IoT-based Bus Location System

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***Abstract*—A bus location system is one method for improving the convenience of users. We had proposed a novel bus location system using a wide-area wireless sensor network based on the 2.4 GHz band, and we had further confirmed its feasibility in a trial operation that revealed some resulting problems. In this paper, we propose an Internet of Things (IoT)-based bus location system by changing the specifications of our earlier proposed system. In the newly proposed system, bus location information is collected with Message Queue Telemetry Transport (MQTT) and MQTT for Sensor Networks (MQTT-SN) through multiple Wireless Smart Utility Networks (Wi-SUNs) based on the 920 MHz band. We further demonstrate how these protocols improve the packet arrival rate and development productivity.**

I. Introduction

A bus location system that provides the current position and operation information of buses to bus users is one method for improving the convenience of users. Most existing systems utilize a cellular network in order to collect bus location information to a management server and deliver bus operation information to bus stops. However, there are cases where local governments could not continue to offer a bus location system, because Japanese mobile communication costs are higher than those in other countries.

On the other hand, information and communication technology have advanced. The Internet of Things (IoT) and Machine-to-Machine (M2M) communication are receiving considerable attention. Researchers and engineers around the world are working toward the realization of smart cities based on these technologies. In smart cities, wireless sensor networks are constructed in the city and are used to collect various information such as environmental data. For example, the Wireless Smart Utility Network (Wi-SUN) has attracted attention as a communication standard for smart meters and Home Energy Management Systems (HEMS) in Japan.

In previous work, we proposed a novel bus location system using a wide-area wireless sensor network that constructed with multiple small sensor nodes installed at all buses and various places along bus routes [1]. This bus location system does not incur any communication costs because information is exchanged through the wireless sensor network using multi-hop communication. We conducted a trial operation for over a year, and confirmed that our previous system could perform normally as a bus location system. However, some issues were revealed. One problem was that the packet loss rate increased when the number of multi-hops increased and when radio waves were reflected. One reason for this was that we used the 2.4 GHz band, which has strong directivity. In addition, our previous system exhibited insufficient development productivity and system maintainability, owing to the use of an original communication protocol.

In this paper, we propose a new IoT-based bus location system. In our new system, multiple Wi-SUNs are constructed, and each wireless sensor network is smaller than the wireless sensor networks in our previous system. The bus location system is operated on these networks. Moreover, Wi-SUN is able to use the 920 MHz band wave, which offers a higher maximum transmission output and stronger diffraction than the 2.4 GHz band wave. Consequently, the arrival rate of radio waves is improved, and the number of multi-hops decreases. We also adopt the MQTT protocol and the MQTT-SN protocol in order to generate bus location messages. MQTT is an OASIS-standard application-layer protocol. Using these protocols, the development productivity and system maintainability are improved.

II. Newly Proposed System

Fig. 1 shows an overview of our newly proposed system. In the proposed system, we install Wi-SUN-compliant wireless sensor nodes at all buses, bus stops, street lights, and utility poles along bus routes, in the same way as the our previous system. Hereafter, we refer to these wireless sensor nodes respectively as “bus nodes”, “bus stop nodes”, “router nodes.” We construct multiple wireless sensor networks that are smaller than the wireless sensor network of the our previous system. A bus node acquires its current location periodically using GPS, or estimates its position using beacon frames transmitted by nearby sensor nodes. Then, the bus node transmits the location information to the gateway. When a router node installed around the bus node receives the packet, it relays the packet to other neighboring router nodes or to the gateway. A gateway has two interfaces–one for the wireless sensor network and one for the fixed local network–and

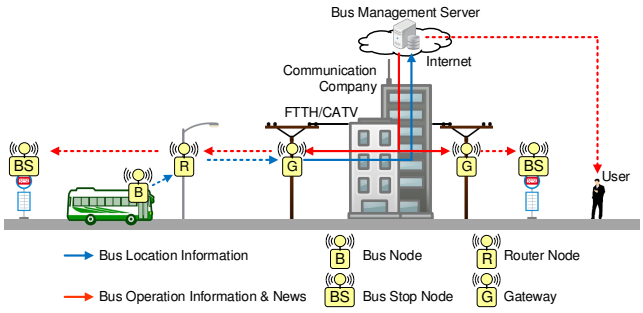

Fig. 1. Overview of our newly proposed system.

TABLE I
COMPARISONS WITH BETWEEN OUR NEWLY PROPOSED SYSTEM AND EXISTING SYSTEMS.

