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著者	Hidayat Arief, Terabe Shintaro, Yaginuma Hideki
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Determine Non-Passenger Data from WiFi Scanner Data (MAC Address), A Case Study: Romango Bus, Obuse, Nagano Prefecture, Japan

Arief Hidayat[1,2*], Shintaro Terabe[1] and Hideki Yaginuma[1]
1 Department of Civil Engineering, Tokyo University of Science
2 Universitas Teknologi Sulawesi
** Corresponding Author, Email: ariefhidayat06@hotmail.com*

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Abstract: WiFi is one of the most useful technologies that can be used for detecting and counting MAC addresses. Many previous studies have interpreted MAC address data into other forms for use in infrastructure development and urban transport. This study uses onboard WiFi scanners, circulated on the "Romango Bus", a hop-on-hop-off bus that has nine bus stops with roaming time from 09.50 to 17.50. The method uses WiFi and GPS MAC addresses as raw data from WiFi devices, collected during the time the bus goes around the route. WiFi scanner devices are placed on two different buses for comprehensive monitoring of the route's operating hours. Raw data obtained in the form of WiFi data and GPS data is combined and processed through five steps to produce non-passenger data. The results are displayed on a map that contains MAC address data, and that specifies non-passenger data categorized into pedestrians, vehicles, and buildings. Obuse is a tourist area that has many tourist attractions, and the results of WiFi at stopover locations shows a high number of pedestrians, especially at Obuse Park and Obuse Station.

1. INTRODUCTION

This is the era of big data, the latest development in information technology. Technological progress and innovation have made it easier to manage and calculate future infrastructure and transportation needs. Recently, technological advances have required faster data retrieval and processing. The technology currently being developed to address this is WiFi, which is presently widely used in the field of transportation. There is an increasing amount of research on the development of WiFi, with some of it primarily concerned with transportation, and mostly focusing on origin-destination movement. Up until this point, the research has been interested in the behavior of travel, origin-destination, travel time, waiting time, and other aspects. This paper analyses bus-related data both from on-bus field observations and WiFi data, which contains all travel data for bus passengers (Hidayat, Terabe, & Yaginuma, 2018) and non-passengers. Non-passenger data is non-bus user data detected by WiFi. The raw WiFi data is simply a count of media access control (MAC) addresses, the unique alphanumeric identifiers for WiFi and Bluetooth (BT) devices. Some researchers have applied Bluetooth and WiFi sensors to get the position of people and vehicles. However, this is usually considerably costly, and suffers from time restrictions with high maintenance levels; with such costs, these methods of collecting data are difficult to apply to further research. WiFi is widely used during use of smartphones, laptops, tablets and other portable devices that are currently in high demand around the world. A MAC address can be detected when people are looking for an access point (AP), and every single networking device is equipped with this globally unique hardware address (Al-Husainy & Fadhil, 2013; Asija, 2016; Freudiger, 2015; Takahiko & Yaginuma, 2017). They are used for such devices as smartphones, tablets, laptops, WiFi routers, car and motorcycle GPS, as well as others. As such, WiFi is now one of the most useful options for getting movement or MAC address data. WiFi tracking data provides an excellent approximation of crowd densities because WiFi has an extended detection range, and so a large area is covered by each sensor (Dunlap et al., 2016) and every year WiFi is being increasingly detected from portable devices (Nishide & Takada, 2013).

The advantage of using WiFi to detect MAC addresses in the field of transportation is that it not only reduces the cost of data collection, but it is easier, more accessible, and more energy efficient. For data retrieval, live experiments were conducted by placing WiFi scanners inside the bus. The collected data is categorised into two groups, travel data, and non-passenger data. This paper focuses on non-passenger data, as travel data is already explained in more detail in other research papers (Hidayat et al., 2018). This study attempts to develop a further interpretation of this data, dividing non-passenger data into three groups, namely pedestrian, vehicle and building data.

