2022/11/09

The International Timing and Sync Forum 2022 (ITSF2022),
Dusseldorf, Germany

Nanosecond Time Synchronization Capability on Wireless Smart Device: Needs and Approach

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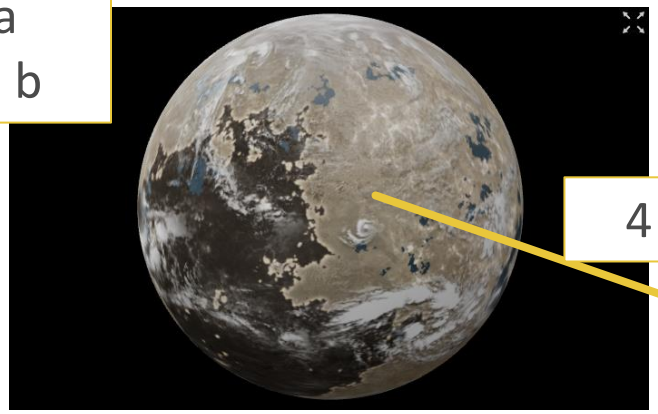
National Institute of Information and Communications Technology
Tokyo, Japan

CONTENTS

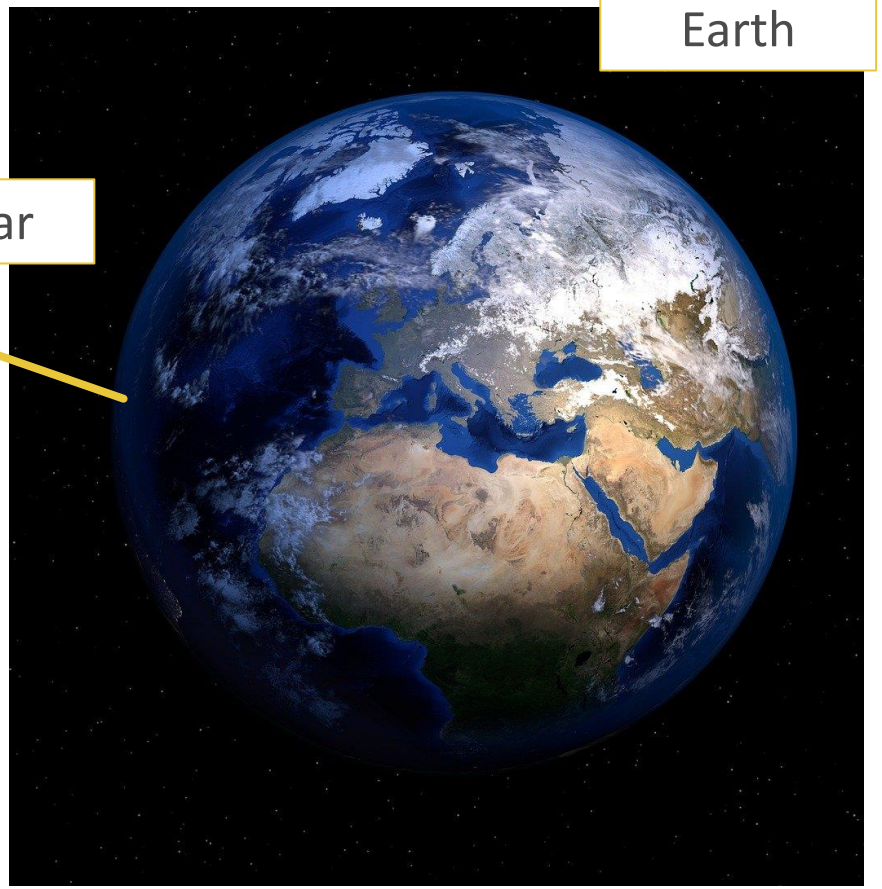
“Just-now”

Proxima Centauri b



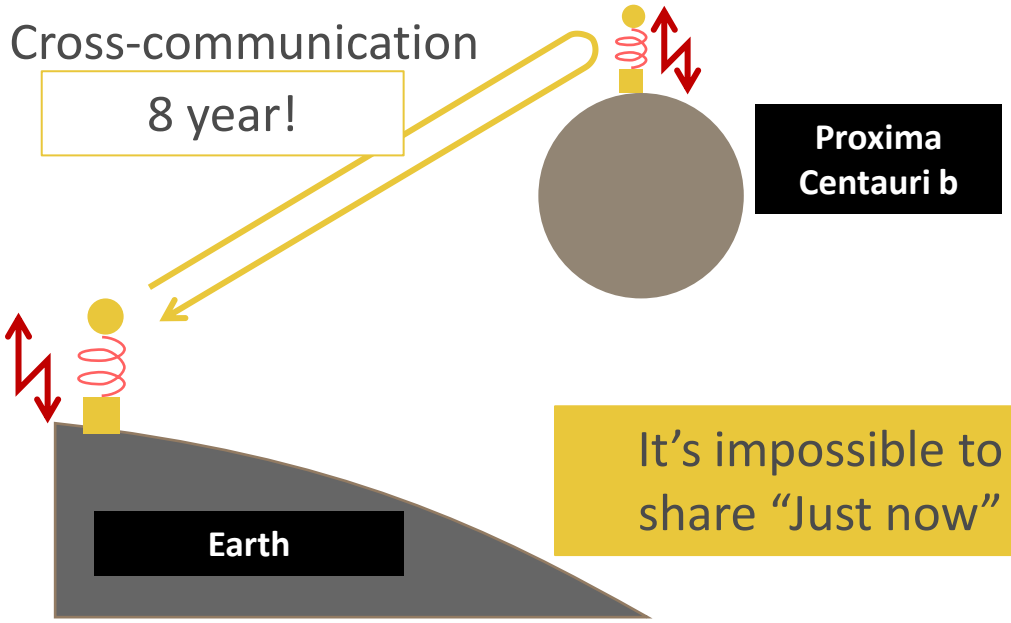
4 light year

Earth



Cross-communication

8 year!



