Wireless network customization technologies to enhance the future wireless-grid applications

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Summary

- NICT has conducted R&D, standardization and promotion activities on Wireless Network Customization Technologies to enable flexible radio device mesh topology (namely, Wireless-Grid) that is essential for future IoT society
- Three major mesh categories:
  - High capacity data collection network
  - Ultra low-energy operation network
  - Reinforced mesh network
- Further enhancements in the future collaborations:
  - Specification customizations
  - Harmonization/coexistence/cooperation with the other systems

Concept of smart utility network

- SUN means a network constructed by Electricity/Gas/Water meters equipping radio devices that can effectively and automatically relay data frames to the collection station, which is expected to further support large amount of monitoring/sensing applications

SUN's technical requirements ➡
- Low-energy performance
- Multi-hop transmission capability

Radio blind spot elimination by the multi-hop transmission

Analysis, visualization and feedback by using the collected data

Monitors/sensors with radio devices

Social cloud

WAN radio

Meters with radio devices (Smart meters)

SUN radio

Expanded area

Conventional area

Collection Stations (CSs)

WAN CSs

Agriculture sensors

Disaster area monitors

Coverage expansion by the multi-hop transmission

Structure monitors

Smart Utility Network (SUN)

Wide Area Network (WAN)

Standardization and certification

- NICT has established "Wi-SUN," the world first certification body of SUN devices, in order to effectively promote the IEEE 802.15.4g compliant devices by holding the conformance and interoperability tests

□ Standardization in IEEE 802
- NICT has proposed the required PHY and MAC specifications for SUN with Gas companies and meter venders in Japan. And, the proposed specifications have been included in IEEE 802.15.4g/4e standards

□ What is Wi-SUN alliance
- World first global certification body that certifies IEEE 802.15.4g compliant devices
- Established in January 2012, by mainly led by IEEE 802.15.4g standardization contributors. NICT is one of promoter members
- Its certification guarantees conformance and interoperability that is not guaranteed by standards thereby effectively promotes radio device products

Standards	Certification bodies	Products
IEEE 802.11 (WLAN) →	WiFi alliance →	WiFi
IEEE 802.16 (WMAN) →	WiMAX forum →	WiMAX
IEEE 802.15 (WSUN) →	Wi-SUN alliance →	Wi-SUN
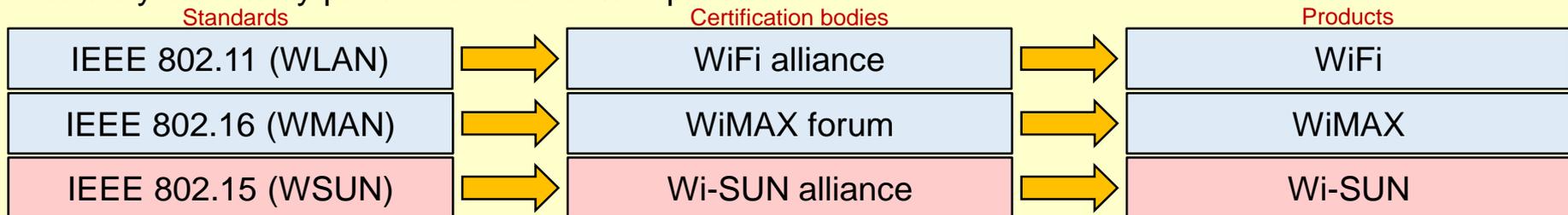
□ Achievements
- Certification profile for ECHONET Lite (a higher-layer communication protocol for home energy management systems) has been selected for 10 major electric power companies in Japan, which means application to more than 80 million houses

Further wireless-grid applications

- NICT has studied on further wireless grid applications promoted by the suitable certifications, such as applications to advanced home energy management systems and fishery fields. Wireless grid also becomes one of the promising technology for IoT and AI applications in the future

