Indonesian Journal of Electrical Engineering and Computer Science
Vol. 30, No. 2, May 2023, pp. 1047~1058
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v30.i2.pp1047-1058

Design and implementation of school bus information and tracking system application

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Article Info

Article history:

Received Jul 4, 2022
Revised Dec 14, 2022
Accepted Dec 20, 2022

Keywords:

Global positioning system
Near field communication
Passenger
School bus information
Tracking bus

ABSTRACT

The school bus is a means of transportation that is very attractive to students because it is free. This study aims to develope an application that can track school bus trips and provide information about bus passengers. Bus location information sent to the user application can help students estimate the arrival time of the school bus at the pick-up point. In addition, information on the identity of school bus passengers can be used by parents to monitor the whereabouts of their children going to or from school on the bus. This application uses the global positioning system (GPS) of the smartphone on the school bus to find out the location of the bus and send it along with passenger identification information to the user application. To read passenger identities, near field communication (NFC) cards are used as passenger identity cards by tapping them on a smartphone on a school bus. Tests have been carried out on all functions of the application features and testing the accuracy of location reading and tracking of school bus trips, obtained latitude and longitude tolerance values of about 3.2 meters.

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1. INTRODUCTION

Transportation is a tool to make it easier for humans to carry out transportation and movement activities [1]. Bus is a means of transportation that is widely used in various countries, including Indonesia. One of the advantages of buses as a means of transportation is that they can carry many people so that the cost is cheap. In X regency (the name is not disclosed due to permission issue), where this research was conducted, buses are not only used as a means of inter-city transportation but also used by the local government as school buses to facilitate students going to and from school for free [2]. The length of the track that the bus has to pass and the bus departure schedule are not yet orderly, making it difficult to predict the arrival of the bus at each stop. As a result, it is not uncommon for students to have to wait for a long time or miss the bus when they arrive at the pick-up point. Lack of information about the position of the buses due to the absence of a departure schedule makes the school buses provided by the local government perform badly. The length of the bus travel route and the lack of orderly bus travel schedules make the obstacles faced because the arrival schedule is often late. This raises concerns for parents who are waiting for their children at home.

This research tries to find a solution to the problem of delays in bus arrivals and the limited information about passengers on the bus, namely developing an application using global positioning system (GPS) and near field communication (NFC) cards. By using GPS [3]-[5], the whereabouts of the bus during the trip can be identified and the NFC card is used as an identity card for students riding the bus [6], [7]. Bus location information and passenger identities are sent to all application users using the internet network [8], [9] so that application users can anticipate the arrival time of the bus at each pick-up location.

2. RELATED WORK

This paper describes telematics technology for various vehicle monitoring applications such as vehicle location tracking and vehicle theft location [10]. The researcher proposes a school bus monitoring system using localization and speed sensors using GPS data communication signal comparison [11]. This allows parents and school authorities to track school bus trips in real-time [12]. A study that develops and tests a vehicle tracking system using GPS and communication devices using global system for mobile (GSM) was conducted so that the position of the vehicle can be tracked in real time using a Smartphone application [2], [3], [6]. The Google maps application programming interface (API) is used to display the vehicle on the map in the smartphone application. Thus, users will be able to continuously monitor a moving vehicle on demand using the Smartphone application and determine the estimated distance and time for the vehicle to arrive at a given destination. In order to show the feasibility and effectiveness of the system, this paper presents experimental results of the vehicle tracking system and some experiences on practical implementations [12].

Passenger identity is needed to record who is riding public transportation so that the public can find out about it. The personal identification in mobile scenarios has attracted a lot of attention in the last few years due to the emergence of new communications paradigms that enable the establishment of ad hoc communications. These communications must be carried out in a secure way since they can be involved in applications such as payments and access systems. Consequently, new secure systems should be proposed for managing security in such complex, mobile, and variable conditions. This paper proposes a new authentication system based on the Spanish identification (ID) card and the wireless NFC technology [13]. It uses cryptography techniques and authentication certificates to establish secure communications between two interlocutors. The proposed network oriented architecture enables the proposed authentication system to operate in both local and remote modes.

3. RESEARCH METHOD

3.1. System design

Figure 1 shows a block diagram of the system for tracking or knowing the location of an object, in this case a school bus. The GPS on the smartphone gets a signal from a satellite [14] which contains information about the longitude and latitude of the object being tracked through an application embedded in a smartphone on a school bus. This information will be forwarded to users via an application embedded in the user's smartphone to indicate the location of the school bus. In addition, information about school bus passenger data is also sent. Passenger identities are read using an NFC card as a student identity card [15]. Data on NFC is read via an NFC reader installed on a smartphone on the bus. This reading can also be used as a sign that the passengers on the bus have increased by one. This information is expected to be known by user 2, namely students who will take the bus, or by user 3, namely parents, through an application that is embedded in the user's smartphone.