It’s impossible to share “Just now”

https://www.nasa.gov/
https://pixabay.com/ja/

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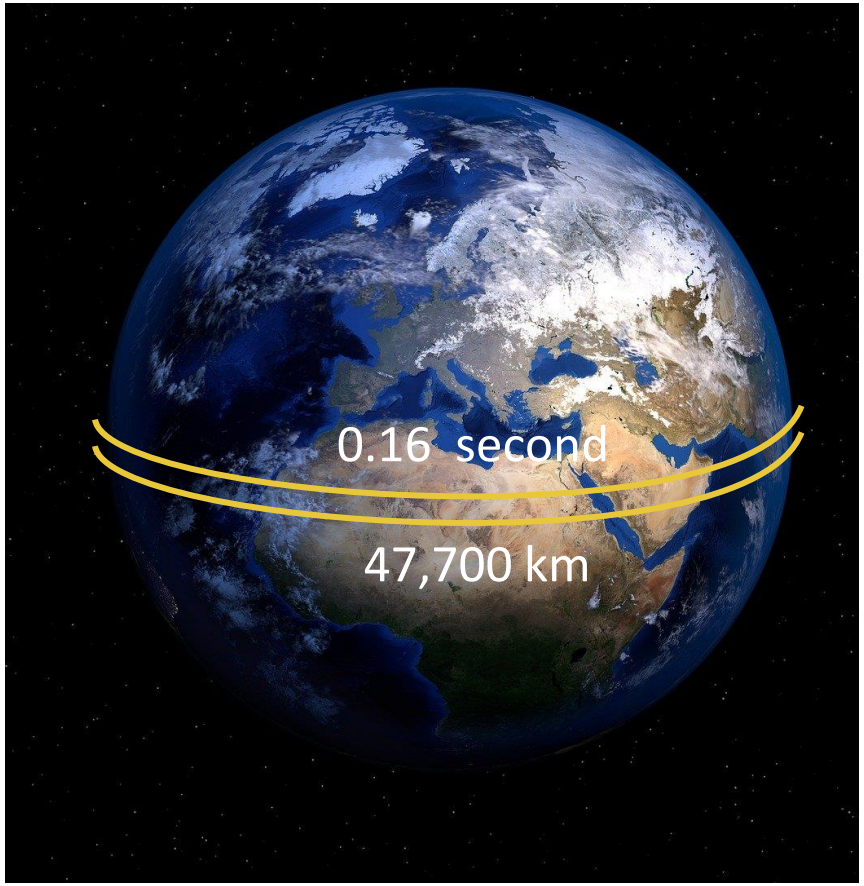
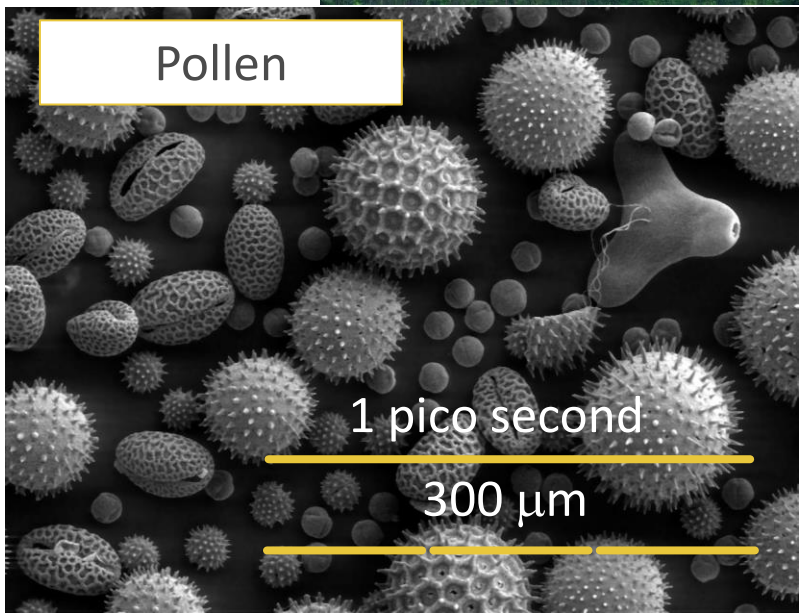
To share the “Just-now”





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https://ja.wikipedia.org/

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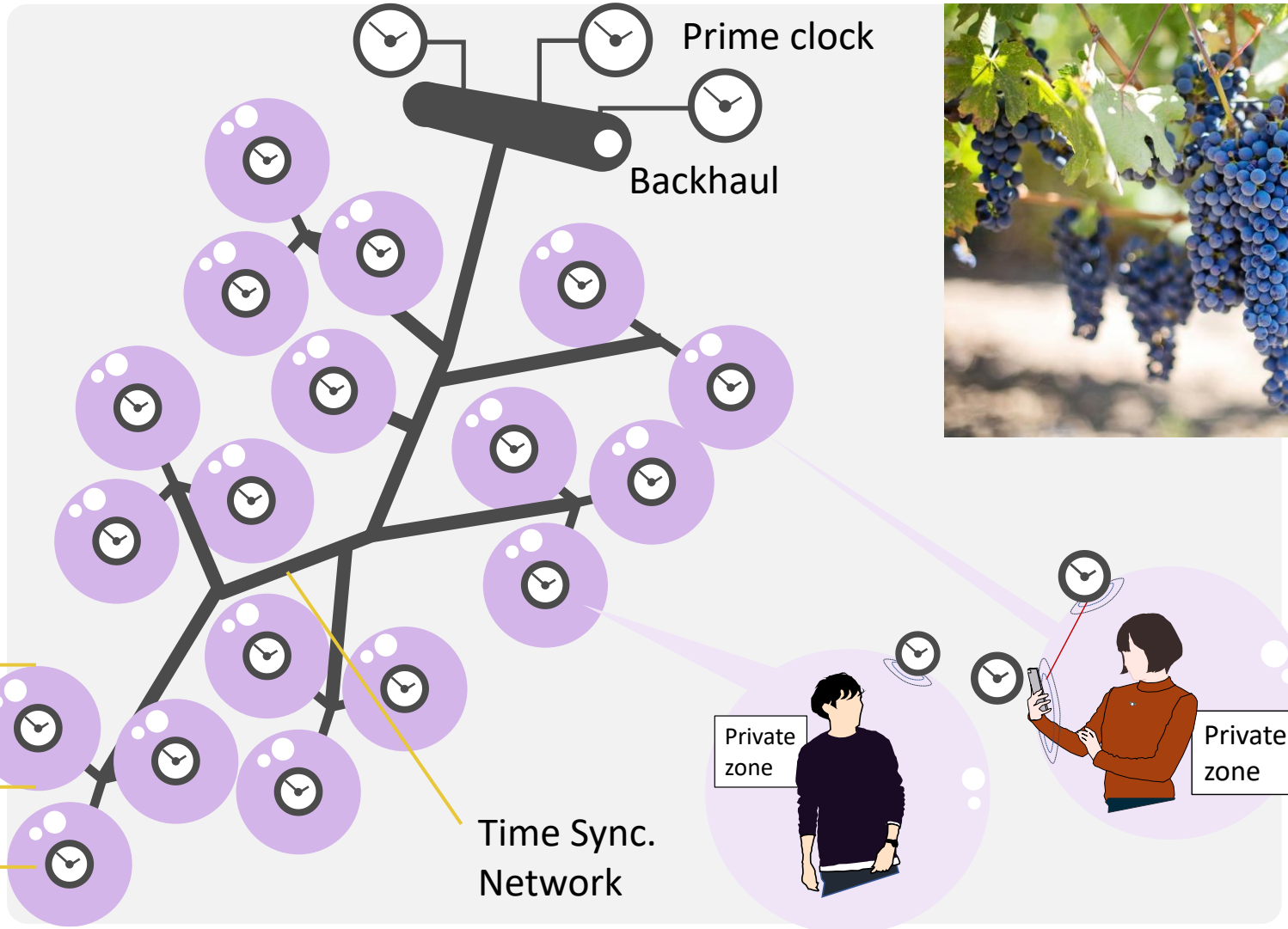
Grape of time (Cluster of our “Just-now”)



