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Evaluation of location estimation method for bus location system based on wireless sensor networks

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Abstract

One of methods to improve the convenience and quality of service provided by bus service operators is to implement a bus location system capable of providing positional and operation related information to the users. We have previously proposed and implemented a novel global positioning system (GPS)-based bus location system using wireless sensor networks interspersed in the city, which does therefore not entail any communication costs. In this paper, we propose a new bus location method that does not use GPS positioning, and thus reduces the manufacturing cost of the transceivers mounted on community buses. We develop prototype devices and conduct an on-road demonstration experiment, confirming that the required bus location information can be estimated with sufficient accuracy.

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Keywords: Bus Location System; Location Estimation; Wireless Sensor Network; Received Signal Strength Indicator; Smart City

1. Introduction

The rising prices of bus fuel and the decreasing number of bus users have recently created a severe business environment for bus operators in the provincial cities of Japan. As a result, many fixed routes of bus services operated by local governments have been abolished or reduced, and bus transportation has been declining, especially in local cities. However, fixed route buses are an important means of transportation for elderly people and students who do not have a driver's license. Therefore, the number of local governments operating community bus services is increasing, in an attempt to ensure transportation means for local residents. However, buses are often unable to

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respect their scheduled timetables, as a result of both weather and traffic. In addition, they typically operate with a low frequency of service-once or twice per hour. The convenience of this type of service is therefore insufficient. In this context, a bus location system providing bus location information and estimated times of arrival at bus stops would dramatically increase the service convenience to users and its perceived quality. Most existing bus location systems (e.g., Kanatani et al. (2010); Shigihara et al. (2013); Farooq et al. (2010)) use a cellular network to collect GPS-based bus location information, send it to a management server, and subsequently deliver bus operation related information to bus stops and, ultimately, to users. However, the mobile communication costs in Japan are unfortunately higher than in other countries, and community bus services are often operated in unprofitable bus routes. Therefore, there are cases where local governments facing difficult financial conditions could not continue to offer a bus location system, simply because they could not afford the involved communication costs.

Simultaneously, the Internet of Things (IoT) and machine-to-machine communication technologies are getting a lot of attention as vital building blocks of smart cities. In a smart city, wireless sensor networks are interspersed in the city and are used to monitor real time information concerning the surrounding environment (Clarke (2013)). For example, the wireless smart utility network (Wi-SUN) (Wi-SUN) has attracted much attention as a wireless communication standard for smart meters and as a home energy management system in Japan.

We have previously proposed a novel bus location system using wireless sensor networks, with multiple sensor nodes installed at various places along the bus routes (Hata et al. (2013)). This bus location system does not imply any communication costs, because the system uses the wireless sensor networks both for collecting GPS-based location information and to provide bus operation related information to the bus stops. We conducted a trial operation for over a year at the service area of "Kururin Bus," which is operated by Nisshin City, Aichi Prefecture, Japan. From this trial operation, we confirmed that our proposed system could perform reliably as a bus location system, while effectively reducing communication costs. However, as already mentioned, community bus services are often operated in unprofitable bus routes, and tax money is sometimes used to compensate for resulting operational deficit. For this reason, local governments operating community bus services desire to further reduce operation costs by as much as possible.

In this paper, we propose a method to estimate the current *traveling section* of a bus by using the received signal strength indicator (RSSI) values of beacon frames periodically transmitted from wireless sensor nodes installed in various places in the city. In this method, we define the concept of *traveling section* as being the road section between two consecutive sensor nodes along the bus travel route. Using the fact that the order of the wireless sensor nodes installed along the bus travel route is known in advance, the bus installed sensor nodes can detect the nearest sensor node from the RSSI values of the received beacon frames, and can therefore estimate the present traveling section of the bus by using a traveling section list. The installation costs of this system are reduced, because it is not necessary to equip the bus on-board unit with a GPS receiver and there is also no wiring work required to install a GPS antenna on the bus. We developed a prototype system of the proposed approach and conducted verification experiments on public roads. As a result, we confirmed that the proposed method can estimate bus locations with sufficient accuracy for a bus location system.

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The rest of this paper is organized as follows. In Section 2, we provide an overview of the previously implemented GPS-based bus location system using wireless sensor networks. Our newly proposed method in presented in Section 3, and the experimental results obtained from a prototype implementation are presented and discussed in Section 4. Section 5 concludes the paper.

2. GPS-based bus location system using wireless sensor networks

2.1. Overview of the implemented system

In this section, we introduce our previous GPS-based bus location system using wireless sensor networks. An overview of the system is shown in Fig. 1. In this system, multiple IEEE 802.15.4-compliant small wireless sensor nodes are installed at all buses and bus stops, and at streetlights or utility poles along the bus routes. IEEE 802.15.4 is a short-range wireless communication standard, which specifies the physical and medium access layers for low rate personal area networks. Hereafter, we refer to these wireless sensor nodes respectively as “bus node,” “bus stop node,” and “router node.” In addition, some router nodes are referred to as “gateways” and can connect with not only other wireless sensor nodes but also with local fixed broadband networks such as cable television (CATV) and fiber to the home (FTTH) networks. The bus location and operation related information is transmitted via the thus constituted wireless sensor network. A bus node periodically obtains its current GPS position, and transmits a bus location information frame to a gateway, containing its position. When a router node located in the vicinity of the bus node receives the frame, it either transmits it to a gateway or relays it to other neighboring router nodes, according to its own routing table, which is automatically generated by a routing protocol. The gateway obtains the bus location information from the received frame, and transmits it to a management server via the local fixed network. The management server stores the bus location information transmitted by the bus nodes, and generates operation related information, such as the bus arrival delay. The management server provides operation related information to bus stop nodes via local fixed networks and wireless sensor networks, and to mobile phones or smart phones via Internet. The bus stop node works as a relay node just like a router node, and displays the operation related information received from the management server on a touch panel. In addition, the bus stop node also provides local event information, administrative information, guidance information of facilities in the vicinity of the bus stop, etc. The convenience of the bus service is therefore much improved, and this naturally promotes its utilization by local residents. Moreover, the bus stop node can display evacuation information even if a cellular network cannot be used at the time of occurrence of a disaster. The bus stop node can therefore work as a kiosk terminal. We are currently upgrading our bus location system using wireless sensor networks to an “IoT-based bus location system” by using Wi-SUN compatible wireless communications and MQ Telemetry Transport (MQTT)--a client server publish/subscribe messaging transport protocol (MQTT). Wi-SUN operates in the 920 MHz band, one

