Sync in 5G: What is really needed ?

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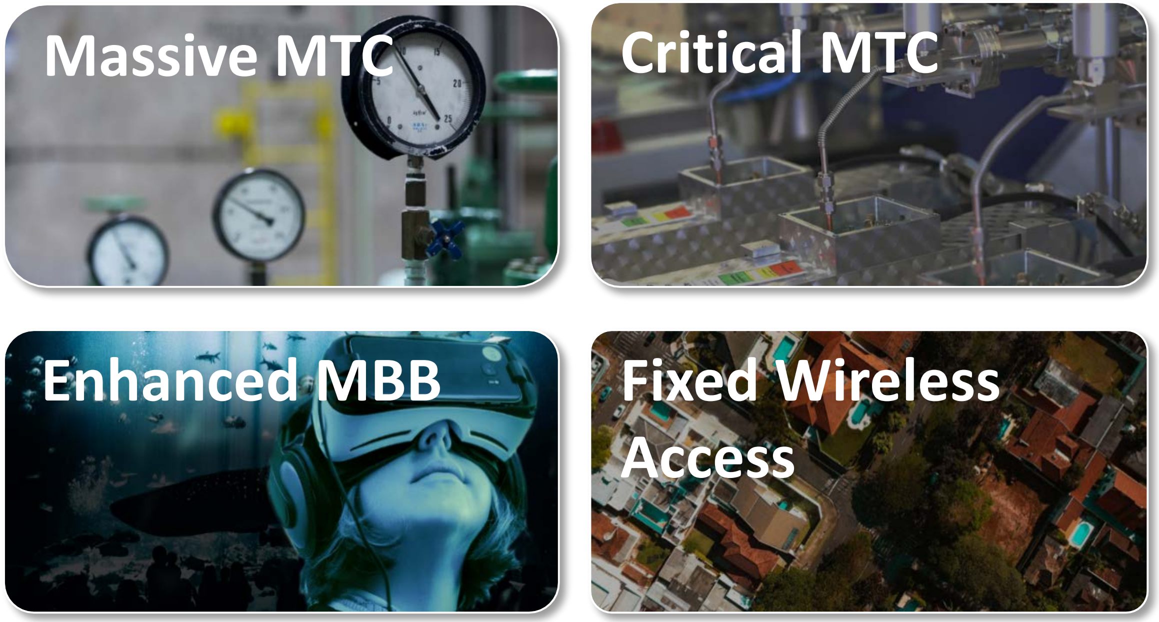


What is 5G?
5G wireless access is not only an evolution of mobile broadband; it will be a key IoT enabler, empowering people and industries to achieve new heights in terms of efficiency and innovation

1000X Data Volumes

5X Nw Energy Efficiency

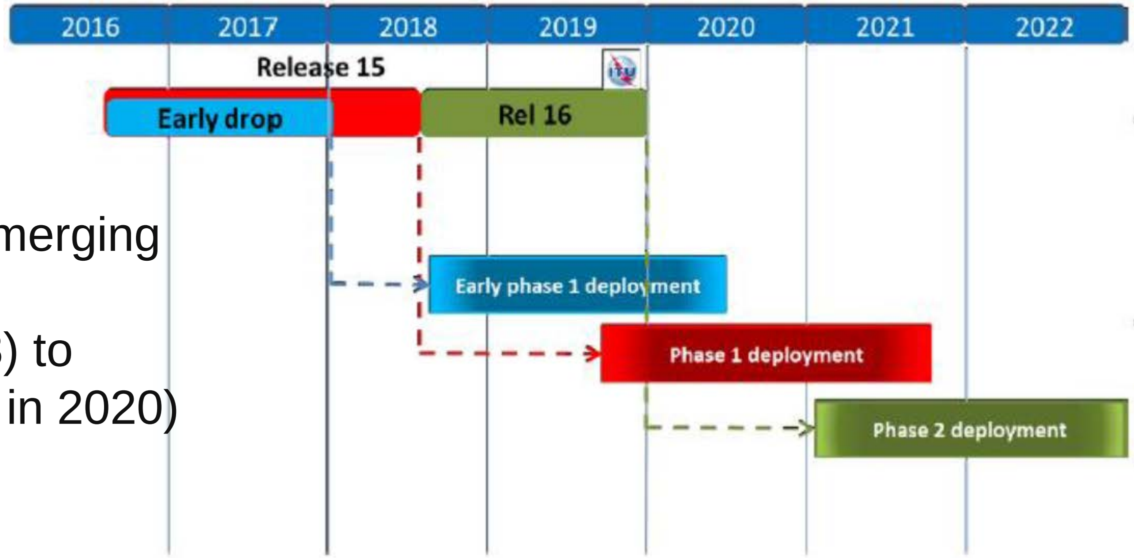
3X Spectral Efficiency

10-100X End user data rates

5X Lower Latency

LTE and 5G
Evolution of today's 4G (LTE) networks and addition of a new, globally standardized radio access technology known as **New Radio (NR)**

