Tracking, Arrival Time Estimator, and Passenger Information System on Bus Rapid Transit (BRT)

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***Abstract*—Trans Metro Bandung is a new Bus Rapid Transit in Bandung, Indonesia. As a new mode of transportation, it proposes comfort, safety, and give an affordable price. However, information systems related to buses are still lacking and far from expectations. That includes the uncertainty of the bus departures and arrivals times at bus stops. Therefore, in this study, an integrated online system is designed to provide information, including bus arrival time, bus position, and the number of passengers on the bus. This information system is a website application that is connected to the Firebase real-time database so that all data can be accessed in real-time and then displayed at the bus stop. The hardware system consists of an infrared detector to count the number of passengers and a GPS module for bus tracking. From the bus position information, the system can estimate the arrival time at the nearest bus stop.**

***Keywords*—Bus arrival time, bus position, Bus Rapid Transit, real-time tracking**

I. Introduction

Transportation is one of the main components in supporting community economic activities. The transportation system is built to meet the mobility needs of the community and other resources that have an impact on economic growth. The Indonesian government is focusing on developing mass public transport infrastructure, as stated in government regulation No. 22/2009 article 139 concerning Road Traffic and Transport (LLAJ). In this regulation, the government obliges to guarantee the availability of transportation for people and/or goods. One of the public road transport that the government focused on developing is the city bus. A city bus is an excellent choice that can serve a short distance route by considering efficiency. At least ten big cities in Indonesia have operated Bus Rapid Transit (BRT). BRT development is expected to be a solution to the transportation problem in Indonesia, especially in urban areas.

Bandung is one of the big cities in Indonesia that applies Bandung is one of the big cities in Indonesia that applies BRT as mass public transportation. Since its inauguration in 2009, BRT Bandung has served routes within the city and outside the small towns that surround it. The number of routes served continues to increase, along with the increasing demand for people with high mobility. The existence of BRT helps the citizen of Bandung because it offers low prices, excellent facilities, comfort, and an on-time schedule. The Bandung city government certainly guarantees the quality of BRT services, one of which is by providing a new bus fleet so that passenger safety and comfort are guaranteed. Although the operations and functions of BRT Bandung are going well, the integrated information system, especially at Bus Stop, has not received much attention. Information such as bus position, arrival time, and the number of passengers has not developed. Under certain conditions, people need to estimate travel time and plan trips. This has become an essential aspect of increasing comfort and safety. The key to the value-added of this service is the implementation of a tracking system with adequate features. The tracking system has been widely used on vehicles for monitoring and security purposes [1], [2]. Applications in mass transportation have also begun to be widely applied, such as buses.

Some research has developed a system for tracking public transportation, specifically buses [3]–[5]. The online tracking system based on the Global Positioning System (GPS) is integrated with the communication module they have implemented. Some of these studies [3], [6]–[8], still use GSM technology in data transfer, making it possible to have a high delay, not appropriate for real-time applications. From some of these studies, no route displays, or digital maps were found, only the notification of the position of the last bus so that it can complicate passengers. A bus position detection system using a simple detector was proposed in research [9], but it cannot be applied to monitoring applications. Application of the tracking system to find the nearest bus stop is proposed in the study [10], this is another added value for bus passengers. The use of a tracking system for estimating bus arrivals is proposed in research [4], [11]–[14]. This is an added value

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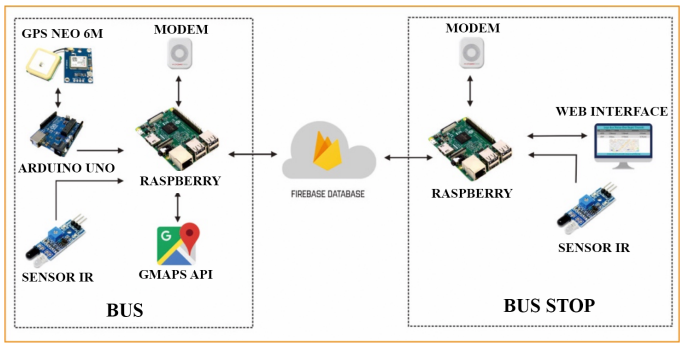