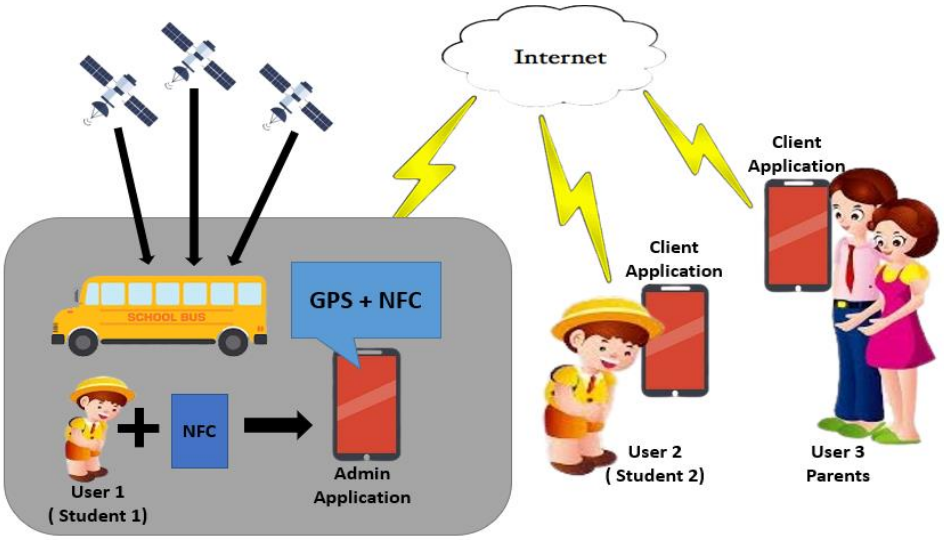
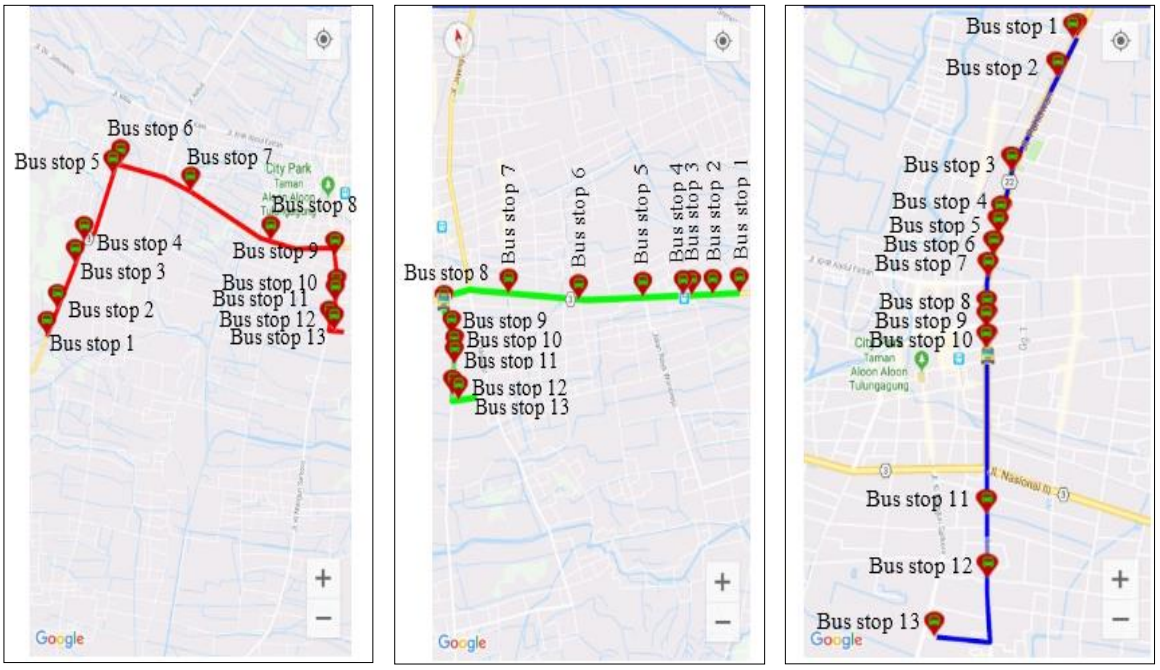


Figure 1. System block diagram

In the block diagram, there are 3 users consisting of user 1 as the student on the bus, user 2 as the student who will ride the school bus, and user 3, namely the parents. User 1 is a student who rides a school bus and already has an NFC card which is then tapped on the admin smartphone. The process of tapping the NFC card when the student rides the school bus will be recorded in the passenger history, when the passenger is boarded [16], what will be recorded is the name of the student's identity, ID number and time of the school bus ride [17]. Then the admin application tracks or finds out the location of the bus using GPS on the admin smartphone. The GPS will receive a tracking signal from the satellite which contains the longitude and latitude data of the current bus location [18]. Furthermore, the location and passenger identity will be sent to other users so that user 2, namely students who will ride the school bus, can see information about the whereabouts of the bus and the number of passengers. Similarly, user 3, namely parents, can monitor their sons and daughters who use school buses for school transportation. The school bus to be tracked is a school bus in X regency which has 3 routes, namely route A, B, and C, each of which has 13 bus stops which will be explained in Figure 2. The A, B, and C routes and the stops are shown in Figures 2(a)-2(c).



