Traffic Light Controlling for Emergency Vehicle Line Based on GPS Tracking and Position Using GPRS Network

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Abstract. In big and metropolitan city, traffic jam is common problem and often to be occured. And that is the most critical problem for emergency vehicles. Where time and urgency are the most priority to be handled. In this research, emergency vehicle was utilized with any GPS device. The vehicle tracking service is provided for real time tracking. We use open source vehicle tracking framework/server Traccar. The same as with common GPS device, the emergency vehicle continuously sends its latitude, longitude and speed to GPS server. The research focused on Traffic Light Device which built of ESP32 microcontroller, GPRS module Air202 and battery power supply with charging function. While emergency vehicle reports its position to GPS server, the traffic light device continuously checks the emergency vehicle’s position data from the GPS server. The idea is to take the advantage of GPS server API, where traffic light device using HTTP GET communication with implementation of embedded cookies, session and keep alive to access the GPS server API. Traffic light device then calculates straight distance to emergency vehicle based on its predefined fixed latitude and longitude. If emergency vehicle located within the user defined threshold radius of traffic light device, then the traffic light turn green to allow emergency vehicle for passed its line. As the result of this research, traffic light device has been successfully read emergency vehicle device’s location data and measured their distance within 1 to 2 seconds.

1. Introduction

Traffic congestion is common transportation problem in big city. It caused of the increasing amount of vehicle including private vehicle and public transportation vehicle. Public transportation service must be improved to resolve this problem. These service improvements are including provision of traffic sign, traffic light, construction of new road or road widening, and adding suffice public transportation vehicle [1]. Emergency vehicle such as ambulance, fire truck and others must be prioritized to cross the road and road intersection with traffic light. This has said in Indonesian government law on number 43-year 1993 about infrastructure and transportation traffic.

Some researches for traffic management also have been developed. A traffic control system based on traffic infrastructure using wireless sensor network (WSN) with sensor of speed and serene sound which physically located near the road intersection [6]. WSN applications automated intelligent traffic control system using sensors, which is used microcontroller device integrated with RF transceiver and some sensors [4]. Traffic intersection system based on wireless sensor network where traffic light of all intersection can communicate each other and prioritize special vehicles [3]. GPS based traffic light pre-
emption control system for emergency vehicles is using SMS communication between emergency vehicle and traffic light controller [2].

In this research emergency vehicle was utilized with any GPS device. Vehicle tracking service is provided for real time tracking and position recording using Traccar. The traffic light device was built of ESP32 microcontroller with any supported GSM GPRS module. Traffic light device continuously checks emergency vehicle’s latitude and longitude position from the tracking server through HTTP request. Then it calculates its distance with emergency vehicle and decides whether the green lamp must be turned on for the emergency vehicle.

2. Research Method

Entire system of this research consists of several components which are Traffic Light Device, Emergency Vehicle device and GPS Tracking Server. In the emergency vehicle device side, common GPS machine can be used, such as in [7]. In this research an GPS client android tracking application is used. Traccar an open source vehicle tracking system is used for GPS tracking server under Linux ubuntu environment. It is included android application as GPS client which is also used in this research for emergency vehicle device. The researcher has been developed and built traffic light device as the main component of this system. It is consisting of ESP32 microcontroller, Air202 GSM GPRS module and battery power supply with charging function.

2.1. Traffic Light Device

For the traffic light device, the researcher uses ESP32 as the microcontroller. The ESP32 microcontroller has dual core processor which is very useful for multitasking. The system utilize all two core of ESP32. Since the Air202 GPRS module communicate in blocking mode, entire system of single core processor must wait for the GPRS module’s response. This situation can makes the traffic light hang for a while. And this is the worst condition which must be never occurred. To prevent this problem, the researcher allocates first core of ESP32 for traffic light controlling and second core of ESP32 for communication with GPRS module. While second core of processor wait for GPRS module’s response, first processor keep running to control traffic light in real time without any delay.

Table 1. Core allocation of ESP32 microcontroller.

| ESP32 Microcontroller | 1st Core                   | 2nd Core                  |
|-----------------------|----------------------------|----------------------------|
|                       | Traffic light control       | GPRS communication         |
|                       | Wifi management (not used)  | Read emergency vehicle data|
|                       |                            | Calculate emergency vehicle distance |

Global variable for all cores:
1. vehicle_urgency
2. red_lamp, yellow_lamp, green_lamp

![Figure 1. Architecture diagram of entire system.](image-url)
As communication device to remote server, the researcher uses GSM GPRS module Air202 S6 board, produced by openluat. It have some rich feature of communication protocols including TCP, UDP, HTTP, HTTPS and MQTT. In this research only TCP and HTTP protocol is used. Based on researcher investigation, this GSM GPRS module can work with all GSM operators in Indonesia, while some other GSM GPRS modules do not support all GSM operators. Air202 connects to ESP32 by using serial port with 115200 baudrate speed. And the voltage level of serial port is 3.3V. Two additional GPIO pin is used to control Air202 poweron and reset.

The last part of traffic light device is the power supply system. It is consist of some LiPo or LiIon batteries in parallel cascading, TP4056 battery charger and MP2307 voltage regulator. This power supply design is intended to support capability of hardware to be charged automatically while the main system is still working. The charging source can be any DC power supply or solar panel. Components and connection diagram between all these parties is shown below.

