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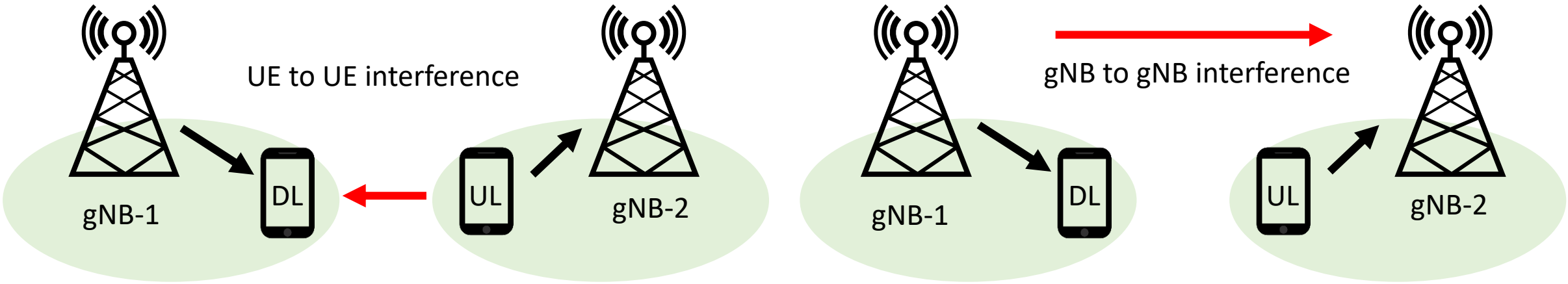
Real Measurements of 5G NR Sync

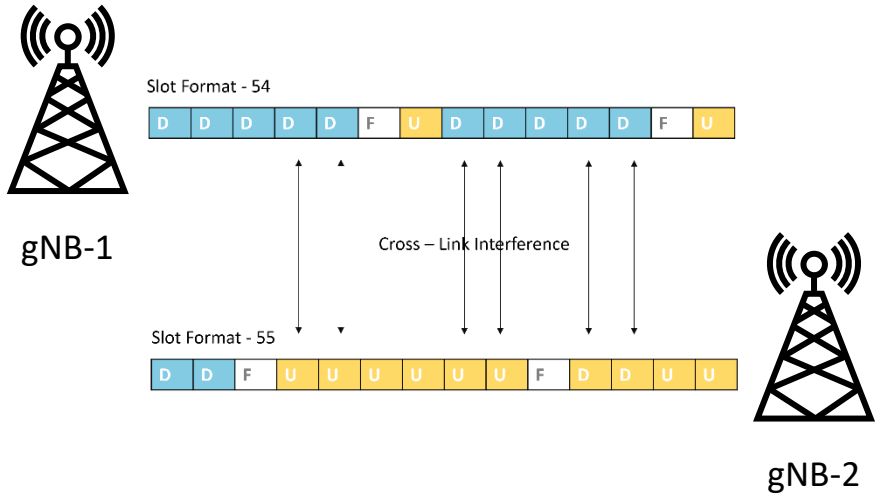
WSTS, March 2021

Topics

- Overview of 5G networks and synchronisation requirements
- Overview of 5G NR Synchronisation Signals
- Measuring synchronisation ‘Over the Air’

