BW
  - Use with QAM results in high spectral efficiency
  - Well understood (!)

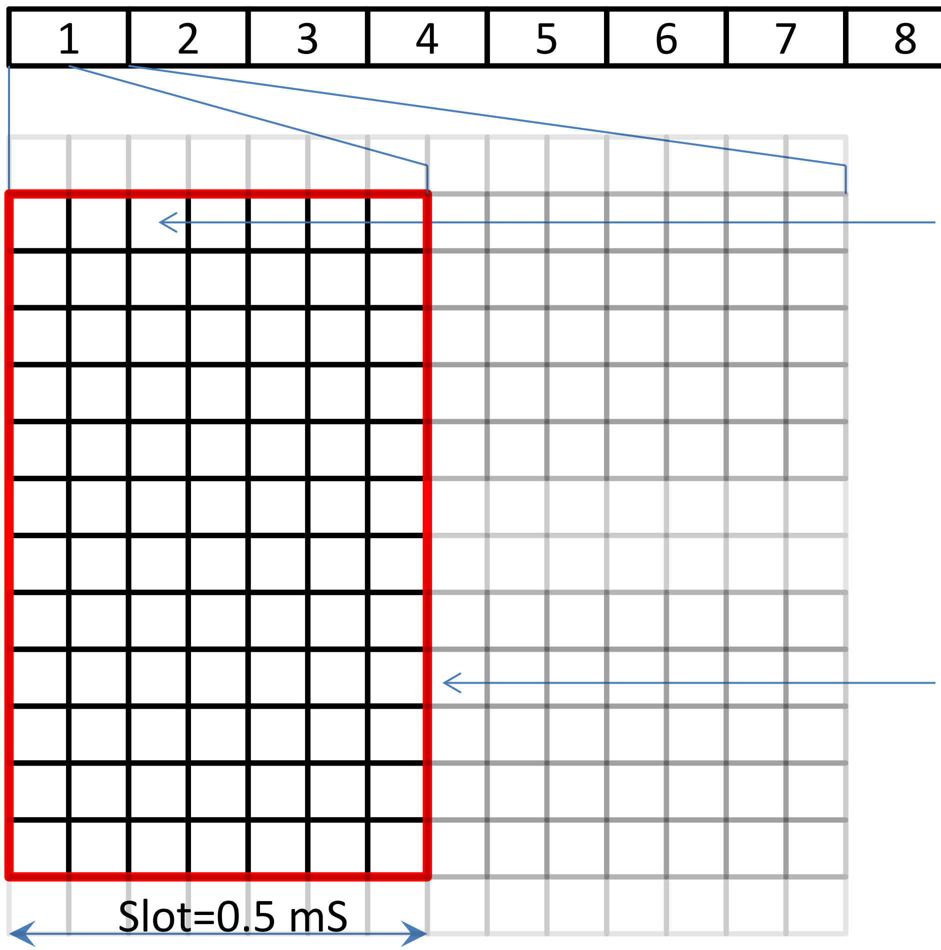
Recall OFDM



Low bit rate OFDM improves performance for multi-path environments, key to wireless

Basic LTE frame (FDD)

10 ms duration, 10 sub-frames



Resource element:
-Contains one OFDM symbol
-May represent data or control
-Consists of symbol plus Cyclical Prefix (CP) (i.e. 15 kSamples/s)

