# Synchronization in Mobile and Telecom Networks

WSTS 2021Tutorial Session

Mar. 25, 2021

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# Fundamental need for Synchronization

## Timing Alignment is Fundamental in Telecommunications

- Wireless Networks:
  - Digital transmission requires carrier recovery and symbol-timing alignment
  - Wireless (Cellular) requires timing alignment between base-stations
- Circuit-Switched (TDM) Networks:
  - Synchronous time-division multiplexing
  - Digital network require synchronization to emulate analog channels
- Packet-Switched Networks:
  - Circuit Emulation (CBR over packet) requires timing alignment
  - Multimedia requires timing alignment



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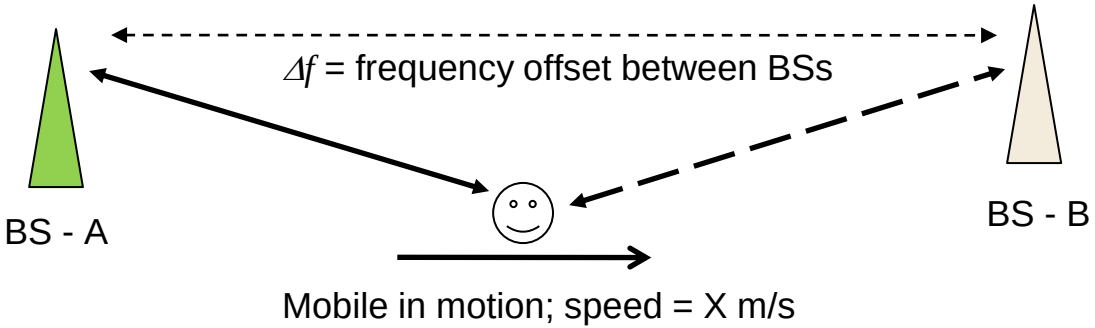
# Wireless Synchronization Requirements

- Frequency Accuracy
  - Hand-off considerations
- Phase/Time Accuracy (between base-stations)
  - IS-95 (CDMA) : distinguish between base-stations
  - LTE TDD (Time Division Duplex)
  - New Technologies
    - COMP: Coordinated Multi-Point Processing
    - Carrier Aggregation
    - Geo-location (positioning services)
    - Other Services/Functions (e.g. MBMS, EICIC, etc.)

# Timing Alignment in Wireless




- Mobile in motion (X m/s) introduces a Doppler shift (X/c)
  - When hand-over occurs, the mobile must reacquire carrier frequency
  - Large $\Delta f$ compromises the reliability of hand-over : $\Delta f$ < 50ppb
- CDMA (IS-95) : base-stations distinguished by time-offset
  - Time Alignment Error (TAE) < 10μs
- Modern Wireless (LTE & 5G) requires stringent time synchronization to support special services/functions
  - Time-Division-Duplex (TDD) requires TAE < 3μs
  - 5G Clusters require TAE < 130ns



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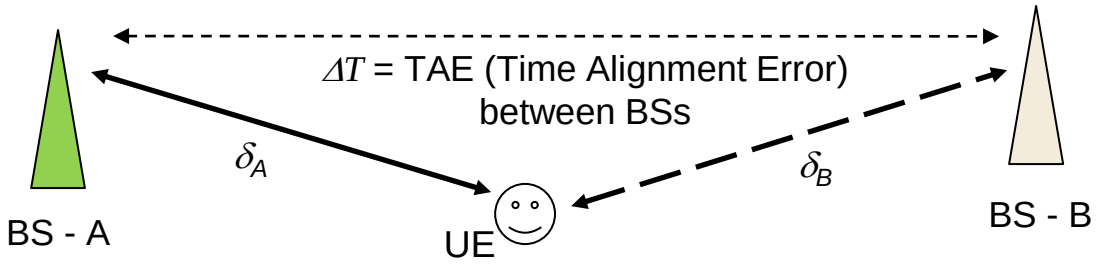
# Timing Alignment in Wireless




CoMP can involve more than 2 base-stations simultaneously communicating with the UE

- Coordinated Multi-Point (CoMP):
  - Simultaneous data transmission from multiple sites to single UE (*aka* Joint Transmission, "JT")
  - Joint reception at multiple sites from single UE (*aka* Joint Reception, "JR")
  - Applies to 4G, 5G
- Performance is a function of time alignment error (*signal processing requires synchronization*)
- According to 3GPP:
  - Typical time offset at UE should be less than 2μs for JT
  - Time offset at UE composed of inter-cell TAE and difference of propagation delays
  - For JT, TAE should be less than 260ns (based on simulation studies)
  - For JR requirements are TBD



