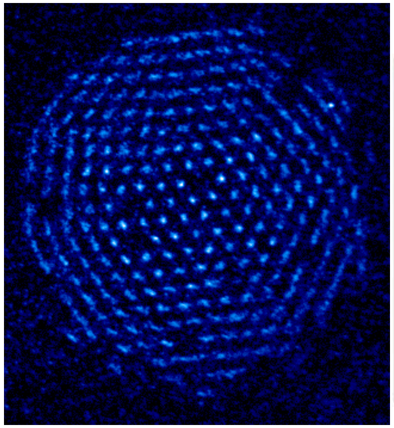
Enabling pico-second level Space-time synchronization

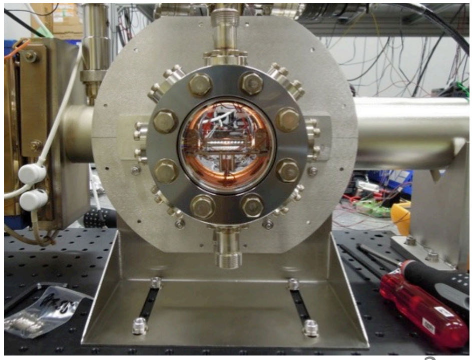
2022.11.23

National Institute of information and communications technology
Global alliance department
Nobuyasu Shiga

Biography

- 1993-1997 U. of Tokyo Applied Physics
- 1998-2004 U.C. San Diego Ph.D in Physics (Plasma Physics)
- 2004-2005 Fairbanks, Alaska (Aurora borealis)
- 2005-2008 NIST Boulder (Trapped Ions, Quantum Info)
- 2008-2019 NICT Tokyo (Atomic clocks, Wireless synchronization)
- 2020-now NICT at Silicon Valley research hub



Overview of NICT

NICT: National Institute of Information and Communications Technology

NICT is the sole national research institute of ICT in Japan

● **Main Services：**

- ◆ **Basic and fundamental R&D on ICT**
- ◆ **Japan Standard Time (JST), space weather forecast**
- ◆ **Cybersecurity training**
- ◆ **Funding to ICT R&D by private sector and academia**

● **Location： Headquarter in Tokyo**

● **Personnel： About 1,000**

● **Budget： 27.1 billion JPY (about 260 million USD) + external funds**

● **Foundation： April, 2004**

● **Silicon Valley Research Hub:**

Objective: Global Deployment of R&D outcomes

Japan Standard Time (JST)

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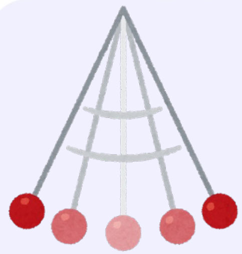


Oscillator

+

+

Counter + Display

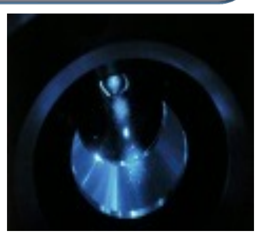
+

Synchronization

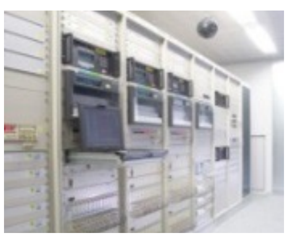
Space-Time standards group

Ultimate Oscillator (Atomic clock)	**Generation and Dissemination of JST**	**Synchronization**