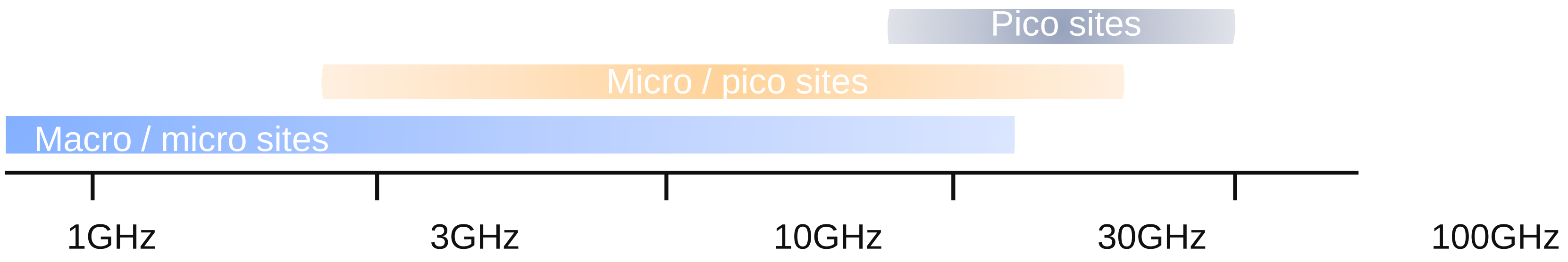
Time Plan
Early drop (Dec 17) to support emerging market needs
Release 15 (Phase 1, June 2018) to enable first phase (Deployments in 2020)



5G (NR) Radio aspects

- 5G NR will operate in the frequency range from below 1GHz to 100GHz with different deployments.
  - FR1: 450 MHz -6GHz
  - FR2: 24.25 – 52.6GHz
- Typically more coverage per base station (macro sites) at lower carrier frequencies, and limited coverage area per base station (micro and pico sites) at higher carrier frequencies.
  - licensed spectrum will continue to be the backbone of the wireless network in 5G, and transmission in unlicensed spectrum will be used as a complement to provide even higher data rates and boost capacity.

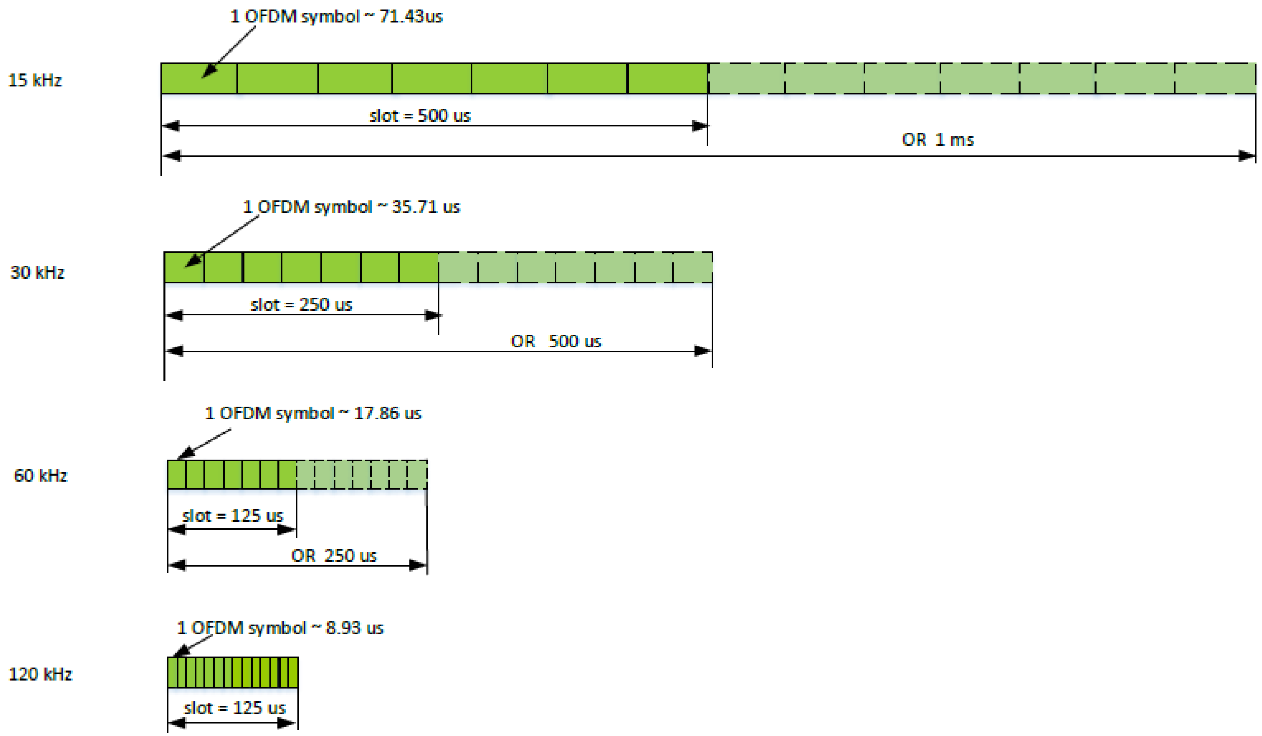
5G Deployments



5G (NR): Scalable Numerology

- CP-OFDM with scalable numerology (UL and DL); in addition DFT-Spread OFDM in UL for coverage limited scenarios
- Scaling factor *n* to ensure that slot and symbols of different numerologies are aligned in time (important for TDD)
  - *n* depends on: type of deployment, carrier frequency, service requirement, hardware, impairments, mobility
- Supports both TDD and FDD
  - FDD common at lower frequencies (moderate number of active antennas)
  - TDD assumed at higher frequencies (larger number of antennas, enabling beamforming)