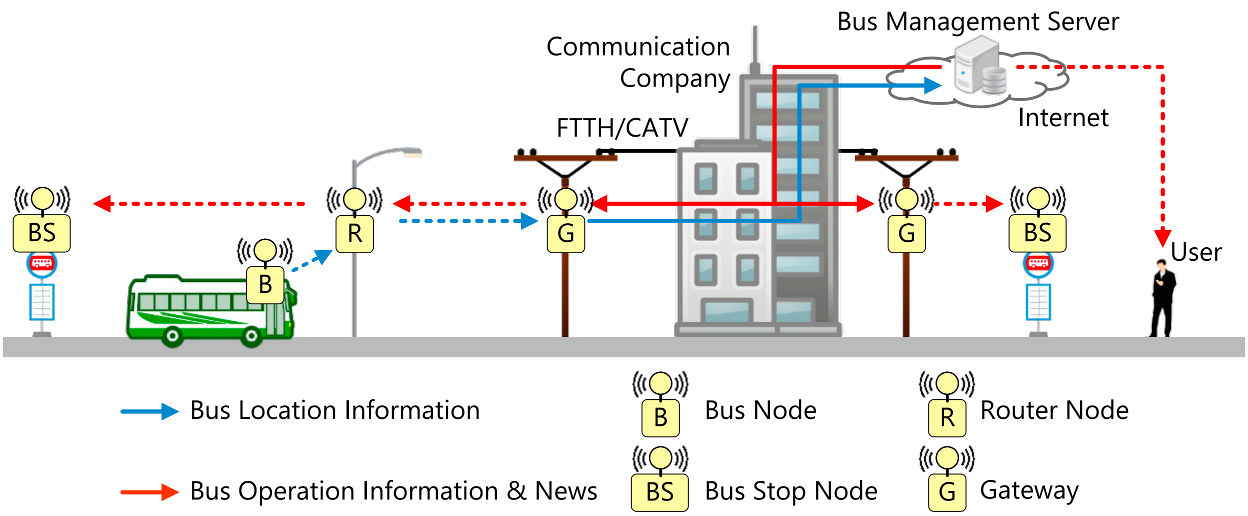


Fig. 1. Overview of our GPS-based bus location system using wireless sensor networks.

of the industrial, scientific, and medical (ISM) bands in Japan. The 920 MHz band has better diffraction characteristics than the 2.4 GHz band, another ISM band; additionally, radio frequency interference is less likely to occur. Therefore, the accuracy of data collection will be improved. In addition, Wi-SUN is adequate for long transmission distances, because it is multi-hop capable, with approximately 500 meters per hop. Thereby, the required number of sensor nodes will be reduced. Moreover, Wi-SUN is also capable of IPv6 communication in wireless sensor networks by utilizing 6LoWPAN (Montenegro et al. (2007)). System providers can therefore provide various service systems (such as a tracking system) for each sensor node. Our bus location system does not require any communication costs--a problem typical of conventional bus location systems relying on cellular networks for communications--because both bus location information and operation related information are transmitted through the wireless sensor network. In addition, the wireless sensor nodes have lower power consumption requirements, and can operate on battery or solar power. Power lines are therefore not needed, and router nodes are easily installed anywhere and/or removed. The wireless sensor network is therefore easily implemented and deployed.

2.2. Bus node

Fig. 2 shows a bus-mounted device. It is constituted by a Linux microcomputer, a GPS module, a small touch panel display, and a wireless sensor module. The device is activated when the bus driver starts up the bus engine, and displays a route-selection screen on the touch panel. The bus driver then selects a route, after which the device's microcomputer starts the periodic acquisition of its own GPS, and generates a location information frame. This location frame is then, transmitted by the microcomputer to a gateway.

2.3. Router node

A router node consists of a wireless sensor module and a small battery pack, as shown in Fig. 3. The router node is enclosed in a water/dust proof box, and is installed at varied places along the bus route. Fig. 4 shows an example of an installation on a safety light. The small battery pack is either a solar battery or a set of two D size cells. The router node receives a frame transmitted from the bus node, and forwards it to its neighboring router nodes or to a gateway. Moreover, router nodes periodically inform the concentrator of their battery status.

