Will 6G require additional synchronization capabilities?

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WSTS 2025

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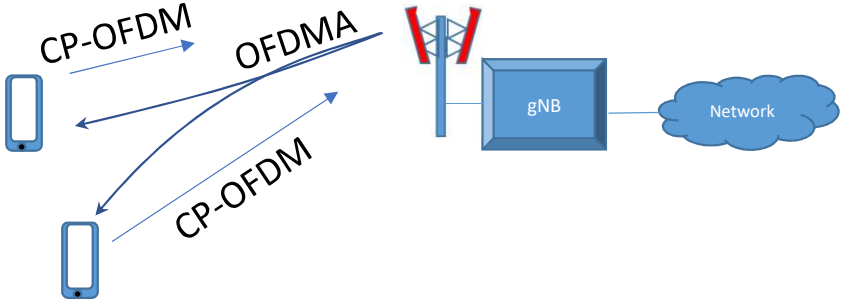
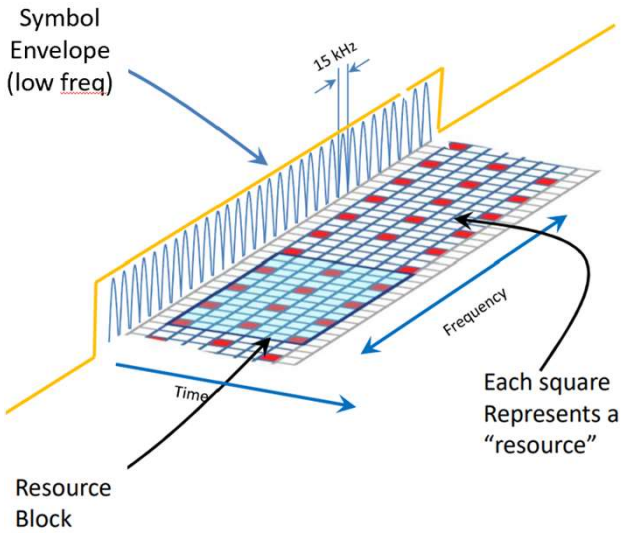
Purpose and focus

- Planning for 6G, also known as IMT-2030, is underway in standardization forums, with detailed standards development to begin within 18 months with the target of deployments in 2030
- New functionality can be expected, but will this require to changes the way we treat synchronization and what scope?
    - Network sync
    - Radio/equipment
- Recall that wireless sync requirements are already stringent
    - time-sync from the network
    - native 50ppb holdover in base-stations
- This presentation focuses on potential sync aspects only, given the nature of this conference

Recall why accurate timing needed in wireless

- OFDMA/OFDM physical layer
  - High user bandwidths, with low symbol rate, tolerant to multipath
  - Supports connection of multiple terminals
  - Performance impacted: inter-carrier interference (ICI) and inter-symbol interference (ISI)
  - Use of pilot-based clock recovery allows managing of ICI, while use of cyclical prefix manages ISI
  - Terminal mobility still requires coordination (timing advance)
  - Maintaining spectrum limits requires frequency
- Timing is provided over backhaul
  - Time and frequency to support both FDD and TDD
  - may include a fronthaul network
  - Goal is to maintain 50 ppb over the air interface with controlled time-offsets





6G objectives build upon previous technology

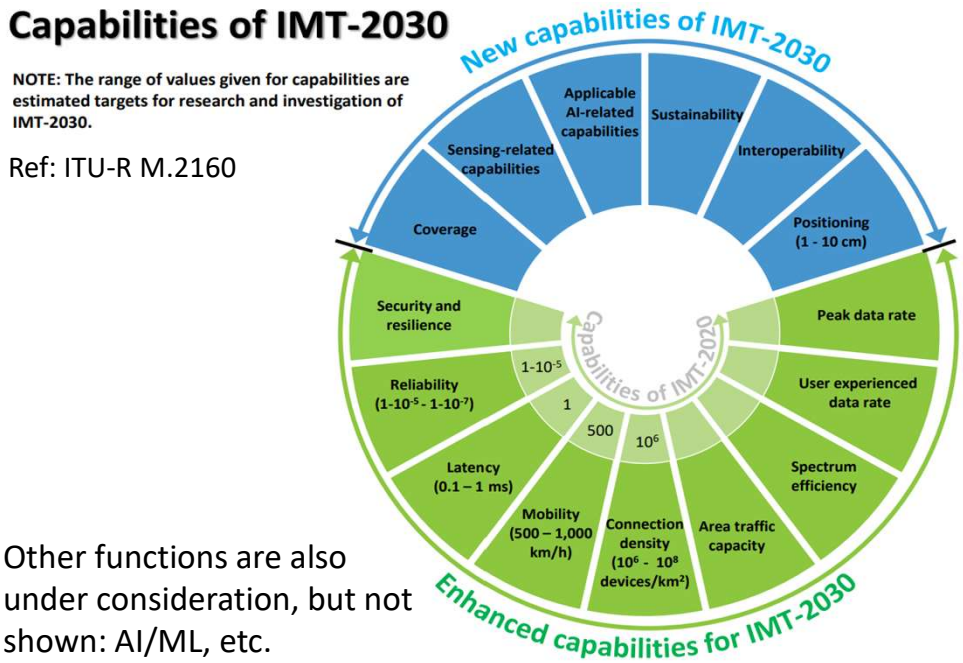
Main guidance currently in ITU-R:

- **ITU-R M.2160**: Framework and overall objectives of the future development of IMT for 2030 and beyond
- "High reliability and low latency noted to support time-synchronized operations (Ref: M.2160)"
- **Report M.2516**, Future technology trends of terrestrial International Mobile Telecommunications systems towards 2030 and beyond

Detailed capabilities to be developed in 3GPP

	5G	6G
User experienced data rate	**100 Mbit/s**	**300,500Mbit/s**
Spectrum efficiency	**3x(over LTE)**	**1.5-3x over 5G**
Mobility	**500 km/h**	**1000 km/h**
Latency	**1ms**	**0.1 ms**
Connection density	**10^6 devices/km^2**	**10^8 devices/km^2**
Network energy efficiency	**100x**	**-**
Area traffic capacity	**10 Mbit/s/m**	**30, 50 Mbit/s/m**
Peak data rate	**20 Gbit/s**	**50, 100, 200 Gbit/s**

New capabilities of 6G/IMT-2030



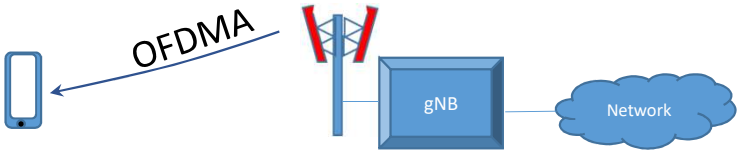
Ref: ITU-R M.2160

Other functions are also under consideration, but not shown: AI/ML, etc.

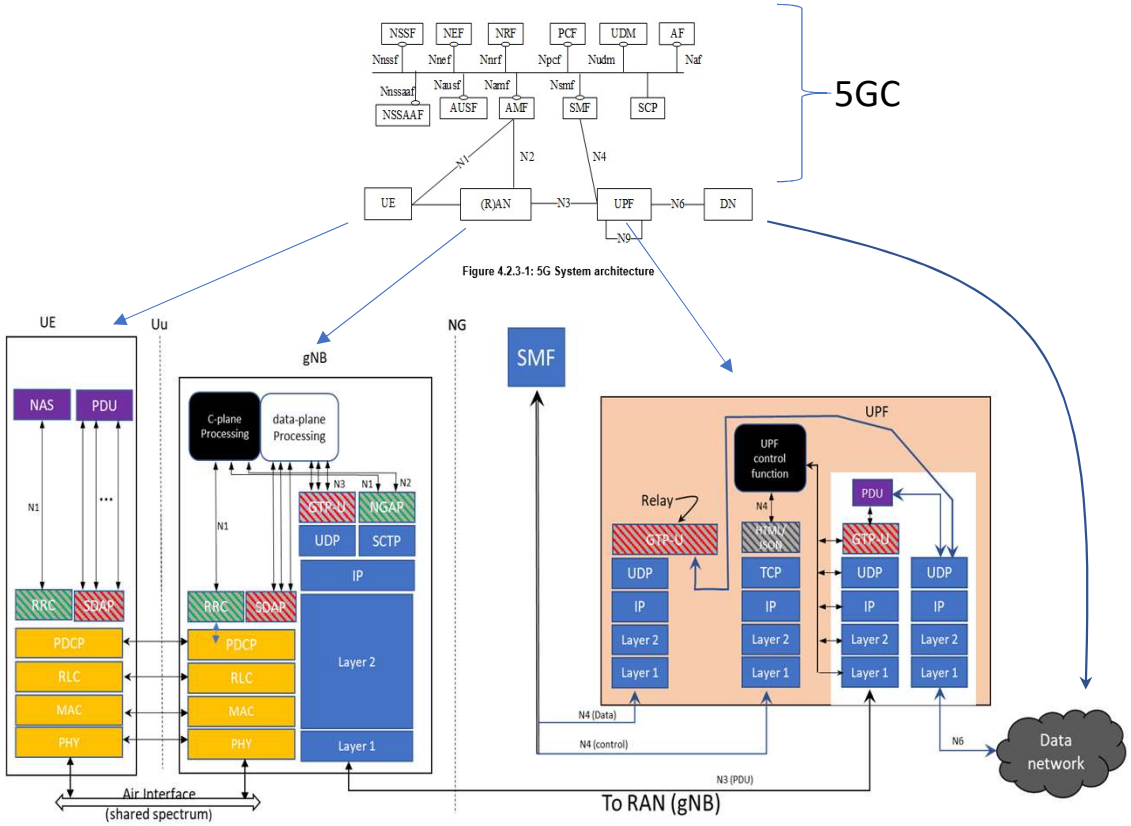
High reliability and low latency noted to support time-synchronized operations (Ref: M.2160)