TDD Interference Scenarios – Why Sync Matters

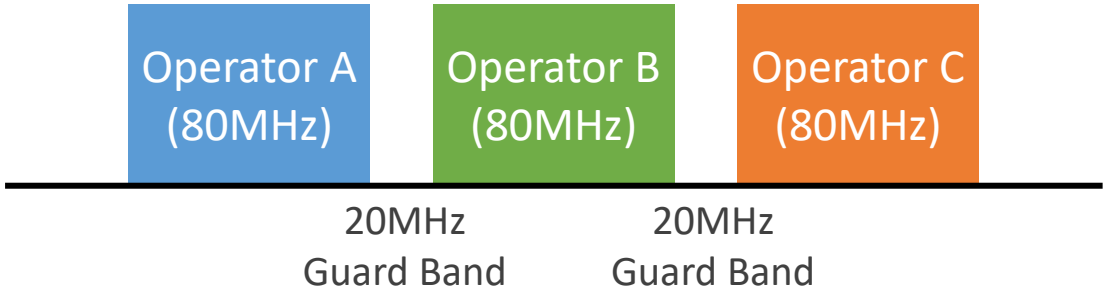




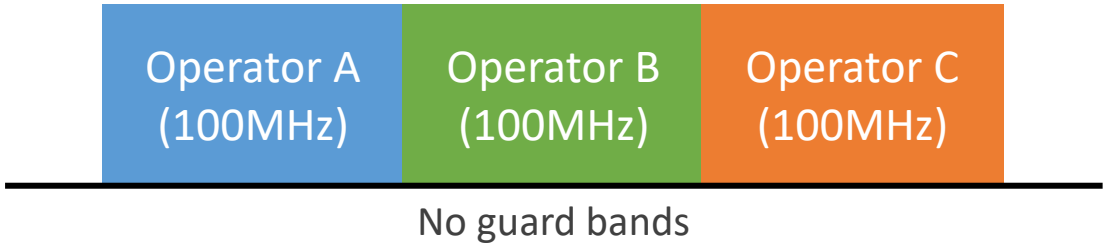
Inter-Operator Synchronisation

- At 5G, operators want to remove frequency guard bands to gain spectrum:

With frequency guard bands:



Without frequency guard bands:

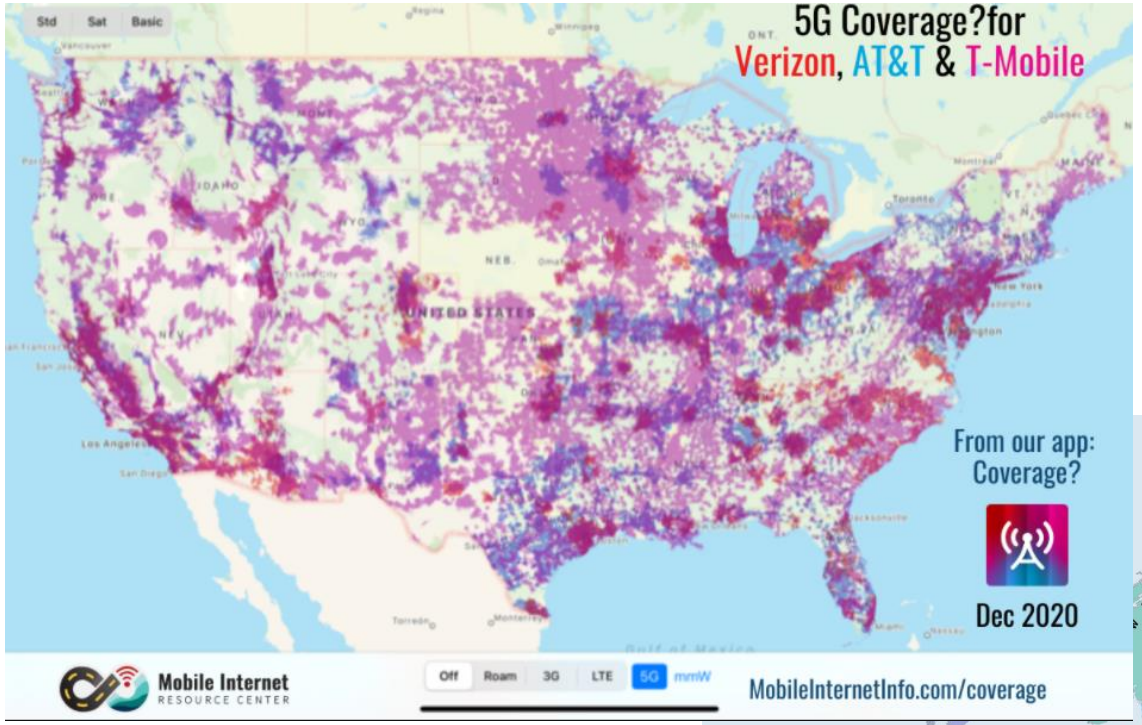


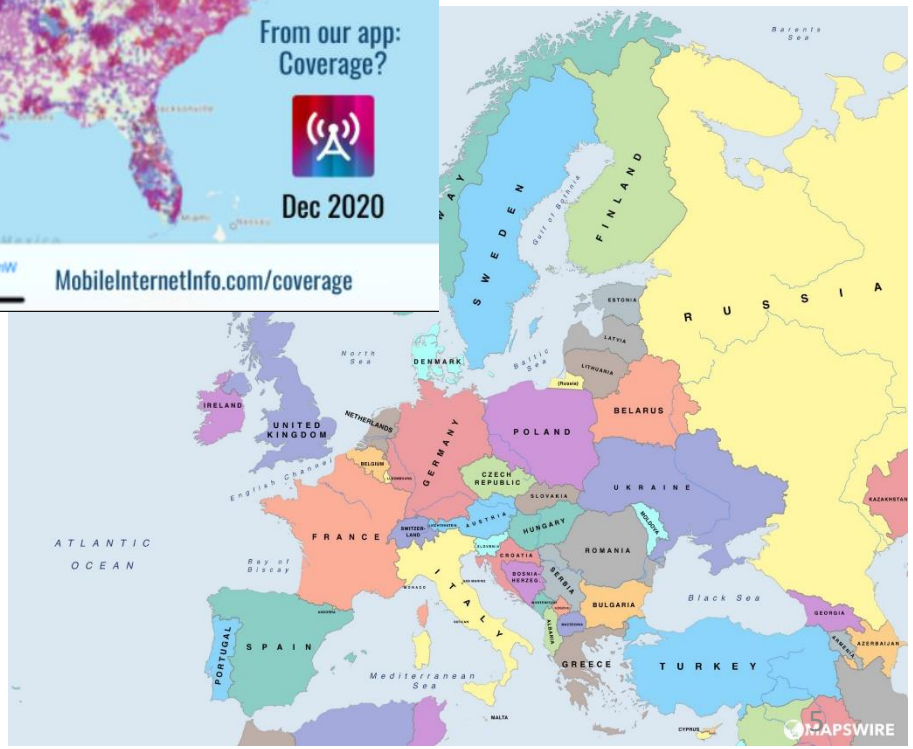
- To avoid interference, all operators must:
  - Synchronise to the same time reference, e.g. the national time reference for the country
  - Use the same frame structure (pattern of downlink and uplink frames)
- National (and even international) co-ordination will be required
  - See *"5G TDD Synchronisation: Guidelines and Recommendations for the Coexistence of TDD Networks in the 3.5 GHz Range"*, GSMA, April 2020

Elimination of Guard Bands Means …

Measure:

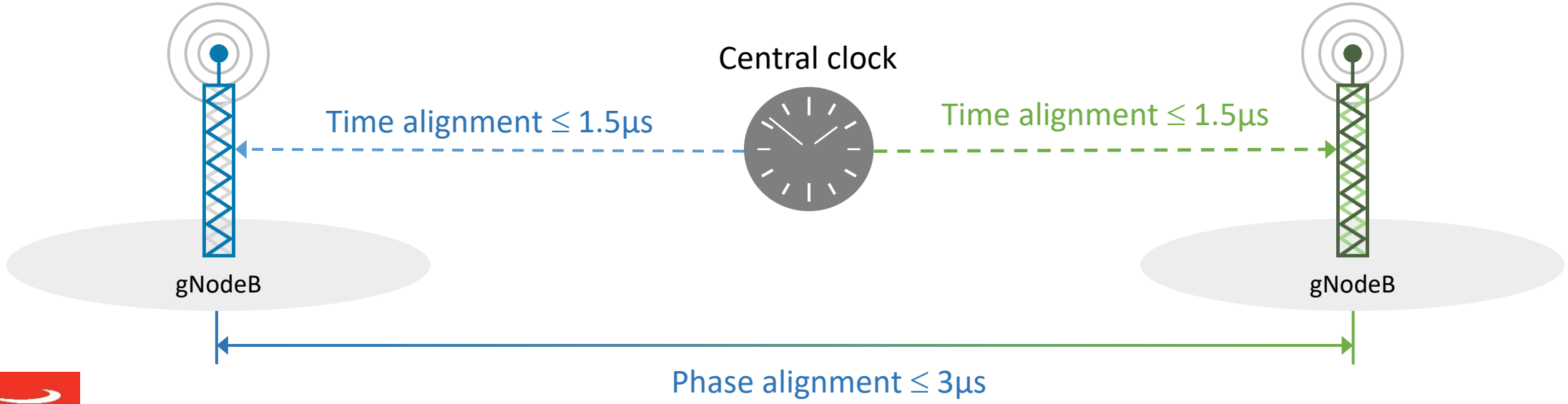
1. Your own network gNbs
2. Between your network and another operator
3. Networks across national boundaries
4. 5GNR Sync **Over the Air**