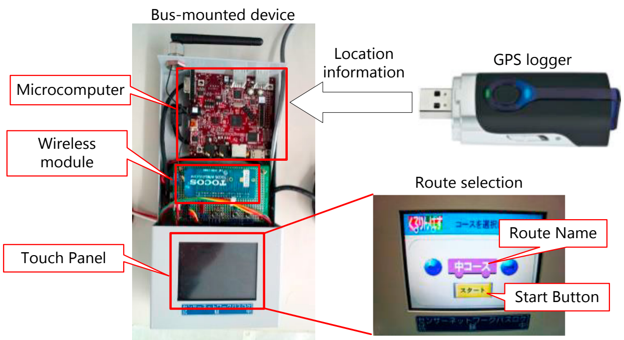


Fig. 2. Bus-mounted device.

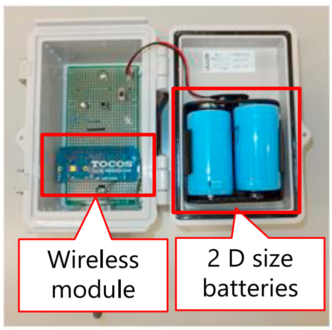


Fig. 3. Router node.

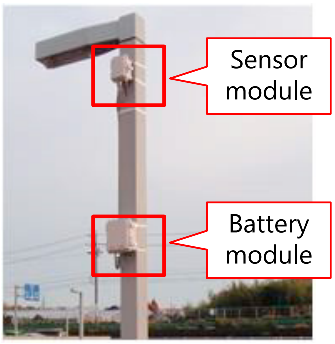


Fig. 4. Router node installed on a safety light.

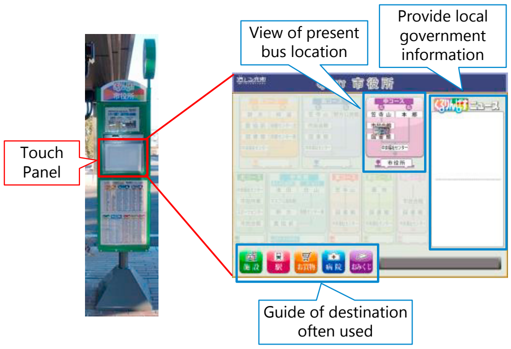


Fig. 5. Developed bus stop.

2.4. Gateway

A gateway is installed at utility poles in the place of a router node. The gateway has both a wireless sensor network interface and a local fixed network interface, and works as a relay device between these two networks. It transmits bus location information frames received from the bus nodes to the management server via a local fixed network, and delivers bus operation related information received from the management server to each bus stop, via the wireless sensor network.

2.5. Management server

A management server is installed at a bus service management facility. The management server stores the data or control messages received from the gateway containing information such as the bus locations and the voltage of the wireless sensor node's batteries. In addition, the management server generates bus operation related information based on the relation between the current bus location and the previously defined bus timetables. The operation related information is transmitted to each bus stop via the gateway, or to the user mobile phones via the Internet.

2.6. Bus stop node

Fig. 5 shows our developed bus stop node. This node consists of an embedded PC, a touch panel, and a wireless module. The bus stop node has a relay function just like the router node. In addition, it uses the touch panel to display operation related information and local government information received from the management server.

3. The new proposed location system

3.1. Background

The above presented bus location system was developed in cooperation with a private company; as mentioned, a trial operation was conducted for more than one year in the service area of "Kururin Bus," operated by Nisshin City, Aichi Prefecture, Japan (Nisshin City). From the results of the trial operation, we confirmed that the proposed system could perform adequately as a bus location system.

Within the scope of this project (Sakata et al. (2013)), we also built a web site for the bus location system where users could check the current bus location information and the operation related information stored in the management server. The web site could accurately display the bus location information on Google Maps (as shown in Fig. 6), or in a considerably simplified map (shown in Fig. 7). We will refer to these maps as the *detailed map* and *simplified map*, respectively. In the simplified map mode, the current bus position is indicated by showing the road section--between two consecutive bus stops--where it is located. From a set of interviews to bus users who use the system, we confirmed that users prefer the presentation of the bus location information using the simplified map rather than the detailed map. For the simplified map mode, high accurate location information like the one obtained from GPS is not always required; to support location display in this mode, it will be sufficient to have the identification of the current bus traveling section.

In addition, local governments will always aim at reducing the initial costs of the bus-mounted devices, even if only by a small amount. Therefore, in this paper, we propose a new method to estimate the current traveling section of a bus without depending on GPS information. Using this method, the initial costs of a bus-mounted device can be reduced by approximately 10 %.

3.2. Traveling section estimation

In the previous system, *bus location* meant an accurate position obtained from GPS. In our new method, by *bus location* we refer to the traveling section between neighboring sensor nodes. A traveling section list contains the relations between each traveling section number and the ID of its nearest sensor, and is defined in advance. When the interval between sensor nodes is very short, adjacent traveling sections can be integrated into a single, bigger one. Based on the identification of the nearest sensor, and using the traveling section list, this newly proposed method can detect the specific road section on which the bus is travelling.