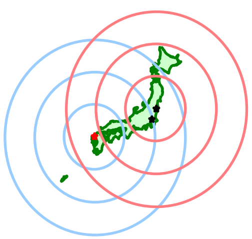
Cs Atomic clock



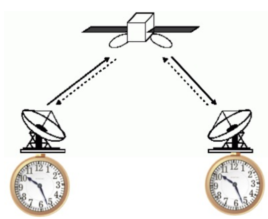
Sr Optical Atomic clock



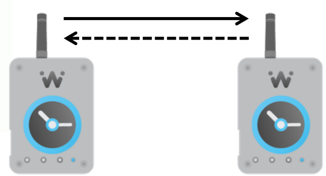
Generation of JST



Radio Clock



TWSTFT

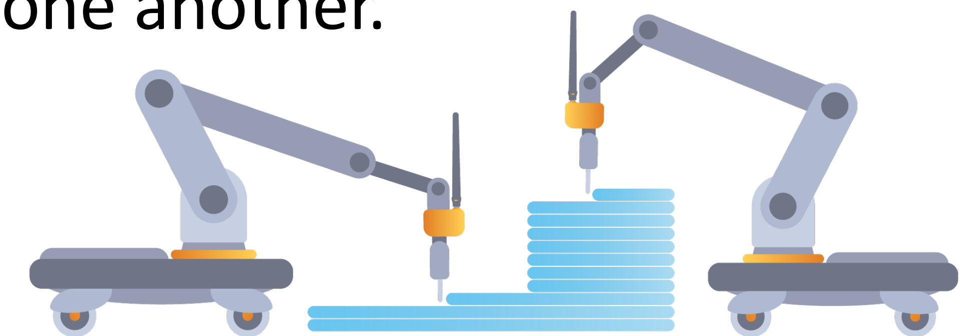


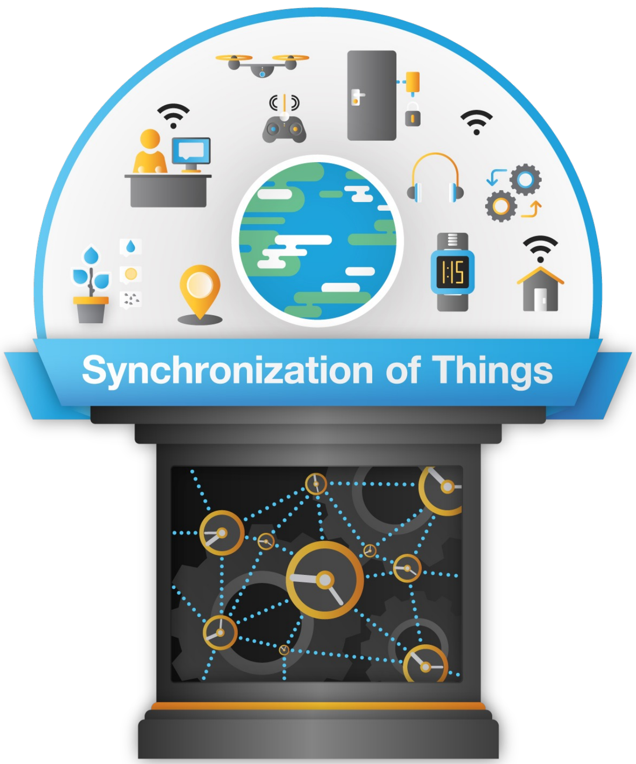
WiWi

Space-Time Synchronization

Our definition:

Space-Time Synchronization is a collective state where **Clocks** of all Devices are synchronized, and the mutual **positions** are shared by one another.





Space-Time Synchronization

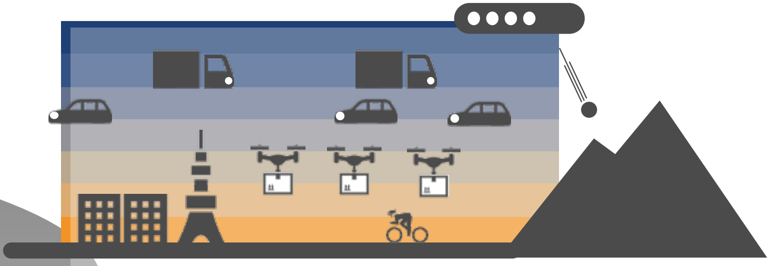
Allows all devices to share a universal clock via wireless communications.

Path to Space-Time Synchronization

Organic collaboration of things

- Service launch
- Top layer for S-T Sync.: Authentication, Security, Privacy

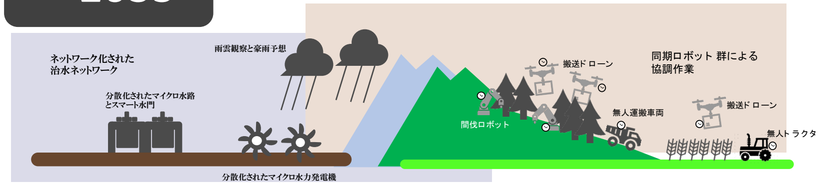
STEP 03
~2040



Vertical flow of humans and things

STEP 02
~2035

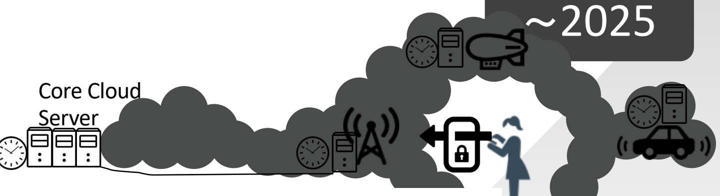
Infrastructure for Space-Time Synchronization
- Reference Base stations
- Position coordinates



Satoyama – resilient village forest

Time Synchronization
- Phi Technology
- Network
- Scaling

STEP 01
~2025



Cloud Synchronization

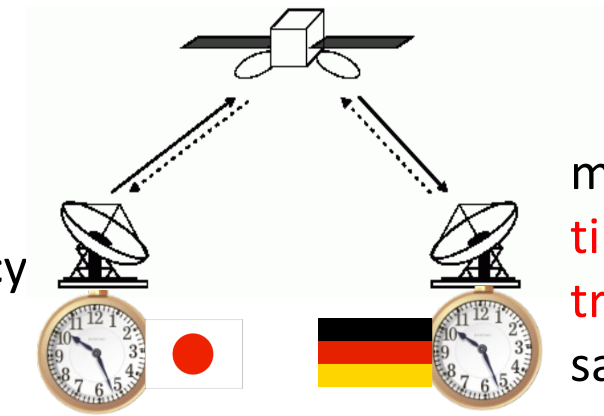
now

Imprecise Synchronization
- logical clock
- Preambles and Sync words

Wireless 2Way interferometry (WiWi)

Pre-existing technology

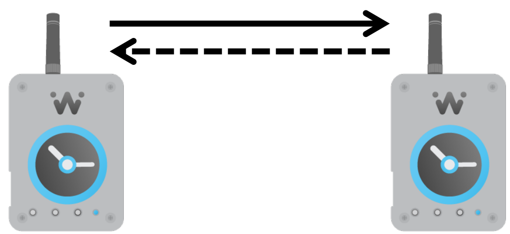
Two-way satellite time and frequency transfer (TWSTFT)



measurement of time difference and transmission time via satellite communication.

New!

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.

