Design of Vehicle Tracking System using MCU STM32F103RET6 and SIM908

P. Daud, J. A. Simalongo, D. Mahmudin, Y. N. Wijayanto, and P. Putranto

***Abstract*—This paper reported the design of a vehicle tracking system using GPS technology and GSM/GPRS. With embedded RTOS systems, the position of vehicles can be located in real time. In this research, a microcontroller unit (MCU) STM32F103RET6 with serial GSM modem and GPS receivers integrated at a single module SIM908 is used. GSM modem transmitted the vehicle's position. GPS modem continuously provided a vehicle's position data and then stored it on web servers. The position coordinate received by the user can be viewed by using google map. The expected result is an applicable VTS prototype on a vehicle with up to 2.5 meters of position accuracy to fulfill the system specifications.**

***Index Terms*—GPS-GSM/GPRS; Vehicle Tracking System; Microcontroller; SIM908**

I. Introduction

PRIVATE vehicles and public safety is a major concern today. In this era of technology, besides road user regulations, various specific information systems can be apllied to ensure driving security such as Vehicle Tracking System (VTS).

VTS is a system containing electronic device installed in a vehicle to enable the user to track the vehicle's location. VTS consists of locating device such as GPS and signalling device such as GSM/GPRS module. Most VTS was made with separated GPS module and GSM/GPRS module so that it is relatively difficult to switch between them. Also, it requires more space.

A SIM908 module is the solution for this because both modules are integrated as one. So, it also saves spaces in the design. GSM/GPRS is chosen to connect the GPS device to the web server because it is relatively cheap. Besides, it has extensive coverage area which is almost the entire territory of Indonesia [1].

To manage the system, a proper microcontroller is required. STM32F103RET6 is chosen because the specification (will be presented at section II.E) meet the requirements of the system. It also has a length of 32-bit registers, which means it stores 32 bits of data in one of its assembly instructions. These instructions will be needed in the industrial application which require high precision and large data capacity. On the software part, free Real Time Operating System (RTOS) is used as embedded systems to ease the programming and real time tracking can be conducted [2].

In this paper, we propose a technique for real-time vehicle tracking using microcontroller with integrated module of GPS and GSM/GPRS. The position of vehicle is identified by the GPS through satellites. The information is transferred to the monitoring station via GSM/GPRS. The GPS and GSM/GPRS are operated by microcontroller. Therefore, the position of the vehicle can be monitored using the proposed technique. Additionally, the vehicle movement can be also tracked using the proposed techniques by taking the position data and sending it to the monitoring station. Therefore, real-time vehicle tracking can be conducted.

II. System Components

A. Basic Principle

Fig. 1 shows the VTS architecture. The basic principle of VTS is started from no.1 when the GPS antenna on the car sends the signal to the GPS satellites and then receives each signal back from the satellites to be proceeded to give the exact coordinate of the car position. Later, the position data is sent to the server via GPRS channel (no.2). The server saves all the data from other vehicles. This provides other information such as traffic density in a certain location. Next, those data are uploaded to the internet (no.3) so that it will be accessible to all users with any kind of device (no.4).

Fig. 2 shows two processes occurring on the microcontroller device. First is the position sensing process by GPS on vehicle under the coordination with satellites, and second is the communication process by the GSM modem which is used for sending the data to a web server using HTTP protocol.

B. GPS Receiver

The GPS receiver is a tool receiving GPS signal for

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determining the actual location of it on earth. It provides longitude and latitude information, and some modified ones also calculates altitude. This device is used in the military, aviation, shipping and consumer product applications. A GPS receiver consists of an antenna, processor and accurate clock. A display may be added to provide location and speed information to the user. A receiver is often described by its number of channels which tells the number of satellites can be monitored simultaneously. The GPS receiver is equipped with an input for differential corrections, using the RTCM SC- 104 format. Many GPS receivers can convey the position data to a PC (personal computer) or other devices which uses the NMEA 0183 protocol.

