Hardware Design of Queuing Free Environmental Friendly Automatic Toll Gate Using RFID

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***Abstract*—The main problem of Indonesian's highway is the long queue at the toll gates due to toll fee payment transaction. This occurs when arriving rate of the vehicles is much higher than servicing rate of the toll gates. Instead of cash payment at manual toll gates, automatic toll gates (GTO) use debit cards to do payment faster. Regardless the gates are manual or automatic, every vehicle should stop for a while to finish the transaction. The more vehicles come, the longer queue be. The longer queue, the more wasting fuel consumption and the higher air pollution be. Further, the conventional payment method at the toll gates makes this situation even worse. Toll gates officers or automatic printers will give a small piece of paper as successful payment notification. These notification papers, however, are not really cared by the drivers and further become trashes around the toll gates. This research aims to improve the quality of service of the toll gates by developing a queuing free environmental friendly automatic toll gates. Instead of debit card to identify the toll customers and do the payment, the proposed system uses a non-contact technology that commonly referred as Radio Frequency Identification. The vehicle is identified by the systems just as it is passing through the toll gate. This method eliminates the queue at the toll gate since the payment is done in fly. Next, a payment notification is sent to the driver's hand phone via short message service. It replaces the need of paper and ink and eliminates paper trashes around the toll gates. This paper presents the hardware development of the proposed system.**

Keywords— Automatic toll gate, RFID, SMS, environmental friendly, green technology

I. INTRODUCTION

Highways or Toll Roads are provided to enhance the traffic, improve the distribution of goods and services, and increase mobility and accessibility of people. [1]

The main problem that occurs recently on the Indonesian highway is the long queue. This queue occurs because the arriving rate of vehicles to toll gates is much higher than the servicing rate. The congestion is caused by some factors, such as the cessation of vehicles at toll gates to do payment of toll fee, less number of toll gates, and volume of vehicles exceeds the capacity. This congestion will lead to wasting time for wait, incendiary fuel combustion, and air pollution caused by vehicle exhaust. Sooner or later these problems will cause health problems.

Utilization of electronic toll collection (ETC) offers some advantages. It improves the service at the toll gates, save fuel, reduce vehicle gas emissions, and save time queue. Another advantage of this system is that it eliminates traffic jam and increases control over traffic flow through administrative control centers. ETC has been widely employed by various countries. This system in America known as EZ-Pass, in Australia known as City-link, while in Asia known as D-Link. All have the same meaning the toll gate serves by employing ETC system. [2, 3].

The toll gates in Indonesia have been utilizing ETC, under the name of Automatic Toll Gate (GTO). This system improves the quality of toll gate services and toll road customer satisfaction [4]. Existing GTO uses debit card for identification and payment process which requires the driver to contact the debit card to the card reader. GTO prints successful payment transaction on a small piece of paper then let the driver to take it. In fact, this payment proof is not really cared by the drivers and becomes trash around toll road or at toll gate. The time consumed by this process (from taping the debit card until taking the payment proof paper) is just a few seconds different to the time consumed by manual toll gate. Therefore, vehicle queue is also common seen in GTO. GTO is not a solution to overcome queueing problem at toll gates and is not environmental friendly either.

Researches have been conducted to improve the quality of service of the toll gates. Two of them have proposed using a non-contact technology that commonly referred as Radio Frequency Identification (RFID) [5] and GSM module which are controlled by ARM7 LPC2148 in [6]. The system used RFID passive tag, which should be placed less than 10 cm to be detected by RFID reader. To increase the detection distance RF transceiver is implemented in [7]. However, this system is costly because it employed ARM7 LPC2129 and many other modules.

With the same goal, this research has developed a queueing free environmental friendly automatic toll gates (Queen ATG). Instead of debit card to identify the toll customers and do the payment, the proposed system uses RFID active tag. The detector is designed better because the vehicle is identified just as it is passing through the toll gate. This method eliminates the queue at the toll gate since the payment is done on the fly. Next, a payment notification is sent to the driver's hand phone

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via short message service (SMS). This replaces the need of paper and ink and eliminates paper trashes around toll road or at toll gate. The low cost, simple, but robust microcontroller Arduino 2560 is chosen to control the proposed system. This paper presents the hardware development of it.