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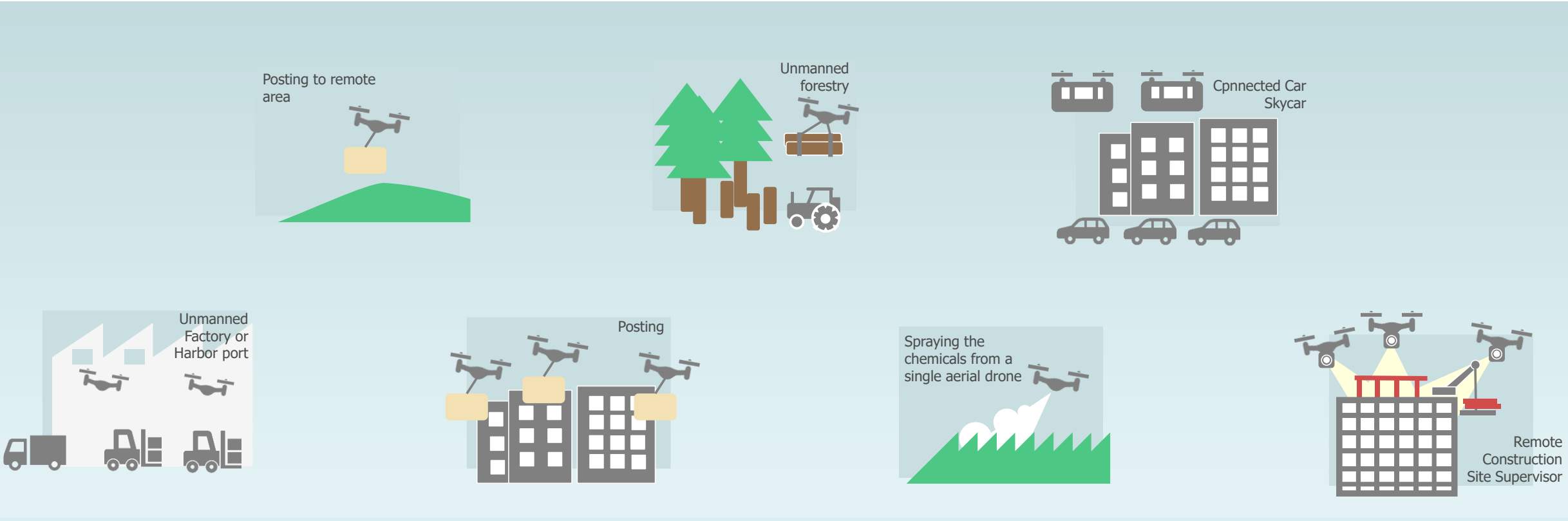
B5G/6G

From the 5G era onwards, communication terminals will expand beyond mobile phones to include drones, robots, and connected cars. Thus, the range of mobility will be greatly expanded, and localization will become a very important issue post-5G.