Subcarrier spacing	15kHz	30kHz (2 x 15kHz)	60kHz (4 x 15kHz)	15 x 2^nkHz, (n = 3, 4, ...)
OFDM symbol duration	66.67 µs	33.33 µs	16.67 µs	66.67/2^n µs
Cyclic prefix duration	4.69 µs	2.34 µs	1.17 µs	4.69/2^n µs
OFDM symbol including CP	71.35 µs	35.68 µs	17.84 µs	71.35/2^n µs
Number of OFDM symbols per slot	7 or 14	7 or 14	7 or 14	14
Slot duration	500 µs or 1,000 µs	250 µs or 500 µs	125 µs or 250 µs	1,000/2^n µs



Sync aspects

Sync in 5G: Several perspectives

Radio interface
- TDD
- Carrier Aggregation
- Dual Connectivity
- CoMP
- Frequency Error
- Regulatory aspects
- …

Applications
- Positioning
- Industrial Automation
- Smartgrid
- …

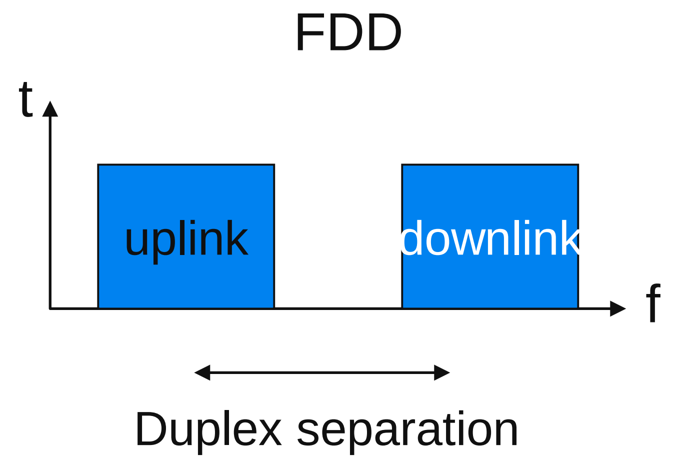
Infrastructure
- 5G
- Transport
- IAB
- Fronthaul
- …

Solutions
- GNSS
- IEEE 1588
- SyncE
- RIBS
- …

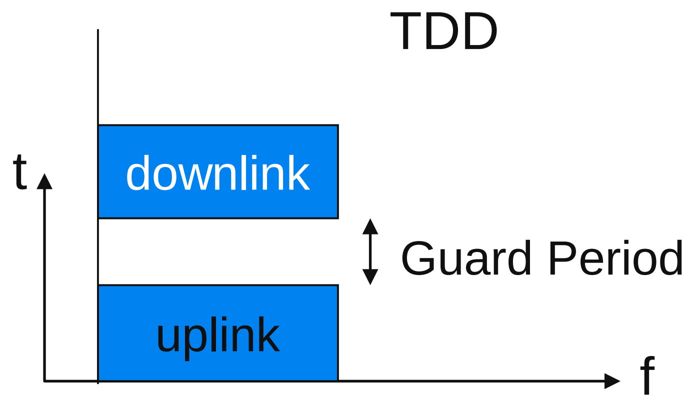
Sync continues to be an important enabler also for future mobile networks

Need for (phase) sync in TDD

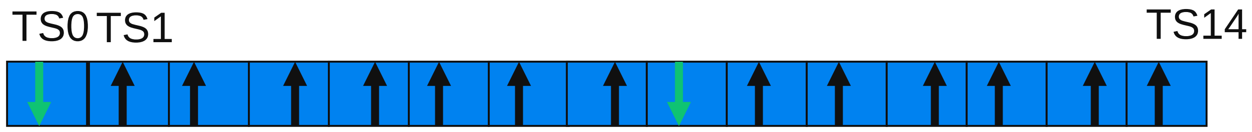
Cell Phase Sync
3GPP TS 38 133:
*cell phase synchronization accuracy measured at BS antenna connectors shall be better than **3 µs***
Note: This translates into a network-wide requirements of +/-1.5 microseconds.
Note: applicable to both FR1 and FR2
Note: Independent from Cell size



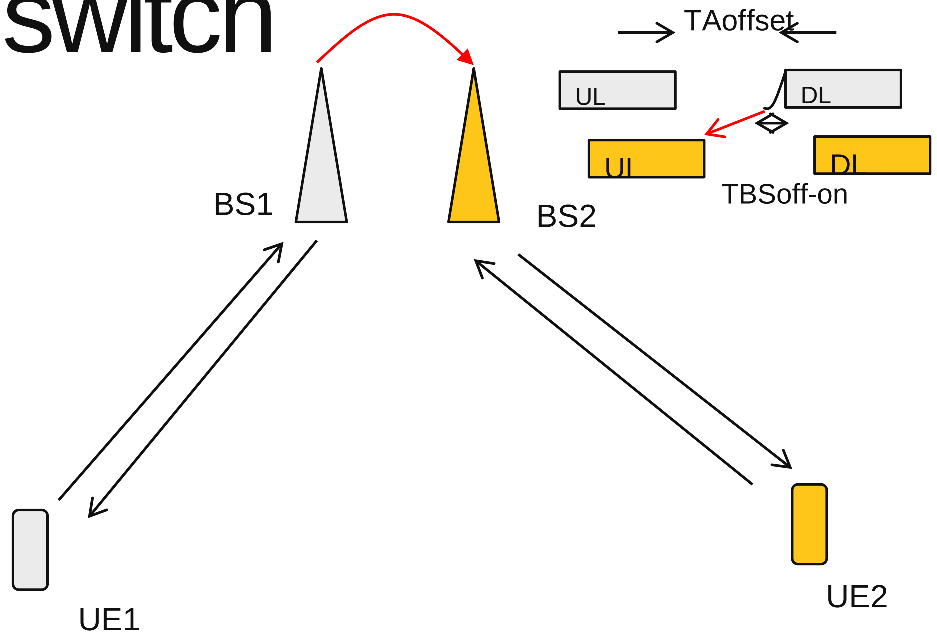
Background information
planned to be included in **3GPP TR 38.803**
Some examples follows in the next slides