2. LITERATURE REVIEW

2.1 WiFi and Bus Experiment

Previously, a study related to the on-bus use of WiFi calculated the Origin/Destination (OD) bus passenger matrix (Dunlap et al., 2016). The study attempted to compare the results of WiFi and Bluetooth usage and develop a raw data filtering procedure (WiFi data and Bluetooth data) into an estimation of passenger numbers. Similarly, in research of travel data in Obuse, Japan, passenger estimation is predicted using a speed indicator as well as the MAC address positional filtering procedure (Hidayat et al., 2018). Previous research on passenger behavior using on-bus WiFi data revealed that MAC addresses that do not change location on the same bus could be understood as a passenger (Jiang et al., 2016). Data filtering is essential for identifying passengers and non-passengers. Other research measured bus passenger loads by monitoring WiFi transmissions from mobile devices, revealing insights into the patterns of travel as well as pick-ups and drop-offs (Fukuda et al., 2017; Oransirikul et al., 2014). This research applies a filtering process to interpret and justify the raw non-passenger WiFi data obtained in the experiment process.

2.2 WiFi and Non-Passenger Data Experiment

Recently, there has been a lot of research into pedestrians and technology-based methods of collecting pedestrian data. Research using WiFi and Bluetooth as tools for counting non-motorized travel users confirm this (Böhm, Ryeng, & Haugen, 2016; Nishide & Takada, 2013; Poucin, Farooq, & Patterson, 2016). There are significant benefits and challenges to the use of WiFi and Bluetooth data for analysis of spatiotemporal dynamics of human movement. Crowd data collection and monitoring (Abedi, Bhaskar, & Chung, 2013), and combining data from both sensor types (WiFi and Bluetooth), results in useful insights into pedestrian dynamics (Heuvel, Ton, & Hermansen, 2016). Previous research has also used WiFi and Bluetooth data of pedestrians inside terminals (Shlayan, Kurkcu, & Ozbay, 2016). This research attempts to detect moving pedestrians and their behavioral patterns within the terminal and to create an origin-destination motion matrix. Similar research on WiFi systems for traffic monitoring focuses on pedestrians, vehicles, and bicycles (Jackson, Lesani, & Moreno, 2014). The study used WiFi and placed it on street lights to capture MAC address data, identifying and estimating numbers of pedestrians, bicycles, and vehicles from the speed of each traveling MAC address. Initially, pedestrians were identified by filtering for MAC addresses that could be captured across a distance of 100 meters (Malinovskiy, Saunier, & Wang, 2012). One study detects vehicles using WiFi and Bluetooth devices installed in the car (Ahmed et al., 2008) as well as vehicle detection, with a focus on travel time (Mai et al., 2017). The process captures and reads the MAC address installed on the vehicle and estimates how long it takes from the starting point to the end point using static WiFi placed in several places. The data is interpreted as vehicles following previous research that used the indicators of further mileage and longer travel time. This paper uses a different approach, interpreting the data based on the movement of WiFi in a bus, and filtering for passenger data and non-passenger data.

The principle method uses multiple sensors to record the different Bluetooth or WiFi MAC addresses for each wireless communication device (Dunlap et al., 2016; Petre et al., 2017). WiFi MAC addresses can be used to identify mobile devices, and they can be used to determine the location of mobile devices when combined with received signal strength at multiple locations (Xu et al., 2013). Android is also widely used to detect pedestrian movements. While it depends on the device, most smartphones usually send probe request frames to associate with a WiFi access point, which includes the MAC address (Fukuzaki et al., 2014). In this study, MAC address data was traced to determine the position of the pedestrian with a probabilistic method consisting of a set of candidate lists of destinations, with the probability of each record of targets being the true one (Hamacher, Heller, & Ruzika, 2010). Using another method, a penetration ratio is calculated by combining tracking and count data from WiFi. This rate describes the ratio between the number of counts and the number of tracked data points (Heuvel et al., 2016). Pedestrian data can be estimated with the system to detect unknown MAC addresses of devices at short distances at fixed locations (Jackson et al., 2014) and the performance of the BT-WiFi method evaluated to identify these unknown MAC addresses (Lesani & Moreno, 2016). Lastly, the research uses WiFi devices paired permanently in strategic locations (Lesani et al., 2016), and the use of software installed on smartphones; it should be noted that most pedestrians do not make use of this software (Shlayan et al., 2016). This research will describe and explain

WiFi scanner data in Obuse, a tourist spot in Japan. The research makes use of WiFi scanners as a detector of MAC addresses. This WiFi scanner is placed on the bus as a moving detector. An explanation is given for the process of filtering raw data WiFi scanner (MAC address) data into non-passenger data, using simple, battery-powered equipment. This paper provides a novel solution for using moving detectors to estimate non-passenger data.

