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An Internet of Things Based Intercity Bus Management System for Smart City

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Abstract: In Indonesia, the bus management system is still manually conducted. The integration of ticketing, tracking, monitoring, and reporting is challenging since it is done manually by different people without a standardized operational standard implementation, depends on the person. To improve the efficiency of the intercity bus management system, the internet of things (IoT) is implemented for ticketing, tracking, monitoring, and reporting system. The ticketing system uses QR codes to store passenger identity and booking data; thus, there is no need for paper-based tickets. Global Positioning System (GPS) tracker embedded in each bus is used to track and monitor bus location and condition. Devices will be connected to the internet, such that all data could be store in the cloud server and processed before displayed via a web-based application. A potential passenger could see the bus schedule and order a ticket via this website. The current passenger could monitor bus location such that they do not need to wait for a long time at the bus stop and ensure their seating on the bus. QR scanner is built in the bus to confirm passenger identity and seating number. Bus company only need to gather all data in the cloud to make a report on bus operations.

Keywords: Bus Management System, GPS Tracker, Internet of Things, QR Code, Web-based Application

1. Introduction

In industrial revolution 4.0, the smart city emerged as a result of technological development. The smart city concept is mainly developed in urban areas since the service, infrastructure, environment, and people condition are more supportive of rural areas. In [1], the authors elaborate on their survey results of smart city initiatives and analyze their key concepts and different data management techniques. IoT arises as the solution to integrate all the required supportive issues since they are quite challenging to be administered. Most smart city concepts implement IoT to establish the connection between each component.

The smart city aimed to simplify people's lives, mainly in the public sector. To support their vast activity, people's mobility needs to be kept efficient. Technological readiness and infrastructure are two of the six determinant factors in smart cities[2]. People could spend most of their time on the road due to the flawed transportation management system. The services provided to passengers by transport systems are essential. [3] states two services that should be provided from the transport system; first is route and schedule information, and the latter is the basic information, includes fare policy and stop locations. It is supported by survey results in [4], picking up Jakarta as the case study, and [5] that review the condition in Malaysia, passengers need an updated information system that could predict arrival time and trip duration. The need for online payment in the current transportation system is also highlighted.

In Indonesia, the bus schedule could not be accessed remotely since it is still in the form of a paper announcement in the bus terminal. Passengers must come directly to the ticketing station to buy tickets or manually buy the ticket inside the bus. Bus drivers use their mobile phone to manually report bus location at specific stops to the head office. Bus arrival in the stops might vary on the road condition, but passengers who wait in the bus stop do not know when the bus will arrive. They could only wait until the bus comes, sometimes in a full capacity such that they could not get on the bus and have to wait for another one [6]. In the case of a local city bus, passengers might not require to wait for a long time for the next bus. Still, since the travel distance is longer in intercity bus cases,

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passengers might need to wait for a longer time, with no guarantee of an available seat.

In this study, web-based applications are proposed to support a smart bus management system. The website could buy a ticket and monitor related bus routes and real-time locations on the passenger side. Passenger general data and pick up/drop off station are displayed in the bus driver, so that driver will not miss the waiting passengers in the station. For bus company admin, report of passengers list and expected income could be accessed via the application.

When a passenger purchasing ticket, a unique QR code that stores passenger ID, bus ID, pick up/drop off station data will be created. QR code scanner is embedded in the bus to validate passenger ID and count the number of passengers inside the bus. Real-time bus location is monitored through a GPS tracker. Raspberry Pi acts as the central controller to process and transmit data via the internet to the cloud server.

2. RELATED WORKS

In recent years, many IoT based transportation systems are proposed. Using both GPS and 3G network providers to track bus location, authors in [7] offer the implementation of a short message service (SMS) gateway for passengers to inquire about bus availability if there is no availability of the internet android smartphone. Multiple sensors are implemented in [8] to ensure the safety of passengers. An alcohol sensor is used to detect the driver's behaviour to avoid accidents due to drunk drivers. Temperature and fuel level sensors are used to monitor bus conditions and scheduling maintenance. An infrared (IR) sensor is used to count the number of passengers inside the bus.