- New capabilities for 6G are defined (from M.2160):
  - Coverage
    - coverage is defined as the cell edge distance of a single cell through link budget analysis.
  - Sensing related capabilities
    - refer to the ability to provide functionalities in the radio interface including range/velocity/angle estimation, object detection, localization, imaging, mapping, etc. These capabilities could be measured in terms of accuracy, resolution, detection rate, false alarm rate, etc.
  - Applicable AI-related capabilities
    - functionalities include distributed data processing, distributed learning, AI computing, AI model execution and AI model inference, etc.
  - Sustainability
    - Energy efficiency
  - Interoperability
    - Interoperability refers to the radio interface being based on member-inclusivity and transparency, so as to enable functionality(ies) between different entities of the system.
  - Positioning
    - Positioning is the ability to calculate the approximate position of connected devices. Positioning accuracy is defined as the difference between the calculated horizontal/vertical position and the actual horizontal/vertical position of a device

Sync in wireless: potentially complex interactions



- Protocol stack description may aid understanding impacts of sync.
  - Timing distribution (PTP or SyncE)
  - Supporting functions in control may be required to support some functions (e.g. ISAC or positioning)
- Logical interfaces N1, N2 etc connect mix of control/data
  - Note, N1 connection is shown from UE to AMF, but relayed via gNB requiring extra processing.



How new capabilities are impacted?

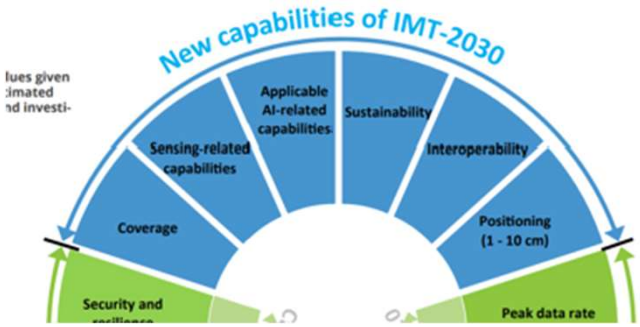
Main areas considered:

Sensing-related capabilities, positioning (treated similarly)

AI-related capabilities

Interoperability (potential NTN sync issues)

New capabilities and sync



What are the sync impacts? (None , possible, likely)

- Coverage
  - Function of the base-station (Sync by design), unlikely to require changes to external (network) sync
- Sensing-related capabilities
  - Sensing is a measurement system and therefore could be impacted
- AI-related capabilities
  - Sync could improve/optimize
- Sustainability
  - No impact on sync
- Interoperability
  - TN/NTN could have some sync impact (PNT)
- Positioning
  - Highly likely to be impacted, given target (1cm-10cm) and existing capabilities (in G.8271)

