3GPP SA Rel-18 workshop
Virtual meeting, 09-10 Sep. 2021
Agenda Item 3

SP-210612

Space-Time synchronization:
Phase synchronization, clocks, and positioning in advanced regime

Perspective for Rel 18

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National Institute of
Information and Communications Technology

Clocks and positioning: Background & Current status

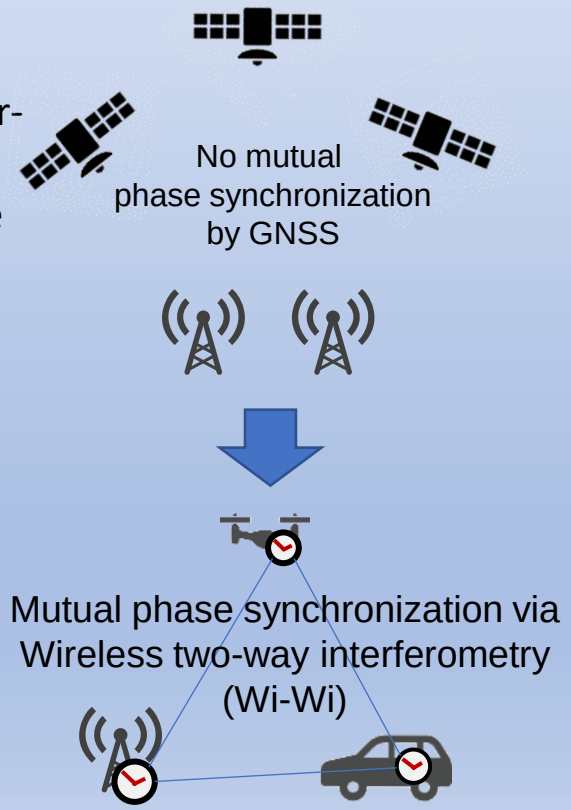
a. Phase Synchronization of network

Phase synchronization is necessary for
wireless power transfer (for cell phonses, drones) &
sub-cm positioning (for outdoor/Indoor)
→ GNSS does not provide phase synchronization

Current situation

- GNSS cannot synchronize the carrier-phase of mm-waves
- Wired synchronization has been the only phase synchronization solution for distanced modules.

- Terrestrial wireless synchronization and positioning anticipated for Indoors, tunnels, and urban area.
- It is also good for the resilience against GNSS non-availability



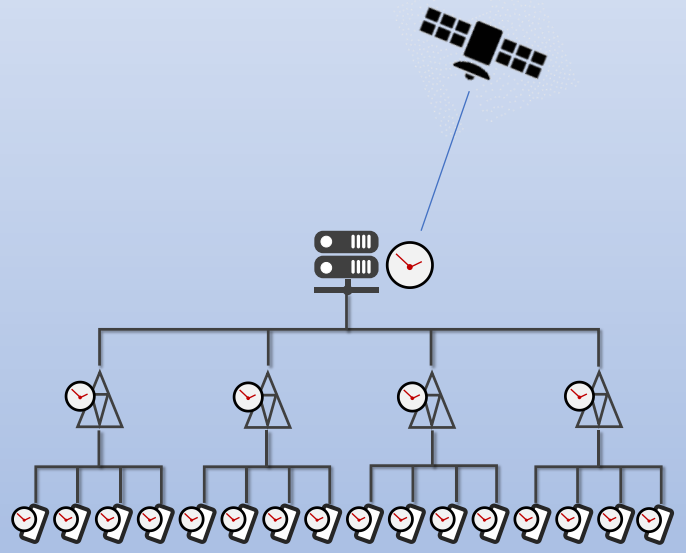
b. Clocks in terrestrial network

M2M, V2X, sidelinks, edge-computing, …

Clock system is becoming more critical as an infrastructure for URLLC

Current situation

- Dependent on GNSS
- GNSS needs lengthy signal integration for high precision
- UE are not synchronized at the GNSS level
- Synchronization error is accumulated at the end of clock hierarchy



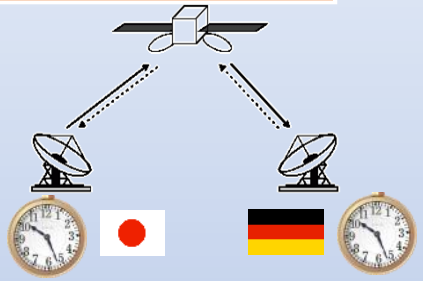
- Local 5G inspires local sharing of various resources. Clocks as well?