3. METHODS

3.1 Field Experiment

The location for this study is Obuse, Kamatakai District, Nagano Prefecture, in October 2016. Obuse (*小布施町* /Obuse-machi) is a town in the Chūbu region of Japan. As of 1 October 2016, the town had an estimated population of 10,698 and a population density of 560 persons per km^2. Its total area was 19.12 square kilometers (7.38 sq mi). The city of present-day Obuse was part of ancient Shinano Province. The modern village of Obuse was created with the establishment of the municipalities system on April 1, 1889. It was elevated to town status on February 1, 1954. Obuse annexed the neighboring village of Tsusumi on November 1, 1954 (Wikipedia, 2008).

Obuse is one of the top tourist destinations in Japan (Nagano Prefecture Government, 2016). The town has a shuttle bus called Circle Bus, or "Romango." The Romango bus is a hop-on-hop-off bus. It has seven circulation journeys from bus stop one to bus stop nine, running from 09:50 until 17:50. One-day tickets cost 300 yen, and group tickets (10 sheets) 2,000 yen. Obuse town operates two circular buses every Saturday and Sunday. The circular route is approximately 15 km long, and it takes 50 minutes for a round trip. Buses start every 30 minutes from 09:00 to 16:00. There are two types of Romango bus, no.1 and no.2, shown in *Figure 1*. The Romango bus traverses seven segments in its circulation from bus stop no. 1 (BS1) to bus stop no. 9 (BS9) and passes nine bus stops: BS1 (Obuse Highway Oasis Park), BS2 (Obuse Station), BS3 (Hokusai Museum), BS4 (Obuse Museum), BS5 (Matsumura Town Parking), BS6 (Obuse Hot Springs) BS7 (Floral Garden), BS8 (Jyokoji Temple) and BS9 (Ganshoin Temple). Refer to *Table 1* for more detail. The circular route is approximately 15 km, and the overall route length is 8.8 km. The longest leg is 2.7 km (2675.92m) from BS1 to BS2, and the shortest is 0.3 km from BS4 to BS5 (304.59m). The total route length is 8805 metres. Refer to *Figure 2* for more detail.

Figure 1. "Romango Circle Bus" No.1 and No. 2

Table 1. Obuse Bus Stop

Number of Bus Stop	Bus Stop Name/Famous Destination Near Bus Stop	Figure
1	Obuse Highway Oasis Park	 
2	Obuse Station	 
3	Hokusai Museum	 
4	Obuse Museum	 
5	Matsumura Town Parking	 
6	Obuse Hot Springs	 
7	Floral Garden	 
8	Jyokoji Temple	 
9	Ganshoin Temple	 

