Collecting Bus Locations by Users: A Crowdsourcing Model to Estimate Operation Status of Bus Transit Service

Kenro Aihara[1,2](✉), Piao Bin[1], Hajime Imura[3], Atsuhiro Takasu[1,2], and Yuzuru Tanaka[3]

[1] National Institute of Informatics, 2-1-2 Hitotsubashi, Chiyoda-ku, Tokyo 101-8430, Japan
{kenro.aihara,piaobin,takasu}@nii.ac.jp
[2] The Graduate University for Advanced Studies, Hayama, Japan
[3] Hokkaido University, N-13, W-8, Sapporo, Hokkaido 060-8628, Japan
{hajime,tanaka}@meme.hokudai.ac.jp

Abstract. This paper describes a crowdsourcing model to collect bus locations from onboard passengers.

Bus location service, or realtime bus tracking service, is getting more and more general these days. Some models are proposed to build such services. One approach is facilitated every vehicle has a function to position itself with location sensor, such as GPS receiver, and transmits its own location with time to the server. Another is an environmental approach that bus detectors are deployed along the route to detect ids of nearby buses and transmit to the server. These models are well-established and practical. However, it is not easy to install such services especially for small operators because costs on devices and data transmission are relatively high.

This paper proposes that a sustainable model even for small operators to provide bus locations to passengers. The key idea of the proposal is that collecting bus locations is not by bus operators but by onboard passengers. To collect them, a smartphone application of bus tracker is provided to public. The application shows current locations of buses in operation on bus transit services, while it detects nearby buses around users and transmits bus ids with time and location of detection to the service platform. That is, locations of buses are collected by users.

Keywords: Internet of Things · Smart and hybrid cities
Crowdsensing · Crowdsourcing

1 Introduction

This paper describes a crowdsourcing model to collect bus locations from onboard passengers.

Bus location service, or realtime bus tracking service, is getting more and more general these days. Some models are proposed to build such services. One

N. Streitz and S. Konomi (Eds.): DAPI 2018, LNCS 10921, pp. 171–180, 2018.
https://doi.org/10.1007/978-3-319-91125-0_14

approach is facilitated every vehicle has a function to position itself with location sensor, such as GPS receiver, and transmits its own location with time to the server. Another is an environmental approach that bus detectors are deployed along the route to detect ids of nearby buses and transmit to the server. These models are well-established and practical. However, it is not easy to install such services especially for small operators because costs on devices and data transmission are relatively high. The smaller number of buses are scheduled, the more necessary the bus tracker service is.

Therefore, this paper proposes that a sustainable model even for small operators to provide bus locations to passengers.

2 Background

2.1 Crowdsourcing for Civil Problems

The term "crowdsourcing" was described by Howe in [3] and defined that crowdsourcing is the act of taking a task traditionally performed by a designated agent and outsourcing it by making an open call to an undefined but large group of people [4]. This can take the form of peer-production, but is also often undertaken by sole individuals [2].

The concept of smart cities can be viewed as a recognition of the growing importance of digital technologies for a competitive position and a sustainable future [8]. Although the smart city-agenda, which grants ICTs with the task to achieve strategic urban development goals such as improving the life quality of its citizens and creating sustainable growth, has gained a lot of momentum in recent years.

Tools such as smartphones offer the opportunity to facilitate co-creation between citizens and authority. Such tools have the potential to organize and stimulate communication between citizens and authority, and allow citizens to participate in the public domain [1,10]. One example is FixMyStreet[1] that enables citizens to report broken streetlights and potholes [6]. It is important that these approaches will not succeed automatically and social standards like trust, openness, and consideration of mutual interests have to be guaranteed to make citizen engaging in the public domain challenging.

Waze[2] is another crowdsourcing service to collect data of traffic. Even though Waze provides users to traffic information collected from users and route navigation function, it seems not enough to motivate users to get involved in, because recommended routes are not as adequate as car navigation appliances, especially in Japan where such appliances are well-developed.