Proof of Principle (2.4GHz ZigBee)

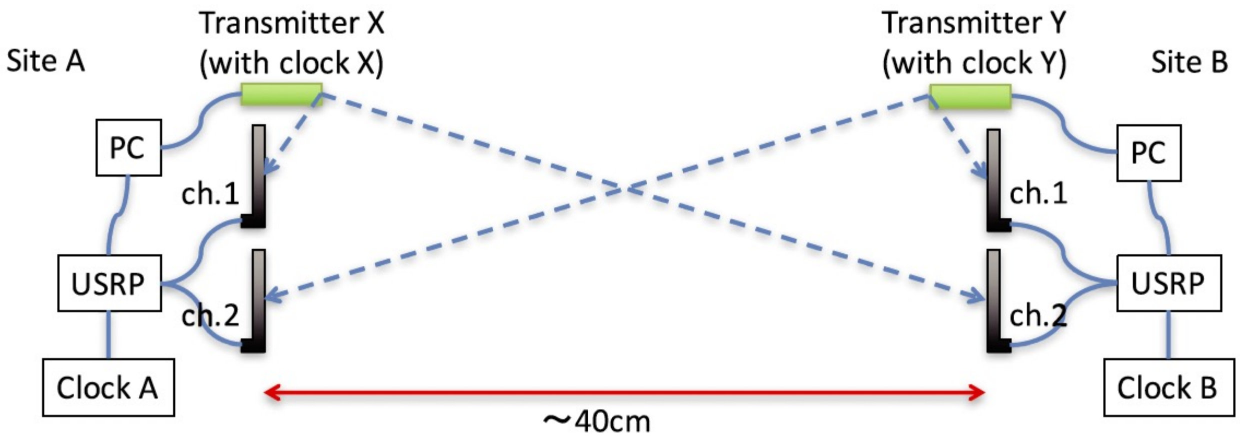


Fig. 1. Experimental setup of Wi-Wi.

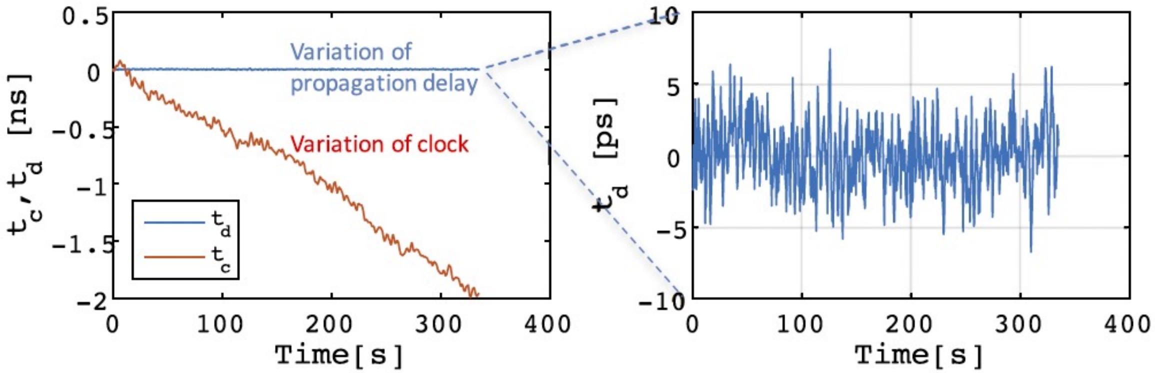
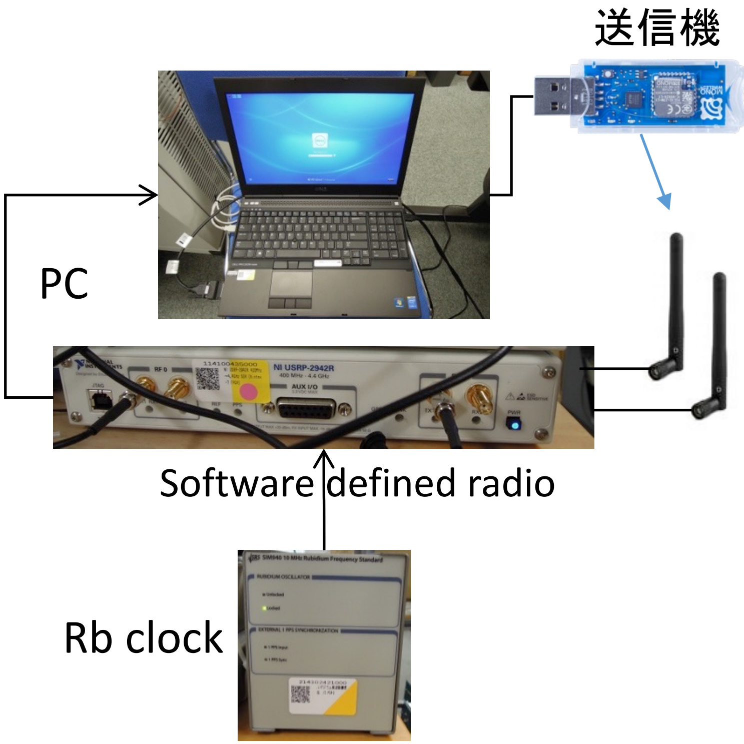


Fig. 3. Measurement of variation in clock difference and propagation delay over a 5 min interval using Wi-Wi.

* N. Shiga, K. Kido, S. Yasuda, B. Patna, Y. Hanado, S. Kawamura, H. Hanado, K. Takizawa, and M. Inoue, "Demonstration of wireless two-way interferometry (Wi-Wi)," IEICE Communications Express, Vol.6, No.2, pp77-82 (2017)