(a) (b) (c)

Figure 2. The bus stops map from route, (a) route A, (b) route B, and (c) route C

3.2. The working of the system

The way the system works is explained as shown in:

- The school bus driver activates GPS and NFC on the admin smartphone on the bus by activating the admin application, so that users 2 and 3 can track the location of the school bus.
- Students and parents can access the user application by using a smartphone connected to the internet to find out the whereabouts and passenger information according to the route chosen by the student.
- Students who ride the school bus can tap the NFC card they already have. If NFC is read, it means that the student has been registered as a passenger. If the NFC card is not recognized, the student must register.
- Students register by filling in their personal identification. The application then reads the NFC card as the name of the student who has registered so there is no need to re-register.
- When the NFC card is tapped on the admin smartphone one time, it indicates the number of passengers has increased and the history will display the name of the student and the time when getting on the school bus.
- Students who get off the school bus re-tap the NFC card to provide information that passengers have decreased and the history will add to the student's time off and the location where the student gets off.

In a flow chart, the working of the system can be described as shown in Figure 3.

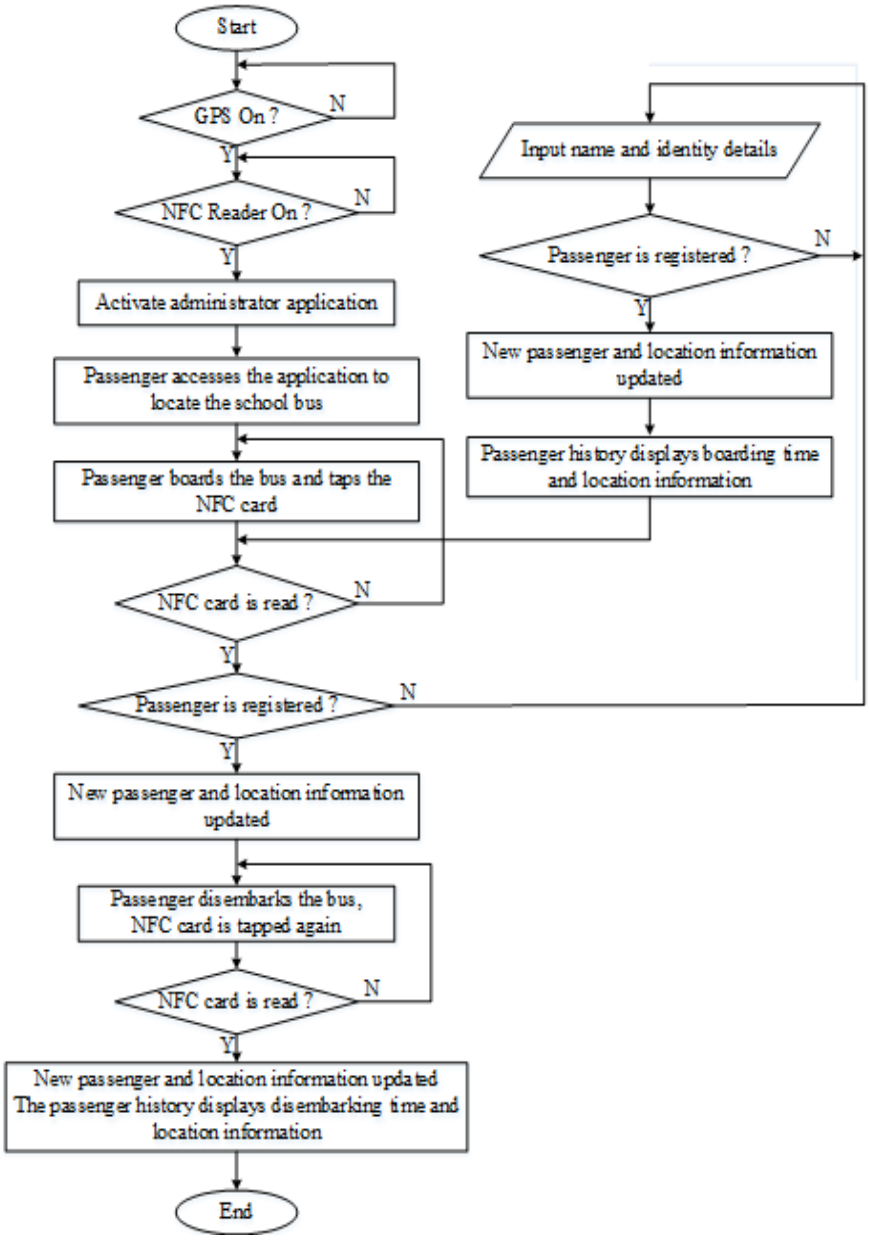


Figure 3. Flow diagram of the working of the system

3.3. Data flow diagram (DFD)