Proposal

a. Phase synchronization of network

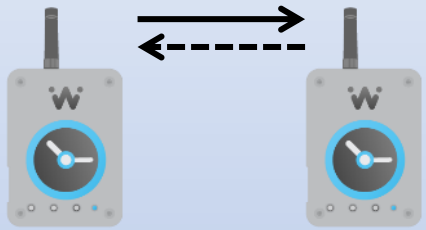
New technique for precision synchronization in pico-second level has been developed.

Pre-existing technology



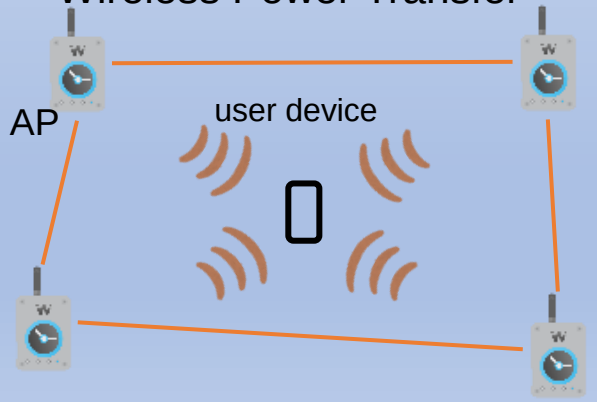
measurement of clock difference and transmission delay via satellite communication. Using carrier-phase for the ultimate precision.

New!



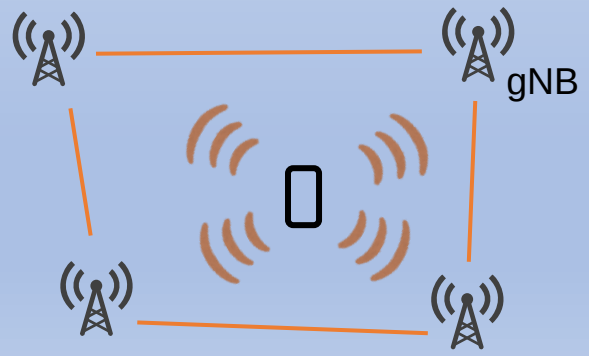
Synchronization of clock difference and distance via wireless communication. Using carrier phase for precision and reduced bandwidth

Wireless Power Transfer



Phase synchronized RU's enable constructive interference for WPT

Carrier Phase positioning



Phase synchronized APs enable precise positioning

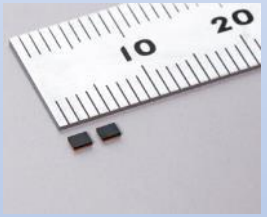
b. Clocks in terrestrial network

Distributed clock system where chip-scale atomic clocks are distributed over RAN.

New trend on Micro acoustic devices

+ BAW OSC. on market
  A clock chip using thin-film acoustic resonator instead of bulk X-tal is put on the market for low power consumption app. (sensor network)
+ Multi-layered SAW operatable in several GHz band
+ Foundry service including on-chip acoustic device

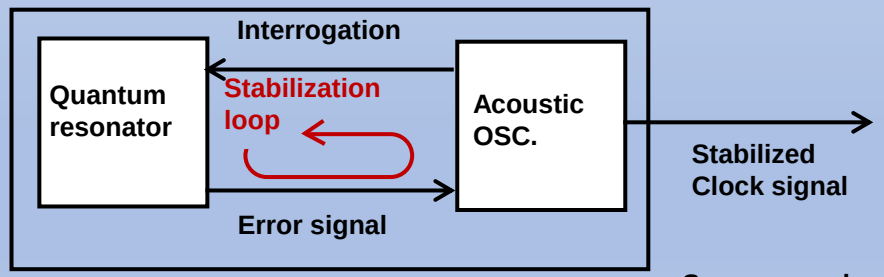
https://www.ti.com/



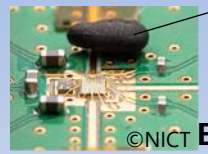
https://www.murata.com/en-us

High-Q acoustic resonators at GHz are now becoming available in a compact size at low cost with affordable design costs.