	Existing system using a cellular network	Our previous system	Our newly proposed system
Extendibility of service area	High	Low to moderate	Moderate to high
Development productivity	High	Low	High
System maintainability	High	Low	Moderate
Introduction cost	Low	High	Moderate
Communication cost	High	None	Low

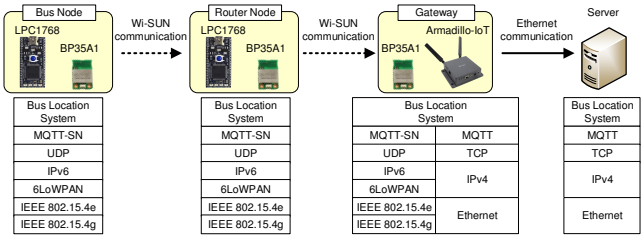

Fig. 2. Structure of the prototype system.

operates as a relay device. The gateway obtains the location information from the received packet, and relays the packet to the management server via the fixed local network. The management server generates bus operation information, and provides this information to bus stop nodes via wireless sensor networks, and to bus users via the Internet.

Wi-SUN is a wireless communication standard provided by Wi-SUN Alliance, and defines the communication-layer specifications between the physical layer and the transport layer. In addition, Wi-SUN has been adopted in HEMS controllers and smart meters (i.e., for gas and electricity meters), and it is receiving considerable attention in the city. Wi-SUN communication utilizes the 920 MHz band as one of ISM bands in Japan. This frequency band benefits from higher diffraction than the 2.4 GHz band. In addition, the transmission output of the 920 MHz band is higher than the 2.4 GHz band. Therefore, the proposed system decreases the number of multi-hops for communicating at long distances. Wi-SUN communication uses IPv6 in the wireless sensor network by adopting IPv6-over-Low-power Wireless Personal Area Network (6LoWPAN), which compresses the IPv6 header or divides data in the IPv6 packet. Therefore, the proposed system requires an IP-based system design similar to most existing systems, and can utilize recent research on these existing systems.

We use MQTT-SN as the application-layer protocol in the wireless sensor network, and we use MQTT in the fixed local network. The gateway performs protocol conversion in order to eliminate the differences between the two networks. Altogether, the wireless sensor node generates packets using MQTT or MQTT-SN, and exchanges them via wireless sensor networks and fixed local networks. As a result, we can expand the bus location system while improving the collection of bus location information.

III. EVALUATION

We developed a fundamental collection function for the bus location information. The bus node and router node consist of a embedded microcomputer (LPC1768) and a Wi-SUN module (BP35A1) manufactured by ROHM Co. Ltd. The gateway consists of a Linux-embedded device (Armadillo-IoT) manufactured by Atmark Techno, Inc., along with the another Wi-SUN module. We confirmed that the system can transmit bus location information by multi-hop communication using MQTT-SN.

TABLE I shows a comparison between our proposed system and existing systems. Our newly proposed system is designed to be able to decrease packet loss caused by the number of multi-hops, and it can be applied to a wider area than the our previous system. In addition, the proposed system is designed based on IPv6. Therefore, development productivity is improved. The wireless sensor node is realized by a communication node that adopts 6LoWPAN. Therefore, the maintainability is improved. The proposed system also benefits from a reduction in the cost of implementation, by utilizing wireless sensor networks that are already constructed in the smart city. Like the our previous system, the proposed system does not require any additional communication cost except the Internet usage fee. Therefore, this system incurs less operational costs than cellular-based bus location systems. From these reasons, we can expect that many local governments will benefit from introducing our bus location system for community buses.

IV. CONCLUSION

In this paper, we proposed an IoT-based bus location system. The proposed system improved the connectivity between wireless sensor nodes by changing the frequency band from 2.4 GHz to 920 MHz. Moreover, we addressed several problems with the our previous system–such as introduction costs, development productivity, and maintainability–by changing the system specifications to IoT technologies such as Wi-SUN, MQTT, and MQTT-SN. In future research, we shall complete the development of our proposed system by conducting a trial operation.

ACKNOWLEDGMENT

A part of this work was supported by JSPS Grant-in-Aid for Young Scientists (B) 15K15987.

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[1] M. Hata, et al., "Proposal for novel bus location system using wireless sensor network," *Proc. of the 20th ITS World Congress Tokyo 2013*, no. 3209, pp. 1–10, 2013.