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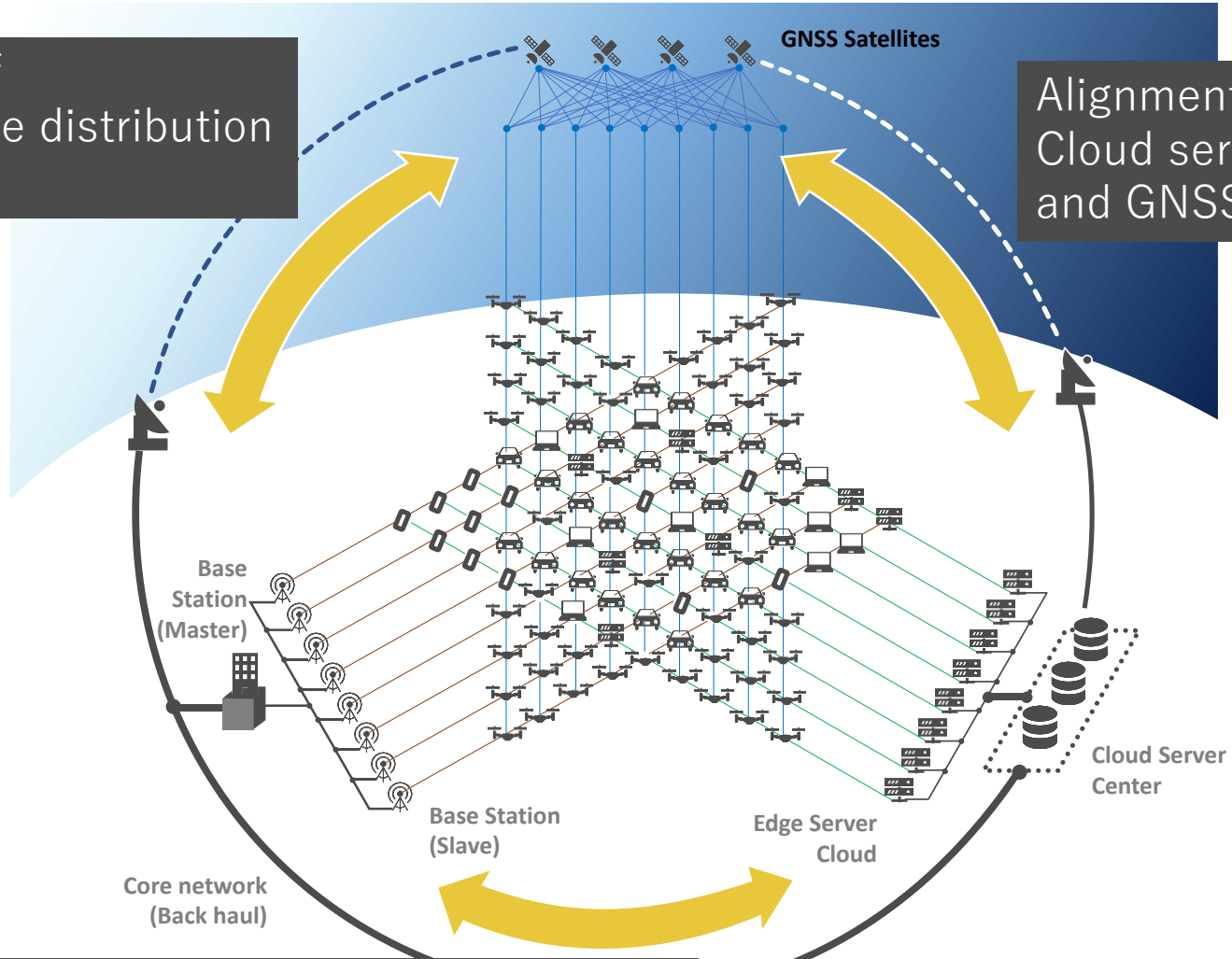
Time-space synchronization (Super localization)

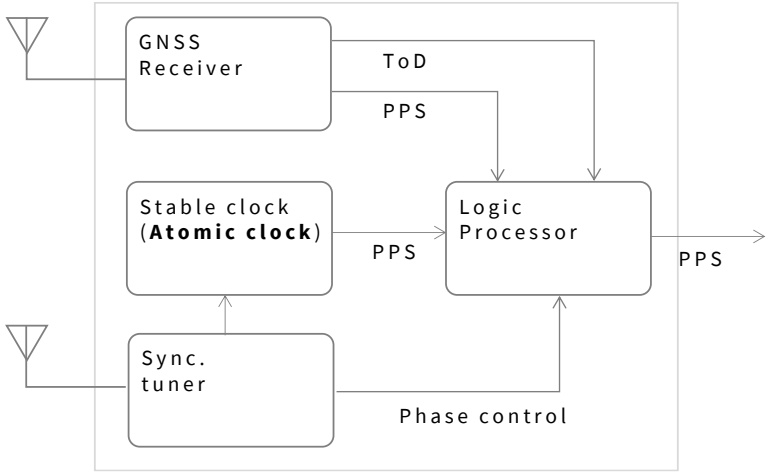
Alignment of standard time distribution and GNSS

Alignment Cloud server, edge cloud server and GNSS



Ex) Google spanner

Ex) Meta Time-card



PTP and NTP (time distribution via network)