Atomic clock



Rb gas cell

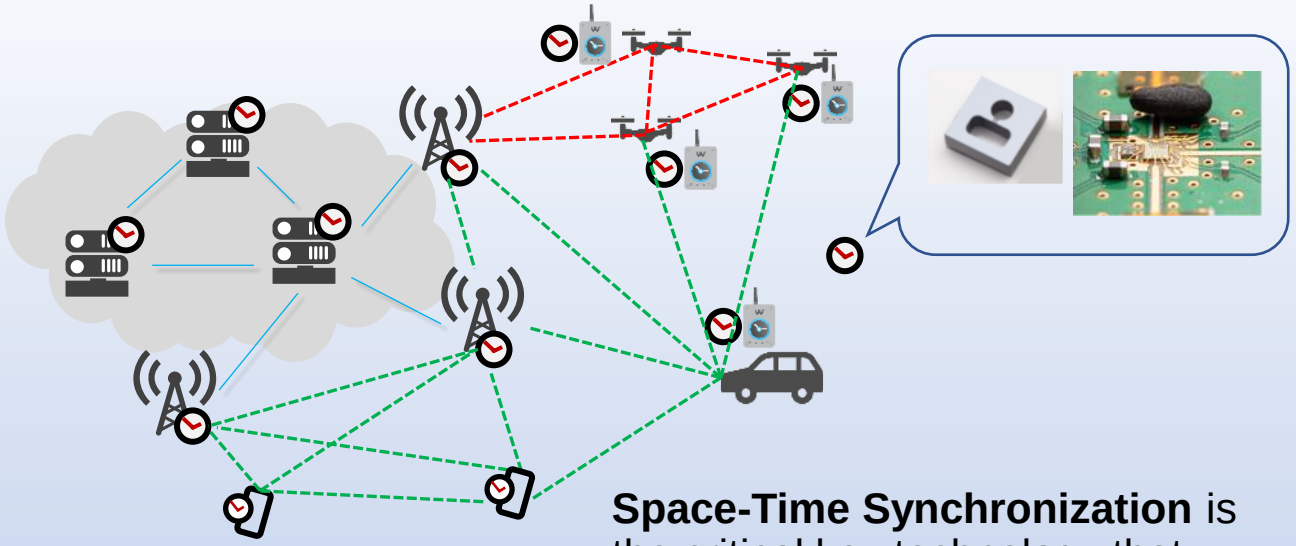


BAW OSC.

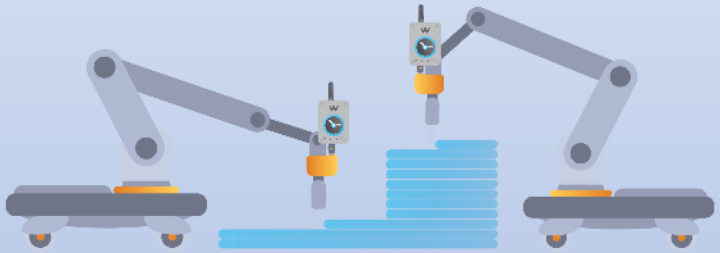
Possible evolution as a system

Carrier phase synch. (Wi-Wi) x Atomic clock chip
+ self clock-correction policy

=Decentralized synchronization (Cluster clock)



- ✓ Flexible
- ✓ Robust
- ✓ Reliable
- ✓ Inclusive
- ✓ Resilient
- ✓ Good stability



Space-Time Synchronization is the critical key technology that allows clock synchronization and indoor/outdoor localization in high precision, providing infrastructure of M2M, V2X, and even highly energy-efficient communications

