920MHz Band Multi-hop Wireless Network System

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One policy aimed at the growth of OKI Group is the development of a "smart society" that solves the energy and environmental problems faced by the society while providing people with safe, secure and comfortable lives. Among OKI's R&D work focused at realization of a smart society is the "smart network", and it is being included in OKI's new area of communication business. Smart network will serve as a foundation that will enable various devices and facilities, which were previously unconnected, to autonomously exchange information. Enabling large volumes of small data, such as sensor information, to be exchanged between numerous devices, extended period of operation while consuming less energy and freedom of installation are some of the requirements of a smart network, and they differ from the currently prevailing broadband networks. In an effort to achieve the described infrastructure, OKI has been working on the development of a multi-hop wireless technology, and in July 2012, announced a "920MHz Band Multi-hop Wireless Network System" for use in smart networks. The system is targeted at the increased need for energy management of buildings and homes to save energy and the need to manage/control various facilities and devices installed as part of the social infrastructure. This article introduces OKI's effort in the smart network field with focus on this new system.

Application of the 920MHz Band Multi-hop Wireless

In a multi-hop wireless transmission, radio waves are used to relay data between several devices much like a bucket brigade. Since communication area is expandable even without a backbone network through deployment of wireless devices, a network required for an application can be achieved flexibly and cost effectively.

The 920MHz frequency band was made available in Japan starting July 2012 for use in growingly demanded applications such as smart metering. 920MHz band has higher signal reachability than the 2.4GHz band used for Wi-Fi and higher throughput when compared with the 429MHz band of the Specified Low-Power Radio Stations making it suitable for building a multi-hop wireless network that requires routing. Furthermore, since wireless base station license is not required for output up to 20mW, ad hoc networks can be built within buildings and certain areas as necessary. Due to the potential shared use of the 920MHz band by numerous sensor devices, Japan's wireless specifications place restrictions on the length of continuous transmission and total transmission time per hour. However, the previously mentioned merits will likely progress the use of the frequency band.

OKI has been involved with research and development of the multi-hop wireless technology from the outset and was quick to experiment/verify the multi-hop's reachability, high reliability and energy efficiency in the 920MHz band. Additionally, OKI has been actively participating in the development of the national 920MHz technical standards and international standardization of the multi-hop communication system.

Managing home energy use through coordination of appliances/energy devices/household equipment (HEMS: Home Energy Management System), managing building and plant energy use through monitoring/control of power meters and measuring devices (BEMS: Building Energy Management System), managing energy use in apartment/condominium complexes (MEMS: Mansion Energy Management System), and wide-area network M2M (Machine to Machine) to connect facilities/equipment deployed in communities or other wide areas are some of the possible applications for the 920MHz band multi-hop wireless system. For example, in case of BEMS, a building's power meters can be interconnected using multi-hop wireless instead of physical wiring to reduce construction cost and speed up service introduction.

Overview of 920MHz Band Multi-hop Wireless Products

The "920MHz Band Multi-hop Wireless Network System" consists of a wireless base unit, wireless sub-units and optional network management server (**Photo 1**). OKI's

aim is to provide an open system based on international standards. The system supports the 920MHz wireless band that complies with the domestic ARIB STD-T108 standard, and wireless layer and network layer are based on IEEE802.15.4g and ZigBee IP international standards, respectively.

Additionally, OKI has started selling software licenses for communication protocol stacks of IEEE802.15.4g compliant MAC layer and ZigBee IP compliant network layer thereby providing support for use of 920MHz band multi-hop wireless even in business sectors where OKI is not directly involved.

Photo 1. External View of Wireless Unit

Features of OKI's Multi-hop Wireless Network

Besides compliance with international standards, OKI's multi-hop wireless network has the following features.

1) Flexible Multi-Hop Network Configuration

In OKI's 920MHz wireless multi-hop network, "network IDs" are set in each wireless node to enable identification of multiple networks. This allows multiple independent networks to be configured without interferences or misconnections of other multi-hop wireless networks regardless of the sub-units' physical locations. **Figure 1** shows an example of a multiple network configuration. Misconnections between the separate networks A and B are prevented using MAC address filtering or exclusive AAA authentication option of the IP integrated model.