2.2 Bus Location Services

Route bus system is a fundamental transit service. However, due to a progress of motorization, the number of bus passengers has been gradually decreasing

[1] https://www.fixmystreet.com/.
[2] https://www.waze.com/.

especially in suburban areas. As a result, the decline in passengers has led to a decline in unprofitable routes and it is in a vicious circle that accelerates the decline of passengers. To attract more choice passengers to route buses, the transit service must not only have a high level of service in terms of frequency and travel time but also must be reliable [11]. Although such efforts often come at a substantial cost, one inexpensive way to improve unreliability from the user perspective is providing real-time transit information.

A bus location service, or realtime bus tracking service, provides up-to-date bus location and estimated times of arrival at bus stops. Most existing bus location systems (e.g., [5,9]) use onboard location sensors, such as GPS receivers, to perceive the current location and then send it to a server. In these systems, it is necessary to prepare a communication line, such as cellular phone network, and GPS receiver in advance.

Another model is a bus detector installed on the environment side along the route detects the ID of the nearby bus and sends it to the server. Typically, these detectors are installed at the bus stop and detect the passing bus. Detectors installed at the bus stop need a communication line for transmitting data to the server.

Both models have high initial cost of equipment and operational cost of communication, and there is a problem in introducing services.

3 Methodology

The key idea of the proposal is that collecting bus locations is not by bus operators but by onboard passengers. To collect them, a smartphone application of bus tracker is provided to public.

Figure 1 shows the proposed method, compared with existing ones. Typical existing methods are equipped with onboard location sensors, such as a GPS receivers, and transmitters. Every perceived latest location will be sent to the server frequently through a wireless communication line, such as cellular phone. That is, bus operators must prepare such devices and a communication line for each bus vehicle.

On the other hand, in the proposed method, bus operators only install Bluetooth beacons on each bus vehicle. Instead of installing a location sensor on the bus, the proposed method uses a passenger's smartphone and our application. An onboard beacon broadcasts its own identification number nearby. In the case of Bluetooth, its range is usually several tens of meters. When the application on passenger's smartphone detects specific Bluetooth information including UUID and vehicle identification number, it perceives its location and transmit it with the vehicle information to the server.

The application shows current locations of buses in operation on bus transit services, while it detects nearby buses around users and transmits bus IDs with time and location of detection to the service platform. That is, locations of buses are collected by users.

We have been developing a bus tracker application called "Ride around-the-corner (Ride ATC)."

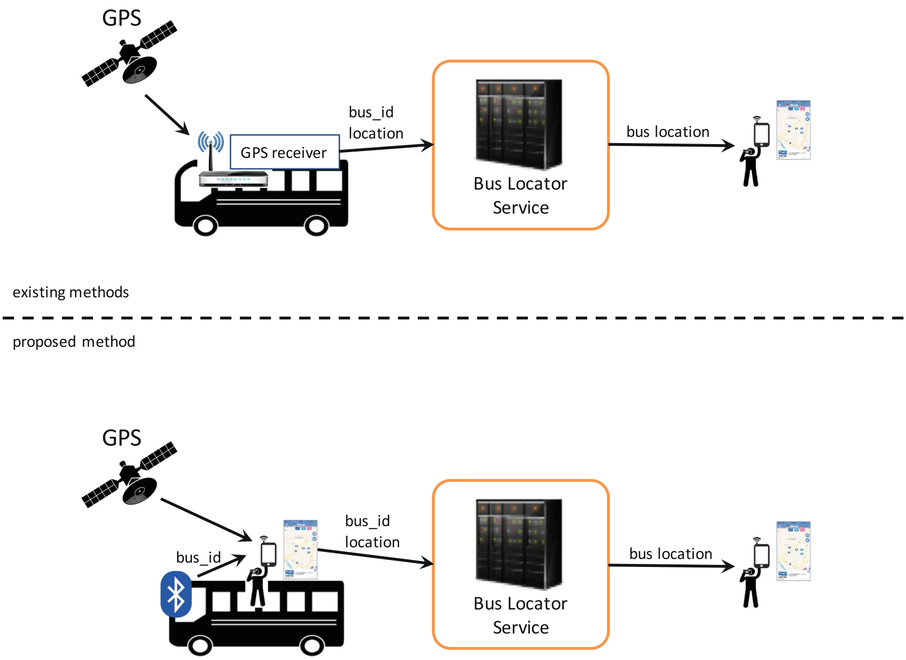


Fig. 1. Comparison of methods

3.1 Onboard Beacon

For enabling mobile applications detect IDs of buses, Bluetooth beacons are deployed on buses. In our preliminary experiment, we set one beacon for each bus vehicle, because the range of Bluetooth signal is usually several tens of meters and that can cover the whole vehicle.