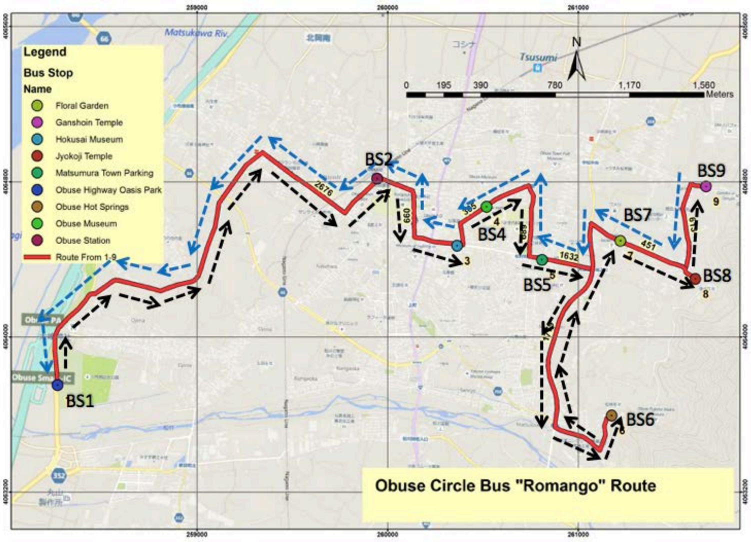

Figure 2. “Romango Bus” Route

3.2 WiFi Equipment

WiFi technology periodically transmits a signal, called WiFi, to all information devices around it. When a device receives a WiFi signal, it sends a query, called a probe request, and the access point returns a reply, called a probe response, which includes the Service Set Identifier (SSID). The probe request can be made in as short as 15 seconds or as long as several minutes (and is on the order of one minute on average), and also includes the media access control (MAC) address that identifies the transmitting device.

This study used a WiFi Scanner to acquire data. This Scanner uses the minicomputer Raspberry Pi 2 B V1.1 (Raspberry., 2015) as a WiFi scanner, GPS tracker, and micro USB power source to save the data. A mobile battery keeps the WiFi scanner on for 12 hours. From collecting and analyzing data, it is possible to grasp patterns, such as the spatial flow and distribution of information device users. The WiFi scanner was placed as per *Figure 3* on the bus. The scanner collected MAC addresses which were interpreted as non-passenger data from the bus.

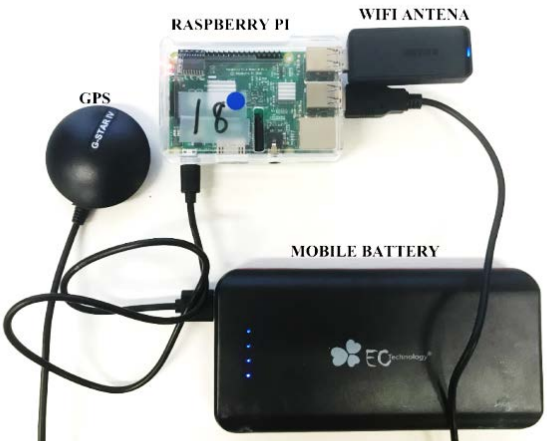

Figure 3. WiFi scanner, GPS, and Mobile Battery

3.3 Experiment

The WiFi Scanner was mounted on bus no. 1 near the left window and on bus no. 2 above the driver between 09:50–17:50 on Sunday, October 30th, 2016 (*Figure 4*). The device installation was simple, and it was placed so that it did not interfere with the bus driver and passengers. No appropriate place could be found to install the scanner above the driver's seat in bus no. 1, which was a different model from bus no. 2. Due to the differences in the internal layouts at the front of the bus, the scanner was unable to be placed in the same position. Therefore, the WiFi scanner was installed near the front-left window on bus no. 1 and above the driver's seat on bus no. 2. The difference in position did not influence the detection results as the differences were negligible concerning WiFi-scanner coverage. It can detect WiFi devices within an approximate 200-300 metre radius (*Figure 5*). This scanner records the unique identification code (MAC address) of mobile devices (Hidayat, Terabe, & Yaginuma, 2017a; Hidayat, Terabe, & Yaginuma, 2017b; Hidayat et al., 2018; Terabe, Hidayat, & Yaginuma, 2017)

Figure 4. Installing WiFi Scanner on Bus No.1 and Bus No.2

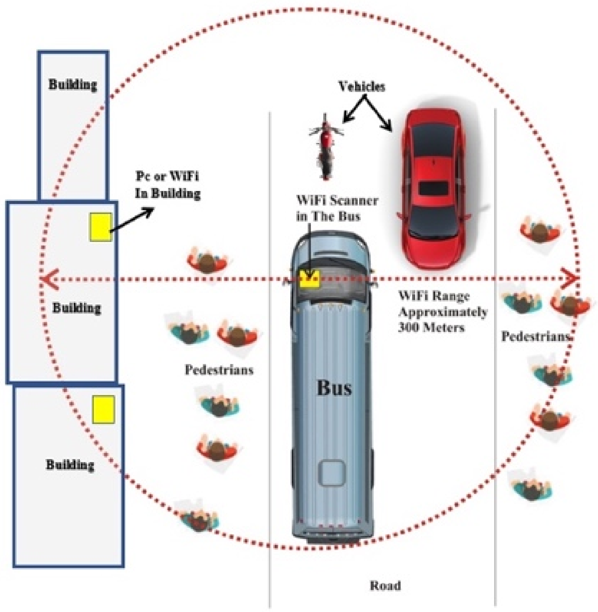

Figure 5. WiFi scanner's Approximate Range.