DFD level 0 in Figure 4 describes the flow of data to and from user and system. Table 1 illustrates the access right at DFD level 0. DFD level 1 shown in Figure 5 describes in more detail the data flow and processes carried out by the system.

DFD level 1 in Figure 5 shows three processes, which are tapping the NFC card, tracking, and showing history, all of which are performed by 3 users, namely the admin, the client, and the guest. The admin is responsible for validating the guest who has performed registration and reading the bus location coordinates with the help of the GPS as the input for tracking. The process of tapping the NFC card allows the device to read the information about the identity of the passenger which is stored in the card. The information is then sent to the admin in order to be recorded in the passenger history as a passenger on-board of the bus. The tracking process manages the bus location coordinate in order to be informed to the client as well as the guest. Meanwhile, the history process manages all activities happening in the bus, including recording the identity of the passenger who gets in and gets out of the bus.

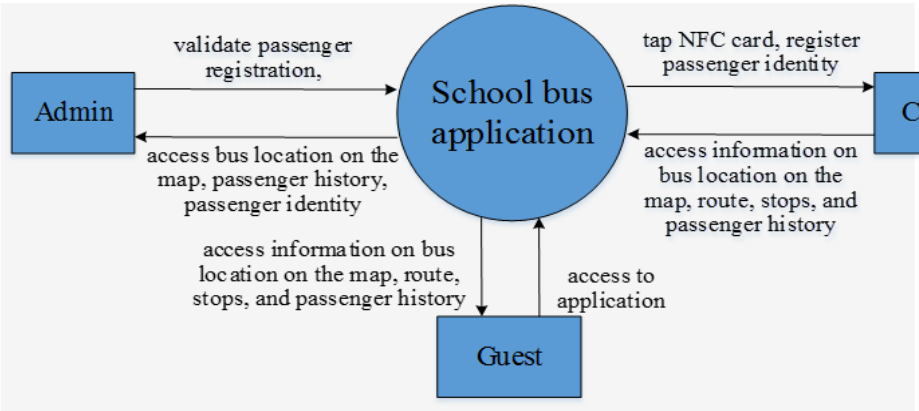


Figure 4. DFD level 0 of the application for school bus information and tracking system

Table 1. Description of data flow diagram level 0

User		Access right
Admin	-	Validating passenger's registration,
	-	Receiving information about bus coordinate location, history, and passenger's identity.
Client	-	Tapping NFC card and performing registration,
	-	Providing the information about departure and getting off location and route in the form of passenger history.
Guest	-	Accessing the application,
	-	Obtaining information about the bus location in the map, route, stop, and passenger history.