To obtain the current bus location without depending on GPS, we propose a location estimation method using received RSSI values, which can be measured in wireless sensor networks. In this method, router nodes and bus stop nodes periodically transmit beacon frames with their node ID, as shown in Fig. 8. A moving bus node receives beacon frames transmitted from the router and bus stop nodes, and measures their RSSI values. The RSSI value is affected by the distance between the bus node and the sensor node sending the beacon frame. In general, it increases when the bus node approaches the sensor node sending the beacon frame, and decreases when the bus node departs from the sensor node region. Using this characteristic, if the RSSI value of the received beacon frame is larger than a certain threshold value, the bus node identifies the corresponding sensor node as the nearest sensor node. However, the bus node may at instances receive several beacon frames. In this case, the bus node determines the node ID

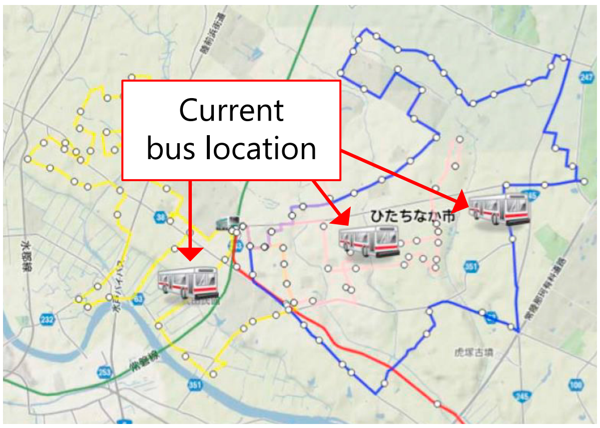


Fig. 6. Detailed map mode.

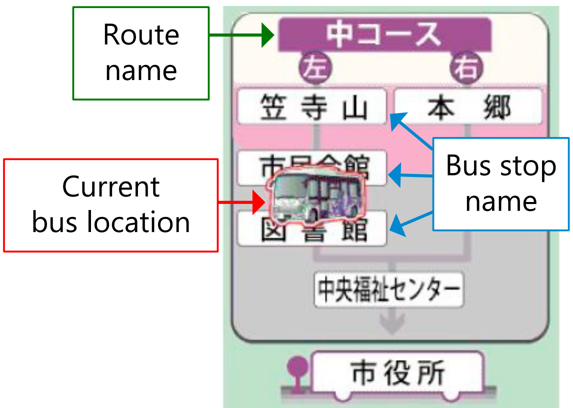


Fig. 7. Simplified map mode.

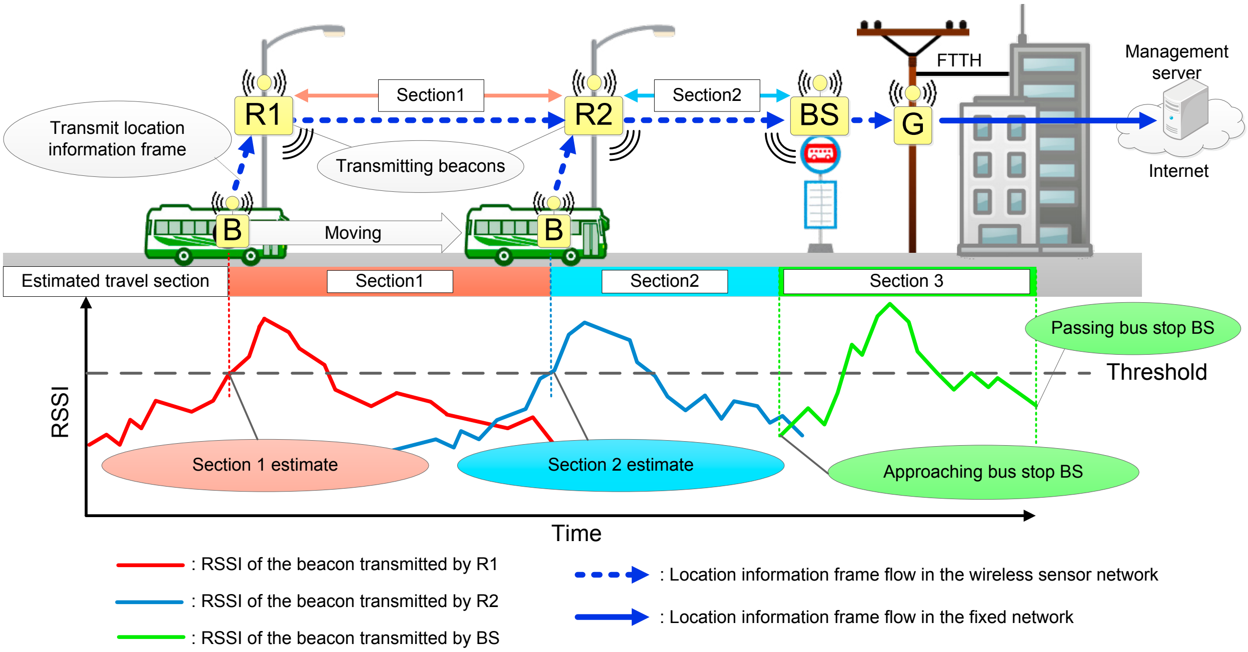
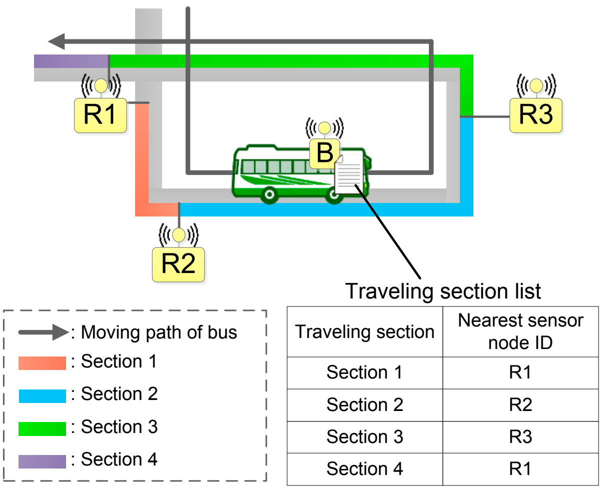


Fig. 8. Overview of our newly proposed method.