Resource block:
Contains seven OFDM symbols for 12 sub-carriers

TDD Frame

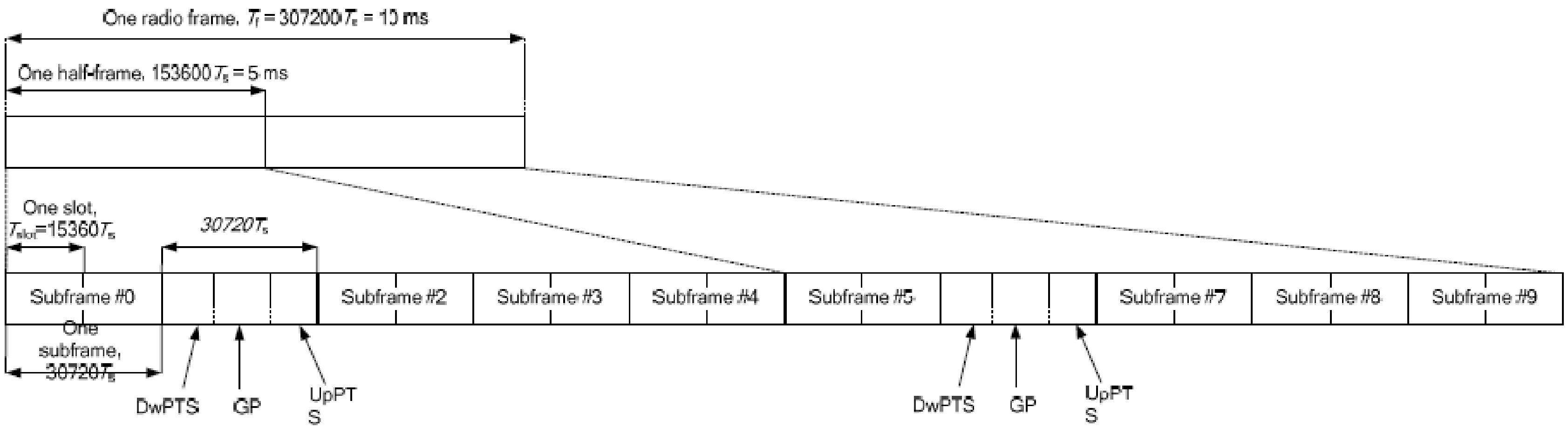
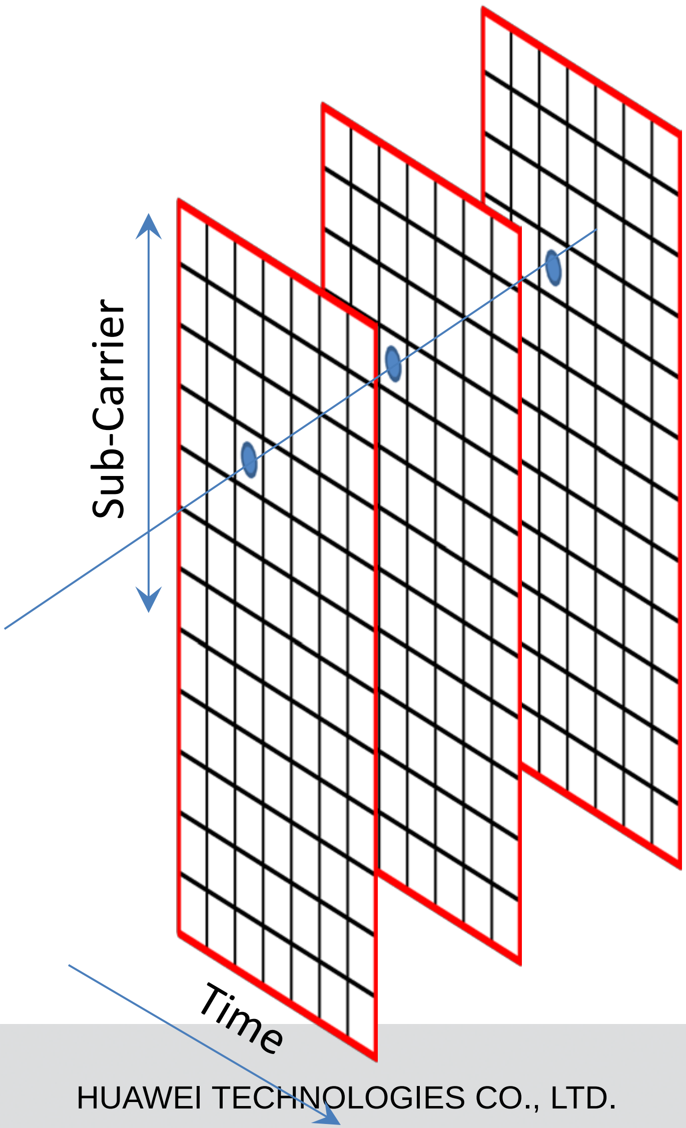
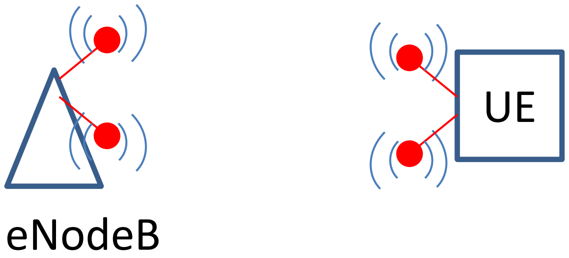