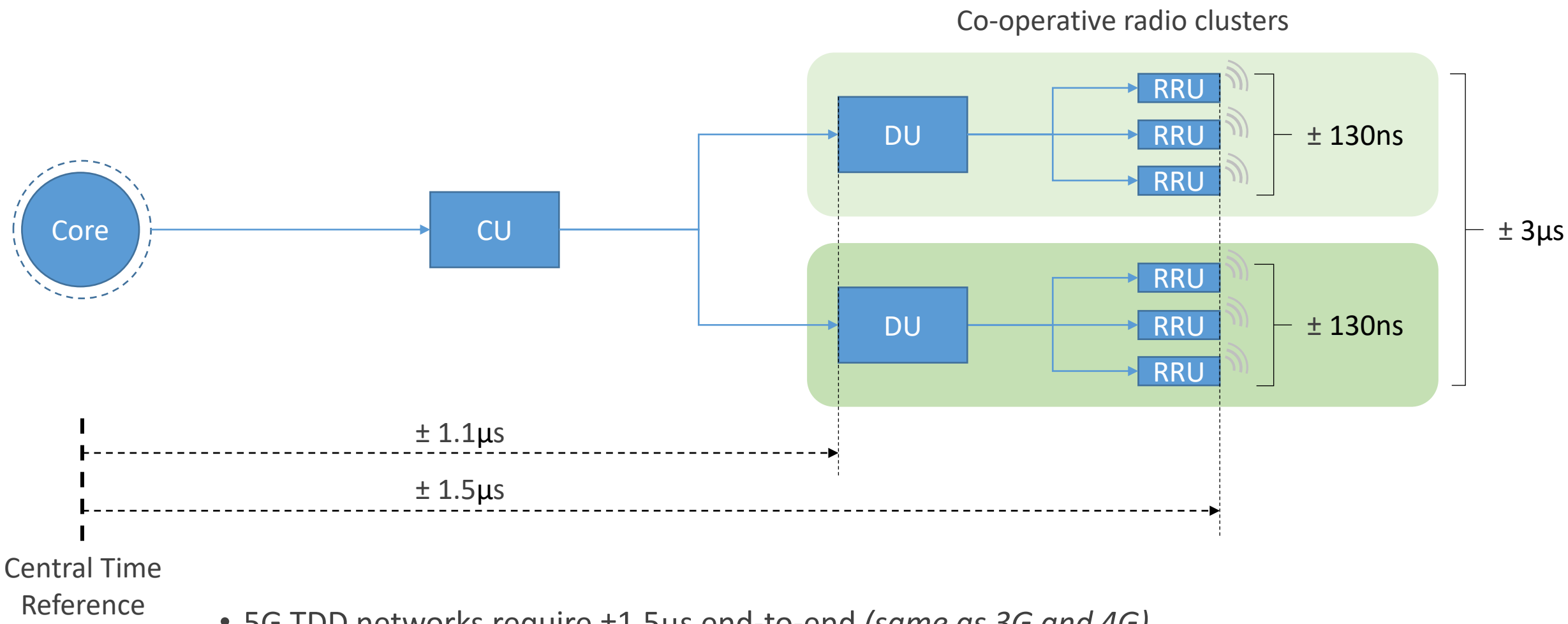
Synchronisation Requirement

- "The cell phase synchronization accuracy measured at BS antenna connectors shall be better than 3 µs" *
- This is a ***phase requirement*** (i.e. it is relative to the other cell), not a ***time requirement.*** It is the same as 4G.
- It is normally implemented as a ***time requirement*** to a ***central clock.***
  - ITU-T requirements specify this as within 1.5µs of a common time reference (G.8271).