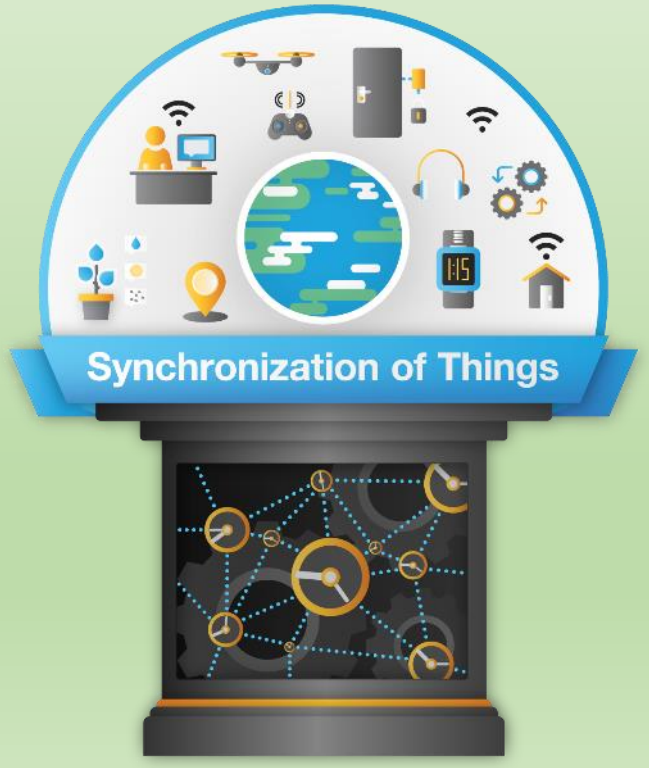
Objective for Rel. 18

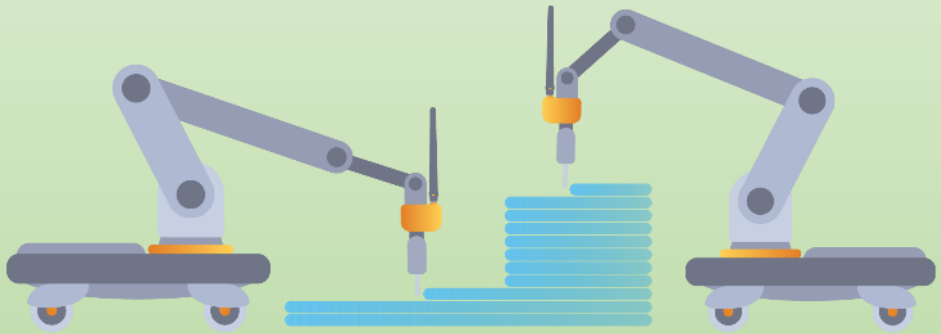
1. Specify the precision and stability of the clock (time/frequency) that gNB, UE and (micro-)cells equip
   - Reliability indicators to refer the external clocks using sidelinks
2. Specify the phase synchronization factor between gNBs
3. Specify the precision of the position
   - Precision indicators to refer the positions of gNB, UE. The accuracy of the positions change dynamically and needs to be updated
4. Study use cases and methods to share and to make use of the space-time information of gNB, UE, RU, …etc.
   - For example, decentralized synchronization for resilience

Appendix

a. Phase synchronization of network: perspective

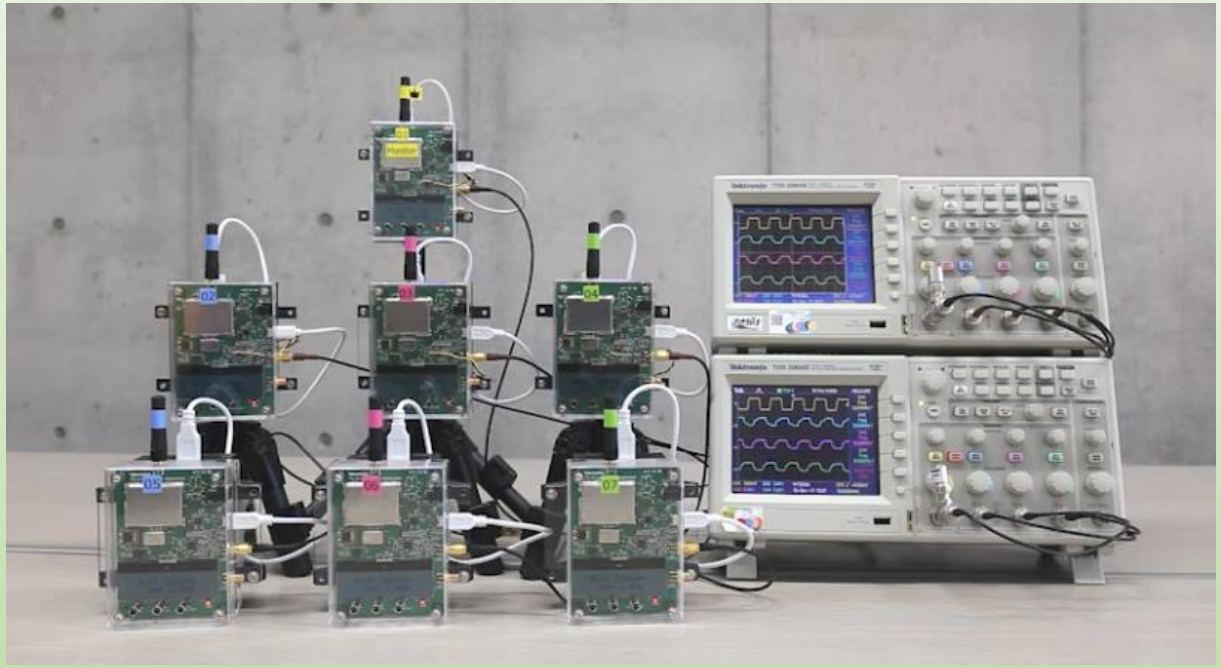
Space-Time Synchronization is a state where the internal clock of devices is **synchronized** and the **position** of devices is mutually recognized in the local area.