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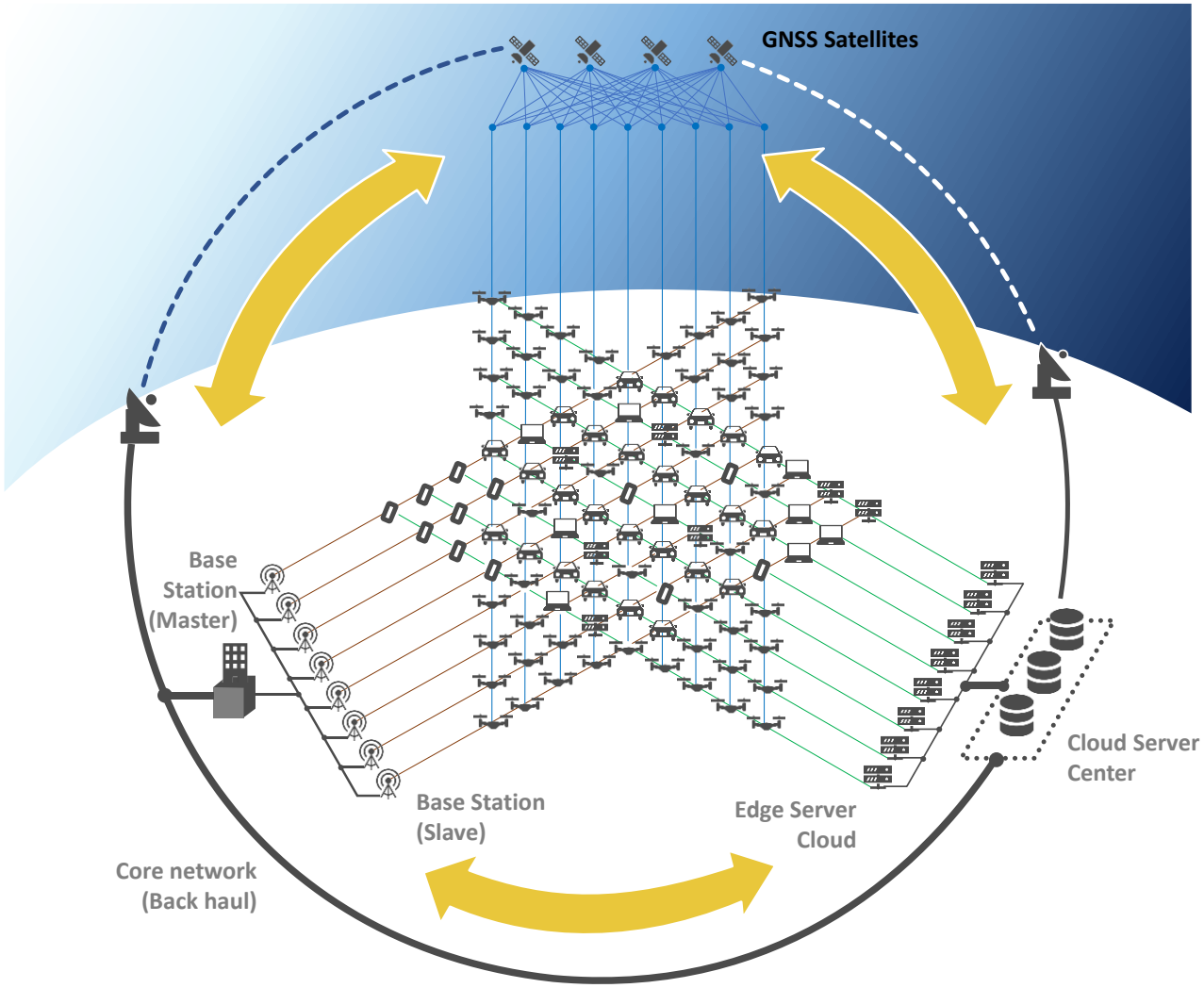
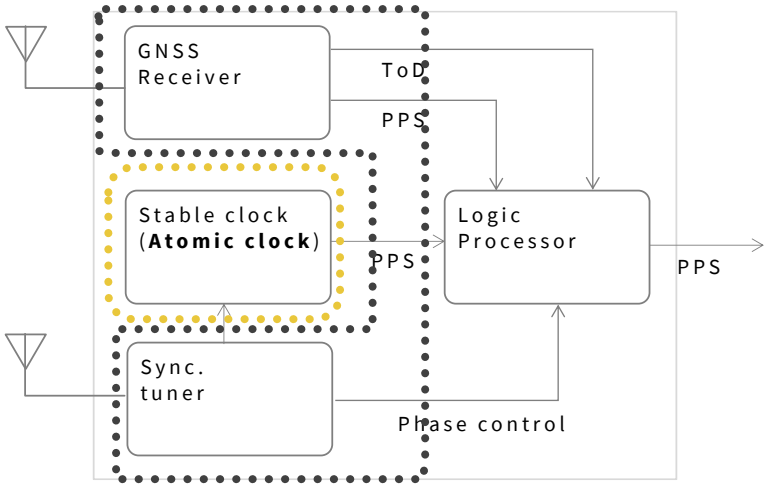
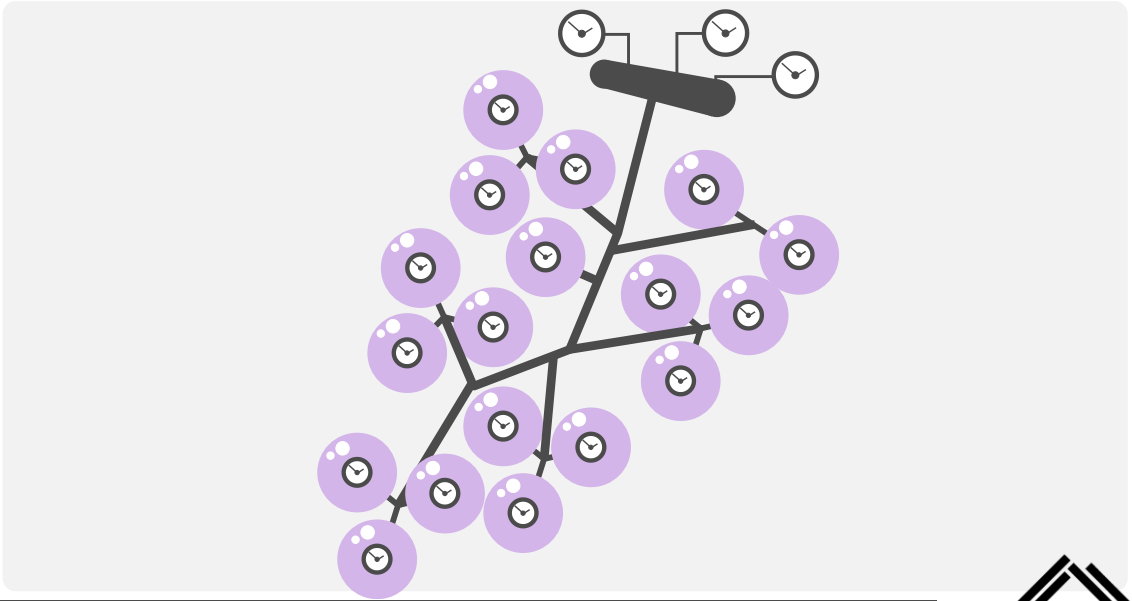
Grain size of the grapes of time







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Our activities for Nanosecond synchronization

Drift-free clock

➡ Ultraminiaturized atomic clock

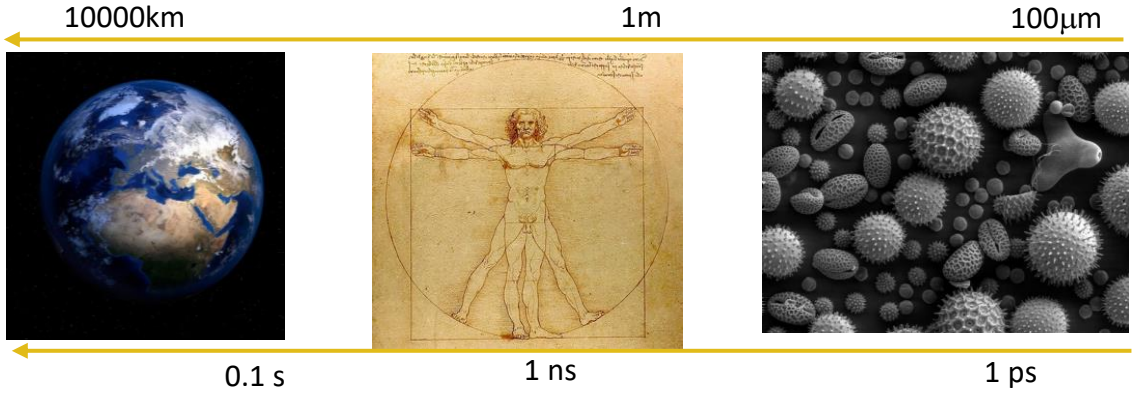
CLIFS
Chip Level Integrated Frequency Standard