Figure 4.2-1: Frame structure type 2 (for 5 ms switch-point periodicity)

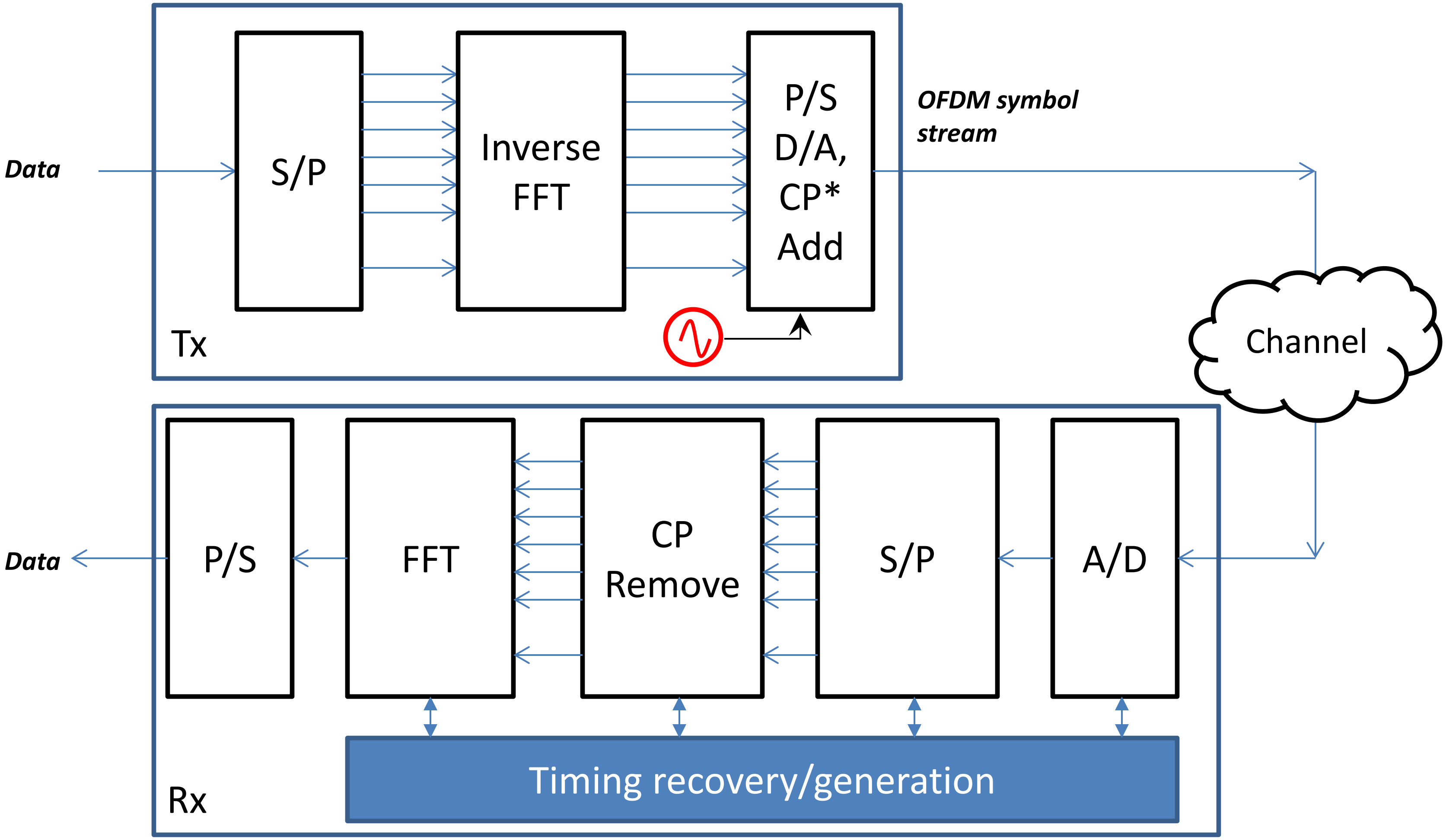
Visualizing for multiple Antennas



- In the case of MIMO, each antenna will have a frame structure.
- Where multiple antennas share the same system clock, usually not an issue.
- CoMP or Carrier Aggregation may need some assistance where antennas are driven by different oscillators.



OFDM in practice



*CP: Cyclical Prefix added to reduce ICI

What goes wrong?