Space-Time Synchronization is the critical key technology that allows clock synchronization, indoor/outdoor localization, wireless power transfer, orchestration of machines, by use of accurate carrier phase manipulation.

a. Phase synchronization of network : R&D in NICT

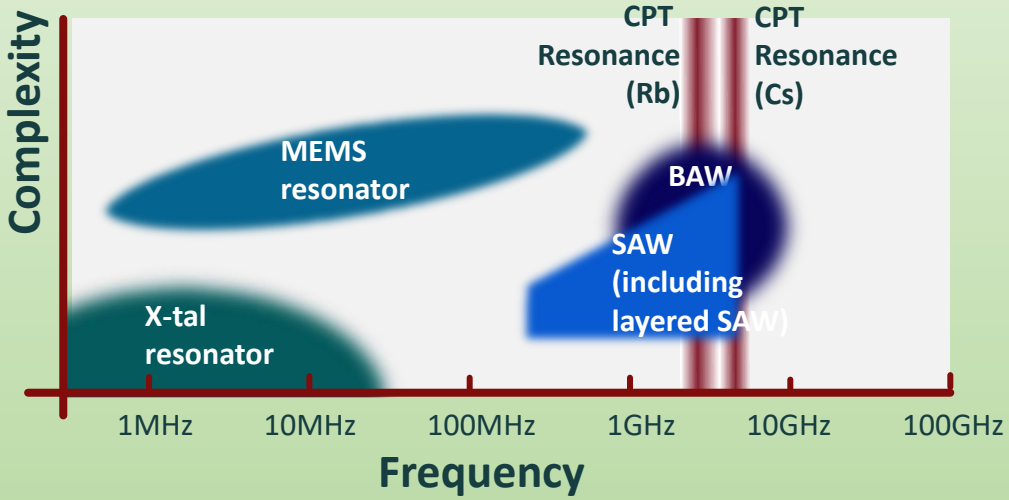


Demonstration of Phase-locked synchronization of 7 modules via Wi-Wi technology

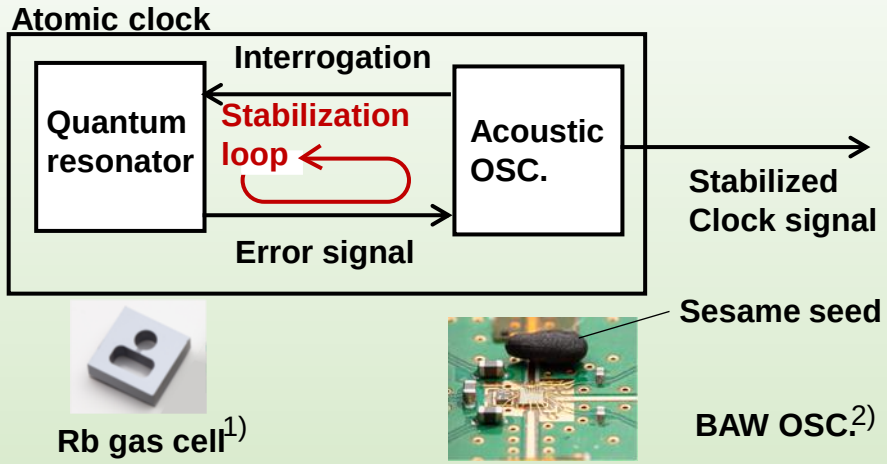
Proof of principle demonstration of
Carrier Phase positioning using Wi-Wi module