Traveling section	Nearest sensor node ID
Section 1	R1
Section 2	R2
Section 3	R3
Section 4	R1

Fig. 9. Relation of between complicated routes and the traveling section list.

corresponding to the received beacon frame with maximum RSSI value, and adopts it as the nearest sensor node's ID. Therefore, even if the nearest sensor node changes while the bus travels, the bus node can detect it.

After having identified the nearest sensor node, the bus node estimates the present traveling section number using the traveling section list. With this list, it is possible for the bus node to estimate the present traveling section correctly, even if the bus travels complicated routes, as in Fig. 9. After estimating the traveling section, the bus node inscribes the estimated traveling section number in a location information frame, which it then transmits to the gateway, to be sent to the management server. The management server stores the identification of the estimated bus traveling sections, and discloses this information to the bus stops.

4. Experimental validation

4.1. Experiment description

The required functionalities of the sensor nodes in the proposed method were developed and implemented; twenty-two sensor nodes were installed (router nodes R1-R21 plus one gateway) at intervals of 100-300 m along the bus service route shown in Fig. 10. The R9 and R10 nodes were installed to create a redundant path and improve the data collection rate. In this experiment, we had to face some restrictive conditions, because we were only allowed to install router nodes on road sign and streetlight poles managed by Nisshin City. The gateway was connected to the management server via a serial cable, and transmitted location information frames to the management server whenever these frames were received at the gateway. We adopted “TWE-001 STRONG” wireless modules (Tokyo Cosmos Electric Co., Ltd. (Tokyo Cosmos Electric Co., Ltd.)) for the sensor nodes. There are wireless communication modules operating in the 2.4 GHz band and designed to work with the IEEE 802.15.4 standard. The router nodes consisted of dust/water proof boxes containing the above sensor nodes and two D size batteries, mounted on streetlight or traffic control sign poles at a height of approximately 3 m. Every router node transmitted a beacon frame broadcasting its node ID at 1 s intervals. We defined eight traveling sections; each section had a length in the 300-500 m range. The traveling section list contained the relation between the traveling section number and the respective nearest sensor node ID, as shown in Fig. 11 and Table 1. The bus node was mounted on a private car, as shown in Fig. 12, and received the beacon frames. In addition, the bus node was connected to a laptop PC for data analysis; the PC was also equipped with a GPS logger to obtain the exact location information, to be used as reference. The bus node sent the RSSI values measured from the received beacon frames to the laptop PC while the private car travelled the defined routes. We drove the private car in the 20 to 40 km/h speed range, to emulate bus traveling speeds. This experiment was conducted 10 times in total.

4.2. Experimental results

Fig. 13 shows the RSSI values measured during one of the experiment repetitions, while traveling the bus route. As can be seen in this figure, the RSSI values of the beacon frames received from the router nodes fluctuate as a result of the car movement, and show their higher values when the car passes near the corresponding router nodes.

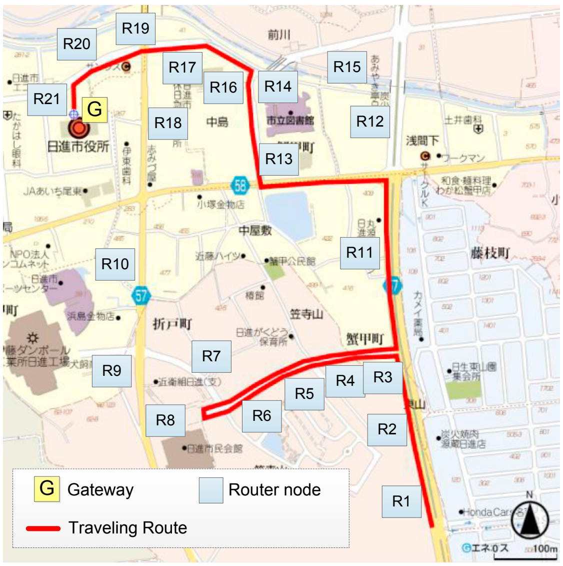


Fig. 10. Traveling route.

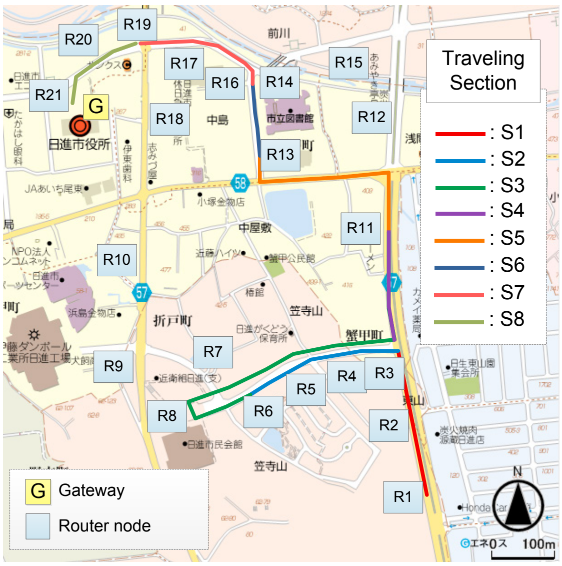


Fig. 11. Traveling sections definition.

Table 1. Definitions in the traveling section list.