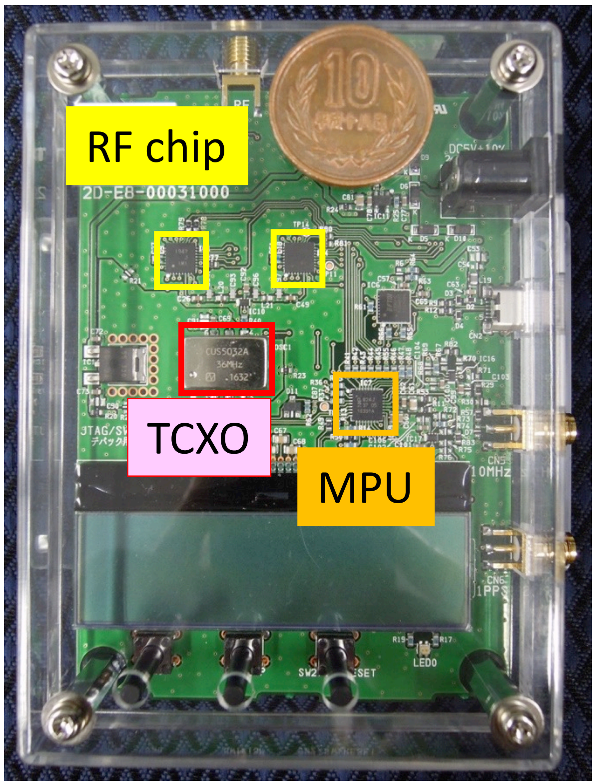
Wi-Wi Module

SDR+Rb clock（～$10k）



low cost
small size
low power

Proto-type Wi-Wi module



- By not using FPGA, we reduced the cost and power consumption.

Prototype modules

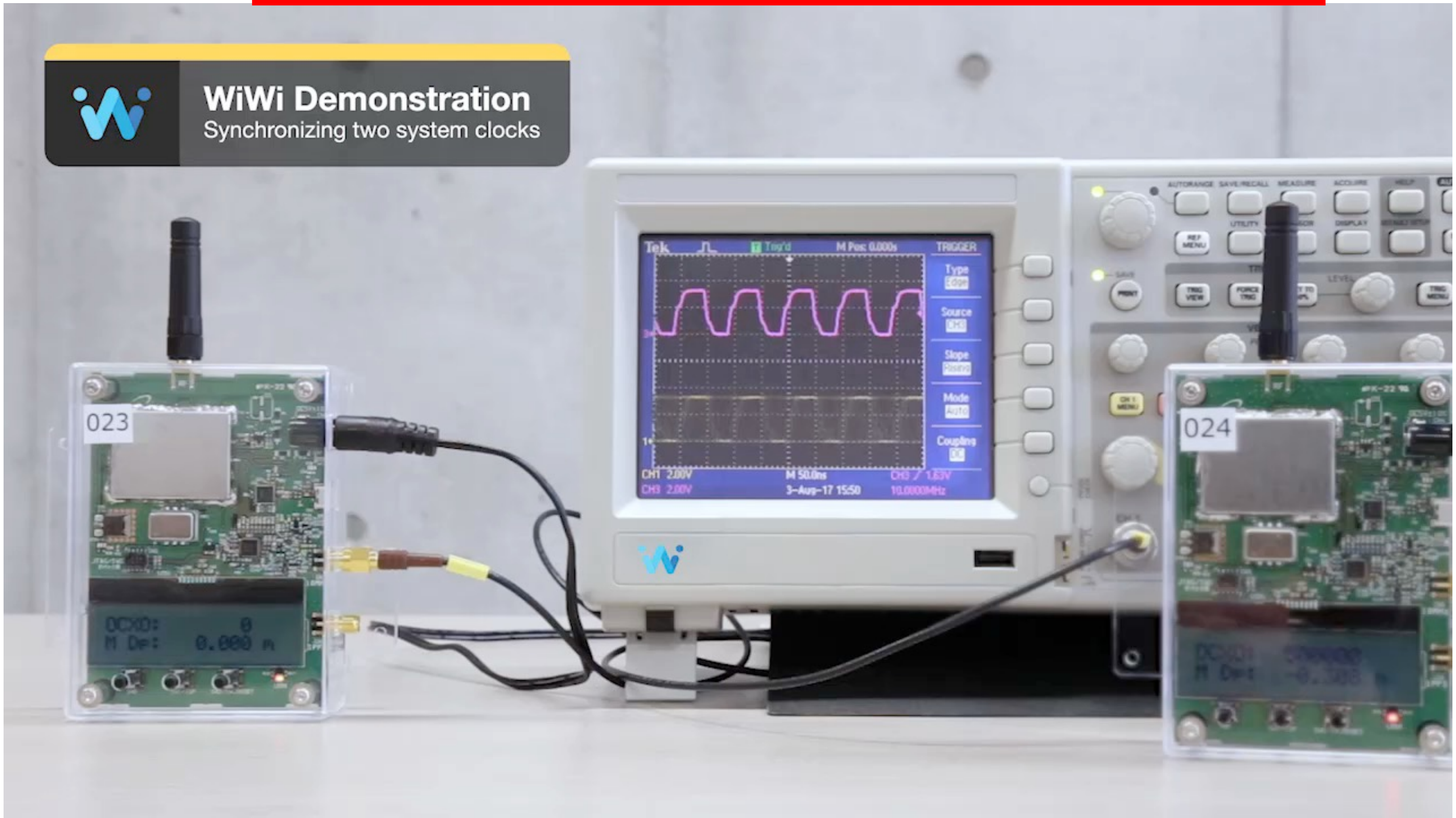
- 920MHz wireless communication module
- Fully compatible with IEEE 802.15.4
- Range 100m(20mW)/5km(250mW)
- Clock accuracy: 35ns with 16ps jitter