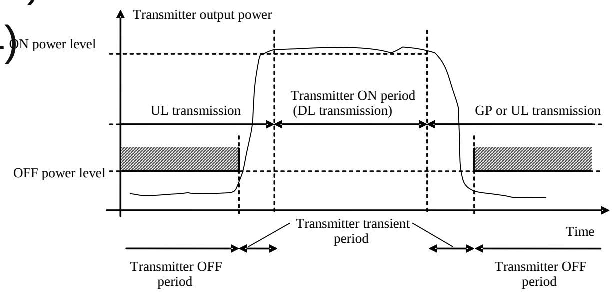
Example of TDD uplink/downlink transmission

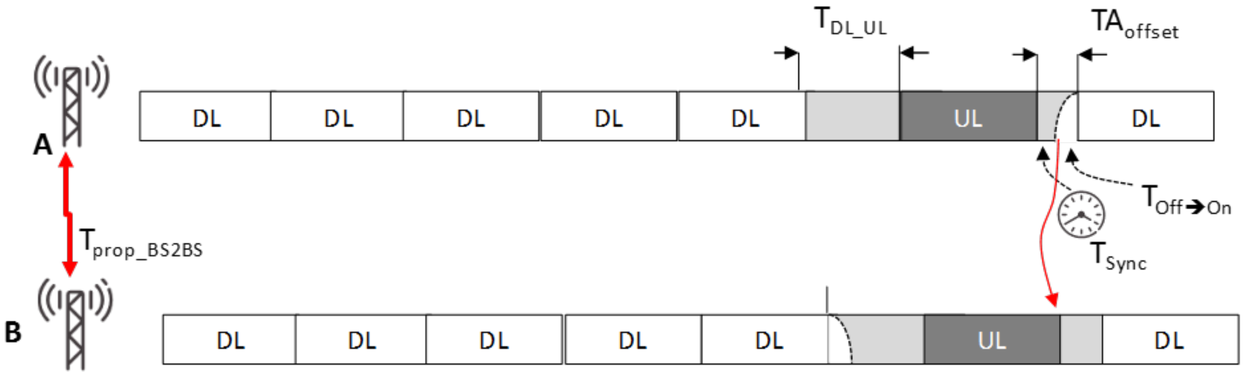


Example:
Base station to Base station interference at UL to DL switch



- Co-located Base Stations (worst case)
- $T_{BS\ off \rightarrow on}$ (FR1)= 10 microsec (TS 38.104)
- $T_{BS\ off \rightarrow on}$ (FR2) = 3 microsec (TS 38.104)
- NTA_offset (FR1) = 13 us (TS 38.133)
- NTA_offset (FR1)= 20 us with LTE-NR coexistence (TS 38.133)
- NTA_offset (FR2)= 7 us (38.133)



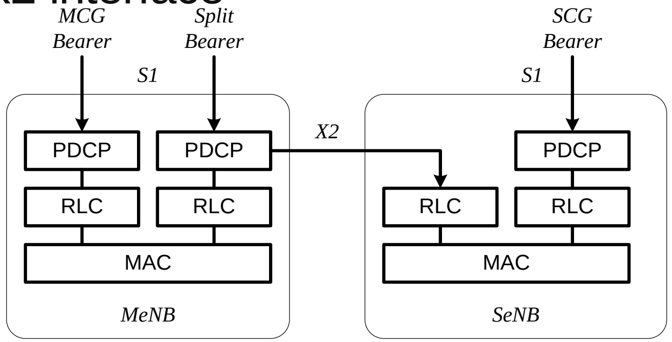


$$\mathbf{TA_{offset} \geq T_{Sync} + T_{BS\ off \rightarrow on}}$$

See 3GPP Contribution R4-1703013 for more details

Dual Connectivity

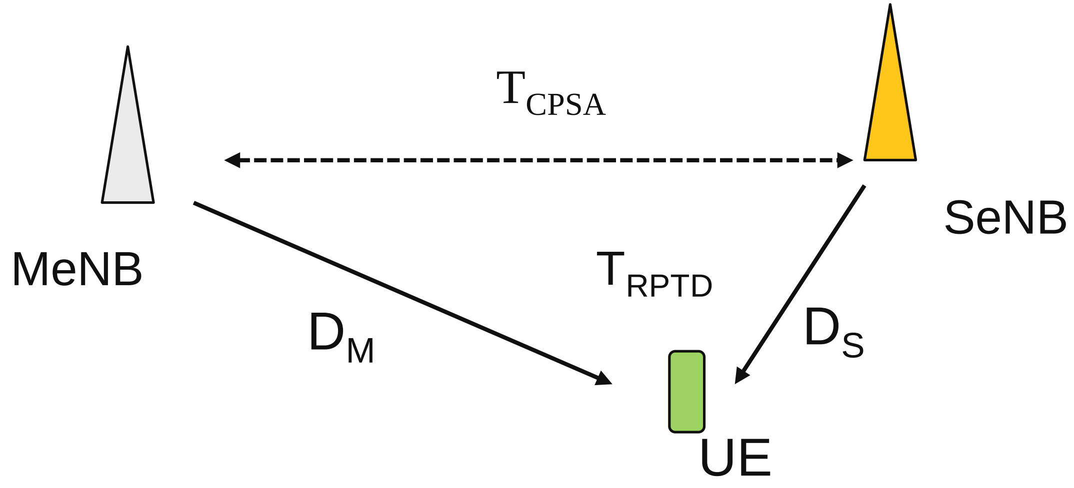
- Description for multi-connectivity operation using E-UTRA and NR **in 3GPP TS 37.340**
- Multiple Rx/Tx UE is configured to utilise radio resources provided by two distinct schedulers, located in two eNBs connected via a non-ideal backhaul over the X2 interface