II. HARDWARE DESIGN OF QUEEN ATG SYSTEM

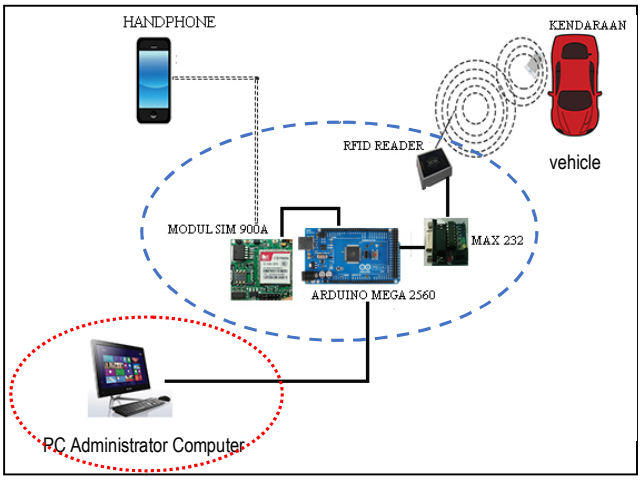
Illustration of the proposed Queuing Free Environmental Friendly Automatic Toll Gate (Queen ATG) is depicted in Figure 1. The development of the system is divided into hardware (dashed blue circle) and software (dotted red circle) parts. This session presents the hardware design of the proposed system which consists of three blocks.

1. Identification Process block. This block is responsible for Automatic Vehicle Identification. It consists of RFID tags, RFID Reader, and IC MAX232.

2. Control Unit block. This block is a collection of control system units that act as regulator and information sender from Automatic Vehicle Identification. It consists of Arduino Mega 2560 and GSM Module SIM 900A.

3. Output Interface block. This block displays the data to customers and administrators of the Automatic Vehicle Identification system. It consists of mobile phones and personal computers of Administrator.

Fig. 1. Overview of the proposed Queen ATG system.



A. Identification Process Block

This RFID block uses an RFID Reader, RFID Tag, and IC Max 232 Module. RFID tags contain unique code to differentiate the class of vehicles passing at the toll gate. This RFID tag will send a signal containing the unique code to the RFID Reader. RFID Reader will read and identify the unique code that is sent by RFID Tag. Since RFID Reader contains serial data then it takes IC Max 232 to convert data from RFID Reader into Control Unit.

RFID reader communications to Block Control Unit use RS 232 serial communications. The data will enter into the PC in the form of unique codes inside the RFID tag. The data will be processed by the program interface to be matched in the database. Before entering into Control Unit block data is processed first into Block 232. The function of Block 232 is to change the data from the reader so that it can be read by Control Unit Block.

MAX 232 is an IC converter that acts as a converter of voltage values into TTL voltage levels. This IC is used so that Control Unit Block can read data sent by Reader. If there is no IC MAX 232 this data cannot be read because of difference of voltage level. This IC for access to Arduino 2560 required 4 pins, as:

1. TX : 1
2. RX : 2
3. VCC : VCC
4. GND : GND

B. Control Unit Block

Control Unit serves as a data communication controller between devices and notification sender to mobile phones. This device uses GSM module SIM 900A and Arduino Mega 2560 as seen in Fig. 1.

GSM SIM 900A module is functioned as a notification sender. The selection of this module is due to the carrier frequency used in Indonesia around 890 - 915 MHz. Through this module communication between toll gate and driver is established. This GSM module can send short message service (SMS) through GSM network operators throughout Indonesia.

Setting this GSM SIM 900A module by installing module components to Arduino mega 2560. That is by connecting serial cable from GSM SIM 900A module to Arduino mega 2560. The configuration of command is sent from Arduino.

GSM SIM 900A module will receive data from Arduino in the form of serial data that contains information. Information sent in the form of mobile phone numbers and text data messages that contain information balance and real time. This module requires 3 pins to access serial data from Arduino to module. These 3 pins connect between 2 devices:

1. TX pin: 2
2. Pin RX: 10
3. GND: GND

The system uses 6 digital input and output pins consisting of 2 pairs of serial pins and 2 output pins. Since it needs 2 pairs of serial pins, Arduino Mega 2560 is chosen because it has 3 pairs of serial pins. It is suitable to be used as a controller on this system. As the overall controller of this system all parts are connected to Arduino

C. Output Interface Block

This personal computer as monitoring data access out - enter from control unit. The computer will display data from the control unit to the program interface to help the administrator. This computer also sends data from the program interface to the control unit.