Satoshi Yasuda

Demonstration of Synchronization

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

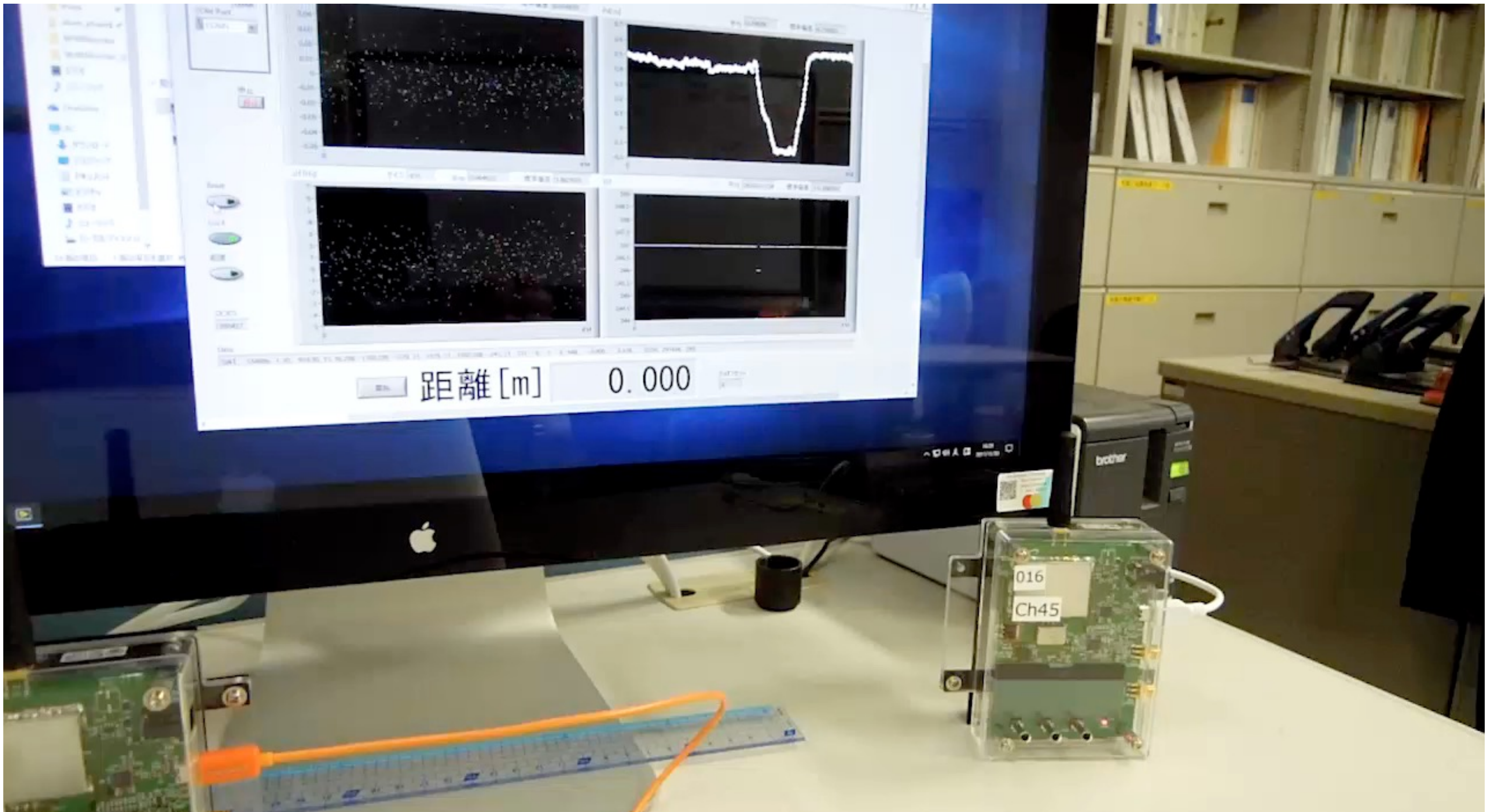
$T_J - T_G =(\Delta T_G - \Delta T_J)/2$（$T_J$-$T_G$=Difference）