Each beacon broadcasts the common service UUID and its own identification number. For IDs, we use the same major number for bus vehicles and an unique minor number. Ids of buses and relations to the fleet are stored in a database in the server. In addition to IDs of buses, some static information, such as bus routes and timetables, are given to the server database. The system can identify which bus on which route the beacon is on by the correspondence table of major and minor number, vehicle and route in the database.

3.2 Beacon at the Bus Stop

For additional services beyond the bus location, we also set up a beacon at the bus stop. Figure 2 shows an scene where a beacon is installed at a bus stop. A beacon is installed near the base of the column of the bus stop indicated by red circle.

Fig. 2. Beacon at the bus stop (Color figure online)

3.3 Mobile Application

User Functions. The Ride ATC provides users with current locations of buses in operation. It indicates the position of the buses on the map. The user can check it and estimate arrival time of their possible target bus on map beforehand so that it is possible to minimize the waiting time at the bus stop without missing it. The authors, therefore, believe that the application can make the bus operations more reliable and then may be able to be preferred by bus passengers.

Logging Functions. While the user is using the application in both the foreground and the background, the Ride ATC application scans a specific range of Bluetooth IDs. Once it detects an ID nearby, the application obtains location from onboard sensors. The location data with bus IDs and time are collected and pooled in the local data store and then transmitted to the service platform.

On the platform, current positions are updated and estimated by using collected bus IDs with spatiotemporal information and static information in database.

4 Scenario

The service is based on the following scenarios.

4.1 Grasping Bus Location and Estimating Arrival Time

The most typical and basic scenario is to check the bus's current position and estimated time of arrival as already mentioned so that passengers can wait for the bus efficiently.

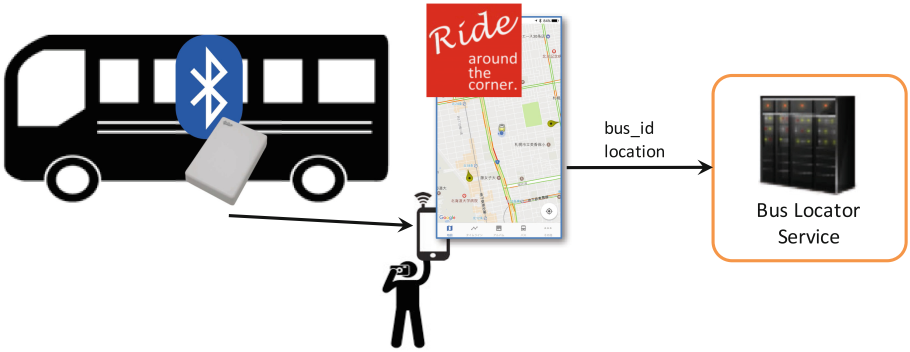
If at least one passenger who enables the Ride ATC is onboard, the service grasps the current location of the bus. Therefore, at least one user of the Ride ATC gets on a bus, this service gets effective. Conversely, it is not possible to acquire the location information of the bus where there is no user onboard. In other words, the more users want to know the location of the bus, the more practical this service will be. The authors think that this point is very important. People who collect information on the location information of the bus think that motivation for their information gathering will be stronger because it is not a position to cooperate on information unilaterally, but a beneficiary of information.

By the way, do we need at least one user in every section of every vehicle to make this service practical? The authors think that it is not necessary because of some reasons. One is that the signal of the beacon on the bus can be received not only within the bus but also in the vicinity of the outside of the bus (Fig. 3a). For example, in the case where the bus passes by the side of the user walking on the sidewalk, the user can provide the location information of the bus to the service.