Fig. 1: BRT monitoring system diagram

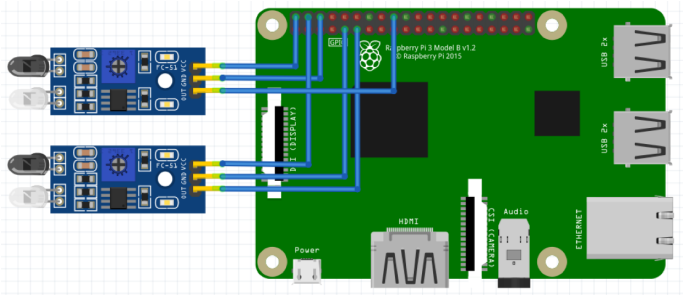

Fig. 2: Schematic Design of IR Sensors

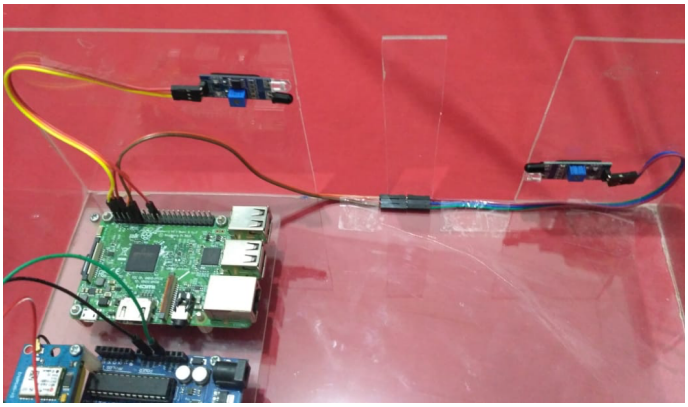

Fig. 3: Hardware prototype

to improve service quality. From the study literature described, the bus tracking application and some of them added with the estimated bus arrival time feature contribute to improving bus transportation services through additional features. Therefore, this work is designed and implemented a tracking system, arrival time prediction, and information on the number of passengers on BRT Bandung. We integrate these three features in a real-time application at a bus stop. Therefore, passengers get complete information so that travel planning can be better decided.

In this work, an information system consisting of hardware and software is implemented to carry out the tracking function, predicting arrival time and available capacity. GPS module and infrared detector are components that are installed on the bus, including a mini PC as the primary control. At the bus stop, an infrared detector is installed to count the number of people who are at the bus stop. A mini PC is also a control device that is installed at the bus stop, which has a function as a data transceiver through the internet network. In addition, the mini PC will display a digital map, bus code, trip route, arrival time, and passenger capacity through the monitor screen.

II. Method and Design

A. Bus Rapid Transit

Bus Rapid Transit (BRT) is a fast transportation system that serves travel within the city, especially big cities in Indonesia. BRT is a flexible mode of fast transportation using a combination of stations or stops, vehicles, services, and special lanes. In Bandung, this mode is called Trans Metro Bandung (TMB). TMB, as a public transportation provider, has operated it since 2004. Trans Metro Bandung has six bus routes in Bandung with 52 bus stops.

B. Internet of Things (IoT)

Internet of Things (IoT) is defined as an infrastructure to control a device or device without human assistance. With the support of this infrastructure, it is possible to access information, monitoring, storing, and retrieving device or device data in real-time that is always connected to each other [15]. In this work, IoT technology was adopted to develop services on Trans Metro Bandung so that users and interested parties can monitor and obtain relevant information in real-time.

C. Firebase as a Real-time Database

Firebase is an open platform for developing software or hardware in building a web or android application that has complementary features [16]. The features of firebase are real-time database, authentication, hosting, and storage. All features are packaged by a Firebase SDK to facilitate software or hardware development. In this study, the Firebase real-time database feature is used to support real-time services. Firebase's real-time database is a NoSQL service that is owned by Firebase SDK. Firebase real-time databases have data storage that can be synchronized in real-time to all hardware or software connected.

D. System Design

The monitoring system is a system that can be used to automatically monitor the devices in BRT using microprocessors, microcontrollers, and IoT-based sensors. This monitoring system is designed to get bus location information, estimated arrival, and passenger capacity in real-time. The aforementioned information can be seen through the monitor display at the bus stop.

The workflow of this system is the reading of GPS data, infrared sensors as a passenger detector, and then these data are sent by Raspberry to the database. The detailed diagram of this system can be seen in Figure 1.