C. GPS Modem

A GSM Modem is a type of modem that uses a SIM card, and operates on a subscription to a mobile phone service providers. This hardware looks like a cell phone. Wireless modem operates like a dial-up modem. The main difference from both is that the dial-up modem is sending and receiving data via wireline or fixed wireless model while wireless modem is

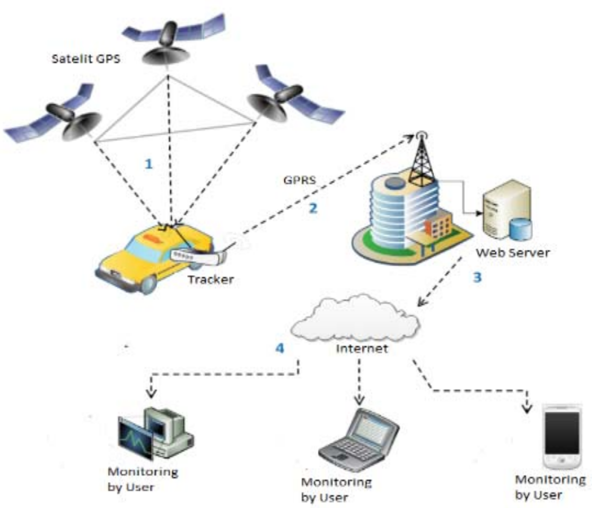

Fig. 1. VTS architecture

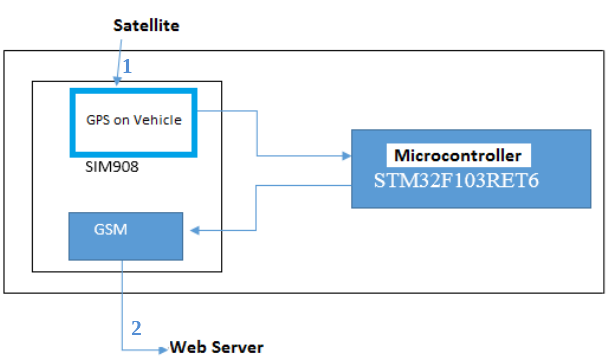

Fig. 2. The dataflow on VTS

sending and receiving data over a radio wave. Like the mobile phone, GSM modem requires a SIM card to operate. Both GSM modem and dial-up models support a common set of standard AT commands. The GPS antenna specifications needed for this research is shown in Table I.

D. AT Commands

AT means ATtentions. AT commands give instructions to mobile devices and public wired telephone. Commands sent to the phone, which can be either a GSM modem or a PC modem. Different manufacturers may have a different number of AT commands.

E. MCU STM32F103RET6

STM32F103RET6 is a type of 32-bit microcontroller architecture developed by STMicroelectronics [4]. This microcontroller included in the family of Cortex - M series. Its specifications can be seen in Table II. The processor in this series has been developed specifically for microcontroller, where the demand for speed, process time determination, and interrupt setting along with the minimum number of gate silicon (minimum silicon area determines the final price of the processor) and minimum consumption power are what consumers favor of.

F. SIM908 Module

The SIM908 module is a complete Quad-Band GSM/GPRS module that combines GPS technology for satellite navigation [5]. This module specifications is shown in Table III. A design which combines GPS and GPRS in one package will significantly save customer's cost and time to develop GPS-

TABLE I
GPS ANTENNA SPECIFICATIONS [3]

Feature	Explanation
Center Frequency	1575.42MHz ± 3MHz
V.S.W.R	1.5:1
Bandwidth	± 5 MHz
Impedance	50 ohm
Peak Gain	> 3dBic
Gain Coverage	> -4dBic
Polarization	Right Hand Circular Polarization (RHCP)

TABLE II
STM32F103RET6 SPECIFICATIONS [4]

Peripheral	Specification
Flash Memory	512 kb
GPIOs	51
CPU Frequency	72 MHz
Operation Voltage	2.0 – 3.6 V

TABLE III
SIM908 SPECIFICATIONS [6]