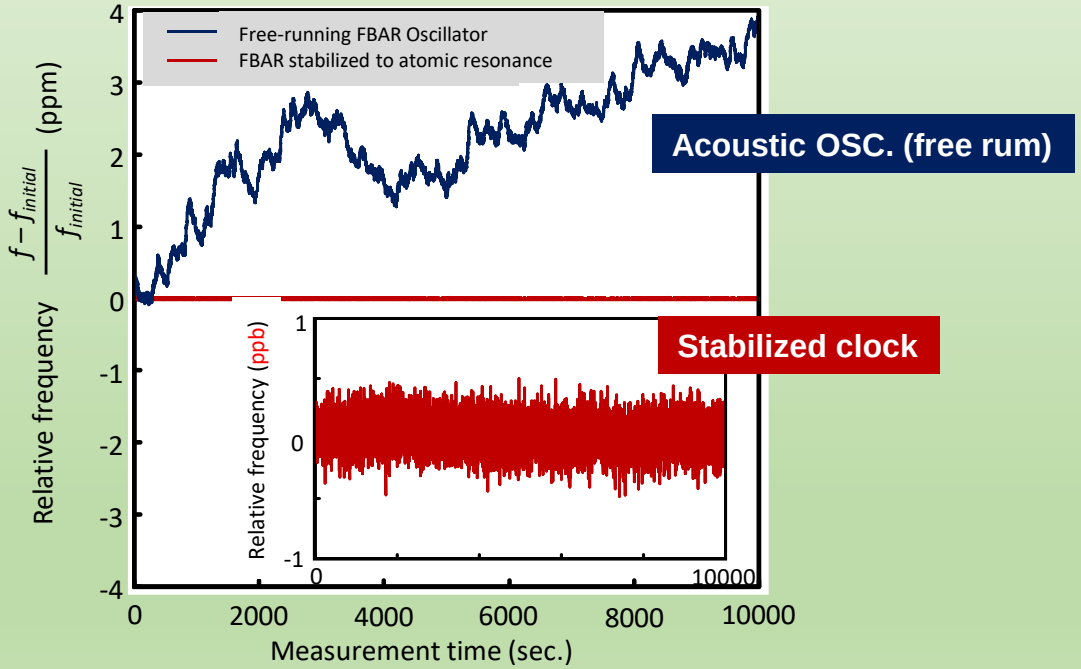
b. Clocks in terrestrial network: R&D at NICT

Acoustic resonance × Quantum
→ Ultra stable (Drift-free) clock



Quantum resonance frequency meets telecommunication band



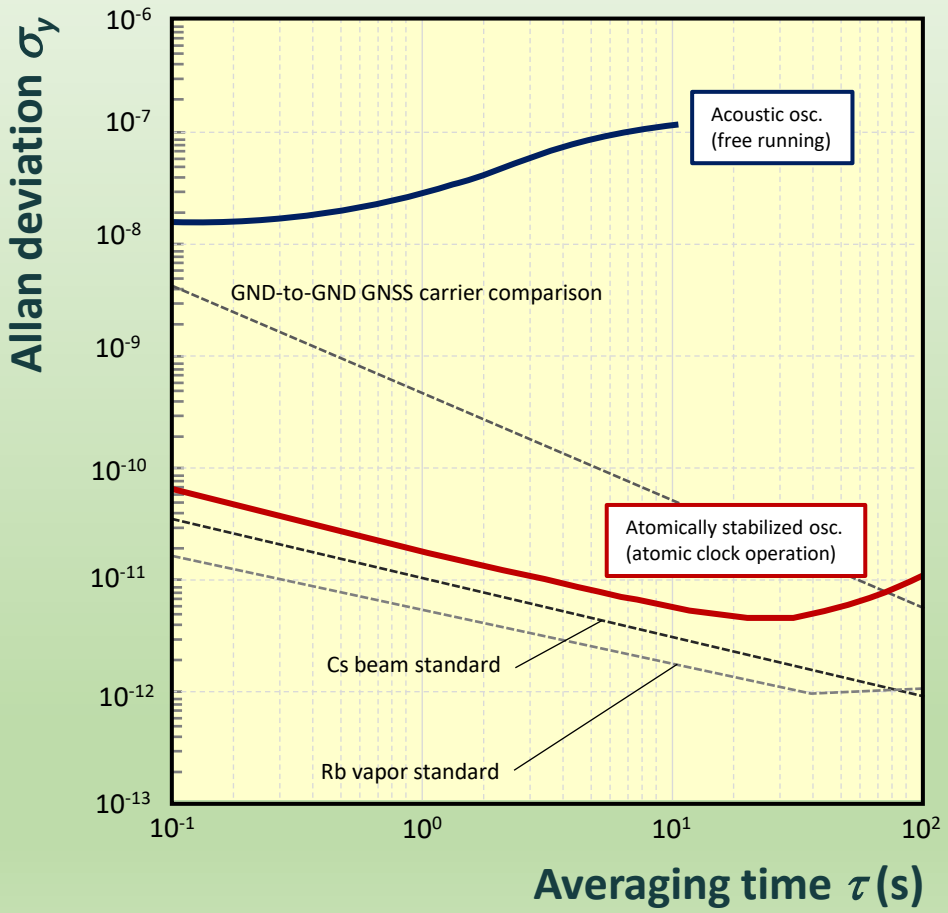


1) M. Hara et. al., “Evaluation of New Solid Rubidium Source Using Atomic Clock Stabilization Loop,” in Proc. Transducers 2021, pp.1158, June. 2021.