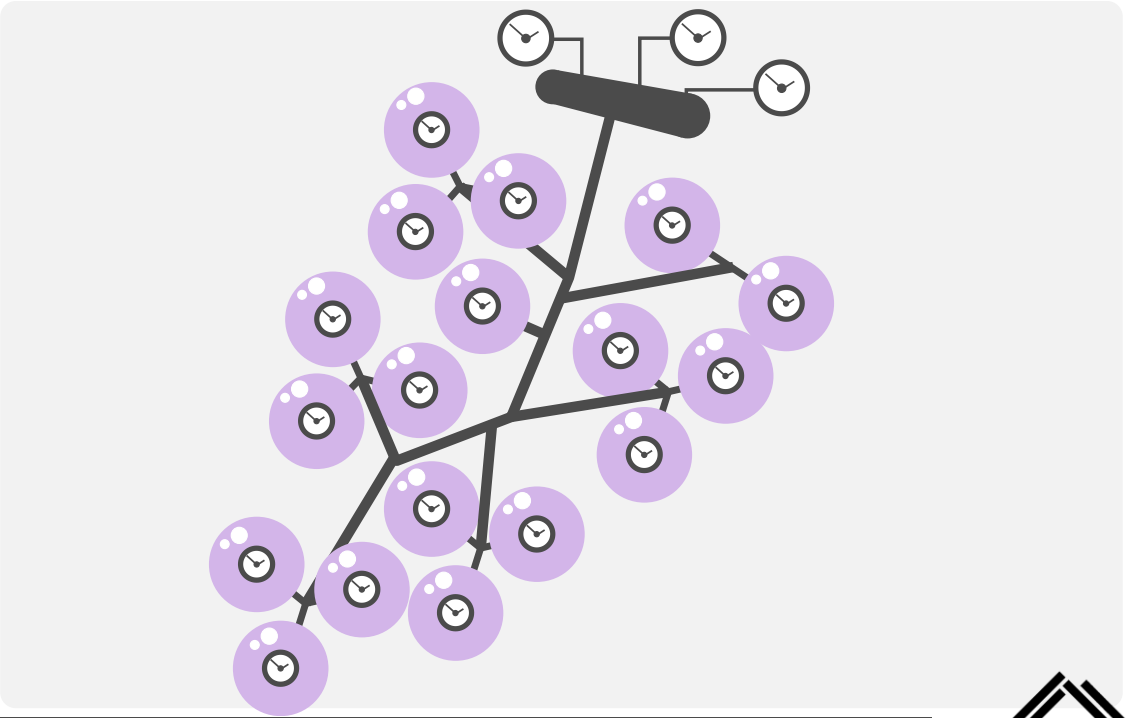
Time synchronization system

➡ Wireless two-way Interferometry

WiWi

➡ Cluster Clock System





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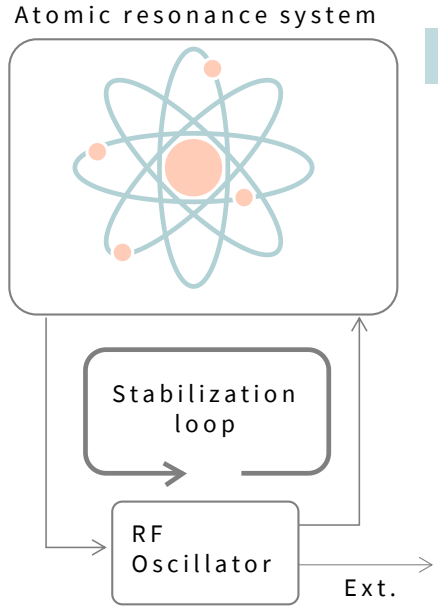
Atomic clock

Atomic clocks are a technology that stabilizes high-frequency oscillators using stable atomic spectra. The principle is simple.

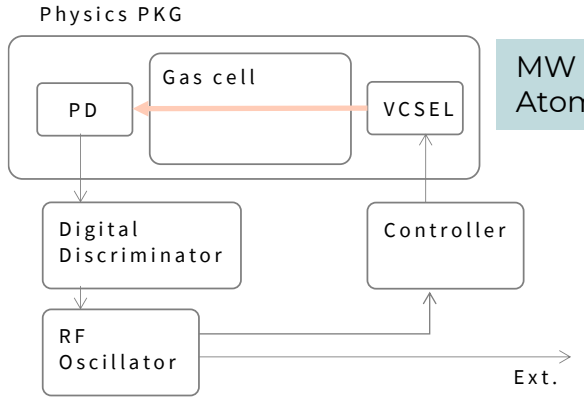
However, some advanced technologies are additionally implemented.

- Stabilize the atomic spectra itself
  - Laser cooling: ex) Optical Lattice Clock, Fountain Clock
  - Ion trapping : ex) Single Ion Atomic Clock

We are focusing on CPT atomic clock technology using laser modulation to narrow absorption lines and increase frequency stability.
Atomic clocks utilizing this CPT resonance are used in many small atomic clock modules.