Feature	Explanation
Specification	850/900/1800/1900 MHz, GPRS ulti-slot class 10, GPRS mobile station class B, Compliant to GSM phase 2/2+, Control via AT commands, SIM application toolkit, Supply voltage range: GPRS 3.2-4.8/GPS 3.0-4.5 V, Low power consumption,
Transfer Data	GPRS class 8/10: max 85.6 kbps(downlink)
GPS	Receiver type: 42 channel, GPS L1 C/A code, High performance STE engine. Sensitivity: Tracking -160 dBm, Cold starts -143 dBm. Accuracy: horizontal position <2.5m CEP. Power consumption (GSM engine in idle mode): Acquisition 77mA, Tracking 76mA

based application. Having an advance in interface and industrial GPS standards, this module allows any changing positioned vehicle to be tracked at any location and any time as long as the signal exists.

G. FreeRTOS

A Real Time Operating System (RTOS) is an operating system required to enable the system takes performance instantaneously whenever it is needed to do so. One of the advantages of an RTOS is its ability to perform consistently in duration it needs as well as in the task of applications that it does [7]. RTOS has an algorithm for scheduling process which flexibility to organize the process and doing priority process in a computer system. FreeRTOS (Free Real Time Operating System) is an open source real time operating system for embedded devices such as microcontrollers [8].

III. Hardware Assembly

Overall vehicle tracking system hardware architecture is shown in Fig. 3. After development and assembly process, the desired device will be obtained as shown in Fig. 4.

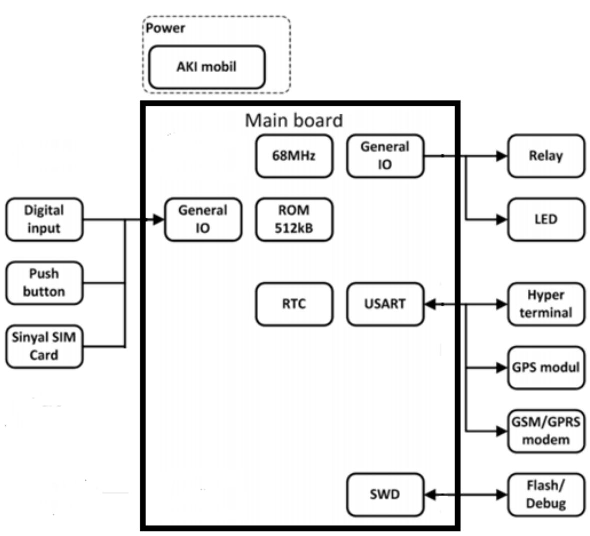

Fig. 3. Hardware architecture design

Fig. 4 Implementation of the hardware design

IV. Software Development

The software is built using the C programming language and IDE CooCox as a platform [9]. The software development process is divided into 3 main tasks and 2 supporting tasks. The main task consists of three stages, namely:

1. GSM Task : to configure and activate the existing facilities on the GSM modem.
2. GPS Task : to take GPS data and to parse the determined variables.
3. HTTP Task : to compile information before transmission via HTTP socket.

The flowchart in Fig. 5 shows how the software system in this research worked.

V. Field Testing

A. VTS Device Performance Testing

For system testing, we used Hercules software [10]. This application is able to see the VTS process. The important data are displayed by this application, including date, longitude, latitude, altitude.

Fig. 6 showed that the device has been successfully performed all 3 tasks. This is called the setup mode. Next, the device will enter the running mode, which is the process of finding a minimum of 6 satellites to determine the location of the vehicle. Once the location is obtained, then the VTS will send them to the web server to be processed and displayed to the user.