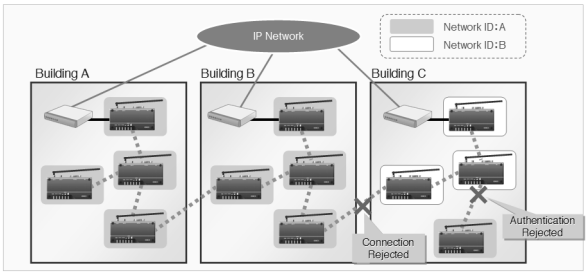

Figure 1. Independent Network Configuration

2) Dynamic Routing Function

In the event of a failure or the state of the wireless route a node is using deteriorates, the node will automatically re-route selecting an alternate path that is most optimal. Furthermore, if a network management server is utilized and abnormality is detected in the base unit, switchover to an alternative base unit can be accomplished (**Figure 2**).

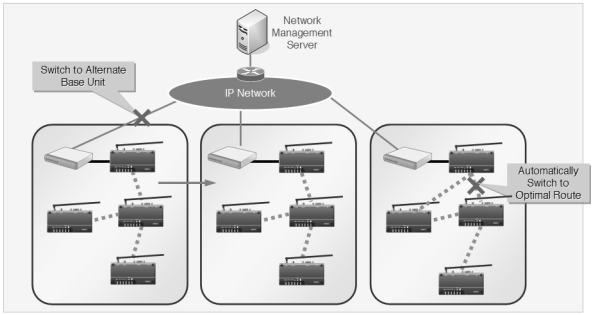

Figure 2. Dynamic Routing Function

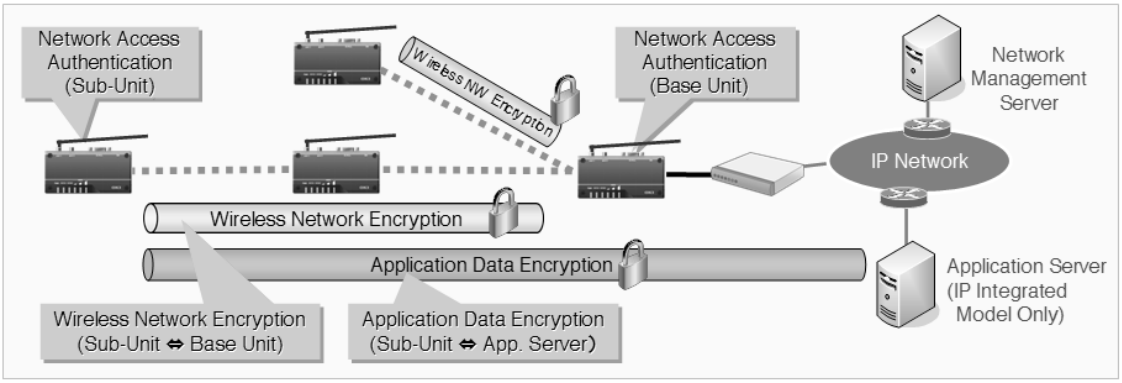

Figure 3. Security Functions

3) High Security Functions

The 920MHz band multi-hop wireless network supports the following security measures to protect the network from data theft, falsification, and unauthorized access (**Figure 3**).

- Network Access Authentication (Base Unit/Sub-Unit): Prevents unauthorized access and spoofing with MAC address filtering
- Wireless Network Encryption: Prevents network (MAC layer) data theft and falsification
- Application Data Encryption: Prevents data theft and falsification between applications (if sub-units are RS232C type)

Wireless Unit

The 920MHz wireless unit is the core device in OKI's wireless multi-hop network system. According to use and devices to be connected, the system can be configured either as a RS485 transmission model or an IP integrated model.

1) RS485 Transmission Model

RS485 is one of the international serial communication standards for handling communications between devices that are connected via bus-type cables. It is generally used with power meters and various measuring devices in BEMS, smart metering and other business applications. In a RS485 transmission model, a wireless unit is attached to the RS485 interface of the measuring or data collection device enabling that device to transmit data through the wireless multi-hop network. Since RS485 interface data is transmitted in the wireless domain, a previously wired network can easily be converted to wireless without modification to the measuring or data collection device. It is effective in cases when BEMS needs to be installed in an existing building, but cable conduits for physical connections cannot be secured.

In a RS485 transmission model, a multi-hop network can basically be configured with only a wireless base unit and sub-units, and it will operate simply by attaching a 920MHz wireless unit to each measuring device, sensor and corresponding data collection device. Hence, operation of a network management server or implementation of a driver in the data collection device is not required and converting a RS485 system to wireless is simple (**Figure 4**).