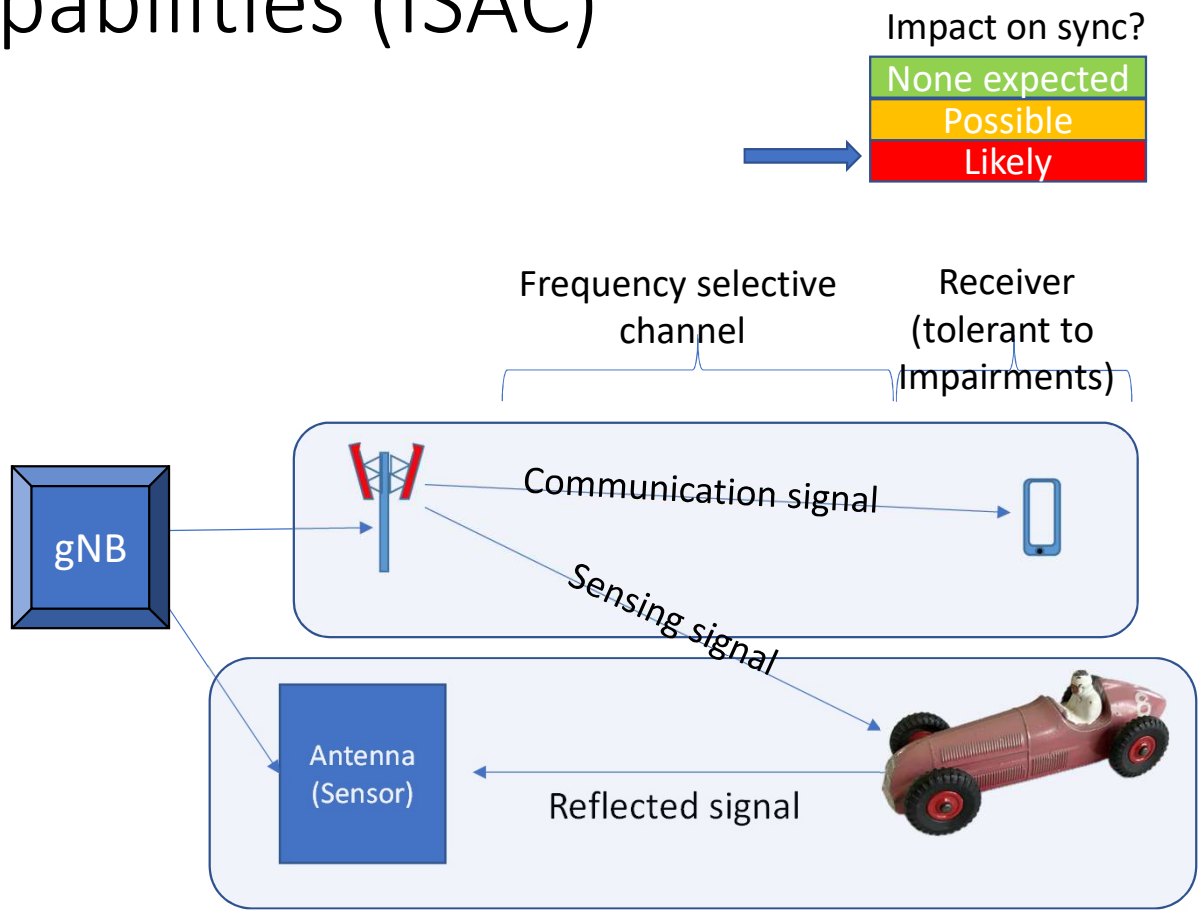
Legend

Impact on sync?

None expected
Possible
Likely

Sensing related capabilities (ISAC)

- Use RF signals from base station to sense surroundings
- Radar-like, early work based on WIFI
- Sense objects/environment
- Sub-meter accuracy
- Utilize algorithms such as MUSIC, SLAM
- Potential to use channel state information



ISAC configurations

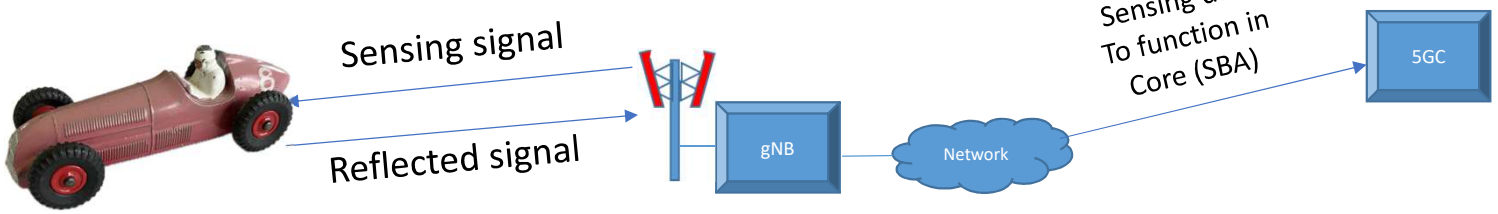
Impact on sync?