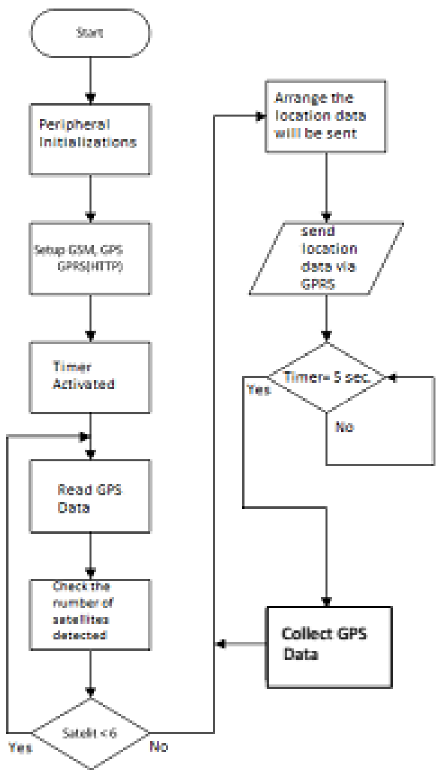

Fig. 5 Flowchart of the program

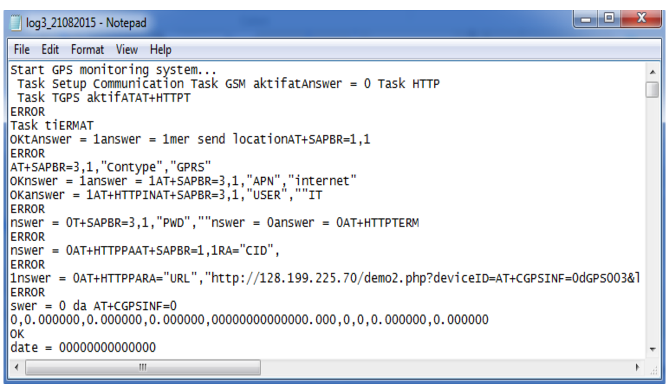
```
log3_21082015 - Notepad
File Edit Format View Help
Start GPS monitoring system...
 Task Setup Communication Task GSM aktifatAnswer = 0 Task HTTP
 Task TGPS aktifATAT+HTTPT
ERROR
Task tiERMAT
OKtAnswer = 1answer = 1mer send locationAT+SAPBR=1,1
ERROR
AT+SAPBR=3,1,"Contype","GPRS"
OKnswer = 1answer = 1AT+SAPBR=3,1,"APN","internet"
OKanswer = 1AT+HTTPINAT+SAPBR=3,1,"USER",""IT
ERROR
nswer = 0T+SAPBR=3,1,"PWD",""nswer = 0answer = 0AT+HTTPTERM
ERROR
nswer = 0AT+HTTPPAAT+SAPBR=1,1RA="CID",
ERROR
1nswer = 0AT+HTTPPARA="URL","http://128.199.225.70/demo2.php?deviceID=AT+CGPSINF=0dGPS003&l
ERROR
swer = 0 da AT+CGPSINF=0
0,0.000000,0.000000,0.000000,00000000000000.000,0,0,0.000000,0.000000
OK
date = 00000000000000
```

Fig. 6. Result of device testing

B. *Position Vehicle Tracking*

Vehicle position data collection is performed by installing a VTS device in a vehicle and then selected the route to be travelled by vehicles. The device received a power from the car. Shortly after the car is turned on, the device will be active and start the process. From the user perspective, vehicle tracking can be done either through a media laptop, desktop, tablet, or mobile phones which have GSM and GPRS connection and web browser applications on the gadget. Users are able to access the server by entering a certain IP address on the web browser so users can see the vehicle position data.

Table IV shows the movement of the vehicle during a certain time by observing the latitude and the longitude of the vehicle. Furthermore, the vehicles position on a map can be seen on Fig. 7.