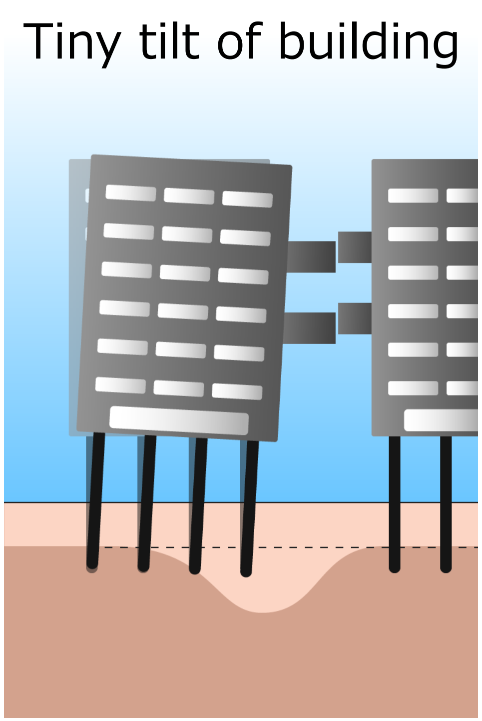
Demo of position variation

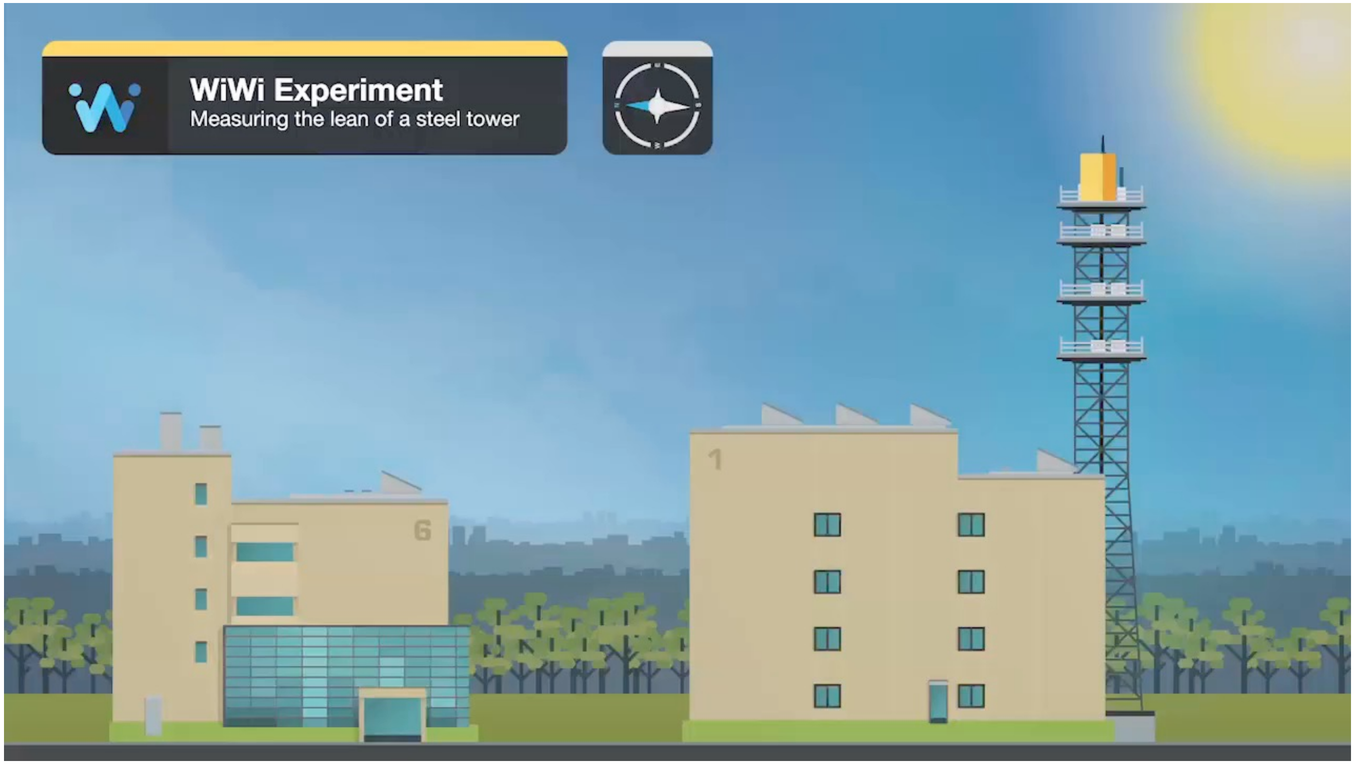
$P = (\Delta T_G + \Delta T_J)/2$（P＝Sum of both meas.）