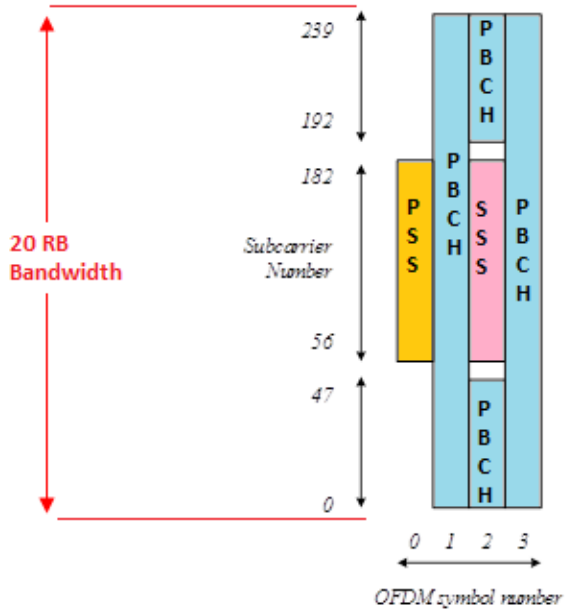
* 3GPP TS 38.133, section 7.4.2

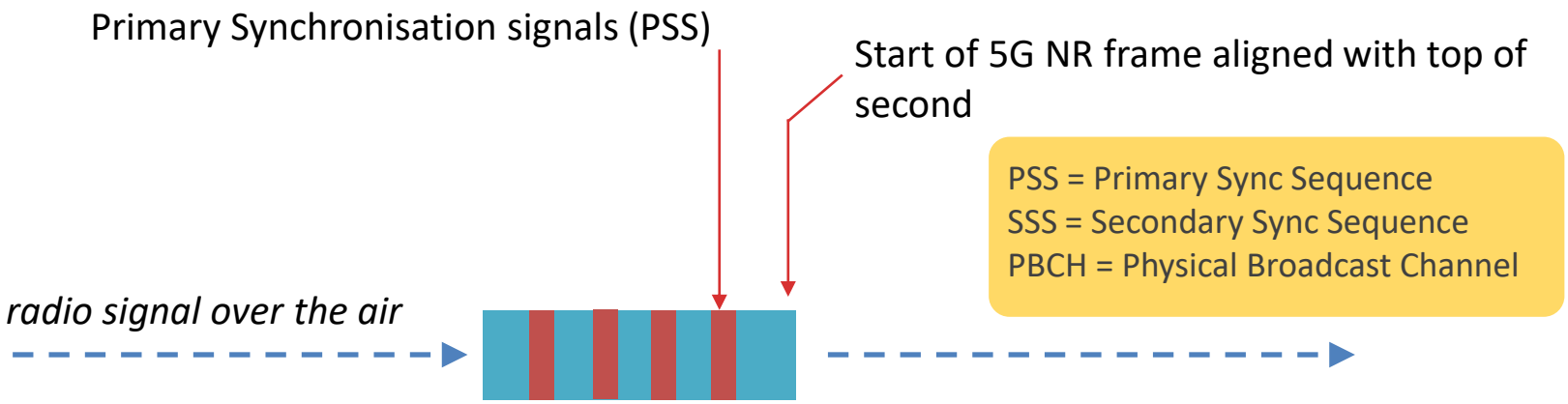
5G Network Requirements



- 5G TDD networks require ±1.5µs end-to-end *(same as 3G and 4G).*
- Co-operative radio techniques (e.g. intra-band CA, CoMP, MIMO) require much tighter synchronization between RRU's.
- ±130ns relative Time Alignment Error (TAE) between each RRU in a cluster.

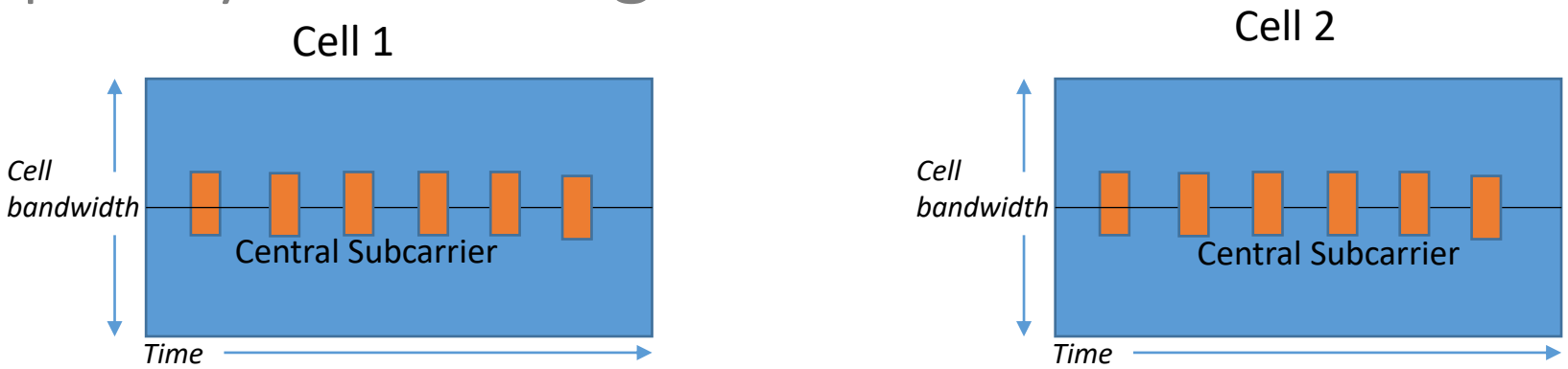
5G Synchronisation Signal Block (SSB)