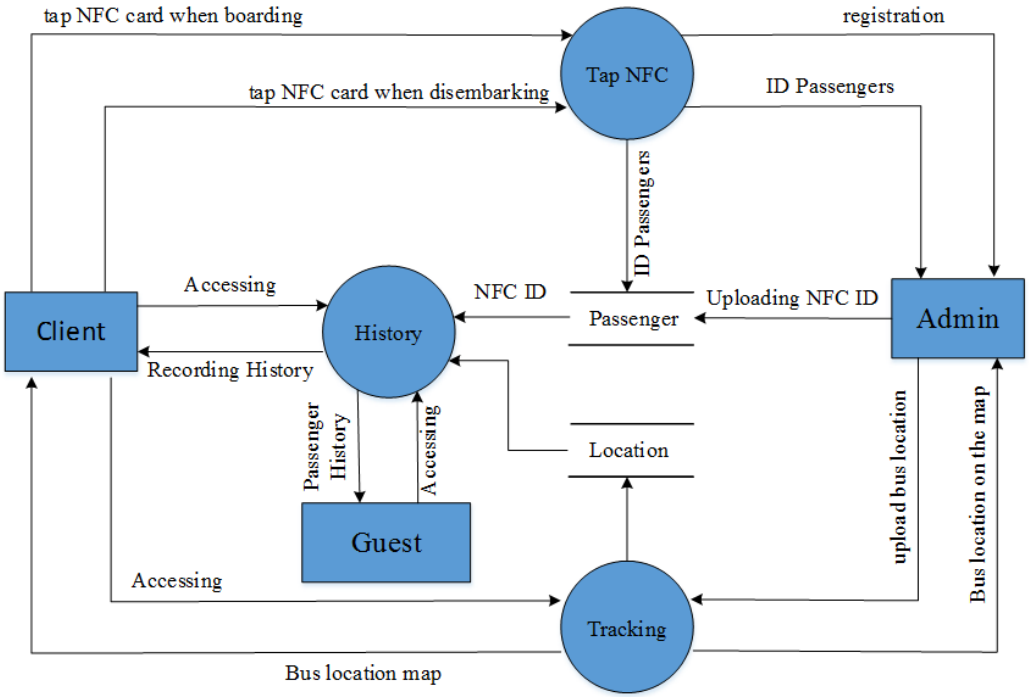


Figure 5. DFD level 1 for the application for school bus information and tracking systems

4. SYSTEM IMPLEMENTATION

The implementation of the system is based on experimental data collection and literature study which provides data used as input for the application for school bus information and tracking system. An overview of the implementation of the school bus information and tracking system application consists of two parts, namely the description of the system in general and how the system works. How to get the desired result is also

explained how the designed application works. The test results will be described in the results section below of this session.

4.1. General system description

The system developed is intended to make it easier for students and parents to find information about the location of buses and information on passengers on the school bus. This system consists of two parts, namely:

a. Admin application, which is an application embedded in a smart phone placed in a school bus and is used as a reader for the location of the school bus and as a reader for student's NFC cards. The application consists the following:
   - Feature to select the route for the school bus to be followed.
   - Feature for coordinate reader which tracks the location of a school bus using the smart phone's GPS.
   - Feature to read NFC card which identify the passengers on the school bus.
   - Feature to register NFC cards that have not been registered.
   - Display of a map that matches the route of the school bus.
   - Feature to manage passenger history in which the information about student's boarding time as well as get off time and location can be accessed.
b. The Client application, which is an application that can be accessed by everyone who install the school bus information and tracking system application. This application tracks the location of the school bus and provides information about the number of passengers on a bus and the passenger history. The functions of this application include:
   - Tracking menu options or passenger information.
   - Feature to display the selections of school bus routes.
   - Feature to display the bus routes, which are colored differently for each route; route A is in red, route B in green, and route C in blue.
   - Feature to display the school bus stops.
   - Feature to display information on the number of passengers on board the school bus.
   - Feature to display passenger history where the information about passenger's boarding time as well as disembark time and location can be found.

4.2. The working of the application

The working of the application for school bus information and tracking system in general is shown in Figure 6. The figure illustrates the working scheme of the school bus information and tracking system application as shown in:

a. Admin application: the administrator (bus driver) selects a route that the school bus will pass. After that, the application reads the location of the school bus using Google Maps. When an NFC card is tapped on the administrator's smart phone, the administrator application reads the NFC card to display data as registered to and stored on the database server. If the data is not on the database server, the passenger is required to register as a new passenger by filling in the passenger's data which include name and ID. Once registered, the passenger's information is read to provide information about the number of passengers and passenger history.
b. Client application: this client application can be used by students, parents, and the department of transportation to monitor the performance of school buses. In the client application, the user can select the desired route out of the three routes, which are shown in different colors, as well as the bus stops that are marked with numbers indicating the order of the stops. The client application also displays information on the number of passengers on the bus and passenger history to help users find out and monitor.

Based on the flow diagram in Figure 6, the process is explained as follow:

- NFC card is tapped to the administrator's smart phone that is used as a reader to identify the passenger's ID number on the NFC card.
- The administrator's smart phone reads the NFC card. If the NFC card is read successfully then passenger proceeds to the next step. If the reader fails to read the passenger's ID, the passenger repeats the first step.
- After the administrator's smart phone successfully reads the ID on the NFC card, registration is required. This registration is done by entering the student's name which is necessary as an ID identifier in the application.
- The data in the form of name and passenger's details that have been registered are then stored in the database.
- After that, the passenger's name, ID number on NFC card, and the boarding time as well as the disembark time and location appear in the passenger history in the application.

The process of school bus information and tracking system shown on Figure 7. Start from tap the NFC card then read the data by administrator. After that the track will saved on database system.