Personal computers use serial access to send data to the control unit. This data will flow back and forth to send messages. Access between personal computer and control unit using a USB cable.

Mobile phone serves as a reminder to customers who pass through toll gates. It provides customer an information because it has passed the toll gate. Mobile phone will receive SMS as customer notification. This SMS also can be considered as a valid payment receipt. SMS notification contain messages with the format "PT Jasa Marga - Toll Gate – Remaining Balance - Time – Date.

D. Algorithm and Universal Machine Language (UML)

Automatic vehicle identification system programming in Arduino is built in C ++ language. It controls the whole system including sends data from RFID reader to PC and sends data from PC to GSM SIM900A to send notification messages in SMS format. The program is designed using the following algorithm:

1. Start the Program.
2. Arduino reads serial code data from Serial1 which is sent by RFID reader which contains the unique codes
3. Arduino sends serial code data to personal computer via serial pins.
4. Personal computer sends data containing information registered customer from the existing database on the computer.
5. Information from personal computer will be divided so that it consists of mobile phone number, remaining balance, and time of passing the toll gates.
6. Provides text notifications that will be sent using SMS format.
7. The data will be sent with the SMS format via GSM module.
8. Mobile phone receives SMS containing data information transmitted through GSM module.

Based on the above algorithm, the UML is generated as shown in Fig. 2.

III. HARDWARE TESTING OF QUEEN ATG SYSTEM

The vehicle identification and notification process is the main purpose of the proposed EFTG system. The input data is a unique code of different RFID active tags. Hardware testing uses several variations that affect the readability of the RFID reader, such as vehicle speed, reading distance, and reading time. It is necessary to analyze their effect on the data can be read right or wrong.

A. Distance vs Reading test

This test is conducted by varying the distance of RFID tag to RFID reader. Both of them are placed so that the reading can be accurate. Testing scenario is depicted in Fig. The result of testing the reading distance between the RFID reader and the active tag is shown by Table I.

Fig. 2. UML program for Arduino 2560 to contol Queen ATG system.

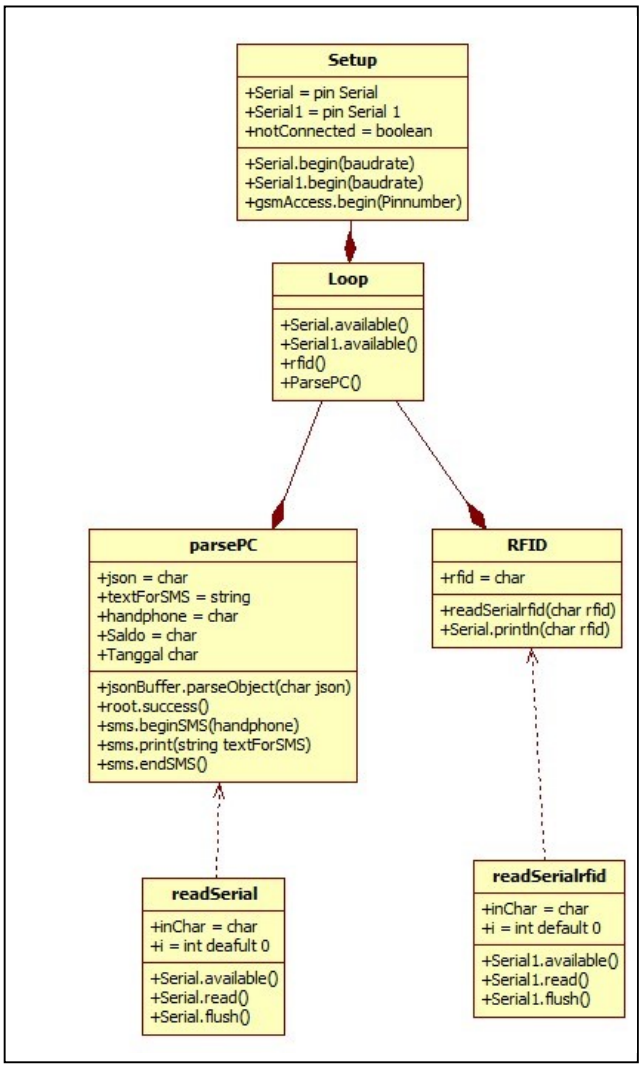


Fig. 3. Distance vs reading test scenario.