High capacity data collection network
- Mesh enhancement
- Data concatenation

Reinforced mesh network
- Reinforced SUN links
- Radio utilization modeling

WAN Collection station

Social cloud

Meters with radio device

SUN radio

Smart meter

WAN radio

Disaster monitors

Factory sensors

Collection station

Agricultural sensors

Sensors/monitors with radio devices

Home sensors

Sensors/monitors with radio devices

Structure monitors

Ultra low-energy operation network
- Intelligent sleeping
- Outdoor device implementation

LE-Superframe performance analysis

● **Ultra low-energy operations** (battery driven 10 year operation, by exploiting sleep period) especially for the outdoor use are studied, developed and tested
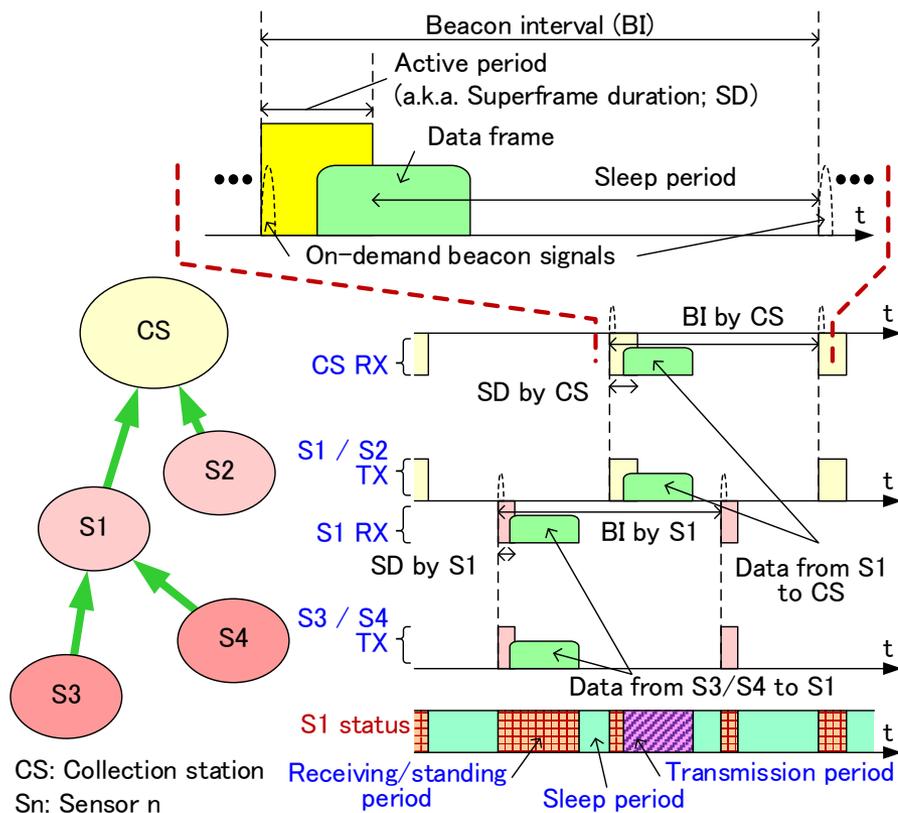
Concept of low-energy multi-hop communications
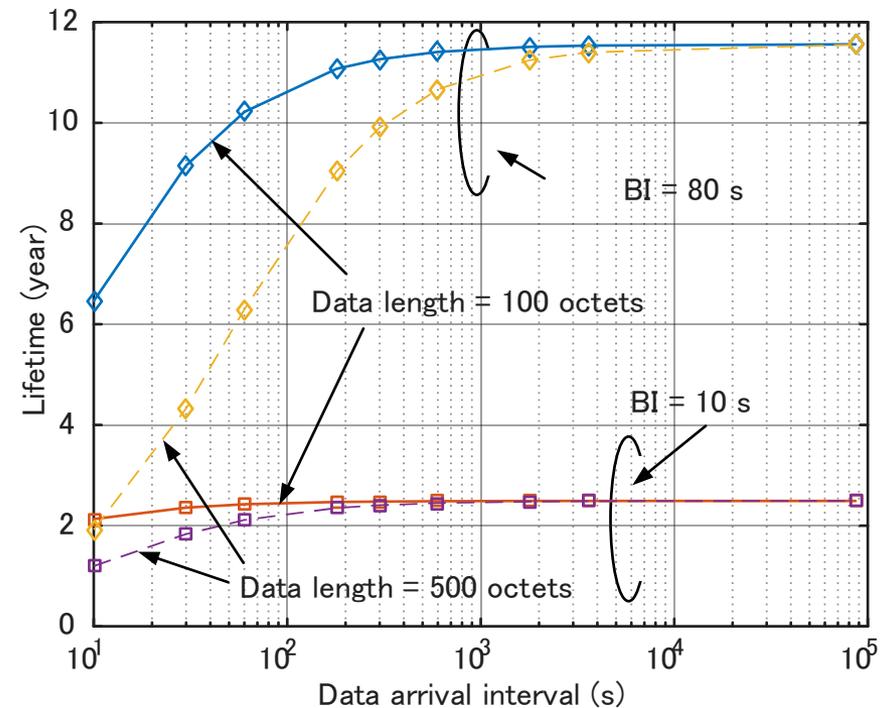
Lifetime estimation