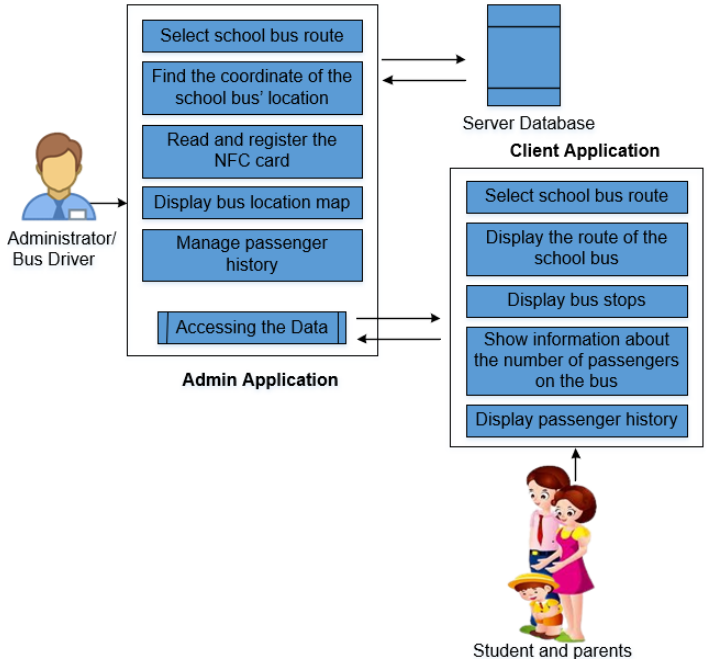


Figure 6. The working of the application

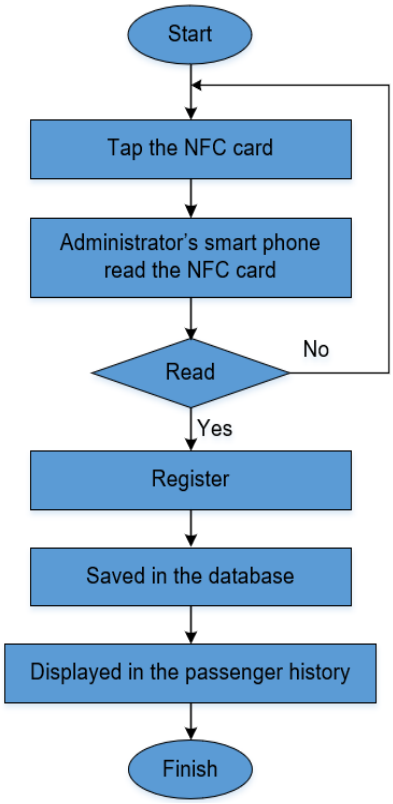


Figure 7. The work flow diagram of school bus information and tracking system application

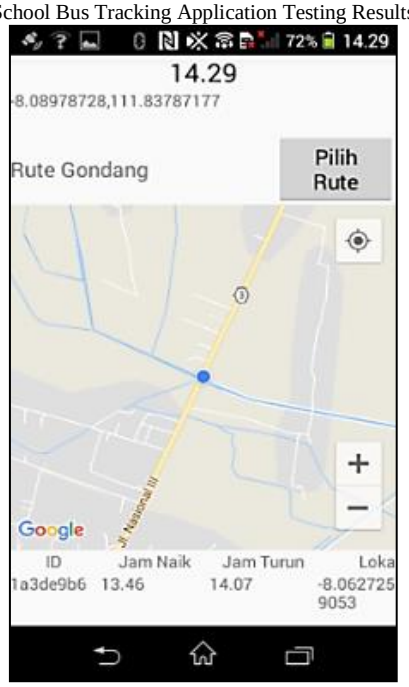
5. RESULTS AND DISCUSSION

This section presents the results of testing and discusses the application that has been built, specifically the functions of each feature and the overall performance of the application. For peformane has been tested about GPS test results with make comparison between school bus tracking application and GPS coordinates application. Smartphone's ability to read NFC was also tested in this research.

5.1. GPS test results

This test includes the performance and accuracy tests of GPS in reading the location of the school bus. The test was carried out by comparing the results of the location reading using the school bus tracking application and the reading results from another device using My GPS Coordinates application. Figure 8 gives information on the readings between the two devices using school bus tracking system application and My GPS Coordinate application.

School Bus Tracking Application Testing Results



Location: Bus Stop 1 (8° 5’ 23.2”, 111°50’16.3”)

Other Device (My GPS Coordinates) Testing Results

Location: Bus Stop 1 (8° 5’ 23.0”, 111°50’16.3”)

Figure 8. Results displayed on the smart phone using GPS location reading

The testing used decimal degree (DD) format, where the latitude and longitude distances are necessary to be converted to degree minute second (DMS) to determine the latitude and longitude distances in meters [19]. The conversion of distance in degrees minute second unit into meter or kilometer uses formula as follows in Table 2. In the comparison testing of school bus tracking application and My GPS coordinates application, the value of latitude and longitude in distance units with a difference of 0.1 seconds is 3.09 meters, which is obtained from the calculation of 0.1 seconds multiplies by 30.92 meters. From the results of this comparison test, the distance difference between latitude and longitude is more or less 3.09 meters. The difference between latitude and longitude that has been obtained proves that the school bus tracking application is working well and stable.