TABLE I. TEST RESULT OF DISTANCE VS READING

Tag ID	Distance (cm)	Identified as	Result
:10008212 02	0	:10008212 02	Detected
:10008212 02	20	:10008212 02	Detected
:10008212 02	30	:10008212 02	Detected
:10008212 02	50	:10008212 02	Detected
:10008212 02	60	:10008212 02	Detected
:10008212 02	80	:10008212 02	Detected
:10008212 02	100	:10008212 02	Detected
:10008212 02	120	:10008212 02	Detected
:10008212 02	130	:10008212 02	Detected
:10008212 02	150	:10008212 02	Detected
:10008212 02	160	-	Undetected
:10008212 02	170	-	Undetected
:10008212 02	180	-	Undetected
:10008212 02	190	-	Undetected

Table I shows that the active tag is successfully identified up to 100 cm distances. As the distance is increased, the tag becomes undetectable.

B. *Vehicle Speed vs Reading test*

This test is conducted by moving the vehicle relative to RFID reader as illustrated in Fig.4. Vehicle speed is increased from 0 to 30 km/h as shown in speedometer in Fig. 5. The test result of vehicle speed with active tag vs RFID reading is listed in Table II.

Fig. 4. Scenario of vehicle speed vs reading test.

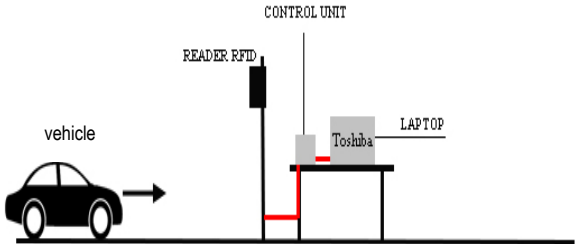


Fig. 5. Increasing vehicle speed from 0 to 30 km/h.

TABLE II. TEST RESULT OF VEHICLE SPEED VS READING

Tag ID	Speed (km/h)	Identified as	Result
:10008212 02	0 – 2	:10008212 02	Detected
:10008212 02	3 – 5	:10008212 02	Detected
:10008212 02	6 – 8	:10008212 02	Detected
:10008212 02	9 – 10	:10008212 02	Detected
:10008212 02	11 – 13	-	Undetected
:10008212 02	14 – 20	-	Undetected
:10008212 02	21 – 30	-	Undetected

Table II shows that the RFID active tag is successfully detected by RFID reader with average speed between 0 – 10 km/h. When the speed of the vehicle is increased the active tag becomes undetected.

C. *Reading Response test*

This test is done by testing the reading time of RFID reader. The RFID reader is placed parallel to the active tag so that the reading can be more accurate and valid. Time is calculated from the beginning of the reading up to 10 readings. The test result of the reading time between the RFID reader and the active tag is shown in Table III.

TABLE III. TEST RESULT OF READING RESPONSE

Tag ID	Reading Time (s)	Identified as	Result
:10008212 02	2.15	:10008212 02	Detected
:10008212 02	2.11	:10008212 02	Detected
:10008412 04	1.27	:10008412 04	Detected
:10008412 04	2.33	:10008412 04	Detected
:10008012 00	2.03	:10008012 00	Detected
:10008202 00	2.45	:10008012 00	Detected
:10007912 06	2.11	:10007912 06	Detected
:10007912 06	1.30	:10007912 06	Detected

Table III. shows that the average time for reading the active tags by RFID reader is less than 2 seconds.

D. SMS notification test

Test is performed by sending SMS notification to customer's handphone registered in the data base. The format contains information of the remaining balance and time passing the toll gates, as shown in Fig. 6.

Fig. 6. SMS notification is received succesfully by registered customer.

IV. CONCLUSION

We have developed a Queuing Free Environmental Friendly Automatic Toll Gate system using RFID. Run test of the hardware gives optimal distance for identification is between 0 to 150 cm. The optimal speed for identification is between 0 to 10 km/hour. The average reading response time of the identification process is less than two seconds which is faster than the existing GTO. Payment proof in form of SMS notification is also received successfully by handphone of the registered customer. The proposed system is eligible to be employed to save the environment.

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