Although using the same IR to count passengers, [9] calculates estimated arrival time to the nearest bus stop using the Euclidean formula, considering moderate traffic. It also implements the K-means clustering algorithm to set bus operations frequency, such as preventing loss of trip when demand is low and reducing the waiting time during peak hours. Random neural networks could predict arrival time [10] with higher accuracy than common statistical approaches and data mining methods, but with higher complexity.

The integration of RFID and ZigBee technology in intelligent bus system is proposed in [11]. Aiming at a smart campus, the authors embed an RFID tag in the bus body. A reader placed in every bus stop will capture the arrival and departure of the bus, and GPS will send its location data. An RFID tag is also embedded in passenger bus card, such that when a passenger uses it to pay the fare, the reader also collects passenger's identification. The data are then processed to calculate the number of passengers inside the bus. The target of this research is the bus scheduling system based on a simulated annealing algorithm. To increase the time prediction accuracy of bus arrival, [12] use an artificial neural network (ANN) as a prediction algorithm with different traffic parameters and environmental condition.

In [13], the authors proposed a mobile application architecture on IoT for public bus service that used Google GPS API to real-time bus location tracking. The application includes a ticketing service such that passengers could book the ticket and choose their desired seat. Using RFID connected with raspberry pi, GSM, and GPS module to track bus location and count the number of passengers inside the bus, authors in [14] proposed a system implemented in school buses. Parents will be notified 5 minutes before the bus arrives at the bus stop. Data from RFID will notify parents when their child enters and gets out of the bus. Implementing the same RFID and GPS to track bus location, [15] use Arduino as the central controller on the system, and data will be sent using the GSM module.

Using Long Range (LoRa) [16] and LoRa Wide Area Network (LoRaWAN) [17] technology to track real-time bus positioning system, authors claimed their system to be lower in cost, power consumption, packet loss rate, and transmission delay compared to the traditional one. However, it needs a data concentrator placed in a high place to receive and transmit data from buses to the cloud server.

While other bus management systems only focus on the passenger side, our proposed system pays attention to passenger needs, improves service quality for drivers and simplifies reporting and scheduling tasks for the bus company.

3. PROPOSED SYSTEM

Figure 1 illustrates the conceptual design of our proposed system. The web-based application acts as the interface between our system and user. The application could be accessed via the user's hand/mobile station using a smartphone or laptop. Before purchasing the tickets, potential passengers are required to register by filling in their identity. When purchasing tickets, bus route, departure schedule, and seat selection are inputted. After finishing payment, each of the passengers will get a unique QR code storing their identity and ticket purchasing data. When passengers enter the bus, the QR code scanner will read the stored data and the database. The validated passengers then sit in their chosen seats according to the stored information.

Using the application, the bus driver and his/her assistant could check the passenger who will get in/drop off the bus at every station. They could remind the passengers if the destination station is near to be ready and not miss the spot. Since the passengers already book the tickets and made payments, drivers and the assistant do not need to prepare change and calculate the cumulative income at the end of the day. This helps minimize bad drivers' behavior that overcharge passengers, not reporting passengers' number and taking the money for themselves.