Table 2. DMS to DD and meter conversion

Conversion DMS into DD and Meter
1 degree (1º)=40.075 Km: 360º=111,320 Km
1 minute (1’)=111,320 Km: 60=1,855 Km
1 second (1”)=1,855 Km: 60=30,92 Meter

5.2. Testing school bus tracking application school bus routes

From comparison testing on the accuracy of the school bus tracking application and My GPS Coordinates application, it is necessary to test the application on the routes that are passed by the school bus. The goal is to determine the performance of the school bus tracking application. The test was carried out by riding a school bus and the data were collected from each bus stop. In this test, the performance of the application was measured by comparing the application's coordinates obtained from Google Maps [20] with the coordinates obtained from My GPS Coordinates application [21].

In Tables 3-5, the comparison of testing results between the school bus tracking application and My GPS Coordinates application for all three routes had used the decimal degree (DD) format, and so it is necessary to convert it to degree minute second (DMS) in order to find out the difference in distance in meter unit [22]. From the comparison of the two applications, it is known that the readings at several bus stops have significant differences in distance. This is because the quality of the communication network is not evenly distributed along the bus route. The results of the tests that have been carried out obtained a comparison between the school bus tracking application and the My GPS coordinates application, with the latitude value difference at approximately 3.09 meters and longitude value at 3.32 meters.

Table 3. The distance difference from testing results of school bus tracking application and My GPS coordinates application for route A

Location bus stop	Latitude		Longitude		Distance differences			
	School bus tracking application	My GPS coordinates application	School bus tracking application	My GPS coordinates application	Latitude		Longitude	
					"	m	"	m
1	8° 5' 23.2"	8° 5' 23.0"	111°50'16.3"	111°50'16.3"	0.2	6.18	0	0.00
2	8° 5' 4.8"	8° 5' 4.9"	111°50'24.6"	111°50'24.7"	0.1	3.09	0.1	3.09
3	8°4'34.5"	8°4'34.2"	111°50'38.9"	111°50'38.8"	0.3	9.27	0.1	3.09
4	8°4'19.1"	8°4'19.1"	111°50'46.2"	111°50'46.2"	0.0	0.00	0.0	0.00
5	8°3'33.7"	8°3'33.9"	111°51'9.5"	111°51'9.4"	0.2	6.18	0.2	3.09
6	8°3'27.4"	8°3'27.4"	111°51'15.4"	111°51'15.5"	0.0	0.00	0.1	3.09
7	8°3'45.2"	8°3'45.4"	111°52'12.1"	111°52'11.9"	0.2	6.18	0.2	6.18
8	8°4'18.7"	8°4'18.8"	111°53'16.3"	111°53'16.2"	0.1	3.09	0.1	3.09
9	8°4'28.9"	8°4'29.1"	111°54'7.9"	111°54'7.8"	0.2	6.18	0.1	3.09
10	8°4'54.4"	8°4'54.4"	111°54'10.2"	111°54'10.0"	0.0	0.00	0.2	6.18
11	8°4'59.7"	8°4'59.7"	111°54'8.5"	111°54'8.5"	0.0	0.00	0.0	0.00
12	8°5'15.9"	8°5'15.9"	111°54'3.6"	111°54'3.7"	0.0	0.00	0.3	9.27
13	8°5'19.4"	8°5'19.4"	111°54'6.9"	111°54'7.0"	0.0	0.00	0.1	3.09
Average distance difference					0.1	3.09	0.1	3.32

Table 4. The distance difference from testing results of school bus tracking application and My GPS coordinates application for route B

Location bus stop	Latitude		Longitude		Distance differences			
	School bus tracking application	My GPS coordinates application	School bus tracking application	My GPS coordinates application	Latitude		Longitude	
					"	m	"	m
1.	8°5'1.1"	8°5'1.2"	111°57'16.3"	111°57'16.4"	0.2	6.18	0.1	3.09
2.	8°2'58.2"	8°4'58.2"	111°56'59.6"	111°56'59.4"	0.0	0.00	0.2	6.18
3.	8°4'55.9"	8°4'56.0"	111°56'46.3"	111°56'46.4"	0.1	3.09	0.1	3.09
4.	8°4'54.9"	8°4'54.8"	111°56'40.7"	111°56'40.8"	0.1	3.09	0.1	3.09
5.	8°4'50.3"	8°4'50.4"	111°56'15.2"	111°56'15.0"	0.1	3.09	0.2	6.18
6.	8°4'43.1"	8°4'43.3"	111°55'34.2"	111°55'34.5"	0.2	6.18	0.3	9.27
7.	8°4'30.3"	8°4'29.9"	111°54'50.6"	111°54'50.5"	0.4	12.36	0.1	3.09
8.	8°4'30.5"	8°4'30.6"	111°54'7.7"	111°54'7.6"	0.1	3.09	0.1	3.09
9.	8°4'44.6"	8°4'44.5"	111°54'9.7"	111°54'9.8"	0.1	3.09	0.1	3.09
10.	8°4'54.5"	8°4'54.6"	111°54'9.4"	111°54'9.5"	0.1	3.09	0.1	3.09
11.	8°4'59.9"	8°4'59.8"	111°54'7.9"	111°54'8.2"	0.1	3.09	0.3	9.27
12.	8°5'15.8"	8°5'15.6"	111°54'3.3"	111°54'3.3"	0.2	6.18	0.3	9.27
13.	8°5'19.6"	8°5'19.6"	111°54'6.9"	111°54'7.1"	0.0	0.00	0.2	6.18
Average distance difference					0.1	3.09	0.1	3.32