Implementation of the passenger counter module uses the infrared sensor, as shown in Figure 2. If the IR sensor detects

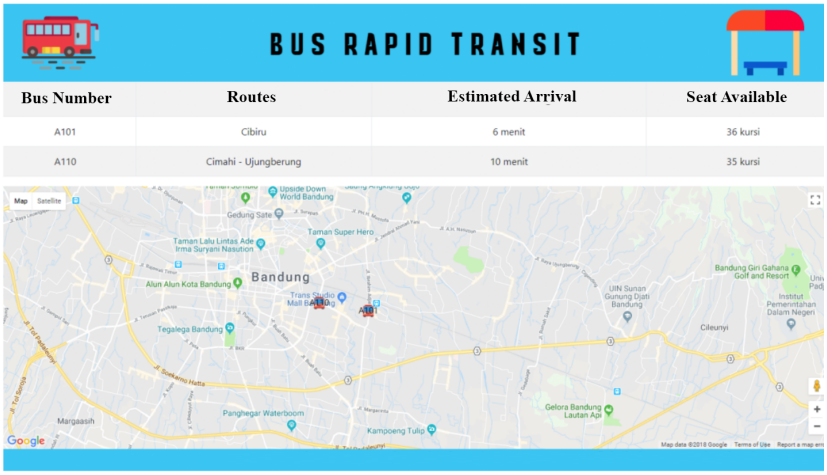

Fig. 4: The designed user interface for information system on bus rapid transit

TABLE I: Delay test result on the sensor

Sensor	Test-n- (seconds)					Average
	1	2	3	4	5	
1	1	0.9	1.5	1	1.5	1.18
2	1.7	1.1	1.4	1.7	1.1	1.4
3	1.5	1.3	1.7	1.3	1.1	1.38
4	1.2	1.3	1.3	1.1	1.6	1.3
Average						1.31

movement entering the bus door, the data value is ”1”, conversely if the sensor detects movement out of the bus door, the data value is ”-1”. The value is then calculated with Raspberry and sent directly to the Firebase database. The implemented design of the prototype is shown in Figure 3.

III. Result and Discussion

Figure 4 shows the interface of the information system, which installed at the bus stop. This information system contains the bus code, destination route, estimated time of arrival, and available capacity. In the application, there is also a bus icon/marker that indicates the bus is running in real-time according to the current bus position. There is also a bus stop icon that shows the bus stop that has passed.

A. Sensor Delay Testing

The testing of the infrared sensor is done by calculating the data transmission delay. Tests are performed at bus stops and buses to calculate the delay in sending data in seconds from the sensor to be displayed on the website application. This test is done with five experiments for each bus stop, which presented in Table I. Based on the trial, the transfer delay is no more than 2 seconds. Based on the study [17], this result is acceptable in the real-time environment.

B. Passenger Counter Module Testing

This test is intended to determine the performance of the counter module in detecting passengers. The simulation was done when the passenger exits and enters the bus. In 10 experiments with various conditions (Table II), the module worked well with 100% detection accuracy.

TABLE II: Counter module test results

No	Real conditions			Detection by sensor			Acc (100%)
	in	out	In the bus	in	out	In the bus	
1	5	0	5	5	0	5	100
2	3	1	2	3	1	2	100
3	3	0	3	3	0	3	100
4	1	1	0	1	1	0	100
5	2	0	2	2	0	2	100
6	8	1	7	8	1	7	100
7	3	2	1	3	2	1	100
8	3	1	2	3	1	2	100
9	1	0	1	1	0	1	100
10	1	0	1	1	0	1	100

TABLE III: Delay test result on the sensor

	Test-n										Total
	1	2	3	4	5	6	7	8	9	10	
GPS	3.3	4.2	4.8	7	10	3.6	4.8	3.3	7	5.1	53.6
Average Error											5.36 m

C. GPS Module Testing

This test is done to determine the location error by GPS. The test was carried out at 10 different locations. Test results are shown in Table III. From the test results, the average of miss location which is detected by GPS is 5.36 meters. This result is used to determine the radius where the bus has approached the bus stop.

IV. Conclusion

Based on the design and prototype of the system, it can be concluded that the monitoring system on the Bus Rapid Transit can work in accordance with the design. The main controller unit and the Firebase database are integrated into a monitoring application. The information system can display the bus code,

destination route, estimated bus arrival, available capacity, and the position of the bus that is moving in real-time. Based on testing the information system functionality, 100% accuracy was obtained. Based on a Questionnaire that has been given to 85 Bus Rapid Transit users, users respond that this information system is needed to determine the estimated bus arrival time and bus position in real-time.

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