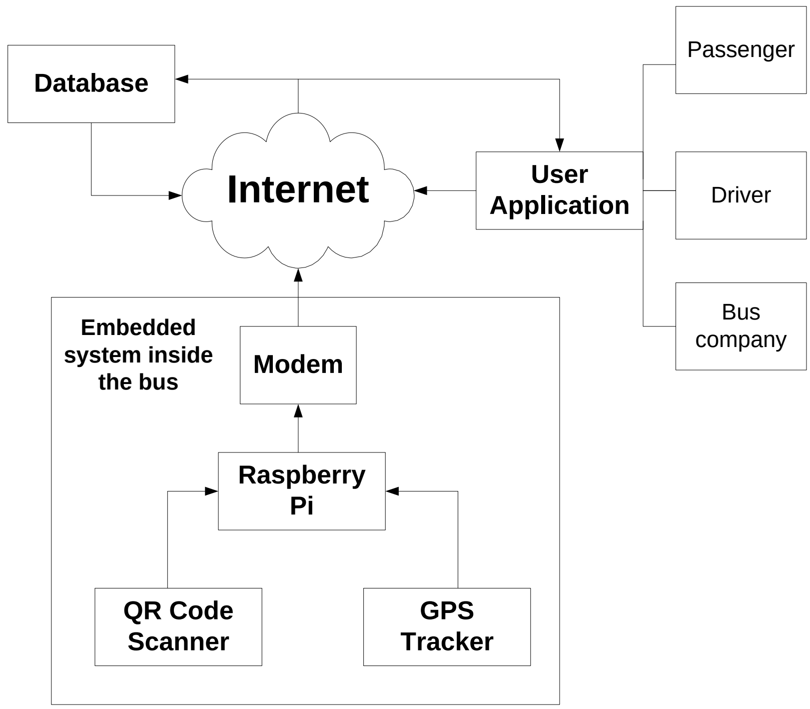

Figure 1. Proposed system design

The bus company could easily maintain the daily report or even monthly and yearly reports by fetching the database's data. This application could minimize human error in calculating the number of passengers and total income. The bus companies could also process the data to improve the service; for example, they could know the popular route and destination that passengers chose. They could increase the bus frequency on those routes, thus increasing their profit.

A modem is used for network communication intermediaries. It transmits both passenger data from the QR Code scanner and real-time location from the GPS tracker to the server.

Raspberry Pi is used to process data collected from a QR Code scanner and GPS tracker. The processed data is then sent via the internet to be stored in the MySQL database system.

4. IMPLEMENTATION AND TESTING

A. Prototype realization

The prototype of the proposed system was realized using Raspberry Pi Zero as the central controller. Location tracking was delivered using GPS gt-7u, and data are stored in MySQL Database

1) Hardware

Figure 2 shows our designed schematic circuit with Raspberry Pi as a microcontroller that processes data sent from GPS Tracker, QR Code Scanners, and modems.

Both modem and QR Code Scanner is connected to the USB port on Raspberry Pi, while GPS Tracker is connected through the General Purpose Input Output (GPIO) port.

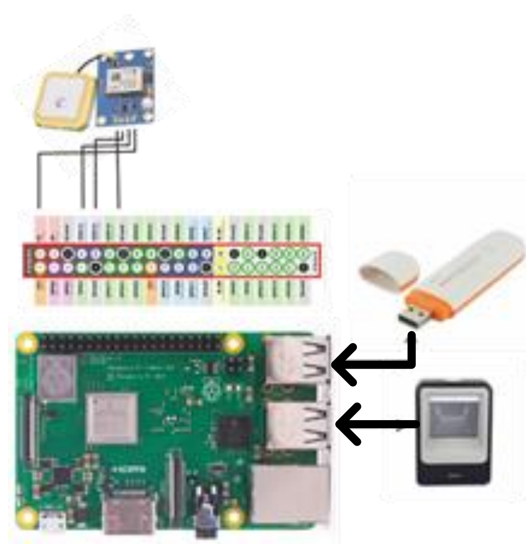

Figure 2. Prototype design

ASCII data from QR code will be processed into characters and sent to a webserver to be displayed in the web-based application. First, the QR scanner should be initialized through a human interface device (HID) library that enables Raspberry Pi to recognize it. If this step is missing, the QR Scanner will not be recognized, and the QR code could not be processed. The code is then being sent to the internet using Curl's initialization.

```python
import urllib2

while True:
        data = raw_input("Silahkan Scan QRCode")
        webUrl = urllib2.urlopen("http://ntech-dev.com/bis_v2/updatestatus.php?id="+data)
        mybytes = webUrl.read()
        mystr = mybytes.decode("utf8")
        print mystr
```