Sensing in MOZUKU seaweed aquaculture

- "Sensor buoys" that equip battery driven low-energy devices and the water-temperature and salinity sensors are located in the MOZUKU seaweed farm in Okinawa, Japan, 1~2 km away from the land.

- Periodically monitored water-temperature and salinity data are collected via the low-energy multi-hop communications among the buoys and then stored in NICT's cloud to be managed

RF IC

Low-energy module

MAC IC   MCU

Rooftop relay device + Indoor collection station

1,060m

Sensor buoy

217m

Relay buoy

210m

Sensor buoy

Made from an aerial photograph (2010) by the Geospatial Information Authority of Japan

Wi-SUN device

Battery

Water temperature and salinity sensor
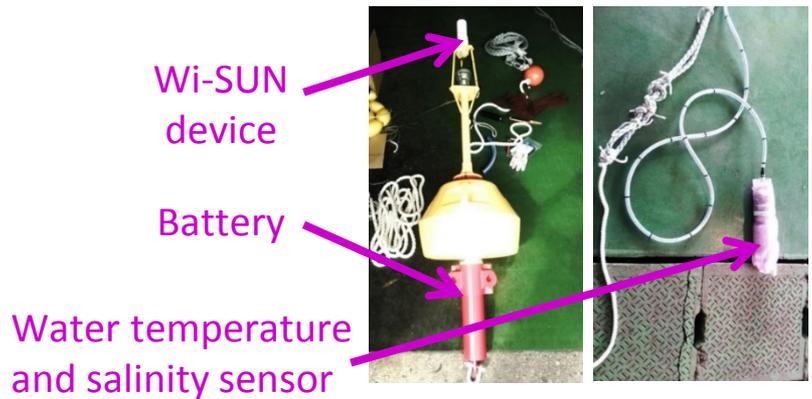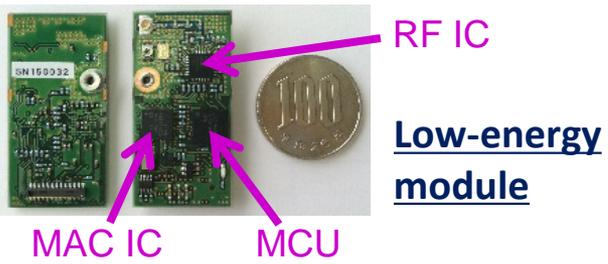
Sensor buoy

Sensor buoy allocation for monitoring

Proof test of the low-latency control

- Low-latency control in the low-energy operation network is confirmed in the laboratory and in the real rice field