- Sync Requirements in 3GPP **TS 38.133**
- **Cell phase sync not explicitely defined (but assumed)**
- Inter-band synchronous EN-DC :
  - MRTD = **33us** ; MTTD = 35.21 us
- Intra-band synchronous EN-DC (**only co-located NB)**:
  - MRTD for = 3us

- MRTD: Maximum Received Timing Difference
- MTTD: Maximum Transmitted Timing Difference

$$T_{CPSA} + T_{RPTD} \leq MRTD$$



T_{RPTD} : *absolute propagation time difference between MeNB and SeNB, which serve the same UE_D*

T_{CPSA} : *the sum of absolute timing accuracy values*

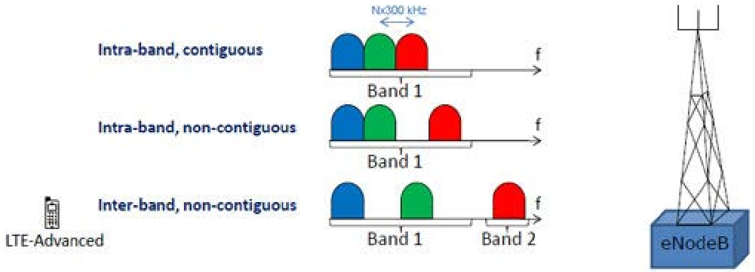
30us allocated to T_{RPTD} (i.e., 9 Km)

3us allocated to T_{CPSA}

Note: DC FDD-FDD operates in Asynchronous mode (Synchronous mode

Carrier Aggregation

— http://www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained



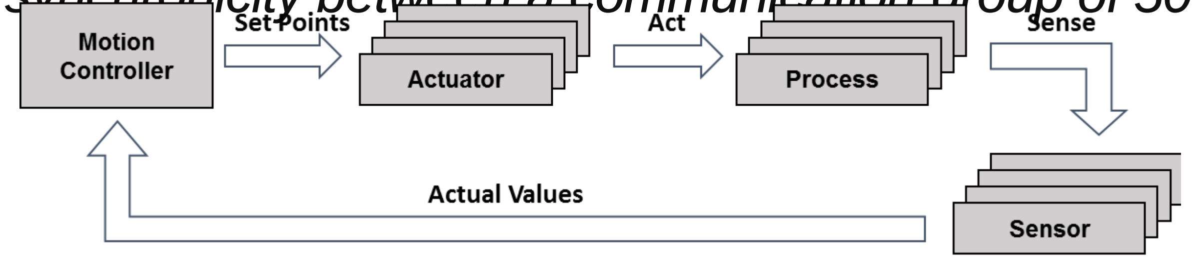
— Sync Requirements in 3GPP **TS 38.104 (TAE)** and **TS 38.133 (MRTD, MTTD)**
  - — **Contiguous Intra-band** Time Alignment Error (TAE):
    - — 260ns for FR1 → *Tight sync to simplify the UE design (only relevant for co-located antennas*
    - — 130ns for FR2 *Note: Requirement based on CP*
    - — Assumes collocated antennas
  - — **Intra-band non-continuous** and **Inter-band** Time Alignment Error (TAE):
    - — TAE: 3 us
  - — **Inter-band MRTD**
    - — 33 us (FR1)
    - — 8 us (FR2)
    - — *FR1-FR2 use case under discussion*

- **Intra-band non continuous MRTD**
  - 3 us (FR1)
  - 3 us (FR2)

Note: For intra-band CA, only collocated deployment is applied (Rel15)

5G support for Industrial Automation, SmartGrid, etc.

- 3GPP TR 22.804, Study on Communication for Automation in Vertical Domains (URLLC Work Item);
  - Note: Informative document
- Motion control
  - *The 5G system shall support a very high synchronicity between a communication group of 50 – 100 UEs in the order of 1 µs or below.*



- Control-to-control communication
  - *The 5G system shall support a very high synchronicity between a communication group of 5-10 controls (in the future up to 100) in the order of 1 µs or below.*

- TR 22.821 Feasibility Study on LAN Support in 5G

And Frequency Sync ?

- Frequency Error for NR specified in **3GPP TS 38.104**
  - *the modulated carrier frequency of each NR carrier configured by the BS shall be accurate to within the accuracy range given in table 6.5.1.2-1 observed over 1 ms.*

Table 6.5.1.2-1: Frequency error minimum requirement

BS class	Accuracy
Wide Area BS	±0.05 ppm
Medium Range BS	±0.1 ppm
Local Area BS	±0.1 ppm