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



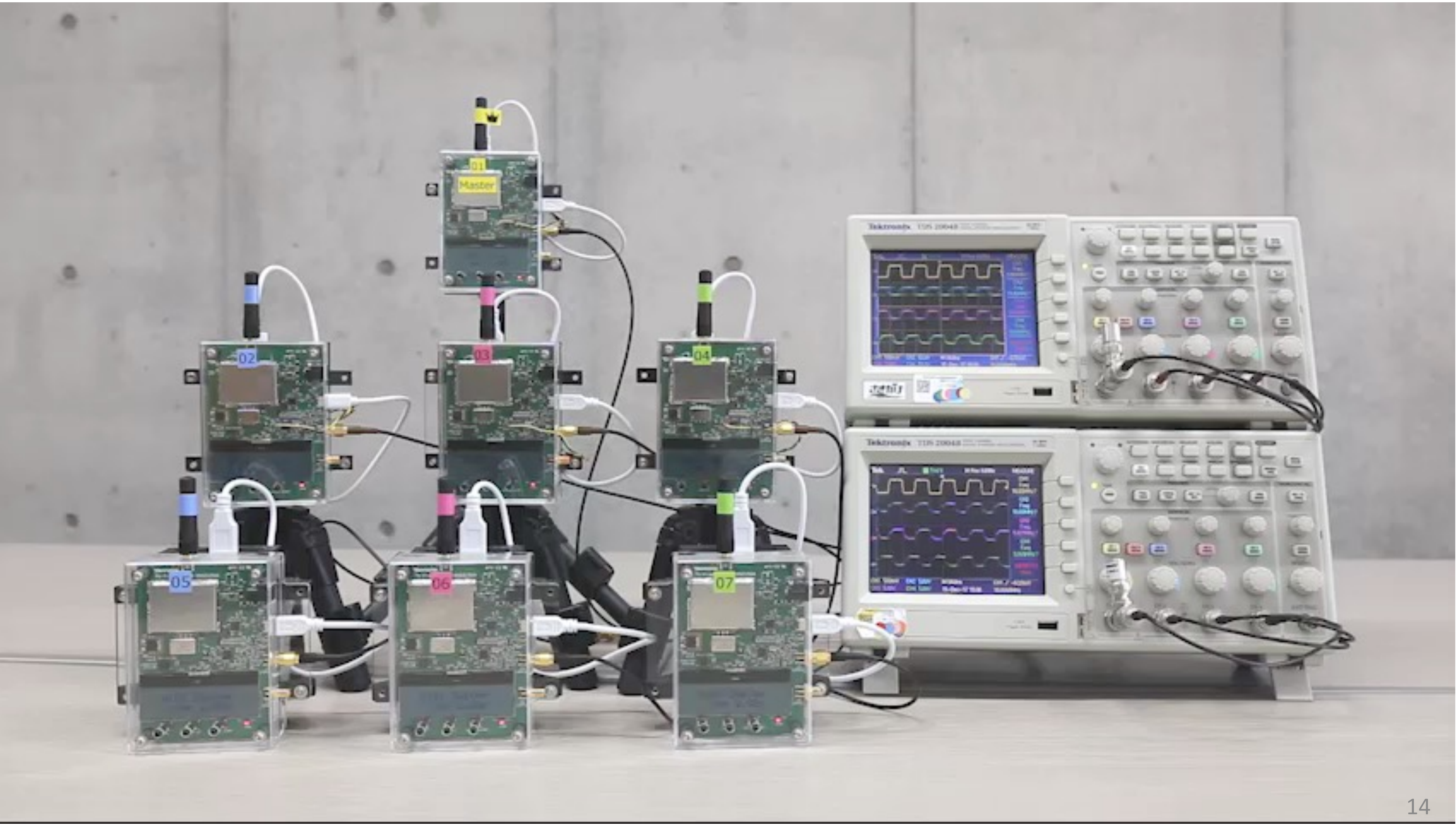
Example 1
Monitoring infrastructure



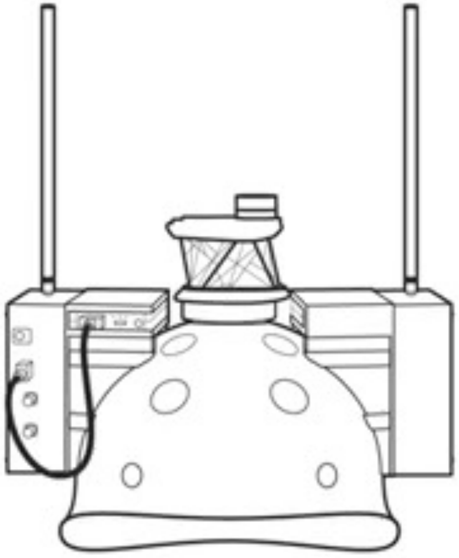


Current issue	Wi-Wi provides
There is no other way to trace the small distance change (mm) for long run.	**Cheap** and **handy** system to monitor the disatance variation at **1mm precision**

7 modules synchronized



Example 2
2D position variation



Data Center Timing application

OPEN Compute Project

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Time Appliances Project

Contents [hide]

Welcome

Welcome to the OCP Time Appliances Project wiki.

This Project is open to the public and we welcome all those who would like to be involved.

Time is a key element to get the highest efficiency in a distributed system. The performance of a distributed system depends on the synchronization of its elements. Several industries such as telecom, mobile, power, industrial, professional audio and video and many more have embraced the need for highly accurate and more importantly reliable distribution and

Mission Statement

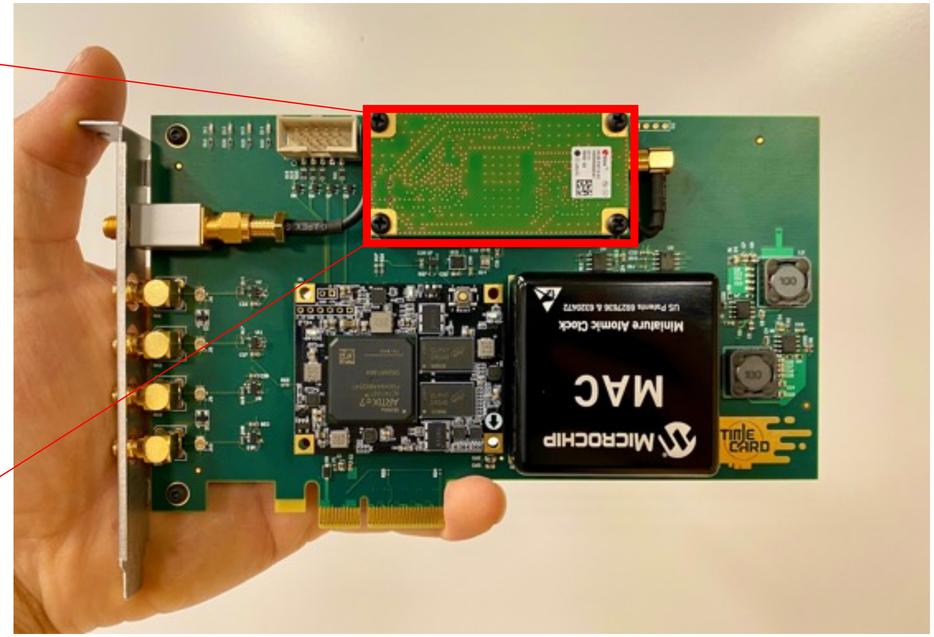
1. Create specifications and references for **Data Center Timing** appliances, applications and networking infrastructure
2. Promote openness in **Timing Appliances** and interfaces through open-source implementations

Project Leadership

- Lead: Ahmad Byagowi, Ph.D. (OCP TAP / Facebook)
- Incubation Committee: Elad Wind (OCP / NVIDIA)

https://www.opencompute.org/wiki/Time_Appliances_Project

Time Card×Wi-Wi



- We just started trying to fit Wi-Wi module into form factor.

https://github.com/opencomputeproject/Time-Appliance-Project/tree/master/Time-Card#Hardware-Implementation

WiWi Standardization

- We work toward Global collaboration of Space-Time Synchronization.
- “Wireless Space-Time synchronization” is in the Future Technology Trend for IMT 2030.