4. RESULTS

4.1 Processing Data

The result of this experiment is a GPS log and WiFi log as raw data. The GPS log contains the time, latitude and longitude data. The WiFi log contains the time and MAC address. The GPS log shows the bus position along the bus journey in the form of data X (longitude) and Y (latitude). The time data for each area also appears in the GPS data. The WiFi data contains time data for each MAC address recorded on the WiFi scanner, its type, and the WiFi signal strength in decibels. This data was then translated into non-passenger data. The data structure for WiFi and GPS is shown in *Table 2*.

Table 2. Structure of WiFi and GPS Data

GPS Data Structure	Day
	Time
	Latitude
	Latitude compass direction
	Longitude
	Longitude compass direction
WiFi Data Structure	Day
	Time
	type
	dB
	Mac Address

The MAC address is the unique ID assigned to each network device to be used as an identification code (Asija, 2016; Senthil Kumar, 2016). There are five steps from processing to mapping the MAC address data and distinguishing non-passenger data;

a. The first step is to combine raw data from the WiFi and GPS logs to get WiFi data containing latitude and longitude. During this step, the “Time” data is combined. This step is necessary for determining the position of each MAC address, so that they have XY data combined from the GPS and WiFi data. Unused information is deleted or eliminated from the combined data.

b. The second step is to eliminate errors in the data using loop and pivot data to retain only unique data. This stage reduces failure or duplication of MAC addresses, time and XY. A lot of data has a lot of mistakes or repetition due to the per second reading interval of WiFi scanning. From this step, we get unique data ready to be processed in the next stage.

c. The third step is to convert the coordinate system in the raw GPS data from the geodetic system of latitude and longitude to universe transverse mercator (UTM) to be more easily processed.

d. The fourth step is to import data to a Geographic Information System (GIS), show the point location, and make a map of MAC addresses. This step processes the data in the GIS so that the initial data is entered into the GIS to be selected using GIS tools.

e. The fifth step is to identify the MAC address that appears by dividing into two groups, fixed and mobile. The fixed group is defined as a static location and can be interpreted as a building and the mobile group is determined as a non-static location, and divided into pedestrian and vehicle, according to the rule as follows;

1) If there are more than six identical MAC IDs in the same location, then it can enter into the fixed category and is interpreted as a building, such as a store, a house, or a convenience store.
2) For MAC IDs appearing between 2-6 times with different locations, it can be classified as moving data. 2-3 MAC IDs are categorized as pedestrians and 4-5 are categorized as vehicles.

All of the processing was done with Anaconda 1.5 Jupiter Notebook 5.0, Python 2.7, Microsoft Excel 2010 and QGIS software. There were 71,630 MAC addresses collected from 09:00 to 18:00. Filtering the result reduced the amount by about 92.05% from the initial data to 5,691 non-passengers data logged along with the bus route. The point data on the map shows the MAC address data with the position located in the field. The flowchart for data processing and the mapping of MAC addresses is shown in *Figure 6*.