- The process of timing extraction at the receiver involves multiple steps.
  - Need to preserve timing relationship of individual sub-carriers when symbols are carried over a complex channel
  - Process generally involves coarse frequency acquisition, followed by fine timing adjustment
- Carrier Frequency Offset: error in recovering the carrier, which leads to loss of orthogonality of individual sub-carriers, and increased BER
  - But, Doppler is also a contributor. The user can be moving in a high-speed train. (5G is targeting 500 km/hr)

Extension to MIMO

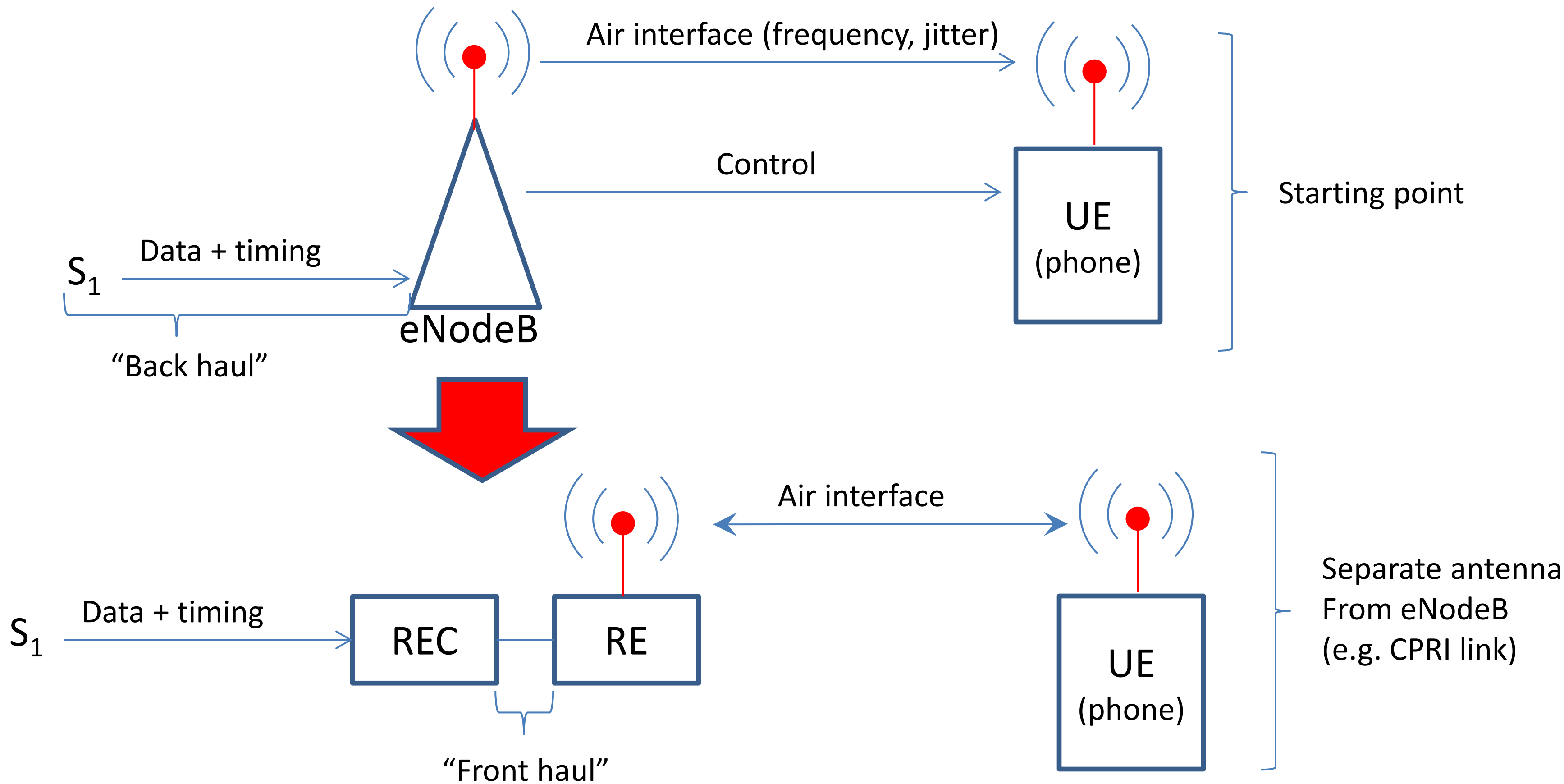
- Timing offset (TO) and carrier frequency offset (CFO) are compensated by the receiver
  - In a single antenna case, only one pair of oscillators, so compensation relatively straightforward.
  - LTE-A frame format appears to be effective in supporting pilot-aided synchronization and channel estimation.
- MIMO:
  - Potential for multiple oscillators and therefore multiple offsets that need to be corrected.
  - Excess time error leads to the possibility of interference with multiple carriers
  - Field reports indicate that current methods are effective, but suggest that tight external synchronization be provided