Atomic Clock



MW CPT Atomic Clock

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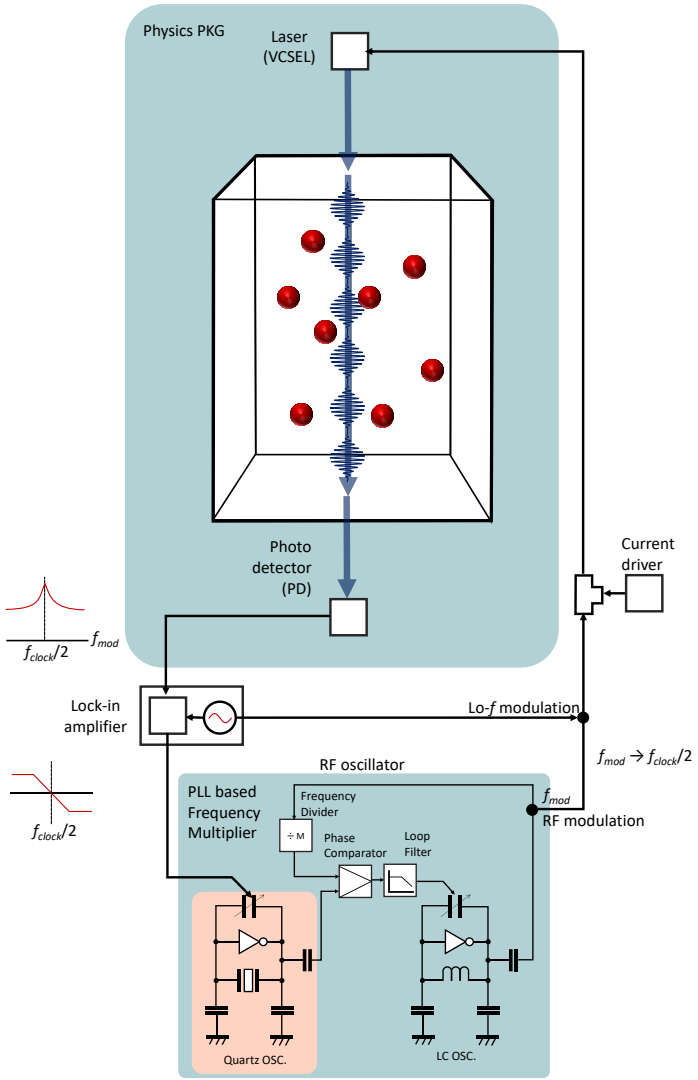
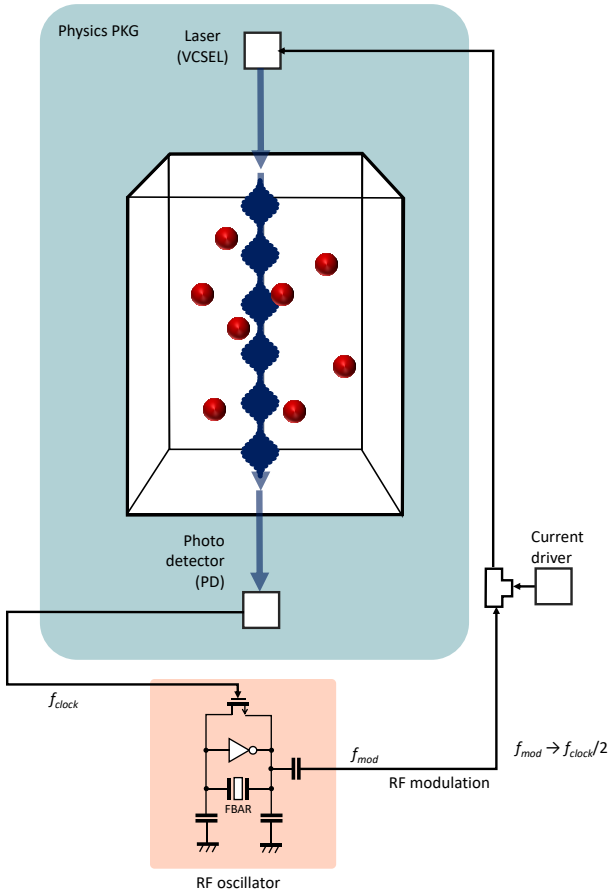
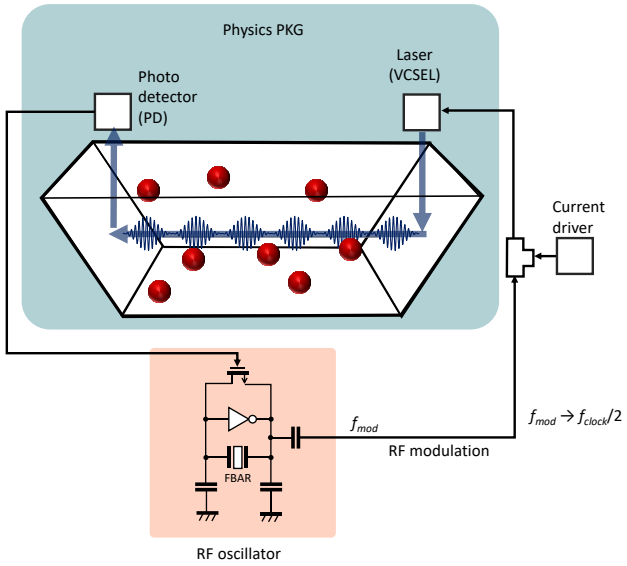
CLIFS







Reflection type gas cell

- Silicon reflector type
  Appl. Phys. Exp., 12(7), 072012 (2019)
- Dielectric multi-layers reflector type
  Opt. Lett., 46(10), 2272 (2021)

Simplification of feedback loop

- PLL-free RF oscillator Rev. Sci. Instrum., 89(10), 105002 (2018)
- Lock-in-amp-free signal loop Electron. Lett., 57(3), 132 (2021)

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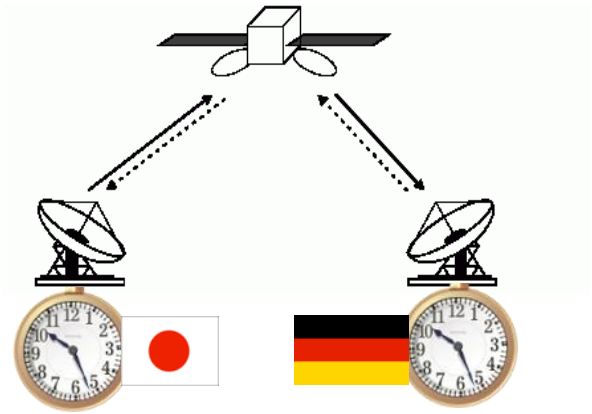
Wireless Two-Way Interferometry (Wi-Wi)

Conventional

Two-way satellite time and frequency transfer (TWSTFT)



$\Delta T_G=(T_J-T_G)+P$: measurement at Germany site

$\Delta T_J=(T_G-T_J)+P$: measurement at Japan site

$P=(\Delta T_G+\Delta T_J)/2$ (P = Sum of both meas.)

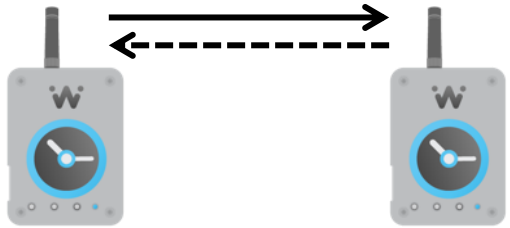
$T_J-T_G=(\Delta T_G-\Delta T_J)/2$ (T_J-T_G=Difference)

T_J-T_G: Clock difference P: Propagation time

measurement of time difference and transmission time via satellite communication.

Our proposal

Wireless two-Way interferometry (Wi-Wi)



measurement of time and distance via wireless communication.