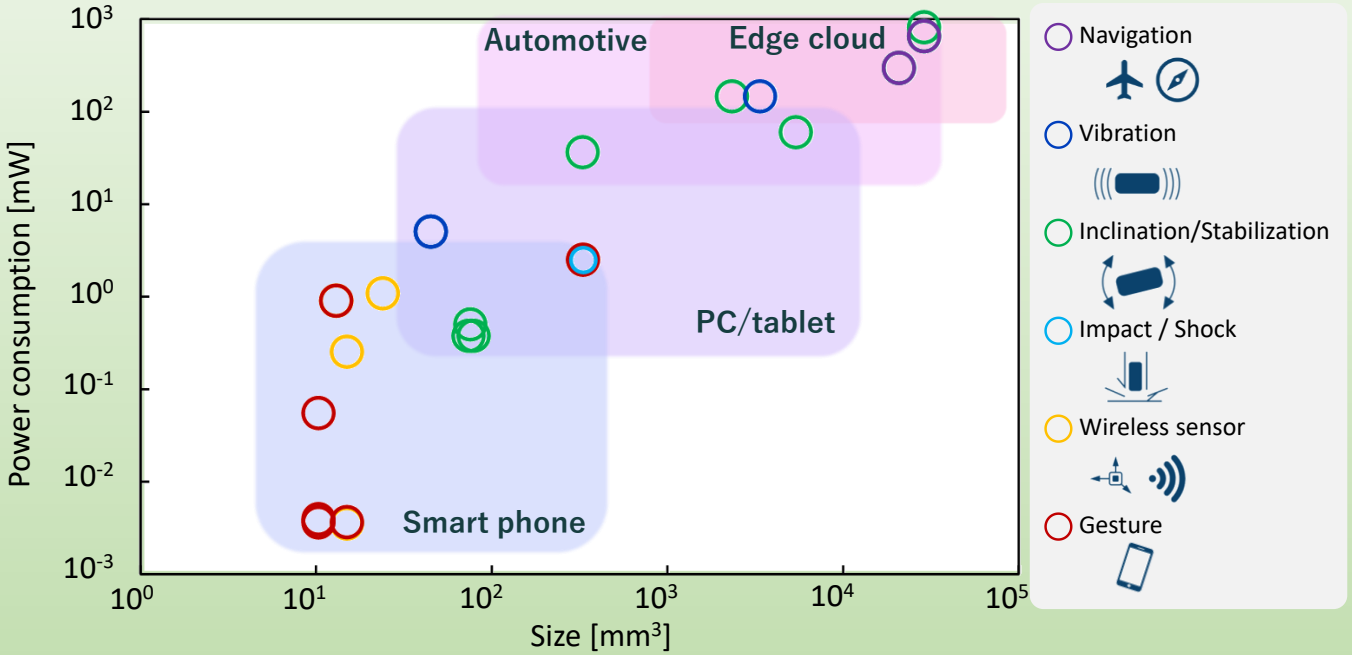
2) M. Hara et. al., “Microwave oscillator using piezoelectric thin-film resonator aiming for ultraminiaturization of atomic clock,” Rev. Sci. Instrum., 89(10), 105002, 2018.