NEW ARCHITECTURE CONSTRUCTS: CRAN AND NETWORK SLICING

New architectural components

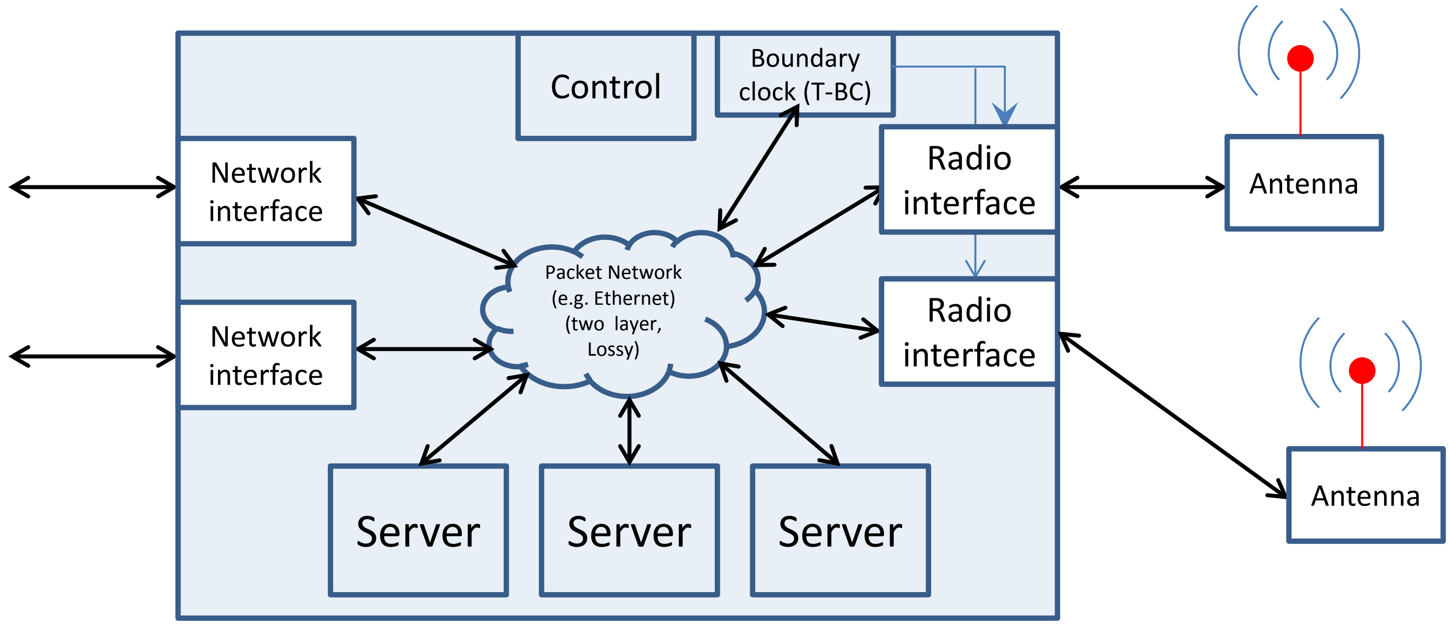
- Centralization of functions and the use of data centre techniques is seen as key to supporting 5G requirements
- Architecture:
  - C-RAN (cloud-RAN, Centralized-RAN)
    - Localizes the functions to allow sharing of resources
  - Network slicing
    - Controlling how the end-to-end network is shared between different user (groups) to achieve different network objectives
    - Involves aspects of virtualization and orchestration

Recall the evolving base-station model



In practice, a network may have hundreds or thousands of base stations. Are there any efficiencies that can be gained by centralizing?