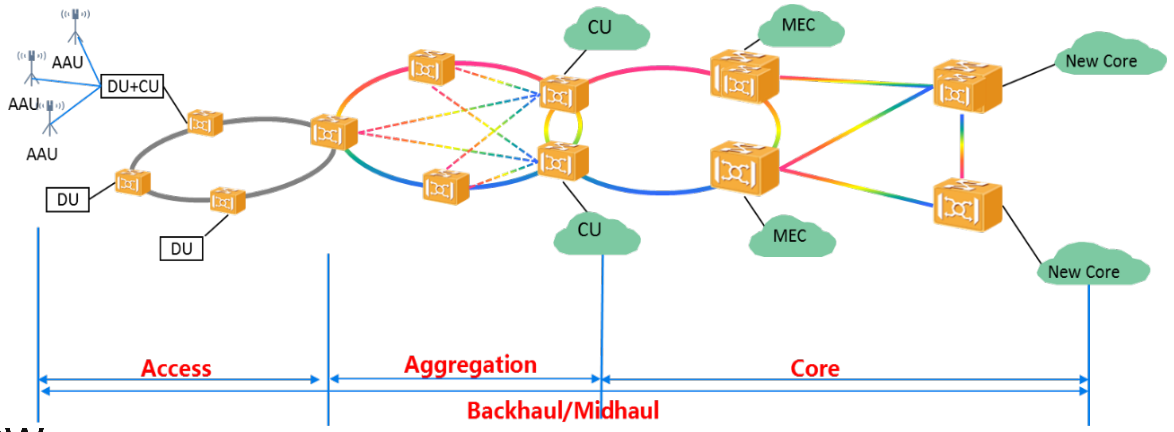
- Most of the error assumed for (UE) Doppler effect
- Short term phase noise (tested over 1 ms)
- The requirement is generally also estrapolated on the long term (e.g., for guaranteed regulatory compliances)

Why tighter sync?

- So, is tighter sync than 3 us needed in 5G ?
- Some optional function depending on Cyclic Prefix (e.g., CoMP), still under study (but not necessarily resulting in standard specifications for inter-site deployments..); see also 3GPP Contribution *R4-1807182*
- Based on request by some operators, studies in ITU-T on the feasibility of solutions targeting end-to-end time synchronization requirements on the order of +/- 100 ns to +/- 300 ns
  - To address specific applications or potential future requirements, not necessarily related to 3GPP 5G requirements, e.g.:
    - Distribution of sync reference in the upper layer of the sync network (monitoring, redundancy)
    - Future proofness
- Related aspects
  - Enhanced SyncE and New clock types being defined in ITU-T
  - Important to select a synchronization interface that can support the relevant accuracy
  - Relative phase error between ports of the same node is also important

Architectural aspects: 5G Transport

- Various standardization bodies are addressing the topic of 5G. One main example from ITU-T (SG15 (Transport, Access and Home)
- **GSTR-TN5N**: Technical Report on 5G transport (February 2018)
  - Reference model for the 5G transport network and deployment scenarios.
  - Requirements on transport networks to support 5G networks and details on the interfaces between the 5G entities and the transport network
- **Gsup.5gotn** :
  - *use of existing OTN technology to address the requirements to support 5G transport in the fronthaul, middlehaul and backhaul*
- **G.ctn5g** :
  - *frame format that provides hard isolation between aggregated digital clients (digital streams to/from 5G entities and other digital clients carried in the access, aggregation and core networks).*
- When is sync is carried over the transport network, specific aspects need also to be studied if new transport technologies and architectures are defined