None expected

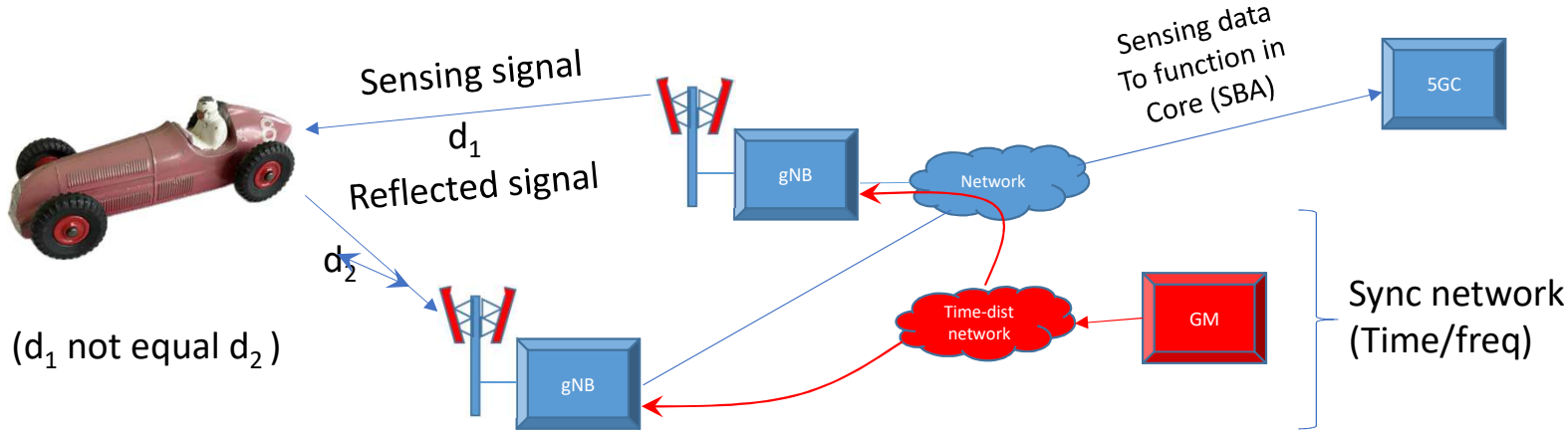
Possible

Likely

Mono-static sensing



Bi-static sensing



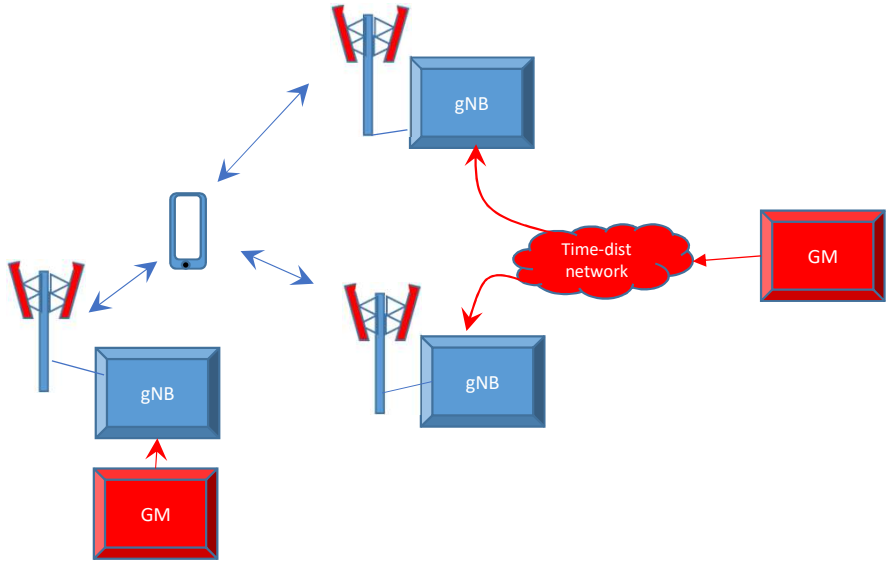
Positioning

Impact on sync?