Algorithm 1. The script of QR code scanner integration to Raspberry Pi

GPS Tracker receives real-time longitude and latitude position from satellites to determine the bus's real time location. These data are then visualized in google maps before being sent to the internet using a modem.

```python
import serial
import urllib2

while True:
        port = "/dev/serial/by-id/usb-u-blox_AG_-_www.u-blox.com_u-blox_7_-_GPS$
        gps = serial.Serial(port, baudrate = 9600, timeout = 0.5)
        line = gps.readline()
        data = line.decode().split(",")
        print(data[0])
        if(data[0] == "$GPRMC"):
                if data[2] == "A":
                        print("Latitude : " + data[3])
                        print("Longitude : " + data[5])
                        webUrl = urllib2.urlopen("https://www.ntech-dev.com/bis$
                        print ("Result Code: "+ str(webUrl.getcode()))
```

Algorithm 2. The script of GPS Tracker integration to Raspberry Pi

The modem is connected to Raspberry Pi via a USB port. Modem installation on Raspberry Pi is required to make use of the modem. Without installation, the modem will appear inactive on Raspberry Pi and could not connect to the internet.

2) User interface

A web-based application is built using PHP programming language to act as an interface between the system and users. Users need to login first before using the application. There are three different kinds of users. First is the administrator. Here bus company administrators could input data such as new bus routes, number of available seats, pricing, bus id, etc. The admin could also make a query on the daily, monthly, or yearly operation report, including the number of users, total income, bus trip history, etc.

The second user is the bus driver. Bus drivers use the application to see the number of customers and their designated seat, identity, pick-up, and destination location.

The last user is customers. Once customers register and log in to the application, they could access the bus route, ticket tariff, trip schedule, available seat, current bus position, and order tickets. Figure 3 shows the flowchart of the customer's ticketing system using the application.

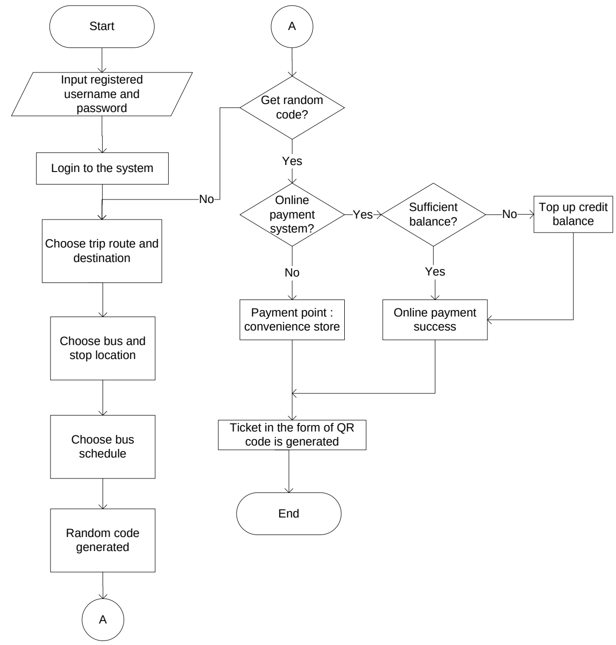

Figure 3. Flowchart of customer's ticketing

B. Testing

There are three different tests done to evaluate system performance.

1) Realization of QR code reader

Here we test whether the generated QR code could be read successfully. Table 1 shows the result of the distance test. The code was placed in parallel with the scanner, and the distance was varied. Although a QR code's readability mainly depends on the scanner type, we need to ensure that our code is readable with the same scanner. Since the optimum scanning distance is ten times the QR code size, with our code width is 4 cm, the optimum scanning distance should be 40 cm.

TABLE 1. QR CODE READER WITH DISTANCE VARIATION

No	Distance between generated QR code and the scanner(cm)	Result
1	0	Not detected
2	10	Success
3	20	Success
4	30	Success
5	40	Success
6	50	Success
7	55	Success
8	60	Not detected
9	70	Not detected

When the distance was set to 0 cm, it means that the code was attached to the scanner. The scanner could not read the code since no light could not make the scanner differentiate the code's black-and-white pattern since all the scanner could read was black. On the other hand, too much light made the scanner identify the code to be all white when the distance was too far, although it was black. It is learned from Table 1 that the farthest distance between the code and the scanner is 55 cm, exceeding the suggested optimum distance. Since the space inside the bus is limited, the distance between the scanner and the code is no further than 50 cm. Thus, our generated code size is adequate for this system.