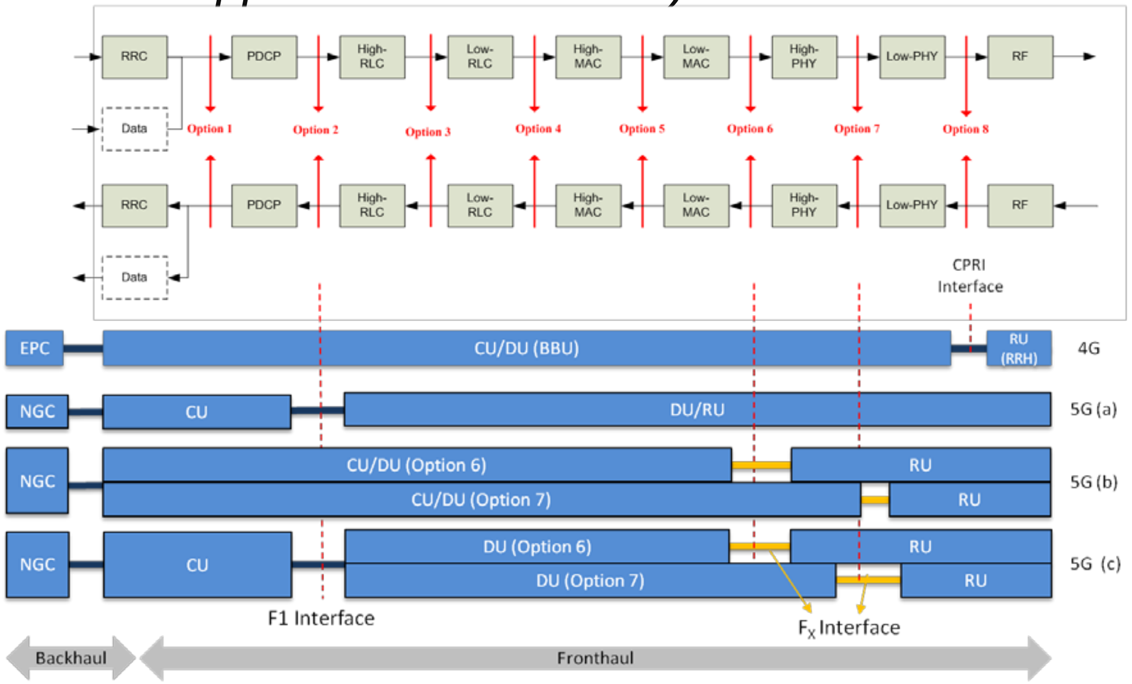
From ITU-T GSTR-TN5G

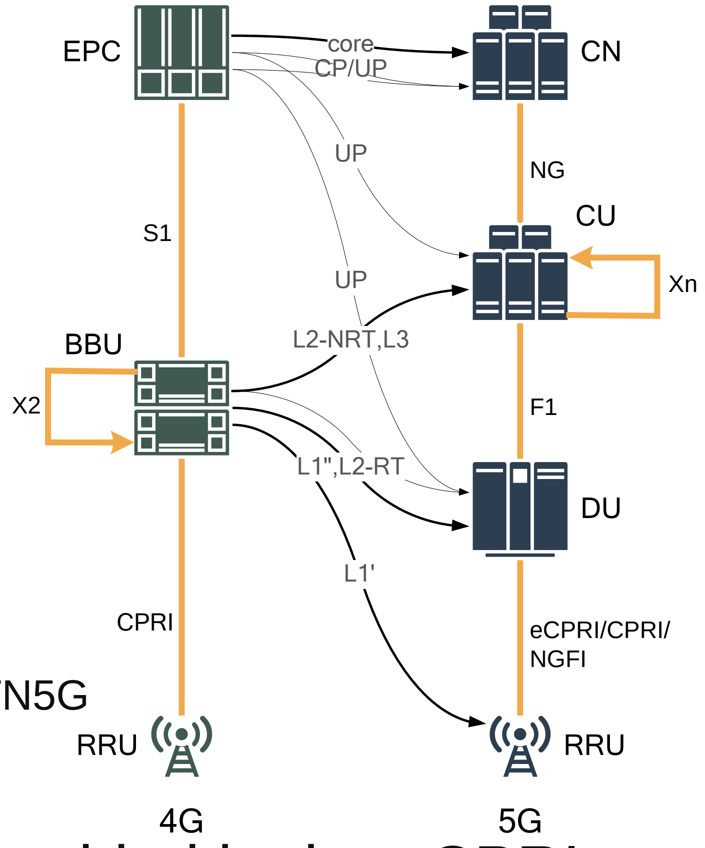
Architectural aspects: Fronthaul

— Fronthaul (Radio access) is evolving in 5G : original BBU function in 4G/LTE is split into three parts: Central Unit (CU), Distributed Unit (DU), and Remote Radio Unit (RRU).

— IEEE 802.1CM referring to eCPRI sync requirements and describing the sync solutions (e.g., ITU-T 1588 telecom profile)

Evolving from single-node in 4G to split function architecture in 5G (from ITU-T TR Transport network support of IMT-2020/5G)





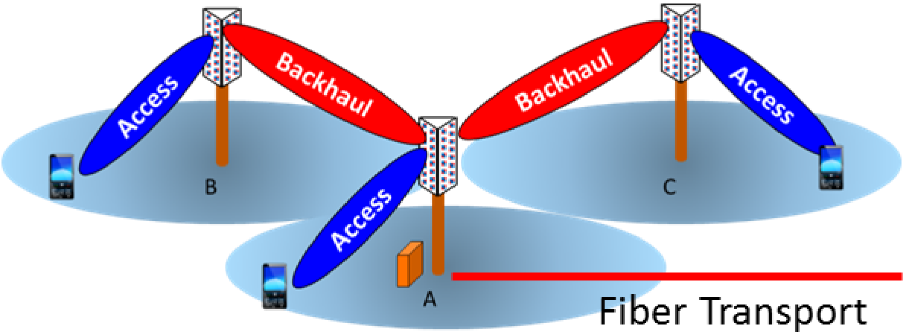
From ITU-T GSTR-TN5G

Sync not embedded in the eCPRI; external methods needed

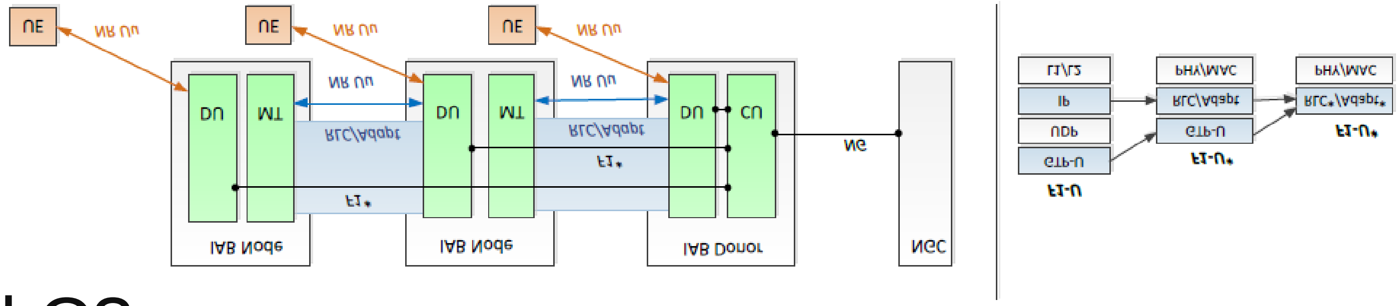
Architectural aspects: IAB

— 3GPP IAB study item to define integrated access and backhauling (IAB) solutions for NR

"A wireless multi-hop self-backhauling architecture is a critical feature for NR"



From RP-170217, Motivation for Study on Integrated Access and Backhaul for NR



From R3-181502, Way Forward – IAB Architecture for L2/3 relaying (WG3 Meeting #99)