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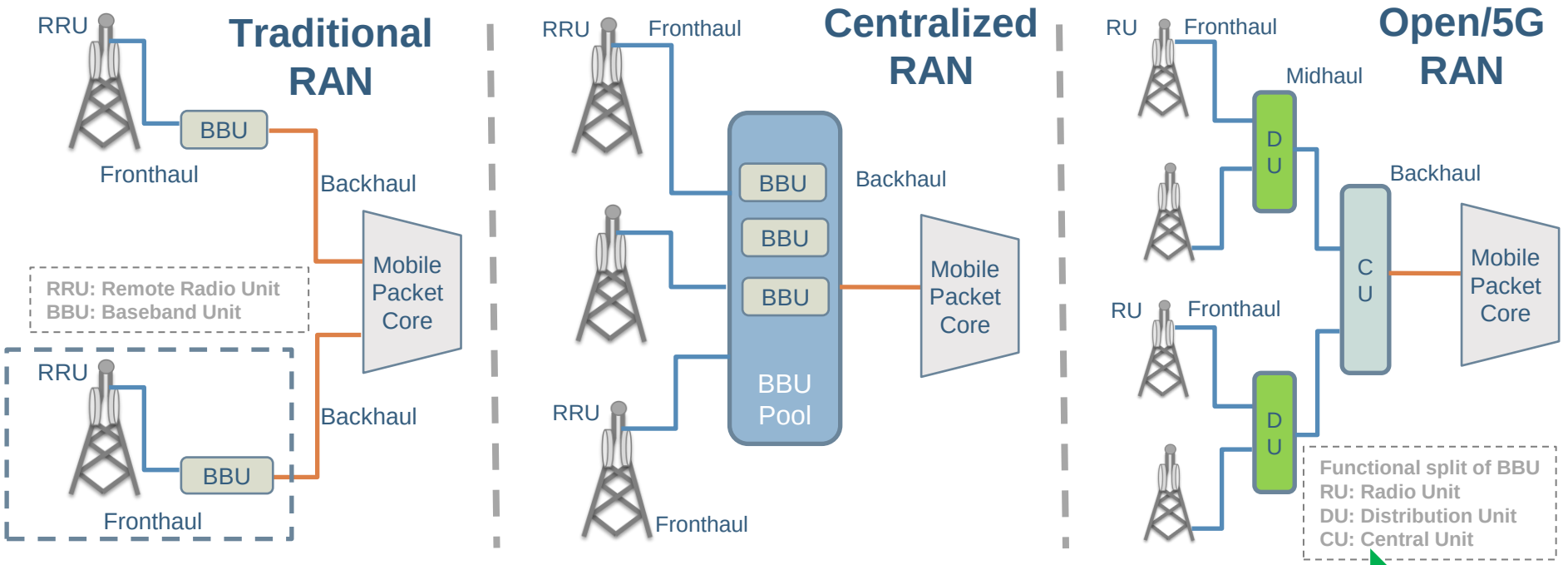
# RAN – RADIO ACCESS NETWORK

# RAN ARCHITECTURE EVOLUTION



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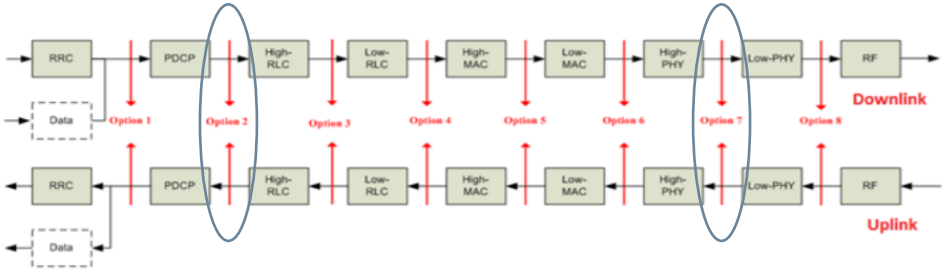
# 5G – Functional Split and Options