2) Accuracy of GPS Tracker

To deliver this test, Latitude Longitude application was used to be the standard value of coordinate. Data from the GPS tracker vas observed in VNC Viewer. The position observed in VNC Viewer in the form of latitude and longitude was then compared to Latitude Longitude application value. Table 2 presents the GPS Tracker test result.

TABLE 2. GPS TRACKER ACCURACY TEST

Test No.	Latitude		Longitude	
	GPS tracker	***Application***	***GPS tracker***	***Application***
1	7°94’81.0”	7°94’80.9”	112°61’63.1”	112°61’63.0”
2	7°94’71.6”	7°94’71.4”	112°61’68.3”	112°61’68.3”
3	7°94’58.7”	7°94’58.7”	112°61’62.1”	112°61’62.2”
4	7°94’51.9”	7°94’51.7”	112°61’47.9”	112°61’47.8”
5	7°94’42.9”	7°94’42.8”	112°61’49.8”	112°61’49.8”

Using Haversine formula [18], the average error from the GPS test could be converted to 3.453 m. The slightly high error probably comes from the type of GPS that we used. Since this is still a prototype, we use the standard GPS with a maximum accuracy of 4 meters [19]. Besides, we use the Longitude Latitude application to compare the result. This application works by converting our position showed in google maps into a coordinate value. At the time of measurement, the WiFi network is used to mark our position on the map. Since the access point is relatively far from the measurement venue, the marking of our position in the map might not be high in accuracy, thus influence the converted coordinate position. Turning on GPS in our smartphone and using the mobile network at the time of the measurement, increasing the accuracy by 42% to 2.05 meters, as shown in Table 3.

TABLE 3. CALCULATED ERROR

Test No.	Error (using WiFi + smartphone GPS off)		Error (using mobile network + smartphone GPS on)	
	Latitude	***Longitude***	***Latitude***	***Longitude***
1	S=0.1”	E=0.1”	S=0.05”	E=0.03”
2	S=0.2”	E=0”	S=0.09”	E=0”
3	S=0”	E=0.1”	S=0”	E=0.05”
4	S=0.2”	E=0.1”	S=0.13”	E=0.04”
5	S=0.1”	E=0”	S=0.05”	E=0”
Total	S=0.6”	E=0.3”	S=0.32”	E=0.09”
Average	S=0.1”	E=0.06”	S=0.064”	E=0.018”

3) Website Functionality

A functionality test was conducted to ensure the website could work properly. Each component was tested by trying each feature to get the desired output. Table 4, 5, and 6 show the list of tested features and its result for the customer, driver, and bus company admin' applications, respectively.

TABLE 4. FUNCTIONALITY TEST FOR CUSTOMER'S WEBSITE

No	Test case	Desired output	Result
1	Dashboard	Main page when customer access the website	Success. Dashboard appearance include username and password form input, login/register choice
2	Register page	It appears when the user wants to register to the system.	Success. This page appears when a user does not have an account on the system. User need to fill in the username, password, phone number, and official ID number
3	View bus schedule	It appears when the user clicks "View bus schedule" in the dashboard	Success. Bus schedule includes origin and destination city of a bus, bus identity, date and time departure, and available seat
4	Order ticket page	It appears when the user click "order" on the bus schedule page	Success. This page contains pick up and drop off bus stop choices, also their pricing, different at each stop. Customers need to input the passenger name and official ID number.
5	Ticket payment page	It appears after the user finishes ordering tickets	Success. This page contains the booking code and payment option
6	QR code-based e-ticket	It appears after successful payment	Success. This page contains written information on passengers' names, ID, bus IDs, chosen routes, pick-up, and drop-off locations. Also, a QR code contains that information. The page could be printed or saved in pdf filetype. Passengers need to scan the code both when they get on the bus and dropped off. Figure 4 shows the pdf style of this page.
7	Real-time bus location page	Appears when passenger enquire bus location in the system	Success. A real-time map showing the bus location is shown.