C-RAN



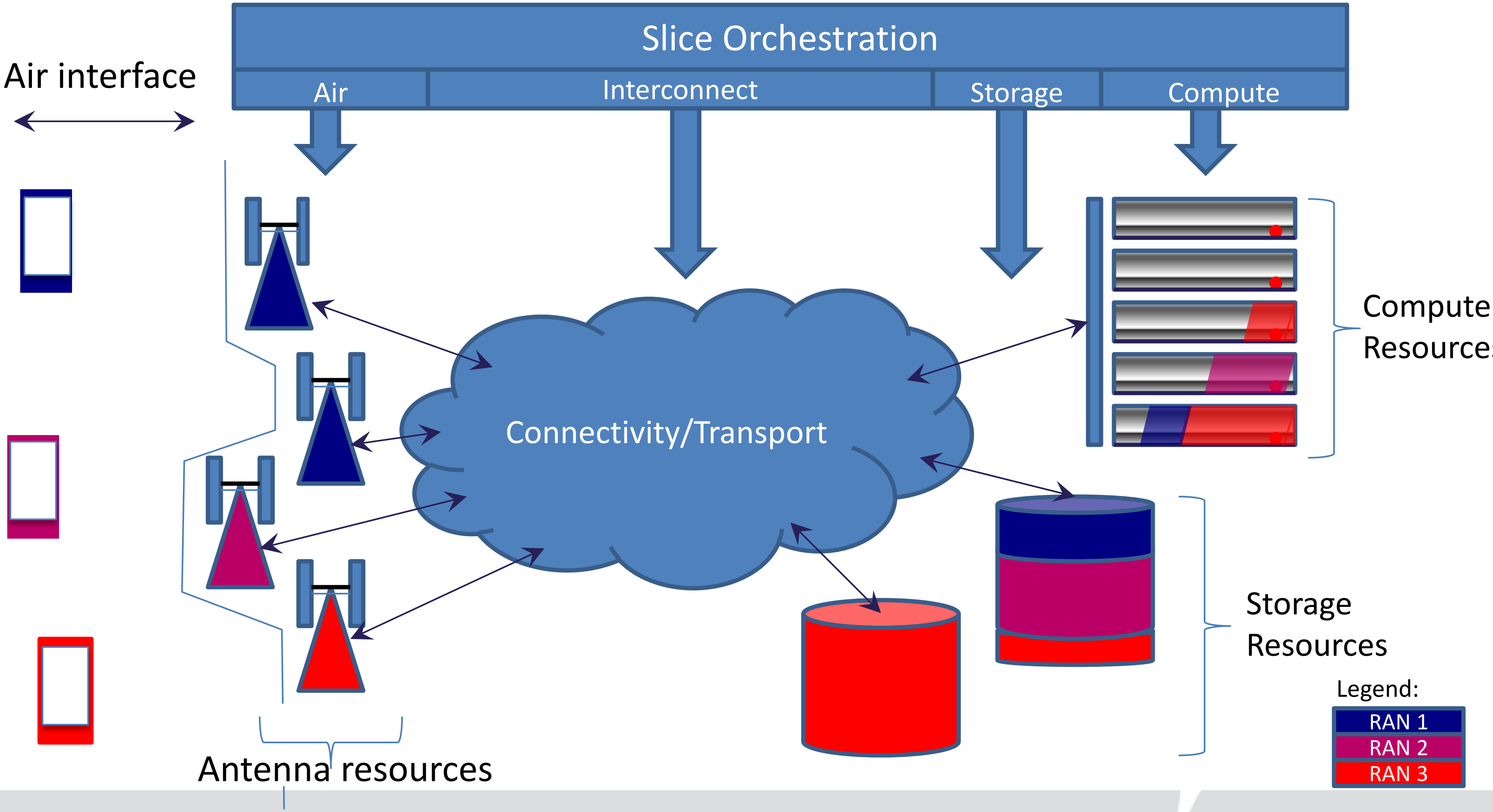
- C-RAN:
  - Localize functions associated with radio base Station control with the goal of achieving statistical gains.
  - Data centre model
  - Allows tighter control of latency and synchronization in the case of distributed MIMO, or CA, where normally separate base-stations would have been deployed
  - Above example shows timing distribution via boundary clocks, but other possibilities exist.
  - Synchronization impact: consistent with existing HRM for time/phase/frequency

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.

Synchronization impact: Slicing orchestration needs to consider synchronization of air Interface.

Slicing: Allocate/connect resources



Summary

- 5G will offer new services and support new technology.
  - Some services may require accurate time (e.g. location accuracy)
- New architectures for 5G appear to be well supported by current synchronization techniques.
  - Some further work may be required to define certain components and potentially new air interface definitions.

Thank you

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