Section Number	Nearest Sensor Node ID
S1	R1
S2	R3
S3	R6
S4	R3
S5	R11
S6	R13
S7	R14
S8	R19

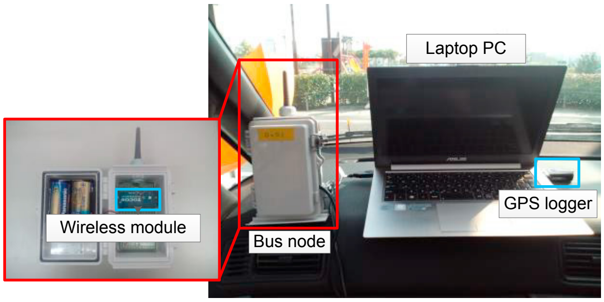


Fig. 12. Car mounted bus node, and laptop PC for data analysis.

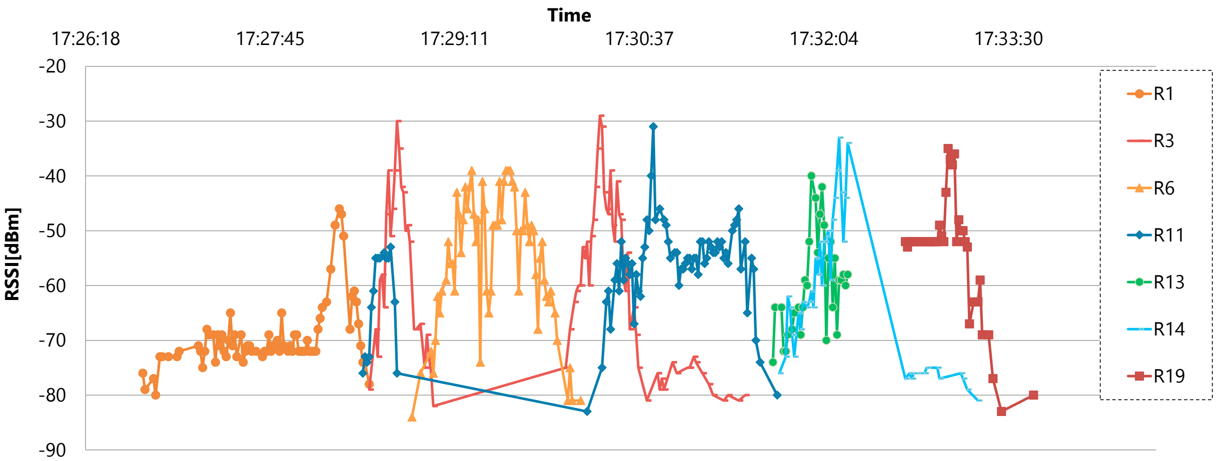


Fig. 13. RSSI data obtained while the car was traveling.

Based on the received RSSI values, we estimated the bus traveling sections using the definitions in Table 1, with the threshold set at -50 dBm. Considering that the traveling section changes when the RSSI value exceeds the threshold, we have eight points in this figure where this happens. In this case, the nearest sensor nodes are detected in the order R1, R3, R6, R3, R11, R13, R14, and R19. Fig. 14 shows the traveling sections estimated using the above results, and the car location information obtained from the GPS logger. By comparing Fig. 14 (estimation results) with Fig. 11 (traveling sections definition), it can be seen that our proposed method did correctly estimate the order of traveling sections according to the traveling section list. Many estimated traveling sections change at points in front of the actual sensor nodes. The maximum distance error between the switch point of the estimated traveling section and the nearest sensor node is of approximately 68 meters. This error may seem large, but it corresponds to an error in the estimated arrival time of only 6 seconds, for a bus traveling at 40 km/hour. Furthermore, bus users can visually detect the bus at a certain distance from the bus stop. Therefore, we can safely sustain that the obtained error is acceptable for our bus location system using the simplified map.

We calculated the estimation accuracy of each traveling section using the location information obtained from the GPS logger. Table 2 shows the estimation accuracy obtained for each traveling section; the accuracy is evaluated based on three descriptors: the average, minimum and maximum value for the 10 runs. From Table 2, it is seen that the estimation accuracy exceeded 90 % for almost all the sections.

Table 2. Accuracy estimation results for each section, with a -50 dBm threshold.

Section	Average [%]	Worst [%]	Best [%]
S1	97.1	94.7	100
S2	81.3	78.2	86.7
S3	94.9	93.5	96.5
S4	86.1	80.0	95.5
S5	94.1	91.1	96.1
S6	98.3	95.3	100
S7	80.2	76.9	84.6
S8	89.7	84.2	93.3
Average	90.2	86.7	94.1