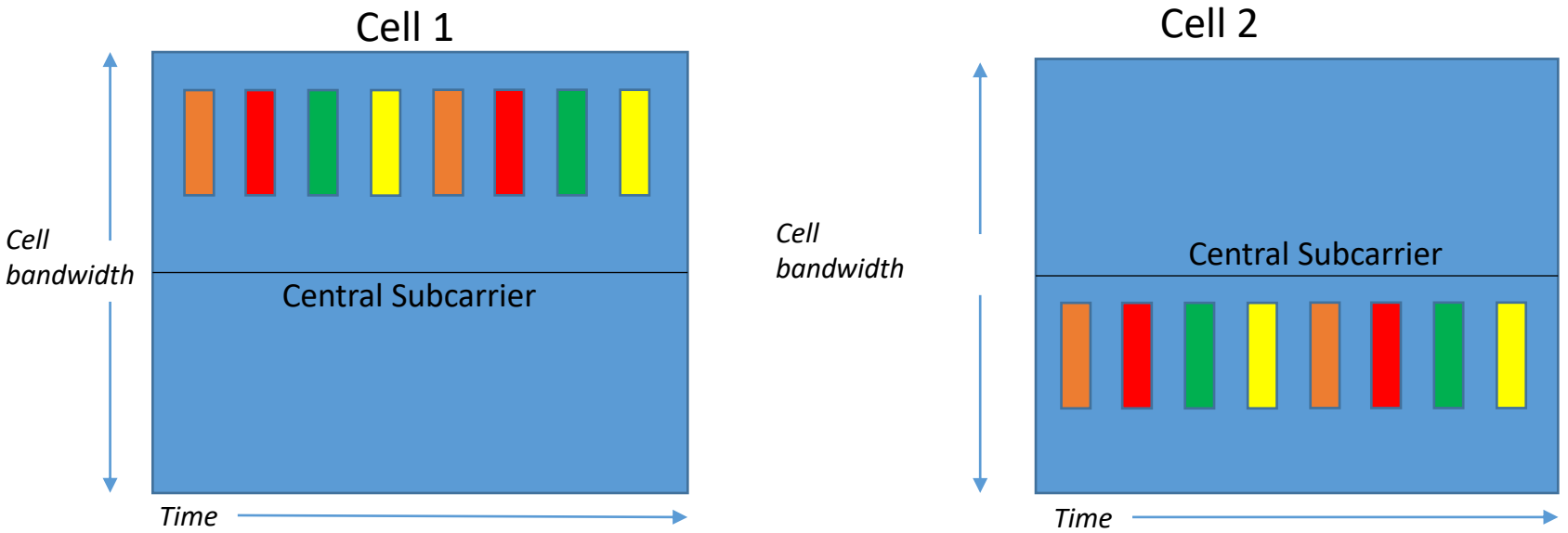


- The cell provides synchronisation signals to allow a UE to align to the radio interface timing.
  We can use these signals to measure the accuracy of the time alignment of the cell relative to top of second.
- The PSS and SSS signals are each 127 symbols wide and one symbol long in time – spread across contiguous sub-carriers , compared to 62 symbols for 4G – better correlation and sync reliability.
- SSBs are transmitted in bursts. There are multiple SSBs per burst. Bursts are repeated periodically.
- The PSS and SSS also encode the physical cell ID (PCI), which ranges from 0 - 1007

