SUMITOMO ELECTRIC TECHNICAL REVIEW
No. 98 · APRIL 2024
INFOCOMMUNICATIONS

Development and Utilization of Wi-SUN FAN for Smart City

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The Wi-SUN FAN (Wireless Smart Utility Network for Field Area Network profile) was initiated in 2012 as an international wireless communication standard for next-generation smart meters. The certification process for the new specification, Wi-SUN FAN 1.1, which includes improvements in communication speed, distance, and low power consumption, is expected to launch in 2024. This paper highlights the features of Wi-SUN FAN in relation to its compatibility with smart cities and provides an overview of our efforts in this field.

Keywords: Wi-SUN FAN, LPWA, smart city, smart meter

1. Introduction

A smart city refers to "a new city which aims to ensure efficient management and operation of basic infrastructure as well as life-related infrastructure and services by using cutting-edge Internet of Things (IoT) technologies, thereby enhancing people's quality of life and achieving sustainable economic development while giving environmental consideration." In smart cities, issues currently faced by cities and communities are expected to be solved by utilizing IoT-based sensing and AI-based big data analysis and maintaining urban functions in an optimal condition.

Wireless Smart Utility Network for Field Area Network (Wi-SUN FAN), which is under development by Nissin Systems Co., Ltd., is expected to be used as one of the communication technologies for IoT in smart cities because of its capability to gather information from a large number of devices in a wide area at low cost. This paper will describe the characteristics of Wi-SUN FAN from the viewpoint of compatibility between Wi-SUN FAN and smart cities and report on Nissin Systems' initiatives.

2. Wireless Communication Technologies to Be Used in Smart Cities

In smart cities, various devices will be connected to networks to exchange information. Accordingly, diverse communication technologies will be used. Wireless communication technologies will be required for efficient data gathering. Such technologies to be used in smart cities include 3G/4G/5G, Wi-Fi, Low Power Wide Area (LPWA), Bluetooth, and Radio Frequency Identification (RFID). As shown in Fig. 1, the communication distance, speed, and cost of these wireless communication technologies vary, and it is essential to select an appropriate wireless communication technology depending on the application.

Notably, LPWA is a wireless communication technology characterized by low power consumption and wide-area, long-distance communication. Although the communication speed is lower than that of Wi-Fi and 3G/4G/5G,

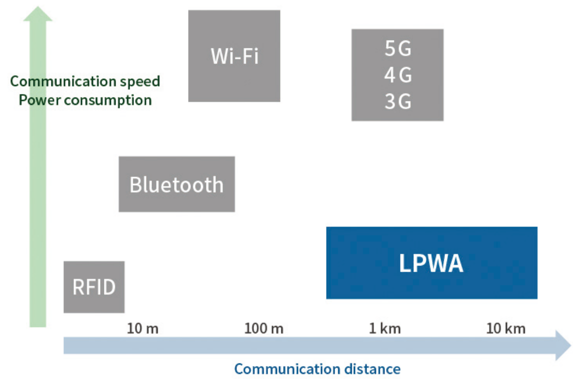

Fig. 1. Comparison of wireless communication technologies

LPWA enables wireless communication over 10 km and achieves relatively inexpensive operation. Thus, LPWA is considered a promising candidate as an IoT technology for smart cities.

3. Various LPWA Standards

There are various LPWA standards, which can be classified as shown in Table 1 based on their characteristics. These standards are operated by taking advantage of their characteristics.

It is difficult for general companies and users to handle standards that require licenses. Such standards are mainly operated by mobile phone carriers. For this reason, general companies and users must pay fees to mobile phone carriers to use such standards. The greater the number of devices, the higher the operation cost.

In terms of network topology, a "star" network features hosts directly connected to a hub, making it difficult to extend the distance. Meanwhile, a "mesh" network enables adjacent devices to serve as relays, making it possible to extend the distance and bypass in the event of a failure.