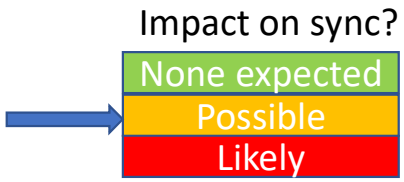
None expected
Possible
Likely

- What is it?
- There has long been a need to allow determination of user location for safety issues (911)
  - Initially mandated use of GPS in handsets
- Related to ISAC, since same system clock
- Methods exist to estimate location without GNSS such as time distance of arrival (TDOA)
  - Multiple base-stations may be involved
  - Accuracy objectives for 6G are very ambitious (1cm to 10 cm)
  - Current capabilities are in the order of 10's of metres
  - Different methods rely on exchange of information between nodes, similar to ISAC, processing differs from the way synchronization has been assessed previously
  - Studies in 3GPP have typically shown sub-metre possible. Sync understood that accuracy is impacted, but so far appears to be constrained to base-station performance, not network
  - High accuracy option
  - Something to watch, given link to emergency services

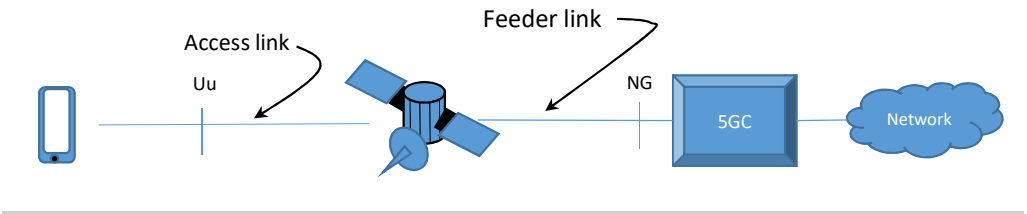
Example methods:
Time of Arrival (TOA)
Time Difference of Arrival (TDOA)
Angle of arrival (AoA)
Angle of Departure (AoD)
(UL/DL and combinations)

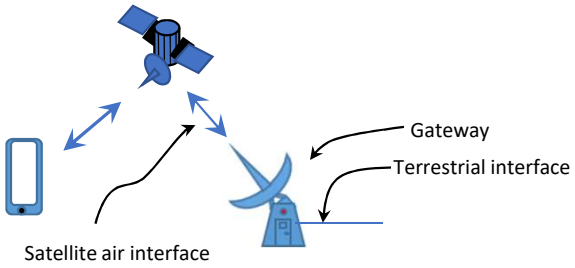


Non-terrestrial networks

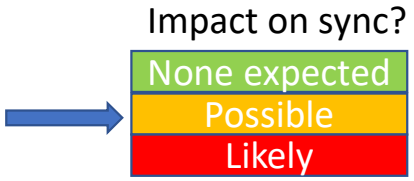


- Non-terrestrial (satellite) networks are part of 5G
  - Generally a “bent-pipe”
  - LEO satellites provided by feeder link with control plane connection to core
  - UE gets location data from GPS
- For 6G, possible operation without GPS
  - What changes to timing over backhaul to support?





AI related issues



- AI/ML is now being considered:
  - 6G to support AI
  - AI to support 6G (e.g. process positioning information)
- Large amounts of data may need to be moved (models, training etc.)
  - No changes needed from sync to support this from the infrastructure perspective
- But, network optimization may benefit from data-centre sync to meet performance goals or to build upon sustainability and energy efficiency.

Summary: potential sync impact of 6G

- Do we need to improve sync?
  - Exact need for greater/different synchronization is still TBD
  - But normative standardization is only 1.5 years away.
- AI/ML are/will be important in 6G
  - Work related to data center sync is an obvious consideration
- ISAC
  - Systems look like the simple monostatic case could work, but further work needed to establish accuracy limits and impact of phase noise from transmitters and from clocks.
  - Key is to make sure that objectives are accurate, to determine suitability if considering safety critical situations
- Positioning:
  - we already have a gap, can we close it? Does synchronization help?
  - Further work is needed to study this.
- NTN
  - NTN relies on GNSS, but direction could be towards a gnss-less operation. Timing distribution in satellites may become an issue.

Thank you.