Frequency Positioning of the SSB



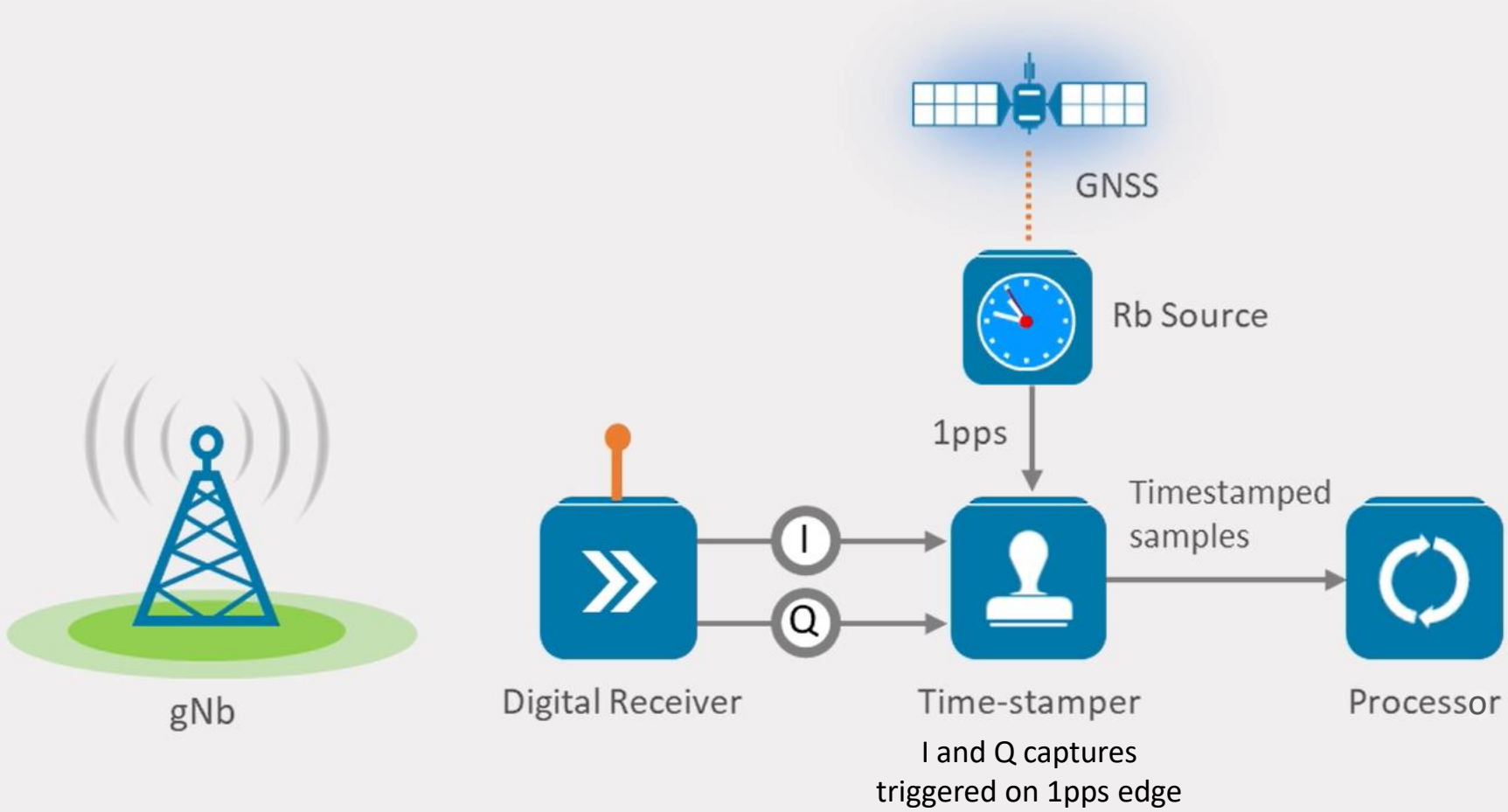
4G – Sync signals are positioned around the central subcarrier – same for all cells.
Leads to interference between cells.



Different colours represent different beams

5G – Sync signals are positioned somewhere on the sync raster – this can be different for each cell.
Less interference but makes them harder to find.

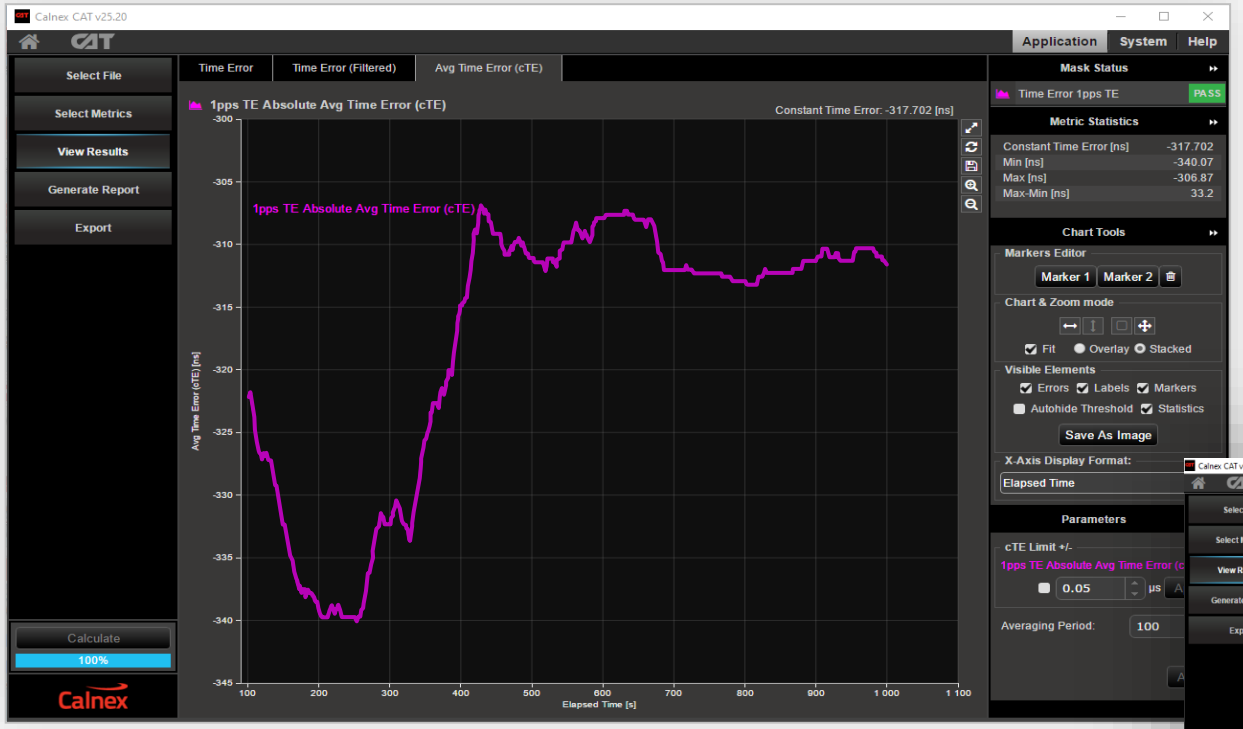
How do you measure 5G NR Sync Over-the-Air?