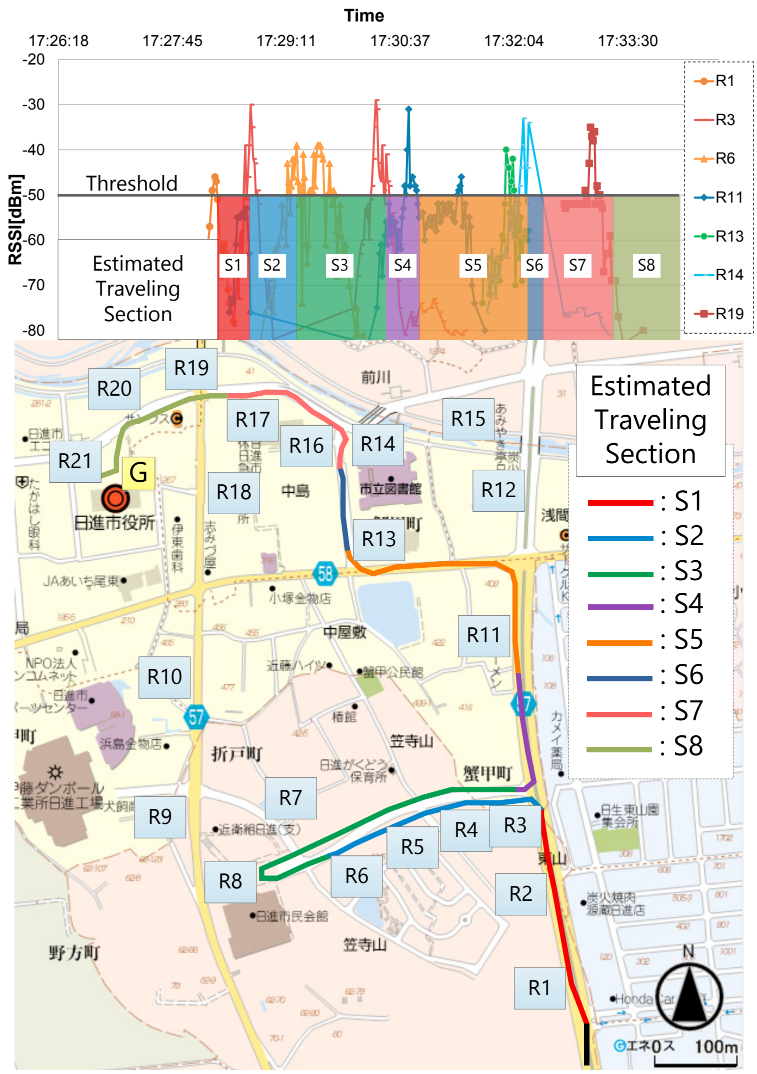


Fig. 14. Traveling sections estimation with a -50 dBm threshold.

4.3. Considerations

Fig. 13 shows that the switch points of traveling sections will occur closer to the outer nodes if the threshold is established at a higher value. Considering that the most important role of the bus location system is to provide users with the correct information concerning the actual traveling section of the bus, it is desirable to improve the estimation accuracy by establishing the threshold at an adequate high value.

We evaluated whether our proposed method could correctly estimate the traveling sections between bus stops on the Kururin Bus routes with a threshold of -50 dBm. The Kururin Bus stops correspond, in Fig. 10, to sensors R1, R8, R11, R13, R19, and the gateway. In this case, the relation between the traveling sections and the installed sensor nodes is shown in Fig. 15. There are five traveling sections: R1-R8, R8-R11, R11-R13, R13-R16 and R16-Gateway. We first consider the R1-R8 section, which contains S1, S2 and a part of S3, as defined in Table 1. We can see from Table 2 that, even though the estimation accuracy of S2 is slightly low, the estimation accuracy of the entry moments in S1 and S3 have sufficiently high values. Hence, our proposed method can estimate the R1-R8 traveling section with sufficient accuracy. Similarly, the proposed method can adequately estimate the R8-R11, R11-R13, and R13-R16 traveling sections. On the other hand, the estimation accuracy of the R16-Gateway section-consisting of S7 and S8-decreases at S7. However, the estimated traveling section S7 changes at the point near R16, which is assumed to be a bus stop. Therefore, our proposed method can detect the switch points of almost all traveling sections with sufficient accuracy.

If the RSSI value is set too high, it will become difficult to identify the nearest router node and correctly estimate the present traveling section of the bus. Additionally, it is possible that the bus node does not observe RSSI values over the threshold value, because of the influence of buildings and traffic conditions around the router nodes. To solve the above problems, two different measures can be considered: the first one is to have the router nodes dynamically adjust the transmission interval of the beacon frames; the second one is to have the bus nodes adopt different threshold values, in accordance with the radio-wave propagation environment.

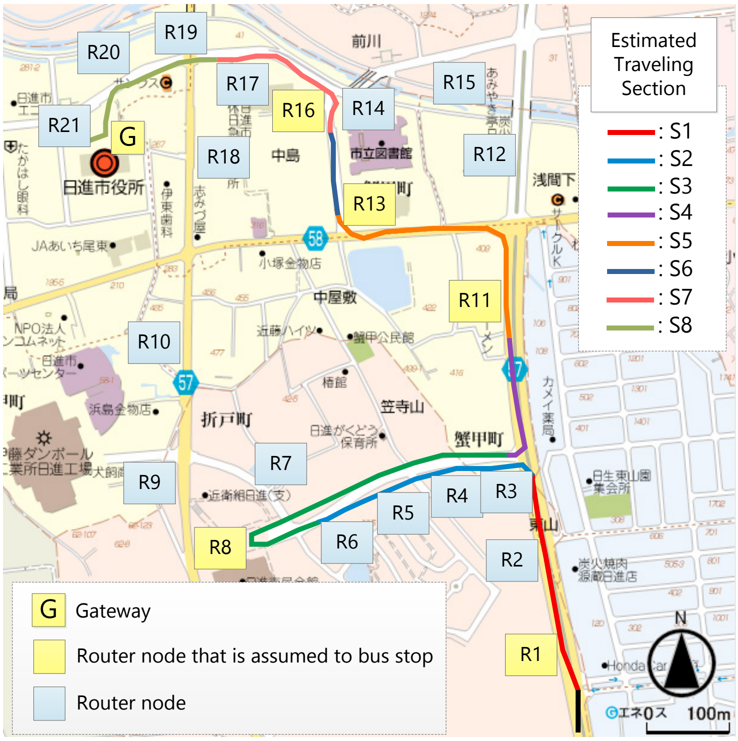


Fig. 15. Installation example, with a fraction of the router nodes assumed to be at bus stops.