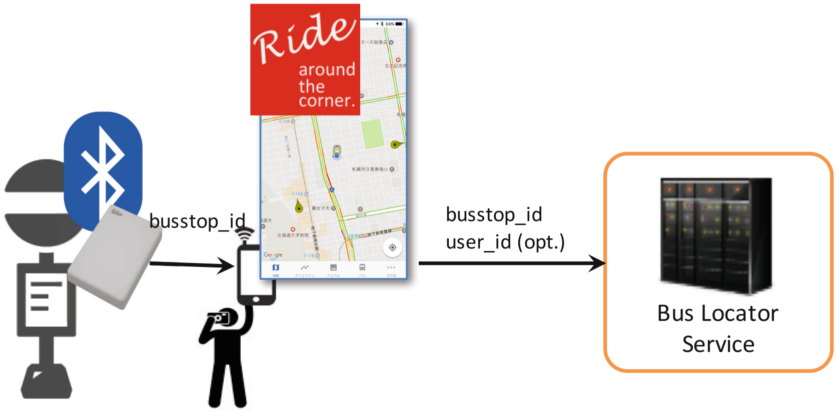
As another reason, the system can interpolate and estimate the position in the section in which the data is missing. Obviously, the greater the loss of data becomes, the larger the estimation error becomes. The authors consider that it is possible to estimate with a certain degree of accuracy by considering the usual travel time and the differences from the usual in other sections on this day. Verification of the estimation accuracy of missing data is a future task.

4.2 Grasping Waiting Passengers at the Bus Stop

By placing a beacon at the bus stop in addition to the bus, it is possible to use methods other than bus location (Fig. 3b). One of them is that bus operators can grasp the situation waiting for passengers at the bus stop. There is a possibility to grasp how many passengers got on and off at which bus stop, but nobody has been able to grasp how many passengers are waiting at the bus stop and how many people are waiting. By acquiring the situation where the application continuously detects the beacon ID of a specific bus stop, the above can be obtained. Considering future bus schedule consideration and service improvement, it seems important to become able to grasp the situation which can not be grasped now.



(a) Detecting Onboard Beacons from Outside the Bus



(b) Detecting Bus Stop Beacons

Fig. 3. Variations of detecting beacons

4.3 Notifying Getting On/Off

As another utilization method, use as a so-called "watching service" can be considered. In Japan, it is common that elderly people going to hospitals and children go to school by using public transportation by themselves. It is important to care for these vulnerable people throughout the society, but close relatives such as families are concerned about whether these close relatives are acting as planned safely.

The service called "Anshin Goopas" (safe goopas) is a service to distribute passing information to parent's mobile phone by e-mail when the child passes through the ticket gate at the station using their IC card [7]. Goopas can only deal with passing through ticket gates corresponding to transportation IC cards. Toll machine on the bus is often offline, so this system can not be used on buses.

Meanwhile, in recent smartphone OS such as iOS, there is a function of notifying a specific other account of its own position, such as “Find My Friends” of iOS. Watching functions can be performed with this function as long as it is a relationship allowing permanent position to be grasped, but privacy problems may arise.

On the other hand, in the proposed method using the beacon and the application, it is possible to detect a bus waiting situation at a bus stop and get on and off of a specific user, and to notify the close relative who has been designated in advance. For this purpose, the application needs to be allowed to transmit the user ID along with the beacon ID and position information of the bus and the bus stop.

5 Discussions

Here the authors compare the proposed method with the conventional method and discuss the characteristics of the proposed method.

5.1 Cost

As for the initial introduction cost and the operation cost, the proposed method has a big advantage over the conventional method. In the conventional method of installing gps receiver on each bus, the cost of installing these devices on the bus takes as much as the number of vehicles. With the conventional method of installing a bus detector at a bus stop, the installation cost of the number of bus stops is necessary. On the other hand, in the proposed method, bus operators need only to set beacons for buses and bus stops, and introduction cost is small.

Regarding the operation cost, in addition to the maintenance of the device, in the conventional method, it is necessary to bear the communication cost for collecting data from each device. In contrast, the proposed method requires only the beacon battery, and the cost is relatively very low.

5.2 Accuracy

The accuracy of position information is discussed from two viewpoints. One is data integrity, and the other is density.

Regarding data integrity, the conventional method can basically grasp the movement of all the sections of all vehicles, whereas the proposed method is disadvantageous in that it depends on the number and distribution of users.

As mentioned before, at least one user of the Ride ATC gets on a bus, this service gets effective. The authors consider that it is possible to estimate with a certain degree of accuracy by considering the usual travel time and the differences from the usual in other sections on this day. Verification of the estimation accuracy of missing data is a future task.