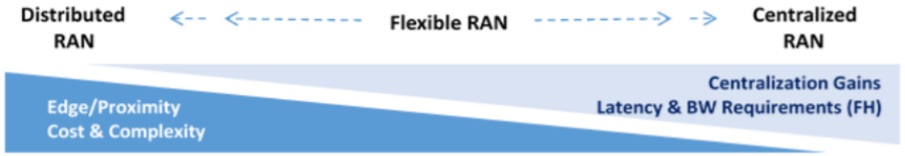




**Figure 1: Functional split options**

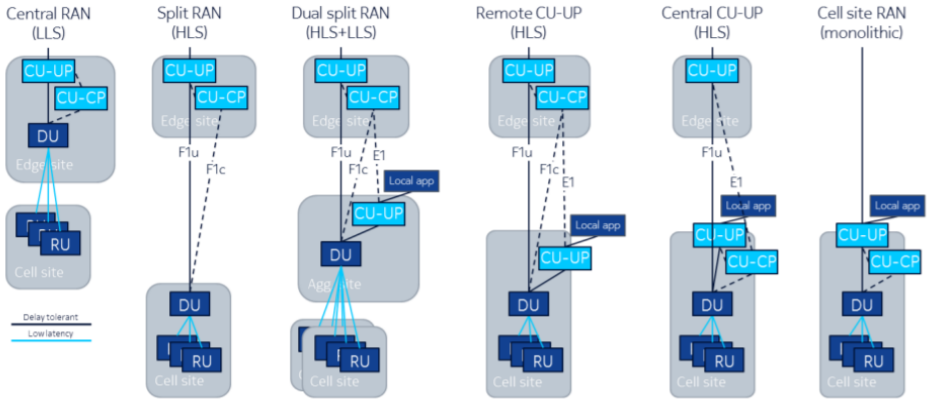
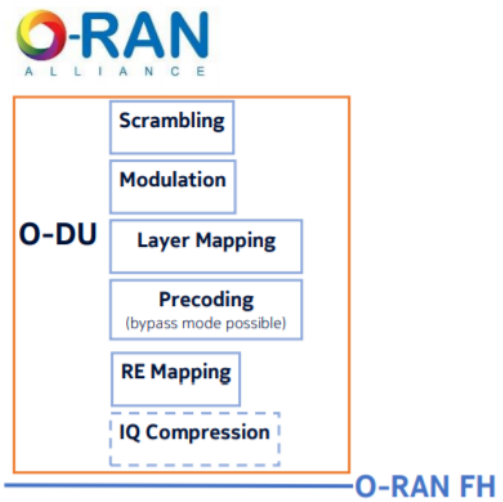



**Figure 4: Example functional placement scenarios**



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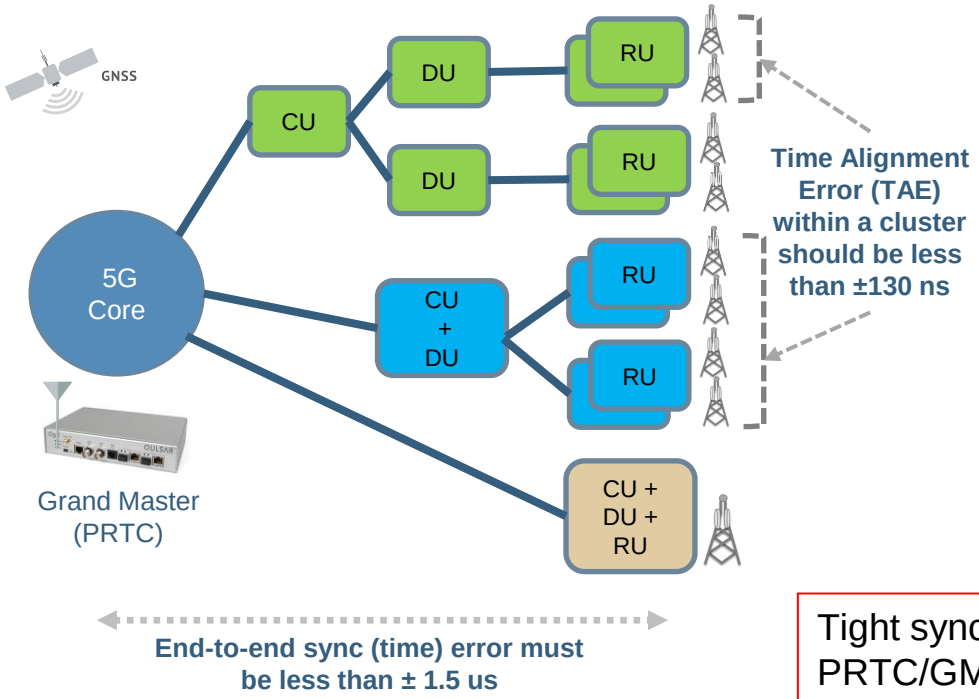
# ORAN SYNCHRONIZATION PLANE (S-PLANE)