TABLE IV
VEHICLE'S POSITION

Time	latitude	longitude
13:32:02	-6.89089864	107.61098704
13:32:07	-6.89089864	107.61098704
13:33:32	-6.89089864	107.61098704
13:33:37	-6.89089864	107.61098704
13:34:05	-6.89089864	107.61098704
13:34:10	-6.89089864	107.61098704
13:34:15	-6.89089864	107.61098704
13:34:20	-6.89089864	107.61098704
13:34:25	-6.89089864	107.61098704
13:34:35	-6.89091880	107.61096860
13:34:40	-6.89090704	107.61096548
13:34:45	-6.89089528	107.61096464
13:34:50	-6.89089544	107.61094840
13:34:55	-6.89089656	107.61084396
13:36:20	-6.89259936	107.61045004
13:36:25	-6.89276184	107.61044824
13:37:00	-6.89325368	107.61034560
13:37:05	-6.89328040	107.61014104

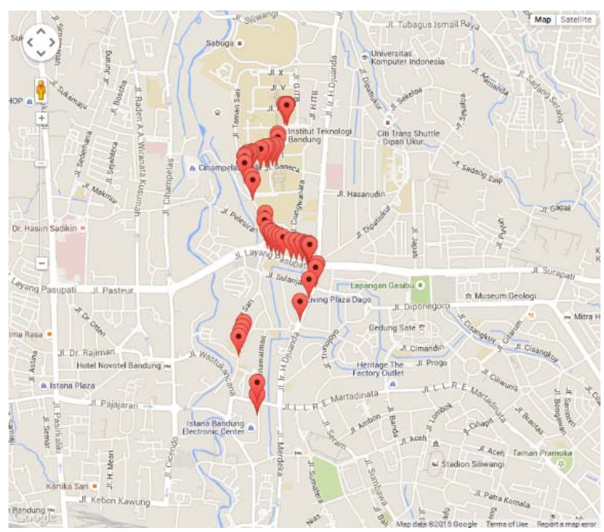

Fig. 7 The position of the vehicles on a map

Vehicle position data (Table IV & Fig. 7) is plotted on a graph shown in Fig. 8 so that the shift of its movement is observable for further analysis. From the observation result graph, it can be seen that at certain intervals, there are greater distance between a marker to the next one. It can be caused by two factors: first, VTS device failed to receive the vehicle's coordinate from the satellites, and / or second, VTS device failed to send the vehicle's coordinate from the satellites to the web server.

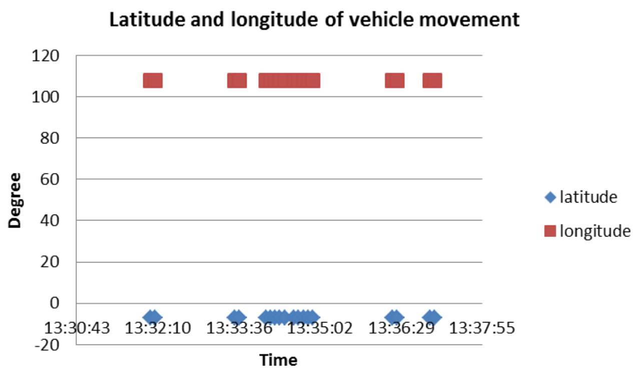

Fig. 8. A graph of the observed vehicle's position.

The first factor can occur if the GPS receiver was unable to capture the satellite signals due to obstructions between the GPS antenna and GPS satellites. While the second one may occur because of GSM signal interference or slow internet connection (GPRS) at that moment so the data did not arrive at the destination (web server).

VI. Conclusion

The main function of this system is to track the vehicle position in real time by utilizing the free RTOS embedded system, GPS technology and GSM/GPRS. This system can run properly. The tracking history feature can also display all the travel history of the desired period. However, the VTS tracking performance is still not perfect because there were more than 10 seconds of delay during deliveries. Delay can be caused by slow Internet connection (GPRS) at that moment.

VTS performance in transmitting the position is good enough bacause it is capable of transmitting the data in 5 seconds interval. This is particularly useful in tracking the vehicle in a narrow area because the displacement of the vehicle will appear so smooth. However, in a large area, it is required to provide a large data storage in order to save the amount of data received by the VTS.

The VTS performance is strongly influenced by the internet connection to the web server. A better internet connection leads to a better vehicle tracking process. This is due to the demand of following the vehicle marker on Google Maps needs a large bandwidth, especially with zoom feature on Google Map,and this goes in continuous time as long as the desired tracking process.

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