The key to this crowdsourced approach is that data providers that enable this service are considered to be more willing to gather information and data by being identical to users who need this service.

On the other hand, regarding the density of data, it is considered that positioning and communication are carried out generally once per minute in the conventional method of installing a GPS receiver on the bus. In the method of installing the detector at the bus stop, since the position of the bus is detected only when the bus approaches the bus stop, its density is smaller and it is impossible to grasp the behavior between bus stops. In the proposed method, the user can continuously measure and transmit the position information while detecting the beacon, and in the current implementation of the Ride ATC, these are performed every second.

5.3 Extended Services

In the conventional method, because it is specialized in collecting and sharing bus location information, it is considered difficult to extend the service beyond utilizing location information. On the other hand, in the case of the beacon installed by the proposed method, as described above, deployment such as watching service to the user and waiting situation at the bus stop, grasping the state of the user and utilization thereof can be considered.

6 Conclusion

This paper describes a crowdsourcing model to collect bus locations from onboard passengers. The model can be installed even to small operators to provide bus locations to passengers.

The authors have been doing preliminary experiments. Under the cooperation of the Hokkaido Chuo Bus, we set up beacons to the bus for the six routes and beacons to the bus stop, and we are proceeding with the operation verification using the developed Ride ATC application. Through experiments, in particular, the authors will clarify the relationship between data integrity and location estimation accuracy and hope to proceed with the verification of the data density at which the proposed method works.

Acknowledgment. The authors would like to thank City of Sapporo, Hokkaido Government, Hokkaido Chuo Bus Co., Ltd. for their cooperation with this research.

Part of this research was supported by "Research and Development on Fundamental and Utilization Technologies for Social Big Data" of the Commissioned Research of National Institute of Information and Communications Technology (NICT), Japan.

References

1. Amichai-Hamburger, Y.: Potential and promise of online volunteering. Comput. Hum. Behav. **24**(2), 544–562 (2008)
2. Howe, J.: Crowdsourcing: a definition. Crowdsourcing: Tracking the Rise of the Amateur (2006)
3. Howe, J.: The rise of crowdsourcing. Wired Mag. **14**(6), 1–4 (2006)

4. Howe, J.: Crowdsourcing: How the Power of the Crowd is Driving the Future of Business. Random House, New York (2008)
5. Kanatani, N., Sasama, T., Kawamura, T., Sugahara, K.: Development of bus location system using smart phones. In: Proceedings of SICE Annual Conference, vol. 2010, pp. 2432–2433 (2010)
6. King, S.F., Brown, P.: Fix my street or else: using the internet to voice local public service concerns. In: Proceedings of the 1st International Conference on Theory and Practice of Electronic Governance, pp. 72–80 (2007)
7. Koyanagi, T., Kobayashi, Y., Miyagi, S., Yamamoto, G.: Agent server for a location-aware personalized notification service. In: Ishida, T., Gasser, L., Nakashima, H. (eds.) MMAS 2004. LNCS (LNAI), vol. 3446, pp. 224–238. Springer, Heidelberg (2005). https://doi.org/10.1007/11512073_17
8. Schuurman, D., Baccarne, B., De Marez, L., Mechant, P.: Smart ideas for smart cities: investigating crowdsourcing for generating and selecting ideas for ICT innovation in a city context. J. Theor. Appl. Electron. Commer. Res. **7**(3), 49–62 (2012)
9. Shigihara, I., Arai, A., Saitou, O., Kuwahara, Y., Kamada, M.: A dynamic bus guide based on real-time bus locations - a demonstration plan. In: 2013 16th International Conference on Network-Based Information Systems (NBIS), pp. 436–438 (2013)
10. Stembert, N., Mulder, I.J.: Love your city! An interactive platform empowering citizens to turn the public domain into a participatory domain. In: International Conference Using ICT, Social Media and Mobile Technologies to Foster Self-Organisation in Urban and Neighbourhood Governance (2013)
11. Watkins, K.E., Ferris, B., Borning, A., Rutherford, G.S., Layton, D.: Where is my bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. Transp. Res. Part A: Policy Pract. **45**(8), 839–848 (2011)