Control to D4

CS

D1

D3 — Sensing from D3

D4 — Sensing from D4

Control target
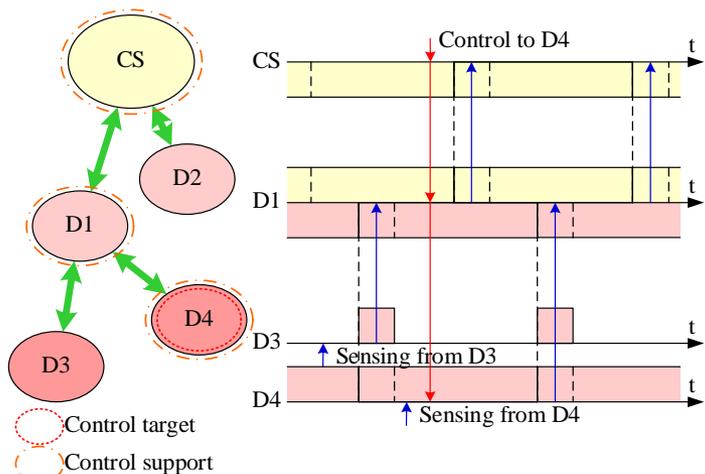
Control support

low-latency control in the low-energy operation network

Low-energy device connected PLCs

Wi-SUN device in the box

Antenna

Wi-SUN device
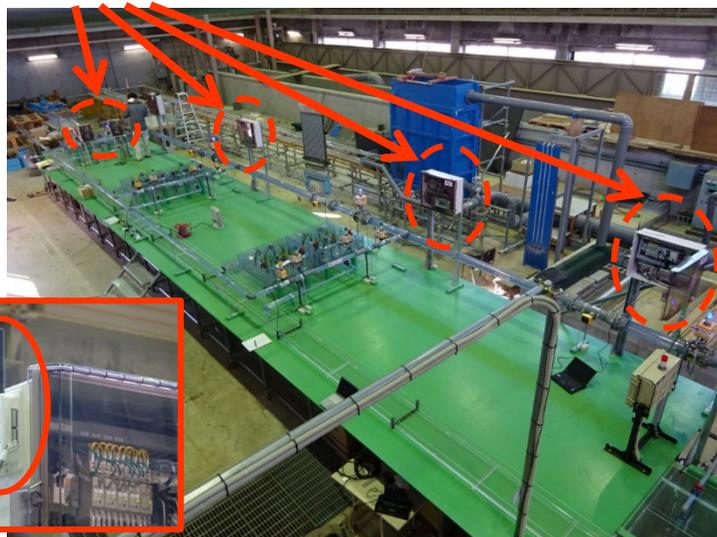
Proof tests in the laboratory and in the real rice field

Large scale mesh by L2R control

- SUN expansion for large scale mesh topologies for the smart-home/ building/ factory

- NICT has proposed HMT (Hierarchical Mesh Tree) deploying IEs (Information Elements) on MAC layer, which is accepted in the IEEE 802.15.10 (Layer 2 Routing)

(i)　(ii)　(iii)　(iv)

- Mesh root
- L2R router
- - - - - IEEE 802.15.4 PAN links
- → Mesh topology construction
- → Paths to the mesh root
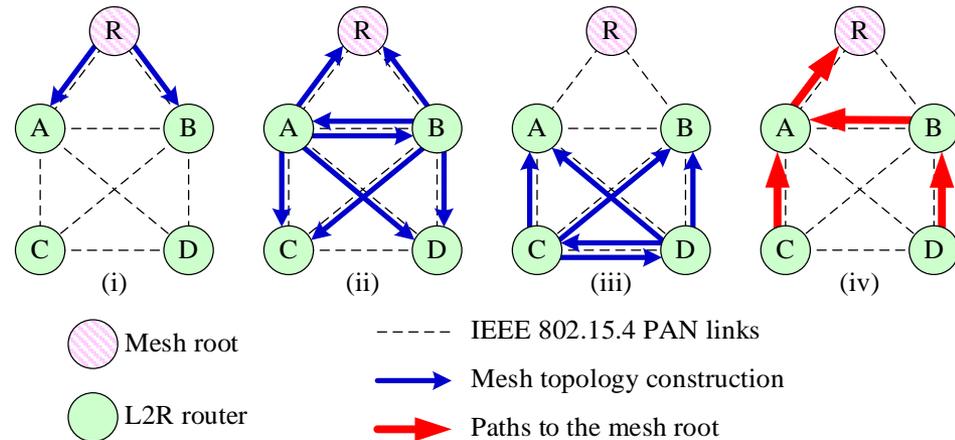
Autonomous mesh topology construction