Process samples to:

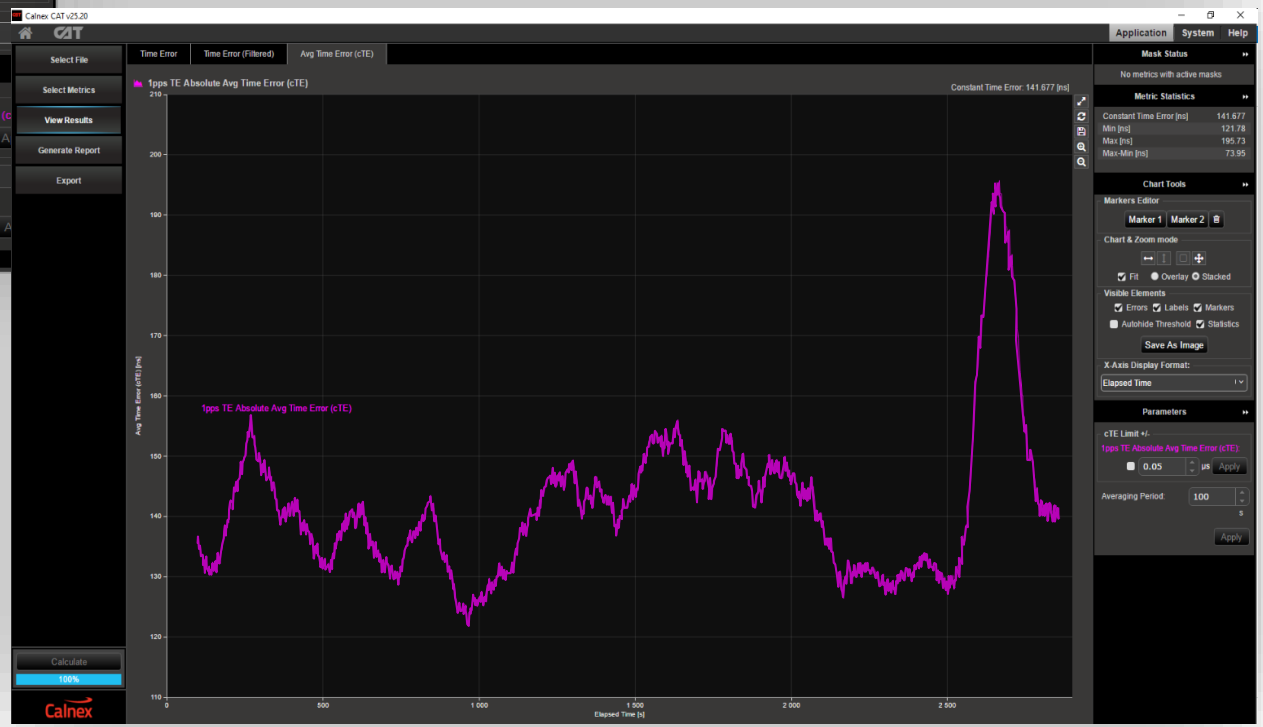
- Find PSS/SSS
- Check cell ID
- Calculate time to start of frame

5GNR Sync OTA Measurements



Constant Time Error (cTE) 318ns
Variation (1000s) 33ns

Constant Time Error (cTE) 142ns
Variation (2800s) 74ns



Conclusions

- 5G measurement requirements
  - Validation of TDD sync for Interference management
  - Validation of TDD sync for Cross-Network Interference management

- The only practical way to measure small cells and to do relative measurements between adjacent cells is using an over the air method.

- The 5GNR synchronisation signals provide a way for doing this – although they are transmitted relative to a central clock – often at the end of a synchronisation chain.

- Operators should plan to measure the timing of these relative to a GNSS and provide an accurate measurement of each cell relative to UTC – or relative to one another.

With thanks to James Orr, Hongyan Kuai, Eric Percival and Tim Frost for their contributions