# Synchronization Requirements in 5G (TE, TAE)




Time Alignment Error:

- Between any two antenna RF points should be less than 3us — 1.5us between antenna and “Core” (the common point)
- Between any two antenna RF points in a cluster should be less than 130ns — 65ns between antenna and common reference point for cluster
- Between any two antenna RF points in an antenna array (beam forming, MIMO) should be less than ~10ns — usually calibrated coax cable (analog)

Tight synchronization is simplified by moving the PRTC/GM closer to the edge, closer to the end-points (antenna RF interfaces)



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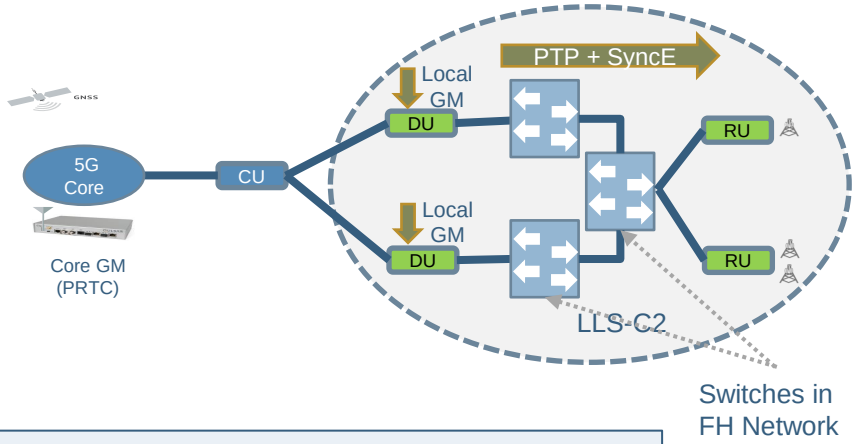
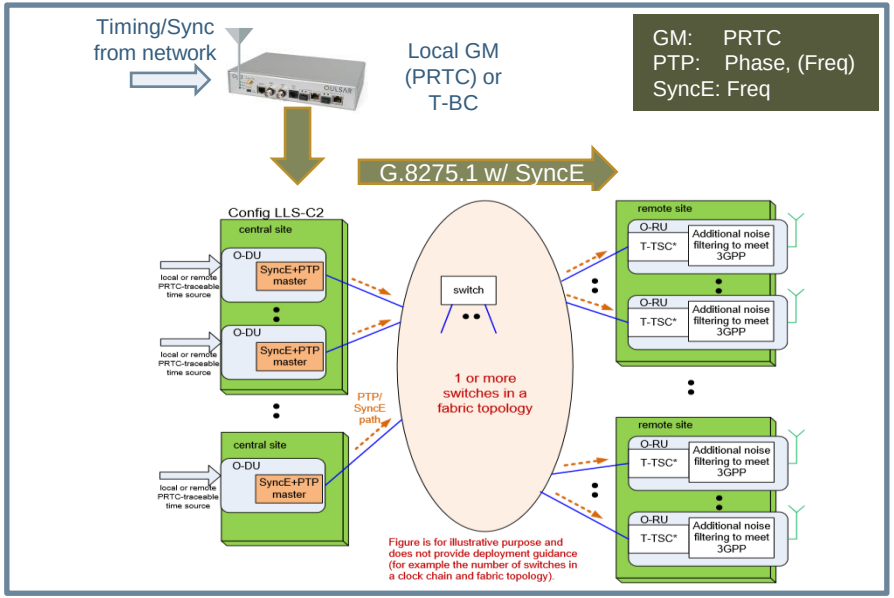
# ORAN S-PLANE: CONFIGURATION LLS-C2




## Configuration LLS-C2

O-DU and O-RU connections through switches

Use Cases:

- 4G/5GNR radios in mesh configuration with DU(s) for load-balancing and BW optimization
- DU's stacked in Datacenters, CORD
- Fail-safe with redundant paths in FH network
- Smart cities, IIoT, eMBB or mMTC network slices

## Timing and Synchronization

- Typical Sync Flow: **Local GM => O-DU (BC/TC) => FH Switches (BC/TC) => O-RU**
- G.8275.1 Telecom Profile - L2, full-on-path support, SyncE
- G8275.2 Profile can be used with PTP-unaware switches with high performance PTP servo at RU slaves. Less cost.