Table 1. Classification of LPWA standards

STD	License	Network topology	Service offering	Intl. STD
LTE-M	reqd.	Star	Base station	✓
NB-IoT	reqd.	Star	Base station	✓
LTE Cat.1	reqd.	Star	Base station	✓
LoRaWAN	Not reqd.	Star	Base station/ Private network	✓
Sigfox	Not reqd.	Star	Base station	
ELTRES	Not reqd.	Star	Base station	
ZETA	Not reqd.	Mesh	Private network	✓
Wi-SUN FAN	Not reqd.	Mesh	Private network	✓
SmartHop	Not reqd.	Mesh	Private network	
UNISONet	Not reqd.	Mesh	Private network	

Regarding standards whose service offering is a "base station," an operating company, such as a mobile phone carrier, installs a base station, and the service is available within the radio wave area. Meanwhile, regarding standards whose service offering is a "private network," users are required to purchase devices and install them at arbitrary locations.

In contrast to standards developed by only specific companies, those indicated with "international standards" are open and can be developed by multiple companies, enabling multi-vendor sourcing.

As described in this chapter, LPWA has various standards. Wi-SUN FAN, which is one of these standards, is considered to be a communication standard suitable for smart cities due to the following reasons: (i) it is easy to handle because it does not require a license, (ii) the distance can be extended easily because of a mesh network, (iii) the operation is easy due to a private network, and (iv) multi-vendor sourcing is possible because it is an international standard.

4. Characteristics of Wi-SUN FAN, Which Is Suitable for Smart Cities

This chapter describes the characteristics of the Wi-SUN FAN standard, which is one of the LPWA standards introduced in the previous chapter and which is highly compatible with smart cities.

4-1 International standard

Wi-SUN FAN is an international standard that has been developed by various companies, including Nissin Systems. Conformity to the standard also enables mutual connection between different devices. In smart cities, which require social infrastructure with high public interest in particular, multi-vendor sourcing is important from the viewpoint of reducing the cost and procurement risks.

4-2 Frequency hopping

Frequency hopping is one of the characteristic functions of Wi-SUN FAN. This is one of the signal modulation protocols and is referred to as the spread-spectrum communication protocol. It achieves transmission by changing the carrier wave frequency at certain intervals. The frequency-switching communication is characterized by noise resistance and high fault tolerance. It can also ensure stable communication in smart cities where communication devices are closely located.

4-3 Multi-hop mesh network

Wi-SUN FAN can cover a wide area based on multi-hop routing (communication between multiple devices via relays) in a mesh network topology. In Wi-SUN FAN, a mesh network is built autonomously only by installing devices. Even if the radio wave environment deteriorates due to the failure of a single device, a bypass route can be built automatically. Thus, Wi-SUN FAN is suitable for a wide-area environment, such as smart cities, where devices and the radio wave environment are subject to change.

5. Wi-SUN FAN 1.1, the Latest Standard

The year 2012 marked the beginning of the initiative to formulate the Wi-SUN FAN specifications. In 2015, Wi-SUN FAN 1.0, the first version of the specifications, was formulated. Subsequently, an initiative to formulate the Wi-SUN FAN 1.1 specifications started in 2019. The Wi-SUN FAN 1.1 (v06) specifications were completed in April 2023. The Wi-SUN FAN 1.1 certification system is scheduled to be launched in 2024. Wi-SUN FAN 1.1 is characterized by improvement in the communication speed and distance and low power consumption of end devices. The specifications have been extended to improve the communication speed and distance, as shown in Fig. 2, encompassing the conventional general LPWA performance.

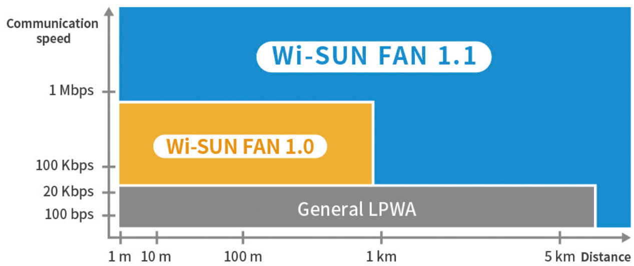

Fig. 2. Comparison based on the communication speed and distance

6. Nissin Systems' Initiatives

Nissin Systems has been working on Wi-SUN FAN-based initiatives to realize smart cities. This chapter explains such initiatives.