Table 5. The distance difference from testing results of school bus tracking application and My GPS coordinates application for route C

Location bus stop	Latitude		Longitude		Distance differences			
	School bus tracking application	My GPS coordinates application	School bus tracking application	My GPS coordinates application	Latitude		Longitude	
					“	m	“	m
1.	8°1’59.7”	8°1’59.6”	111°54’58.3”	111°54’58.8”	0.1	3.09	0.5	15.45
2.	8°2’12.4”	8°2’12.3”	111°54’51.9”	111°54’52.6”	0.1	3.09	0.3	9.27
3.	8°2’44.0”	8°2’43.9”	111°54’35.2”	111°54’35.1”	0.1	3.09	0.1	3.09
4.	8°3’0.6”	8°3’0.4”	111°54’31.4”	111°54’31.3”	0.2	6.18	0.1	3.09
5.	8°3’4.9”	8°3’4.6”	111°54’30.2”	111°54’30.1”	0.3	9.27	0.1	3.09
6.	8°3’12.0”	8°3’11.9”	111°54’28.7”	111°54’28.6”	0.1	3.09	0.1	3.09
7.	8°3’19.3”	8°3’19.1”	111°54’26.6”	111°54’26.8”	0.2	6.18	0.2	6.18
8.	8°3’32.2”	8°3’32.3”	111°54’26.1”	111°54’26.3”	0.1	3.09	0.2	6.18
9.	8°3’36.6”	8°3’36.7”	111°54’26.2”	111°54’26.1”	0.1	3.09	0.1	3.09
10.	8°3’43.3”	8°3’43.2”	111°54’26.1”	111°54’26.1”	0.1	3.09	0.0	0.00
11.	8°4’38.6”	8°4’38.8”	111°54’26.0”	111°54’26.6”	0.2	6.18	0.6	18.54
12.	8°4’59.9”	8°4’59.9”	111°54’26.2”	111°54’26.5”	0.2	6.18	0.3	9.27
13.	8°5’19.3”	8°5’19.2”	111°54’7.0”	111°54’7.1”	0.1	3.09	0.1	3.09
Average distance difference					0.1	3.09	0.2	6.41

5.3. Testing maximum distance of a smartphone to read an NFC card

Table 6 provides information about the test data from the reading of distance of the NFC card with reader on Sony Xperia M dual smartphone [23], [24]. In this test, the maximum distance reading data was obtained at 7 cm. At a distance of 6 cm, the NFC Card can still be read, but the positioning of the phone and the NFC card needs to be considered so that it can be read. The further the distance between the NFC card and the smartphone, the lower the success rate of its reading.

Table 6 Testing results of NFC card reading distance

Distance reading (cm)	Success in reading
0	Successful
1	Successful
2	Successful
3	Successful
4	Successful
5	Successful
6	Successful
7	unsuccessful
8	unsuccessful
9	unsuccessful
10	unsuccessful
11	unsuccessful

5.4. Testing the position of smartphone readable NFC card

Table 7 shows data on the reading position of the NFC card with a reader on the Sony Xperia M Dual smartphone. In this test, the card was successfully read by the reader when the NFC card was on the right, left and behind the smartphone. This is because the NFC feature is located on the back of the smartphone. As the name suggests, near field communication (NFC), which means close-range communication [25], [26], reading is successful when the two objects are close to each other.

Table 7. Testing results of NFC card reading position

Positions	Reading success rate
Above smartphone	Unsuccessful
Below smartphone	Unsuccessful
Right side	Successful
Left side	Successful
Behind smartphone	Successful
In front of smartphone	Unsuccessful

6. CONCLUSION

The application for school bus information and tracking system has been implemented into the actual school bus and resulted in several concluding points are made and described as shown in: i) based on the test results obtained from comparing the results of the reading of My GPS coordinates application, the latitude distance difference is 3.09 meters and the longitude distance difference is 3.32 meters. This indicates that the school bus tracking application has worked well; and ii) there are differences in the results of GPS readings at several bus stop locations because there are some areas that have poor quality communication networks, causing the uploading of locations not optimum. From the reading distance test, the maximum distance for reading data in the NFC card is 6 cm and the positions of the NFC Card which can be read are on the right, left and back of the smartphone.

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