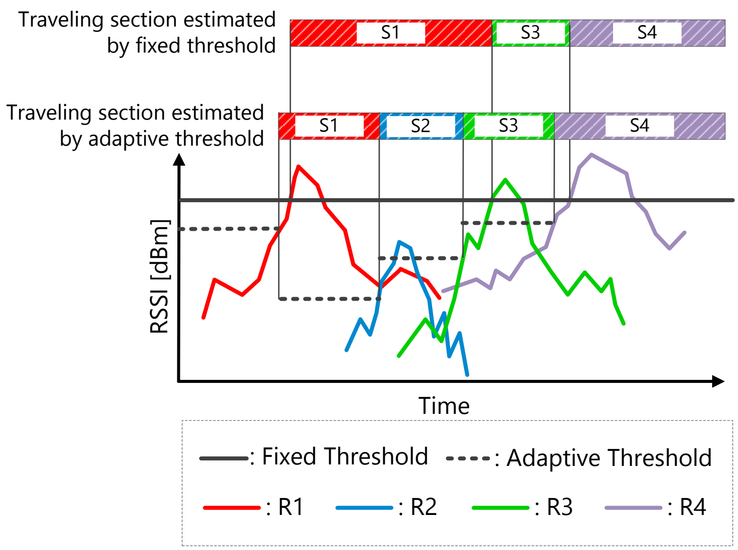


Fig. 16. Example of an application of a variable threshold value.

The mechanism to dynamically adjust the beacon frames transmission interval is to have the bus node notify the router nodes when approaching them. When the router node receives the notification of an approaching bus, it shortens the transmission interval of the beacon frames. By doing so, the bus node will receive more beacon frames, and as a result, the estimation accuracy will be improved. After determining the nearest router node, the bus node instructs the router node to return to the original interval between beacon frames, thus avoiding unneeded and wasteful power consumption.

Even if the aforesaid measure is adopted, it will be pointless if the obtained RSSI values are always below the chosen threshold value. Therefore, a second type of measure can also be adopted (as previously mentioned), which consists in varying the threshold value in accordance with the radio-wave propagation environment (Fig. 16). The traveling section list will contain different values for the threshold, associated with the ID numbers of the router nodes. The bus node can therefore dynamically change the threshold, and estimate the traveling section with increased reliability. As a result, the number of miss-detections of the nearest router nodes will be decreased, as exemplified in Fig. 16.

5. Conclusion

In this paper, we proposed a new location estimation method for a bus location system, based on the RSSI values of the used wireless sensor networks. In addition, we conducted a fundamental experimental validation of the method, on the actual envisaged bus service route. As a result, we confirmed that our proposed method could estimate the present bus location with sufficient accuracy for a bus location system using a simplified map.

Hereafter, we will improve the bus location system evolving it toward an “IoT-based bus location system,” by using Wi-SUN compatible wireless communication modules and MQTT. In this improved system, the operating frequency range will change from 2.4 GHz to 920 MHz. As a result, longer communication hop distances will be achieved, and the data collection accuracy will be improved. This means that not only will the estimation accuracy be improved, but the number of installed sensor nodes will also be reduced. We will also implement the above-discussed approaches to increase detection reliability: adjusting the transmission intervals of the beacon frames, and adopting a variable threshold value. After having implemented these improvements, an experimental validation of our estimation method will be again performed.

Acknowledgements

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References

Kanatani, N., Sasama, T., Kawamura, T., Sugahara, K., 2010. Development of bus location system using smart phones. Proc. of SICE Annual Conference 2010, 2432-2433.

Shigihara, I., Arai, A., Saitou, O., Kuwahara, Y., Kamada, M., 2013. A dynamic bus guide based on real-time bus locations. Proc. of the 16th International Conference on Network-Based Information Systems (NBiS 2013), 436-438.

Farooq, U., Haq, T., Amar, M., Asad, M.S., Iqbal, A., 2010. Gps-gsm integration for enhancing public transportation management services. The 2nd International Conference on Computer Engineering and Applications (ICCEA 2010), 13-17.

Clarke, R.Y., 2013. Smart cities and the internet of everything: The foundation for delivering next-generation citizen services. IDC Government Insights. URL: http://www.cisco.com/web/strategy/docs/scc/ioe citizen svcs white paper idc 2013.pdf.

Wi-SUN alliance. URL: http://www.wi-sun.org/.

Hata, M., Adachi, H., Suzuki, H., Matsumoto, Y., Watanabe, A., 2013. Proposal for novel bus location system using wireless sensor network. Proc. of the 20th ITS World Congress Tokyo 2013, 1-10.

MQTT.org. URL: http://mqtt.org/.

Montenegro, G., Kushalnagar, N., Hui, J., Culler, D., 2007. Transmission of IPv6 Packets over IEEE 802.15.4 Networks. RFC 4944. IETF.

Nisshin City, Information on how to ride the nissin city bus. URL: http://www.city.nisshin.lg.jp/shisetsu/bus/013046.html.

Sakata, A., Matsumoto, Y., Suzuki, H., 2013. Development of bus location system with smartphone and effect of providing regional information added on bus information. Journal of the Eastern Asia Society for Transportation Studies 10, 1311-1322.

Tokyo Cosmos Electric Co., Ltd., TWE-Strong. URL: http://tocos-wireless.com/jp/products/TWE-001STRONG.html.