2) IP Integrated Model

IP integrated model is configured with devices/sensors that are connected to an IP network and wireless units are

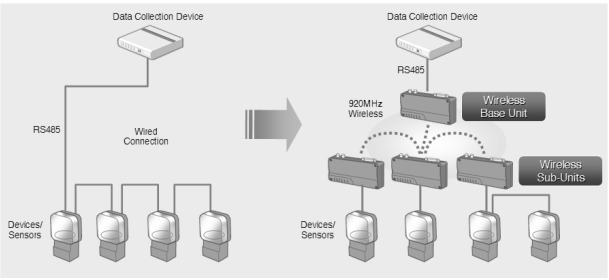

Figure 4. RS485 Transmission Model

managed from a network management server located at a data center. Network management server will enable integrated management of multiple networks thus a large-scale multi-hop network operation is possible. Additionally, there is a function to dynamically switch base stations in an event of failure and security functions (authentication, encryption) capable of integrally managing multiple networks (**Figure 5**).

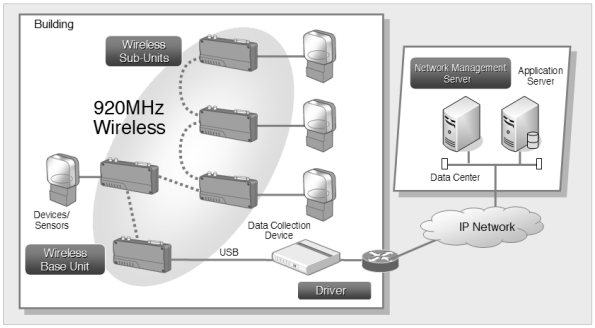

Figure 5. IP Integrated Model

In an IP integrated model, data from wireless sub-units can be delivered to the data center's upper-level equipment (application server) as IPv6 packets via the base unit and USB connected data collection device. The configuration is achieved by installing a driver for the wireless base unit in the data collection device. This allows wireless units (base/sub-unit) to communicate with the application server and network management server using IPv6, and from the data center, various settings and firmware downloads to the wireless units can be accomplished.

Network Management Server

The network management server in the 920MHz band multi-hop wireless network system is server software for centrally managing the distributed wireless units. In addition to monitoring/controlling the wireless units and managing the entire multi-hop wireless network, the network management server provides service APIs to external application servers. The network management

server can be operated using a Web browser on a client PC, and dynamically changing communication paths of the multi-hop wireless network can also be displayed. The main functions are shown in **Table 1**.

Table 1. Main Functions of the Network Management Server

Main Functions		Description
Security	Connection Authentication	Performs AAA authentication when wireless unit accesses the multi-hop network
Service API	IP Address Response	Obtains IP address from wireless unit's MAC address
	Pre-Shared Key Registration	Registers pre-shared key used in channel encryption of wireless unit
Monitoring	Alarm Monitoring	Receives alarm information from wireless unit
	ICMP Monitoring	Monitors life of wireless unit (base unit)
	Address Registration	Registers IP address or ID of wireless unit to system
	Route Information Collection	Manages route information of wireless unit (periodic/non-periodic)
Maintenance	Logging	Server's application log and client operation log
	Periodic DB Information Purging	Erases DB's alarm information that has elapsed a set period
	Backup/Restore	Provides system backup and restore functions

Software Licenses

Other available 920MHz band multi-hop wireless system products are communication protocol stack software licenses for the MAC layer supporting IEEE802.15.4g and network layer compliant with ZigBee Alliance's 920MHz ZigBee IP standards. As shown in **Figure 6**, MAC layer software consists of both the wireless IC chip control driver and the MAC layer software. Network layer software includes the IP layer (6LowPAN, IPv6, RPL), TCP/UDP, TLS (encrypted session) and PANA (access authentication). The products are available as a standalone MAC layer license or MAC+network layer license. They are being utilized by 920MHz wireless IC chip vendors and wireless module vendors. There is high expectation the 920MHz band multi-hop wireless will spread to various fields.

Home Network Application

With the spread of smart metering and HEMS, home use of multi-hop wireless is highly anticipated. As **Figure 7** shows, a multi-hop wireless network can be connected to the home gateway (HGW) that accesses the communication provider's broadband network. Then linking appliances and power devices in the home with the power meter through a sensor network, energy use can be visualized and power consumption can be controlled.