6-1 Development of products supporting Wi-SUN FAN 1.1

In January 2019, Nissin Systems developed the world's first Wi-SUN FAN 1.0-certified radio in collaboration with Kyoto University. Subsequently, Wi-SUN Alliance, the Wi-SUN FAN standardization organization, launched a project to formulate the Wi-SUN FAN 1.1 specifications. Nissin Systems has been working with Kyoto University to meet the Wi-SUN FAN 1.1 specifications. The company also participates in all the events, which are held about three times a year and organized by Wi-SUN Alliance, for interconnection among products of different companies to improve the interconnectivity. At present, we are working to improve the quality and performance and upgrade the supported hardware toward Wi-SUN FAN 1.1 certification.

6-2 Demonstration of multi-hop connection using 1,000 radios

In November 2021, Kyoto University and Nissin Systems conducted R&D on elemental technologies to connect 500 radios, based on Wi-SUN FAN multi-hop connection, by using the test equipment, which integrated and gathered information from many radios to a single trunk radio. As a result, we confirmed that high-quality communication was realized in an environment using 500 radios when data was transmitted from the respective radios with the communication traffic volume of the expected actual operation of smart meters. In anticipation of the operation of next-generation smart meters whose deployment is under study in FY2023 and beyond, it is required to accommodate up to 1,000 radios in a single autonomous network.

In this project, we conducted R&D on the following two points to realize high-quality communication in an environment using 1,000 radios.

(i) Investigation into optimal values for various parameters related to Wi-SUN FAN communication control

(ii) Porting of the Wi-SUN FAN protocol stack to a radio supporting a single-board computer to accommodate 1,000 radios

We have succeeded in building and maintaining a multi-hop mesh network using 1,000 Wi-SUN FAN radios, which leveraged the results of the R&D, and realizing data communication with the communication traffic volume expected in actual operation (see Photo. 1). We have also succeeded in attaining a cumulative data communication success rate of 99.9% or more, which meets the requirements of next-generation smart meters.

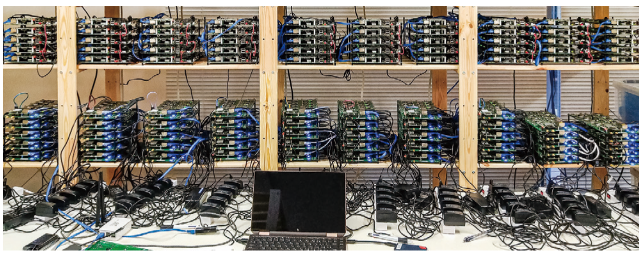

Photo 1. Test using 1,000 radios (photo courtesy: Kyoto University)

6-3 Demonstration in a large field

Kyoto University and Nissin Systems conducted a demonstration in a large field, where 400 Wi-SUN FAN radios were installed in high density at random locations within a 68,000 m^2 (170 m × 400 m) area on the premises of Kyoto University, on the assumption that Wi-SUN FAN radios were used for a sensor network in a smart city.

We demonstrated that a multi-hop network was built autonomously by respective Wi-SUN FAN radios and that information from the respective radios was transmitted to the trunk radio for gathering data (border router) at a communication success rate of 97.1% or more during a demonstration period of over two days. We confirmed that an autonomous multi-hop network was built using 400 radios and succeeded in the communication test. It should be noted that we did not design the installation locations in advance. We installed radios with high density so that they could transmit and receive sufficient radio waves. The network was continuously operated during the two-plus-day demonstration period.