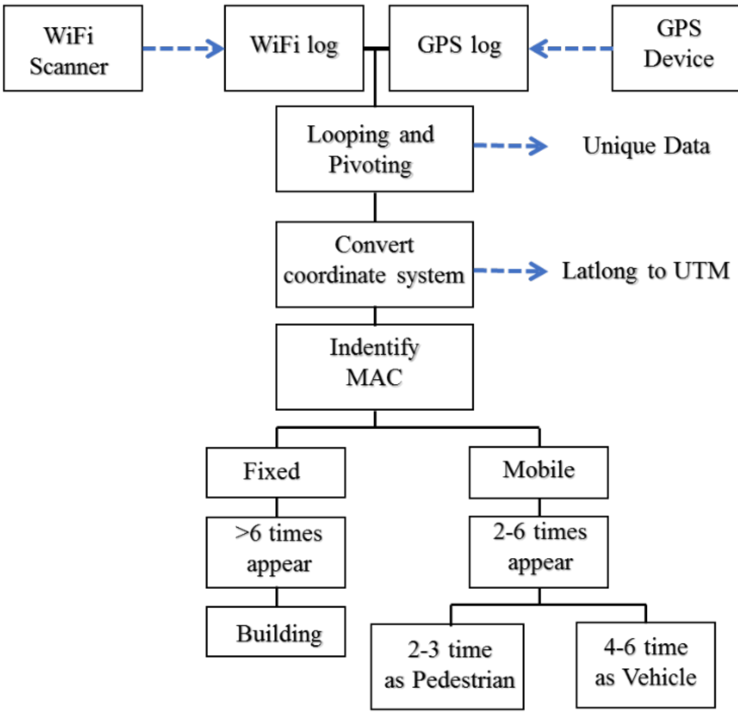

Figure 6. Flowchart of Processing Non-Passenger Data

4.2 Estimate Non-Passenger Data

Based on the processing of the distribution of MAC addresses in the map, *Figure 7* shows them regularly located around the bus route. The points on the map indicate a direction or a line following the bus route, which demonstrates the accuracy of the GPS detectors and devices and success of the field study. This raw data has been analysed into non-passenger data such as pedestrian, vehicle, and building data.

The results are obtained from the process of filtering raw data into non-passenger data from both buses. For bus no. 1 there are as many as 2,649 MAC IDs and for bus no. 2, there are as many as 3,042 detected MAC IDs, which could be rated as non-passenger (*Table 3*). The distribution of non-passenger data based on the results of the filtering process is shown in *Figure 8*.

The number of buildings, such as shops, convenience stores and others that have WiFi devices, comes to 58 units on bus no.1 and 35 units on bus no.2. For the classification of vehicles (cars and motorcycles using WiFi devices) as many as 320 units from buses no. 1 and 197 units from bus no. 2 were identified. There were 2,271 people on bus no. 1 and 2,810 persons on bus no. 2. These results show that WiFi data can be used in the process of counting field data, especially non-passenger data. The difference between the data for bus no. 1 and bus no. 2 is not significantly large, because the two buses differ only by 30 minutes along the same route. This estimate comes from the processing of data and may require more trial and error in testing.