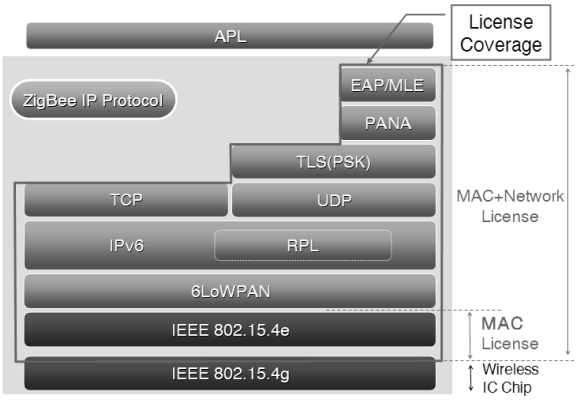

Figure 6. Software Licenses

ECHONET Lite defined by ECHONET Consortium is a set of specifications intended to standardize the monitoring and control of various home appliances. It is a key technology for achieving a smart home ensuring the interconnection of home equipment. In an effort to apply 920MHz band multi-hop wireless to the home network, OKI has developed prototypes of USB dongle-type wireless unit for HGW connections and adaptors for connecting non-networked home devices to the ECHONET Lite network. They are being tested in field trials conducted with partners.

There are plans by the power companies to implement smart meters. When these smart meters are linked with HEMS devices, new services such as demand response (DR) are expected. 920MHz wireless is considered to become the dominant communication method between the smart meters and HEMS devices.

Examples of Network Configuration

Examples of several 920MHz band multi-hop wireless configurations are introduced below.

Configuration Example (1):
BEMS (Building Energy Management System)

In BEMS, power meters are attached to distribution panels and high-voltage power receiving equipment (cubicle) located throughout the building. The purpose is to measure and visualize the power consumption of each floor or tenant and suppress peak power usage. Implementation is urgently needed to reflect government recommendations and cope with the energy situations seen in recent years. Using wireless communication to monitor the power meters in both existing and new buildings reduces construction time, thus promotes implementation of BEMS. Due to its characteristics, the

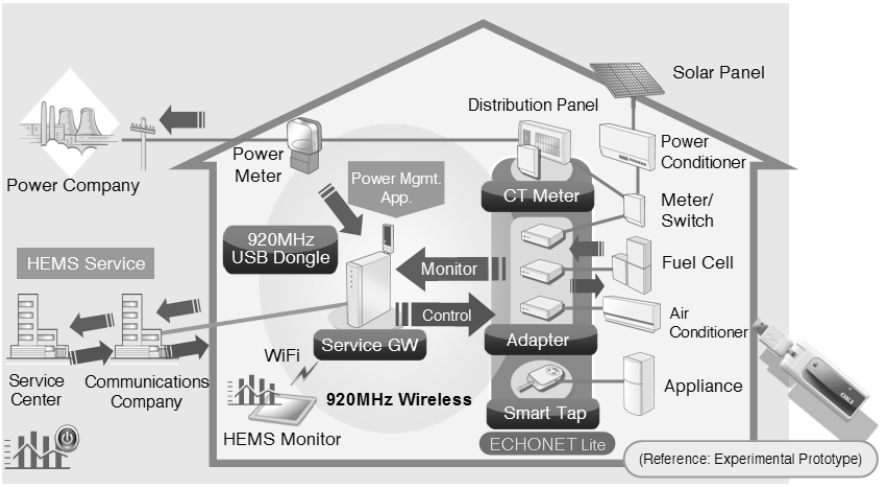

Figure 7. HEMS Application

920MHz band multi-hop wireless provides excellent reachability capable of covering an entire building. Since most power meters are equipped with a RS485 interface and OKI's 920MHz wireless unit is compatible with communication specifications of major power meters, use of RS485 transmission model is suitable (**Figure 8**).

Configuration Example (2):
MEMS (Mansion (Apartment/Condominium) Energy Management System)

Utilizing the high reachability of 920MHz band multi-hop wireless, readings from the smart meter of each unit in the housing complex is sent to a data collection device. Wireless communication and dynamic routing function ensures ease of installation, thereby reducing construction costs. Not only will new complexes benefit, but existing complexes will see substantial reduction in costs since the meters can be deployed without the time-consuming wiring work (**Figure 9**).

Configuration Example (3):
"Shared Network Services"

Shared network services accommodate multiple services such as smart metering (meter readings), HEMS/BEMS and M2M. Sharing instead of maintaining individual networks will greatly reduce communication equipment costs for service providers. Security and flexible network paths will be provided to allow multiple services to coexist. The services can connect to smart meters, RS485/232C compatible devices and variety of other devices/sensors (**Figure 10**).