The radios were also placed at locations blocked by multiple buildings. However, Wi-SUN FAN's function to autonomously build a multi-hop network made it possible to automatically build a network to bypass buildings that obstructed the radio waves. We confirmed that all the radios installed within the area were accommodated in the network. We also confirmed that the respective radios autonomously changed the network configuration to improve the communication success rate depending on the installation environment. This function is expected to automatically build a wireless multi-hop network in response to changes that significantly affect the wireless communication route, including the construction of buildings and land readjustment during operation in urban areas, and to achieve stable operation.

The data was transmitted from all the radios at intervals of 5, 15, and 30 minutes, and a communication success rate of 97.1% or more, which is almost equivalent to that of the large-scale demonstration that was previously conducted using 1,000 radios in an indoor environment, was attained (Fig. 3).

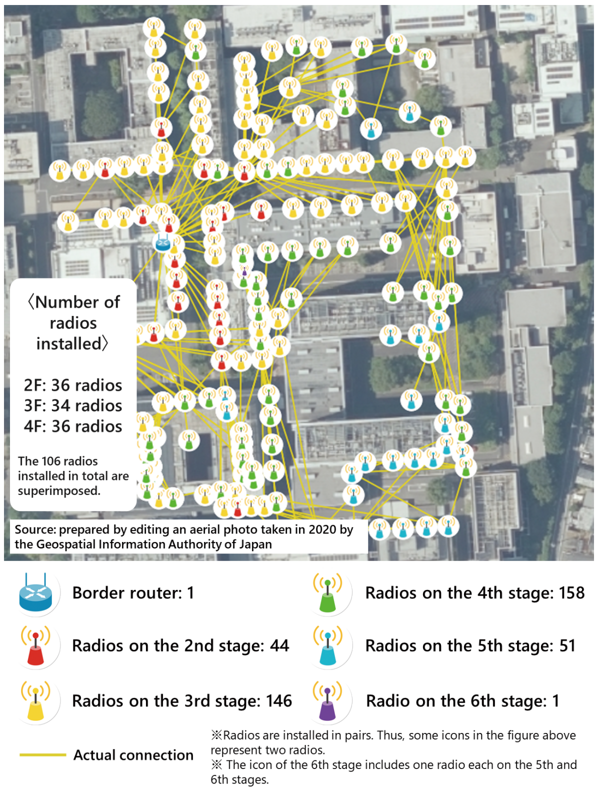

Fig. 3. Connection status of radios installed on the premises of Kyoto University
(prepared by editing an aerial photo taken in 2020 by the Geospatial Information Authority of Japan)

7. Conclusion

Kyoto University and Nissin Systems have continued to work on the development of Wi-SUN FAN and conducted demonstration experiments to determine whether the performance and quality of Wi-SUN FAN are appropriate in terms of practical use. Based on the demonstration results presented in this paper, Wi-SUN FAN is expected to be utilized as a wireless communication technology for smart cities even in situations where it is necessary to gather information from many devices in a wide area, such as a smart city.

We will continue to work on development toward Wi-SUN FAN 1.1 certification, which will be launched shortly. We are determined to prepare products and solutions for actual operation.

8. Acknowledgements

Part of the R&D was conducted as part of "R&D on large-scale, high-density multi-hop international standard wireless data communication system (Wi-SUN FAN) to realize Society 5.0," a joint R&D project under "SCOPE – R&D on technologies for robust/flexible radio resource utilization and new applications, and its support program for the training of radio experts (JP196000002)" adopted through a call for applicants for the Wireless COE R&D Program of the Strategic Information and Communications R&D Promotion Programme (SCOPE) by the Ministry of Internal Affairs and Communications.

We would like to take this opportunity to express our deepest appreciation to Professor Hiroshi Harada of the Graduate School of Informatics, Kyoto University, for his support and cooperation in conducting this research.

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Source of reference
Yuichi Hamada, "Development and Utilization of Wi-SUN FAN for Smart City," Nissin Electric Technical Report Vol.68, No.2, pp.71-75 (December 2023)