Concept of HAN

Mesh roots
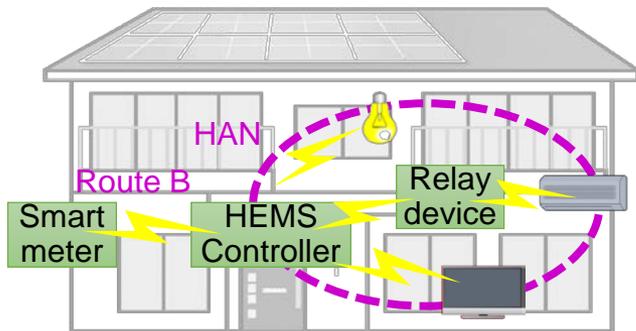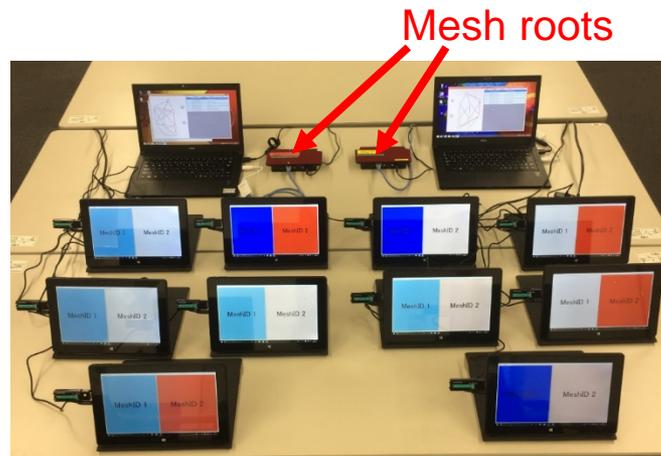
Routers
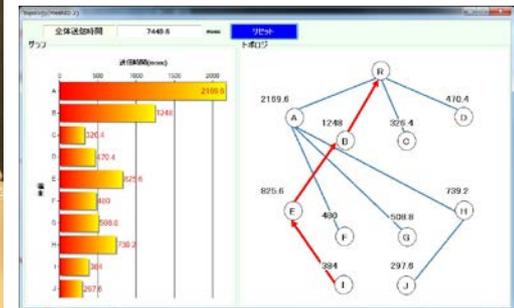
Routing test for large scale mesh

Reinforced mesh network in the factory

- NICT has investigated the applicability of radio signals on the several frequency bands including SUN's to the factory use that realizes flexible manufacturing-line deployments

Experimental setup for radio signal monitoring in the factory

Experimental environments employing Automated Guided Vehicle (AGV)
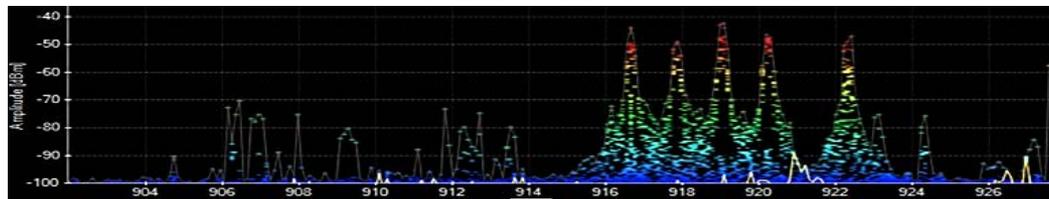
An example of monitored signals in the factory area (920 MHz)