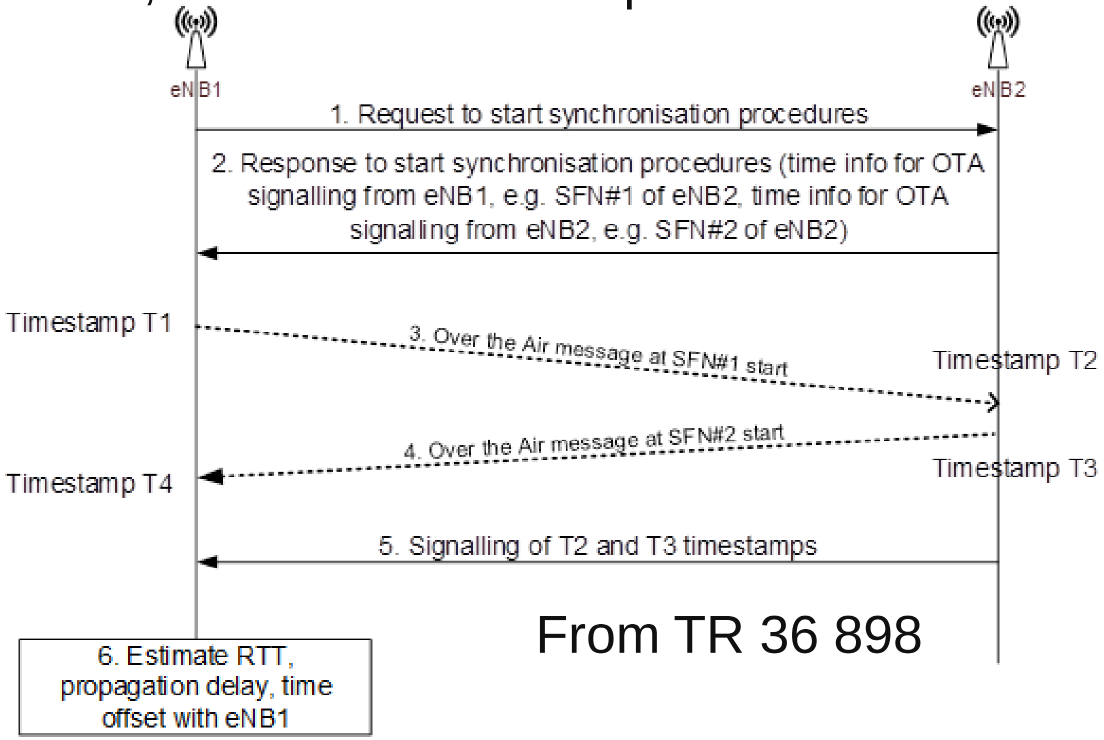
How to deliver sync to B and C?

Solutions

- Sync methods outlined in G.8271: GNSS and PTP with full timing support for the most stringent requirements as main approaches.
- To address cases where the last segment of the network does not provide IEEE 1588 support, alternative methods may be considered (APTS, RIBS - Radio Interface-Based Sync)
  - RIBS is presented in 3GPP TR 36.922; signalling messages in TS 36.413 and TS 32.592; TR 36.898 Network Assistance for Network Synchronization, with solution to compensate for the delay

Specific additional requirements for RIBS:

- Compensation for delays from the source cell (for phase sync)
- Optionally distribution of Time sync information (GPS time, UTC, time etc.) for applications requiring it



From TR 36 898

Conclusions

Sync in 5G

- Sync is one of the key enablers for 5G

Requirements

- LTE sync requirements generally still valid: current sync networks can support 5G

Architectures

- New Architectures and transport technologies may impact sync solutions

Solutions

- GNSS; PTP with FTS
- Complementing solutions (APTS, RIBS)

References

- 3GPP TS 38.211, NR; Physical channels and modulation
- 3GPP TR 23.501, System Architecture for the 5G System, Stage 2 Release 15
- 3GPP TR 38.401, “Architecture description”
- 3GPP TR 38.801, “Technical Specification Group Radio Access Network; Study on new radio access technology: Radio access architecture and interfaces”
- 3GPP TS 38.104, Base Station (BS) radio transmission and reception (Release 15)
- 3GPP TS 38.133, Requirements for support of radio resource management (Release 15)
- 3GPP TS 38.300, NR; NR and NG-RAN Overall Description; Stage 2
- 3GPP TS 38.340, Evolved Universal Terrestrial Radio Access (E-UTRA) and NR;Multi-connectivity;Stage 2
- 3GPP TS 36.300, Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description
- 3GPP TR 36.898 Network Assistance for Network Synchronziation
- 3GPP TR 36.922 TDD Home eNode B (HeNB) Radio Frequency (RF) requirements analysis
- 3GPP TR 38.803, Study on new radio access technology: Radio Frequency (RF) and co-existence aspects
- 3GPP TS 38.913, Study on Scenarios and Requirements for Next Generation Access Technologies.
- eCPRI Specification V1.0, "Common Public Radio Interface: eCPRI Interface Specification", August 2017
- 3GPP TR 38.874 (Study on Integrated Access and Backhaul)
- 3GPP TS 36.133, Requirements for support of radio resource management
- R4-1807182, Input to WF on NR BS TAE for inter-BS for MIMO, TX diversity and continuous CA (http://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_87/Docs/R4-1807182.zip)
- R4-1703013, TDD timing budget (http://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_82Bis/Docs/R4-1703013.zip)

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