Shared Network Services have the following advantages.

Wide-area coverage: Several multi-hop networks can be configured in a wide area to provide intercommunication (M2M) coverage for variety of devices. Network management server will enable centralized management.

Shared network: Security and flexible network paths can be provided to allow multiple services to coexist. Sharing instead of maintaining a separate network for each service will reduce equipment costs, and connection to smart meters, RS485/232C compatible devices and variety of other devices/sensors is possible.

Cost reduction: Wireless simplifies installation work. Networking the devices with self-operated 920MHz wireless reduces data center connection costs.

Future Efforts

OKI will continue its contribution to the realization of a smart society by supporting the rapid deployment of M2M/BEMS/HEMS and improvement of device interoperability using the recently introduced products as a base. ◆◆

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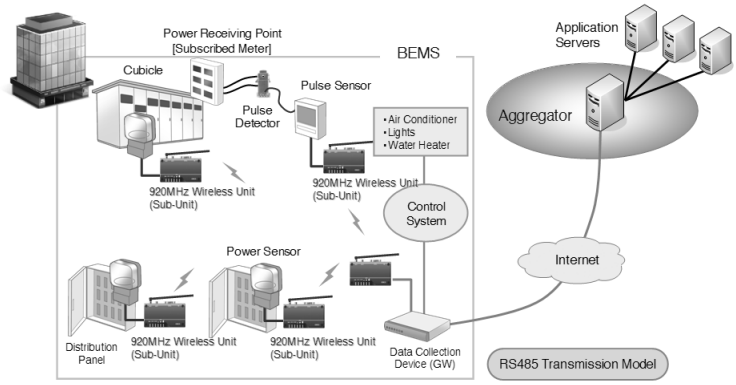

Figure 8: Configuration Example: BEMS

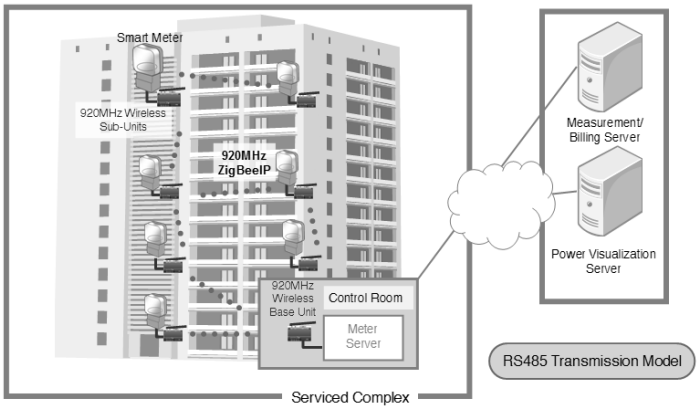

Figure 9. Configuration Example: MEMS

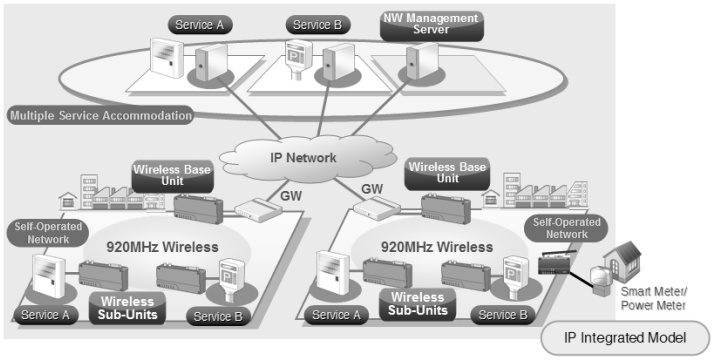

Figure 10. "Shared Network Services"

【Glossary】

IEEE802.15.4g

IEEE802.15.4 is a widely used wireless system such as in a wireless sensor network. IEEE802.15.4g is a modified standard intended for the physical layer of smart meters.

ZigBee IP

ZigBee, which is an international specification for multi-hop wireless networks, is under study and development by ZigBee Alliance. ZigBee IP is an IP-enabled version of the specification. IP-compatible multi-hop wireless communication is possible when combined with 6LoWPAN and IPv6/RPL technologies standardized by IETF.

The ZigBee IP 1.0 specification has been standardized in Japan by the Institute of Information and Communication Technology Committee (TTC) as TTC JJ-300.10 Method B. Standard can be viewed in Japanese at http://www.ttc.or.jp/j/info/topics/201302251/.