Enhancements for the wireless-grid

- NICT is considering about **further enhancements** for the wireless-grid systems

  - ▶ **Specification customizations** according to the assumed applications

  - ▶ **Harmonization/coexistence/cooperation** with the other wireless systems
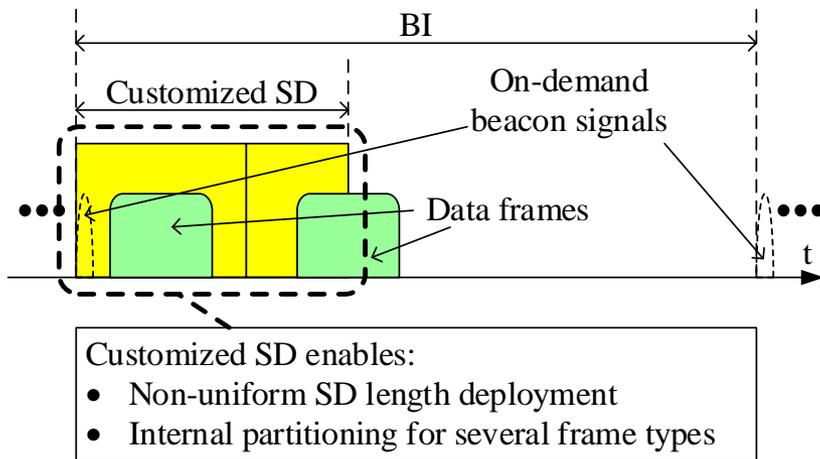
SD customization

Customized SD enables:
- Non-uniform SD length deployment
- Internal partitioning for several frame types

Ch_C : Common channel
Ch_U : Upstream channel
Ch_D : Downstream channel
⟷ : Common route
◀ - - : Upstream route
◀ ···· : Downstream route

Previous case   Enhanced case
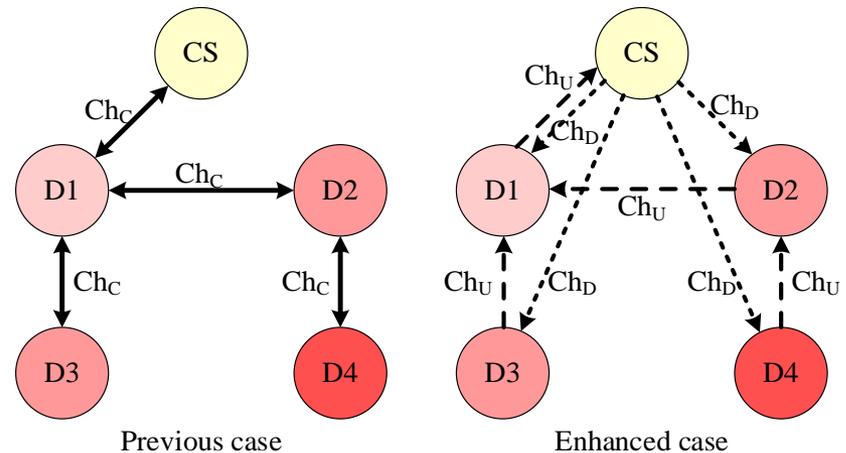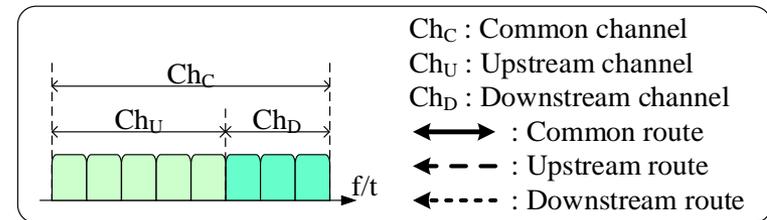
Separate management of upstream and downstream frame forwarding

Conclusions

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Hope our collaborations promote the system customization activities for the IoT society in the future!