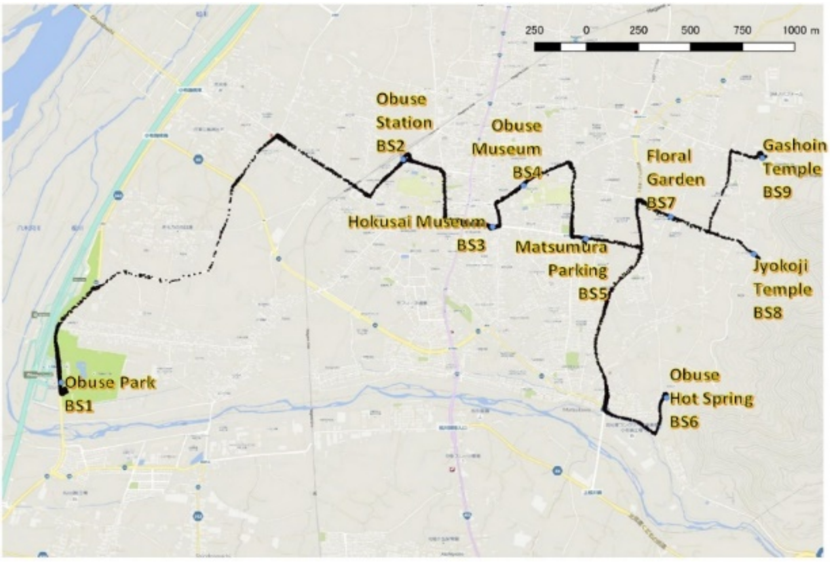

Figure 7. Mapping of MAC Address

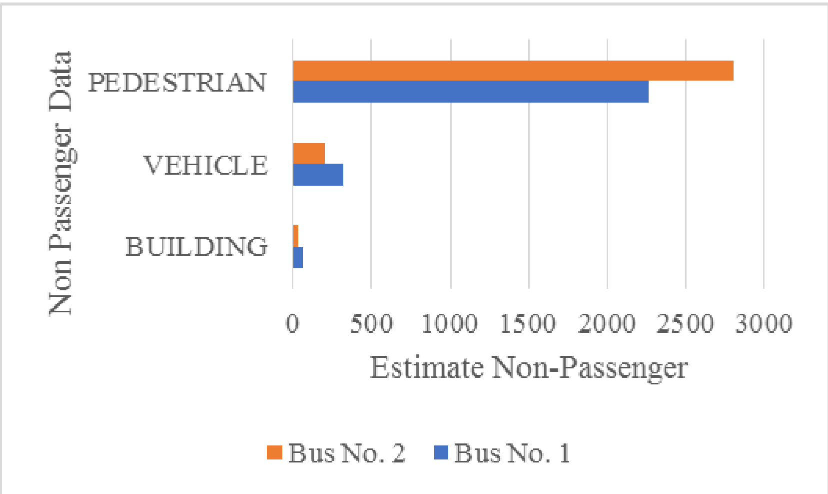

Figure 8. Estimate Non-Passenger Bus Data

Table 3. Estimate Non-Passenger Data

Bus	Building	Vehicle	Pedestrian	Total
Bus No. 1	58	320	2271	2649
Bus No. 2	35	197	2810	3042
Total	93	517	5081	5691

4.3 Spatial Distribution

Pedestrians are detected in more densely packed areas of pedestrian movement around Obuse Park and Obuse Station. Obuse Park is the entrance area to Obuse and is a heavily utilized recreation park on Saturdays and Sundays. The WiFi scanner will detect the pedestrians around Obuse Park. The area where most pedestrians were identified was Obuse Station, bus stop no. 2. Obuse Station is a bustling area for walkers, due to the many people who use the train in the morning and evening and becomes one of the busiest nodes in Obuse. Vehicles were detected when they were unidirectional or in line with a bus where the speed of the vehicle was equal to that of the bus; parked vehicles were not detected. Buildings were detected along Obuse Park to Matsumura Town Parking.

5. CONCLUSION AND FUTURE WORK

The results of this paper are:

a. This article developed a data processing procedure to combine WiFi raw data, and GPS log data into non-passenger data.

b. MAC addresses can be processed as non-passenger data by several methods and interpreted as pedestrian, vehicle, and building data.

c. WiFi scanners are simple and powerful for reading and capturing MAC address data and can be used for transportation surveys.

d. Composition analysis and data processing will be suitable for analyzing big data in the future

The results of the conducted experiments indicate not only the benefits of the developed equipment but also the challenges to be addressed in future work. WiFi scanners could be used for several other purposes:

1) The proposed method is appropriate for long-term data collection with daily variations.

2) There is no need to communicate with people or objects when collecting the data.

3) The WiFi-scanner data can provide information about busy areas such as bus stops, shops, parking lots and bus terminals. If the WiFi scanners detect an area that has many visitors, this data could inform operators about the need for increased capacity. For local governments, WiFi-scanner data could be used to improve the ability of facilities and provide input to urban planning related to transportation facilities and public transportation and could also be used to enhance the marketing of tourism support facilities in towns and cities.

The results of the conducted experiments indicate not only the benefits of the developed equipment but also the challenges to be addressed in future work. However, at present, there are several limitations. The WiFi scanner can produce inaccurate results when there is less use of WiFi-enabled mobile devices; there are false WiFi readings because the devices are out of range, the MAC address changes (when upgrading system devices), or because of slight GPS inaccuracies. As there have been few case studies, the technology needs to be tested in several different places with larger survey areas and longer survey times to improve the analysis and procedure.

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