We adopted the satellite technology to achieve Time synchronization (pico second accuracy) and Distance measurement (mm accuracy) at extremely high precision with Low cost and small size.

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Cluster clock system

Modeling

State of clocks ➡ State vector x=(time, frequency, drift, etc) ➡ State space $\boldsymbol{x}=\begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{pmatrix}$

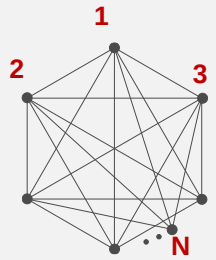
State equation $\boldsymbol{x_{k+1}=A\,x_k+v_k}$

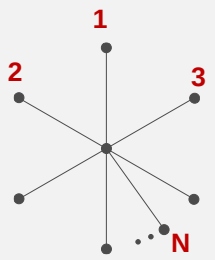
Observation equation $\boldsymbol{y_k = c\,x_k + w_k} = x_{k,n} - x_{k,m} + \boldsymbol{w_k} = \Delta t_{nm} + \boldsymbol{w_k}$

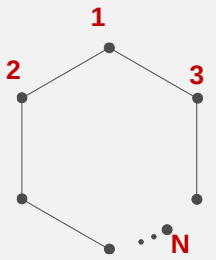
Kalman filtering $\hat{t}_n$: Max. likelihood t

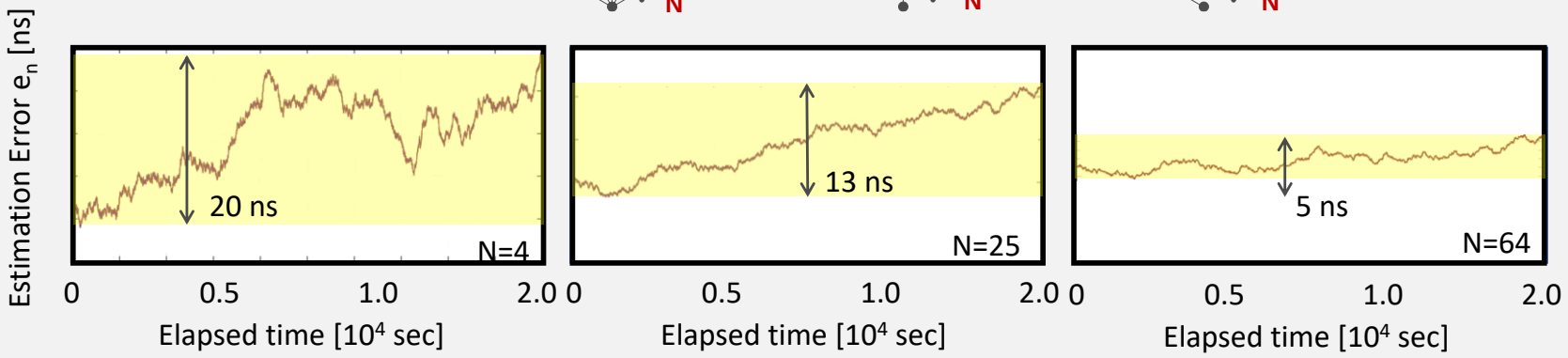
Evaluation $e_n=\hat{t}_n-t_n$: Estimation error

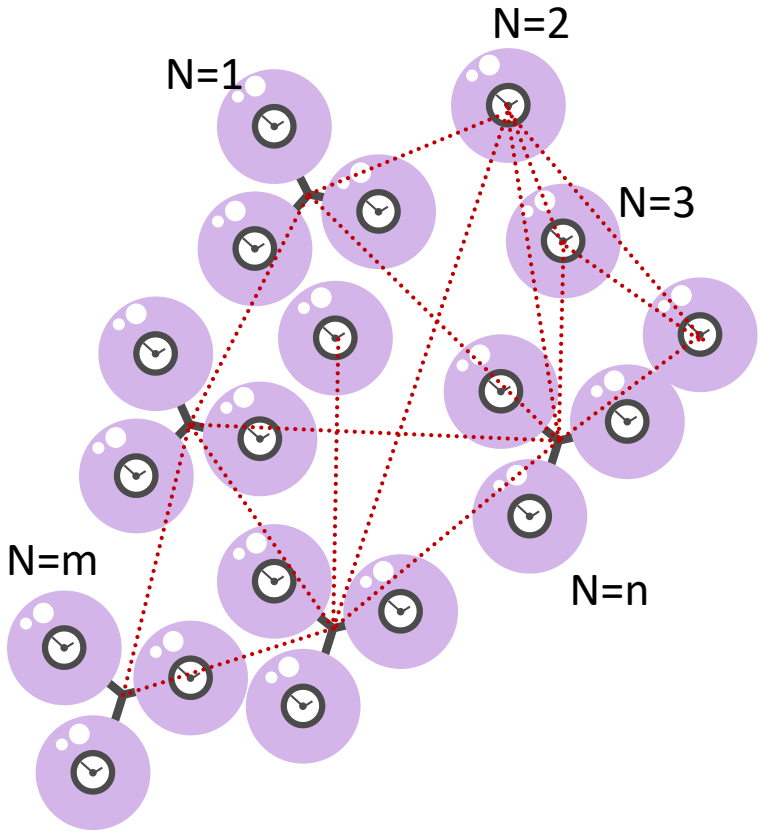
ex) Full-mesh network











Clock node # : *N*

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Summary

- In this presentation, from the physical range where "Just-now" can be shared, we targeted nanosecond synchronization and attempted to introduce a cluster-like time synchronization network composed of them.

- This cluster-like time synchronization network will provide appropriate answers to the requirements of next-generation B5G/6G.

- To achieve this cluster-like time synchronization network, we introduced the development project of Atomic Clock Chip (CLIFS) as a proposal for drift-free clocks, and the Wi-Wi, which was developed as a handy time synchronization system. We also showed the investigation activity for the techniques that link the modules of CLIFS and Wi-Wi with a high degree of freedom.

If you are interested in the NICT activities introduced today, please do not hesitate to contact us: **hara.motoaki@nict.go.jp**

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Thank you for your attention.

Part of this work was supported by SCOPE (No. 195003003) and research and development for expansion of radio wave resources (JPJ000254) from the Ministry of Internal Affairs and Communications (MIC), Japan.

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