Figure 4. QR code-based e-ticket for passenger

TABLE 5. FUNCTIONALITY TEST FOR DRIVER'S WEBSITE

No	Test case	Desired output	Result
1	Login page	It appears when drivers first open the website	Success. Drivers need to input their username and password given by the company to log in to the system
2	Passengers list	It appears after drivers successfully log in	Success. This page contains a list of the booking passengers, including their name, pick up and drop off location, also their status whether they already get on the bus or not. Drivers could also check the real location where users dropped off, as shown in Fig. 5

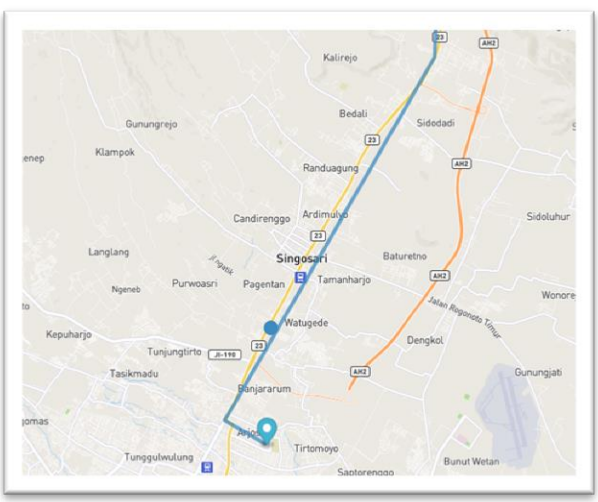

Figure 5. Real location on passengers' drop off point

TABLE 6. FUNCTIONALITY TEST FOR ADMINISTRATOR'S WEBSITE

No	Test case	Desired output	Result
1	Login page	It appears when the administrator first opens the website	Success. The administrator needs to input their username and password given from the company to log in to the system
2	Transaction History	It appears when the admin choose "Riwayat" Menu	Success. This page contains a list of passengers' names, IDs, and detailed booking. Admin could ask for daily history, monthly, or during a specific period. Total income during the asked period is also given, as shown in Figure 6.

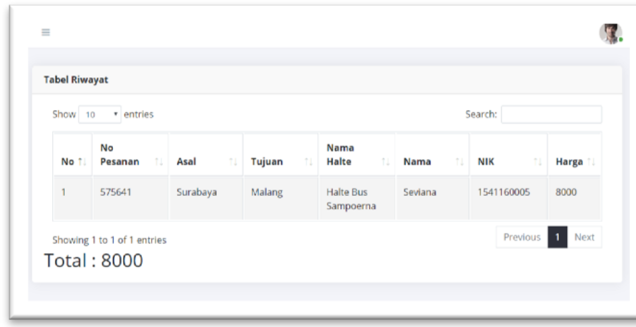

Figure 6. Transaction history

It should be noted that our work has better performance than similar works. In [20], the authors only proposed a bus monitoring system using a black box with the RFID reader, GPS, and GPRS as a communication system installed on the bus. In [21], ZigBee is used as a communication system to transmit bus location every time it reaches a station. It costs more to install ZigBee detection devices at each bus stop. The authors provide no interface on accessing the system. Using RFID to identify the bus, [22] develops an android based transportation system. However, there is no quantitative or functionality evaluation explained in the paper. The ticketing system in [23] has the advantage of implementing ISO 9126 as the assessment instrument. However, the system is only for ticket purchasing. There is no service on bus monitoring or company report generator. On the other hand, our proposed system integrates ticketing and real-time monitoring system. Moreover, it also provides reporting facilities for the bus company.

5. CONCLUSION

Our proposed intercity bus management system utilizes a GPS tracker to real-time monitor bus position and implements QR code to store ticketing information. Three different websites based application was developed for passengers, drivers, and bus company administrator. The test result shows that our system could work correctly and accurately, as shown that bus position error is around two to three meters. Generated QR code sizing is suitable for this system, as proven from the readable test over varied distances. Our web-based application's functionality test shows that the website is adequately developed based on the initial design. However, the payment system's security issue and private data confidentiality should be considered for future works.

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