Path to Space-Time Synchronization

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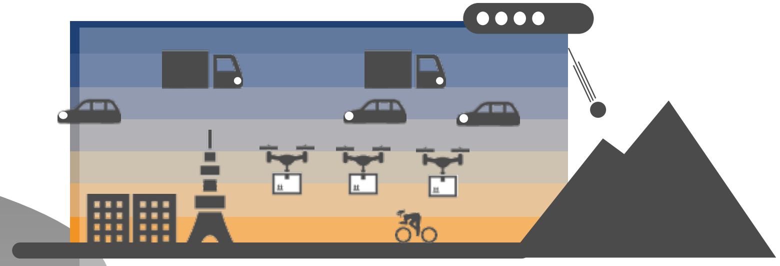
- Service launch
- Top layer for S-T Sync.: Authentication, Security, Privacy

STEP 03

～2040



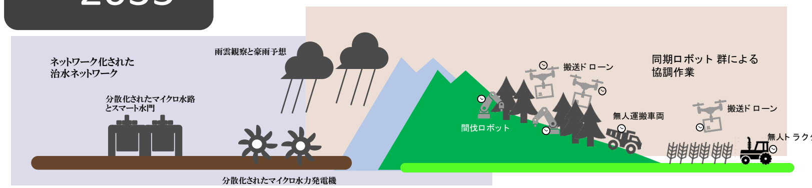
Vertical flow of humans and things

STEP 02

～2035

Infrastructure for Space-Time Synchronization

- Reference Base stations
- Position coordinates



Satoyama – resilient village forest

Time Synchronization

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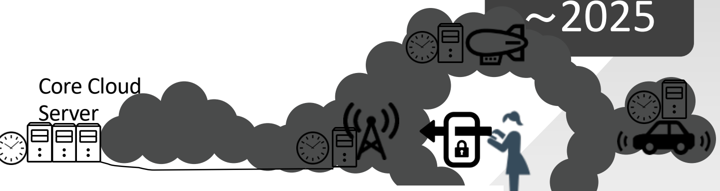
STEP 01

～2025



Cloud Synchronization

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Imprecise Synchronization

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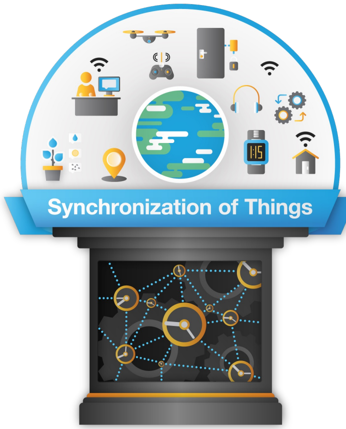
WiWi Summary

- We have demonstrated the **feasibility** and **cost effectiveness** of

"Space-Time synchronization"

module.



- **Modules** that are small, low cost, low energy consumption is essential in implementing the Space-Time synchronization.
- We are aiming to contribute to Data Center Timing solution.
- We are seeking international collaborations.

Papers

1. N. Shiga, K. Kido, S. Yasuda, B. Patna, Y. Hanado, S. Kawamura, H. Hanado, K. Takizawa, and M. Inoue, “Demonstration of wireless two-way interferometry (Wi-Wi),” IEICE Communications Express, Vol.6, No.2, pp77-82 (2017) https://www.jstage.jst.go.jp/article/comex/6/2/6_2016XBL0181/_article/-char/en

2. Satoshi Yasuda1, Nobuyasu Shiga1, Bohla Panta2, Kaori Fukunaga,
"TOWER TILT MONITORING WITH WIRELESS TWO-WAY INTERFEROMETRY (WI-WI)"
International Symposium on Structural Health Monitoring and Nondestructive Testing 4-5 October (2018), Saarbruecken, Germany
https://www.ndt.net/article/shmndt2018/papers/SHM-NDT-2018_paper_57.pdf

3. S. Yasuda, R. Ichikawa, Y. Hanado, S. Kawamura, H. Hanado, H. Iwai, K. Namba, Y. Okamoto, K. Fukunaga, T. Iguchi, N. Shiga, “Horizontal atmospheric delay measurement using wireless two-way interferometry (Wi-Wi),” Radio Science 54 (2019)
https://doi.org/10.1029/2018RS006770

4. Bhola Raj Panta, Kohta Kido, Satoshi Yasuda, Yuko Hanado, Seiji Kawamura, Hiroshi Hanado, Kenichi Takizawa, Masugi Inoue, and Nobuyasu Shiga,
“Distance Variation Monitoring with Wireless Two-way Interferometry (Wi-Wi)”, Sens. Mater., Vol. 31, No. 7, (2019), p. 2313-2321.
https://doi.org/10.18494/SAM.2019.2212

5. Daijiro Koyama, Yunzhuo Wang, Nobuyasu Shiga, Satoshi Yasuda, Nicolas Chauvet, and Makoto Naruse,
"Low latency information transfer based on precision time synchronization via wireless interferometry," Nonlinear Theory and Its Applications, IEICE, vol. 12, no. 2, pp. 225–235 (2021)
https://doi.org/10.1587/nolta.12.225

6. YUSUKE YAMASAKI, NICOLAS CHAUVET, NOBUYASU SHIGA, SATOSHI YASUDA, KENICHI TAKIZAWA, RYOICHI HORISAKI, AND MAKOTO NARUSE, "Delay-bounded Wireless Network Based on Precise Time Synchronization Using Wireless Two-way Interferometry," IEEE Access, (2021)
https://doi.org/10.1109/ACCESS.2021.3087866

7. HARUAKI TANAKA, YUSUKE YAMASAKI, SATOSHI YASUDA, NOBUYASU SHIGA, KENICHI TAKIZAWA, NICOLAS CHAUVET, RYOICHI HORISAKI, AND MAKOTO NARUSE, "Experimental Demonstration of Delay-Bounded Wireless Network Based on Precise Time Synchronization," IEEE Access, (2022)
https://doi.org/10.1109/ACCESS.2022.3203997