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# Some Wireless Specifications (3GPP Requirements)

| Application/ Technology | Accuracy | Specification |
|---|---|---|
| CDMA2000 | ±3 µs with respect to CDMA System Time, which uses the GPS timescale (which is traceable and synchronous to UTC except for leap second corrections)<br>±10 µs with respect to CDMA System Time for a period not less than 8 hours (when the external source of CDMA system time is disconnected) | [b-3GPP2 C.S0002] section 1.3<br>[b-3GPP2 C.S0010] section 4.2.1.1 |
| TD-SCDMA<br>(NodeB TDD mode) | 3 µs maximum deviation in frame start times between any pair of cells on the same frequency that have overlapping coverage areas | [b-3GPP TS 25.123] section 7.2 |
| WCDMA-TDD<br>(NodeB TDD mode) | In TDD mode, to support Intercell Synchronization and Handoff, a common timing reference among NodeB is required, and the relative phase difference of the synchronization signals at the input port of any NodeB in the synchronized area shall not exceed 2.5 µs | [b-3GPP TS 25.402] sections 6.1.2 and 6.1.2.1 |
| W-CDMA MBSFN | 12.8 µs for MBMS over a single frequency network, where the transmission of NodeB is closely time synchronized to a common reference time | [b-3GPP TS 25.346] sections 7.1A and 7.1B.2.1 |
| LTE MBSFN | Values < ±1 µs with respect to a common time reference (continuous timescale) have been mentioned | Under study |
| W-CDMA<br>(Home NodeB TDD mode) | Microsecond level accuracy (no hard requirement listed) | [b-3GPP TR 25.866] section 8 |
| WiMAX | 1) The downlink frames transmitted by the serving base station and the Neighbour base station shall be synchronized to a level of at least 1/8 cyclic prefix length (which is equal to 1.428 µs).<br>At the base station, the transmitted radio frame shall be time-aligned with the 1PPS timing pulse<br>2) The base station transmit reference timing shall be time-aligned with the 1PPS pulse with an accuracy of ± 1 µs | [b-IEEE 802.16]<br>Table 6-160, section 8.4.13.4<br>[b-WMF T23-001] section 4.2.2 |

Source: G.8271/Table II.1 – Time and phase end-application requirements

# Some Wireless Specifications (3GPP Requirements)

| Application/ Technology | Accuracy | Specification |
|---|---|---|
| LTE-TDD<br>(Wide-Area Base station) | 3 µs for small cell (< 3 km radius)<br>10 µs for large cell (> 3 km radius)<br>maximum absolute deviation in frame start timing between any pair of cells on the same frequency that have overlapping coverage areas | [b-3GPP TS 36.133] section 7.4.2 |
| LTE-TDD<br>(home-area base station) | 1) 3 µs for small cell (< 500m radius). For large cell (> 500 m radius), 1.33 + $T_{propagation}$ µs time difference between base stations, where $T_{propagation}$ is the propagation delay between the Home base station and the cell selected as the network listening synchronization source. In terms of the network listening synchronization source selection, the best accurate synchronization source to GNSS should be selected. If the Home base station obtains synchronization without using network listening, the small cell requirement applies.<br>2) The requirement is 3.475 µs but in many scenarios a 3 µs sync requirement can be adopted. | [b-3GPP TS 36.133] section 7.4.2<br>[b-3GPP TR 36.922] section 6.4.1.2 |
| LTE-TDD to CDMA 1xRTT and HRPD handovers | eNodeB shall be synchronized to GPS time. With external source of CDMA system time disconnected, the eNodeB shall maintain the timing accuracy within ±10 µs with respect to CDMA system time for a period of not less than 8 hours | [b- 3GPP TS 36.133] section 7.5.2.1 |
| LTE-A | Phase/Time requirements for the applications listed below are currently under study:<br>• Carrier aggregation<br>• Coordinated multipoint transmission (also known as Network-MIMO)<br>• Relaying function | [b- 3GPP TS 36.814] |

Source: G.8271/Table II.1 – Time and phase end-application requirements

# Thank you …

## Questions?

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