b. Clocks in terrestrial network: Perspective

<Instability comparison>



<Size trend, a target>

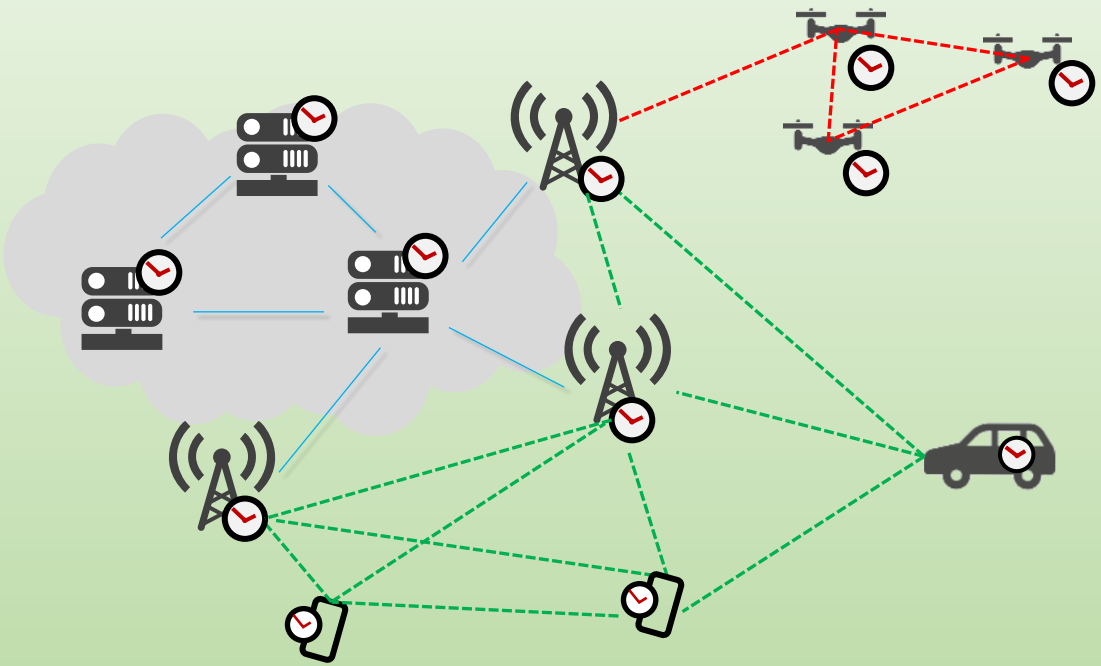


Market area prediction for which a highly stabilized clock should aim from the relationship of size, power consumption, and application in commercially available inertial sensors.

c. Cluster clocks

carrier phase technique (Wi-Wi) x Atomic clock chip

= Decentralized synchronization (Cluster clock)



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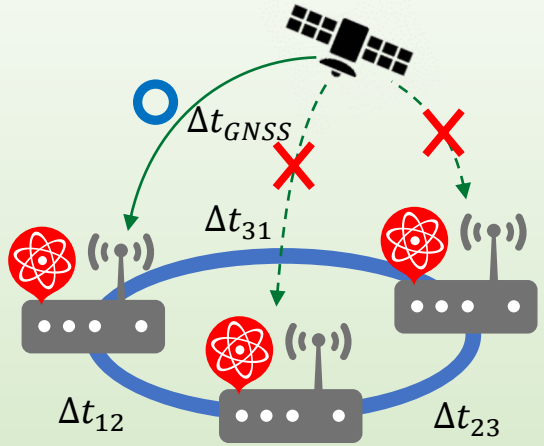
Numerical simulation

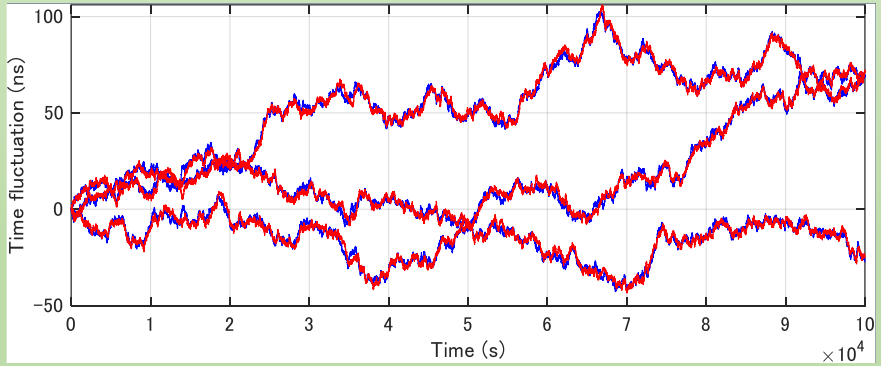


Network model of cluster clock

1. Data collection (Δt_{12}, Δt_{23}, Δt_{31},Δt_{GNSS})
2. Time estimation using Kalman filter
3. Supply the estimated data to nodes

Synchronization procedure

Simulation results



True time

Estimated time

If measuring the time difference with the neighbor, the relative time from the maximum likelihood clock on entire network is calculated.