2.2. Traccar GPS Tracking Server

Traccar is open source GPS tracking system with support of various GPS tracker devices. It is built of Jetty Java HTTP server, MySQL database, and Netty network pipeline framework. Actually, traccar server is only used for manage and record GPS tracker position. It is never to be used for controlling any other device except GPS tracker. In this research, traccar server is used for various function. Emergency vehicle’s GPS position and speed is recorded to traccar server continuously. Its data attribute also can be managed within traccar system. In the other hand, traffic light device can access the traccar server. It has been permitted to read emergency vehicle data by assigning access token of traccar emergency vehicle to it. The data is accessed through the traccar server HTTP API.

Figure 2. Components and connection diagram of traffic light device.

Figure 3. Communication between traffic light and emergency vehicle.
There are various sets of Traccar server API that can be used. Based on research, only three sets of API are used. Those API are session, position, and device. Session API is used to initiate communication between traffic light device and Traccar server. The traffic light device sends an access token parameter within this API request. On the server, API reply is included cookie string to be used by traffic light device for the next API request. Position API is used to read emergency vehicle’s latest data included latitude, longitude, and speed. Once emergency vehicle sends its position data to the server, the traffic light device directly get that data from the server. The timing between each send or get data is three seconds.

Device API is used for managing traffic light device’s parameters, such as duration of each traffic light red, yellow, and red. Other parameters are defined as latitude and longitude position of the traffic light device. At the power on, traffic light device reads its parameter from the server, and sets those parameters as its global variable for its configuration. So, the traffic light device can be dynamically configured for its duration of each lamp and its position in the road map based on defined latitude and longitude. Defined latitude and longitude of traffic light device is used to calculate its distance to emergency vehicle. And further to be used for decision making to prioritize emergency vehicle to pass the road. Detail of the HTTP API example described in Table below.

Table 2. Detail Property of Traccar HTTP API

| HTTP API   | Example                                                                 |
|------------|-------------------------------------------------------------------------|
| Session    | Request http://{ServerIP/Domain}/api/session?token=Ry5J9akxLW1JpzYQm80TpEDfcRWPi5yU  
Reply HTTP/1.1 200 OK  
Date: Wed, 20 Nov 2019 06:55:10 GMT  
Server: Jetty(9.4.20.v20190813)  
Expires: Thu, 01 Jan 1970 00:00:00 GMT  
Content-Type: application/json  
Content-Length: 512  
Set-Cookie: JSESSIONID=node09ys4cxiwk3i5131z579g37dgc5.node0; Path=/  
Keep-Alive: timeout=5, max=100  
Connection: Keep-Alive |
| Position   | Request http://{ServerIP/Domain}/api/positions  
Reply accuracy: 1500  
deviceId: 1  
fixTime: "2019-11-07T06:21:27.000+0000"  
id: 1116  
latitude: 3.5657507  
longitude: 98.657824  
protocol: "osmand"  
speed: 0 |
| Device     | Request http://{ServerIP/Domain}/api/devices  
Reply attributes: {latitude: "3.563022", longitude: "98.660203"}  
latitude: "3.563022"  
longitude: "98.660203"  
id: 2  
name: "Traffic Light"  
status: "offline"  
 uniqueld: "94927212cfa4"  |
2.3. Emergency Vehicle Device

Actually, as the emergency vehicle device, any GPS tracker can be used since GPS data in sent to Traccar GSP Server, and this server support various GPS tracker client device available in market. In this research an Android GPS tracker application is used. This application is also open source developed by Traccar. In this application there are some configuration that must be set.

![Traccar Client Configuration](image)

**Figure 4.** Android GPS tracker application configuration.

2.4. HTTP API Request

An HTTP request must be sent by client to GPS server to access HTTP API. It is an easy way to access this HTTP API from browser interface as client. Because the browser has already integrated with HTTP syntax and format. It also has ability to manage session and cookie for any visited website. But that is not an easy way in integrated system such as microcontroller with GPRS communication. Some HTTP sentences must be suited correctly to meet server requirement for understanding and replying the request. HTTP request must meet the standardization of HTTP 1.1 protocol. The researcher has been tested some HTTP sentences which are working well in this environment. These HTTP sentences can also handle session and cookie well. Table below describe those HTTP sentences.

| HTTP API | Tested working HTTP API request sentences |
|----------|------------------------------------------|
| HTTP API request for initial session | GET /api/session?token=RY5J9akxLW1jpzYQm80TpeDfcrWPi5yU HTTP/1.1
Host: {Server_IP_or_Domain}\nUser-Agent: Seniman-Embedded-System\nConnection: keep-alive\n |
| HTTP API request to read traffic light device configuration | GET /api/devices HTTP/1.1
Host: {Server_IP_or_Domain}\nUser-Agent: Seniman-Embedded-System\nCookie: {cookie got from initial session};\nConnection: keep-alive\n |
| HTTP API request to read position and speed of emergency vehicle device | GET /api/positions HTTP/1.1
Host: {Server_IP_or_Domain}\nUser-Agent: Seniman-Embedded-System\nCookie: {cookie got from initial session};\nConnection: keep-alive\n |
3. Implementation and Result
In this research, we have been successfully built a prototype of traffic light device. It is constructed with two stacked boards, packed using plastic box. Bottom layer of the board consist of ESP32 microcontroller, voltage regulator, battery and its charger module, and GSM module. While on the top layer of the board has LEDs and relay module for external traffic light controlling. Dimension of prototype product is around 12.5x8.5x5 cm³.

![Traffic light device prototype product](image)

**Figure 5.** Traffic light device prototype product.

Emergency vehicle and its configuration in server can be accessed from administrator side through web interface. Its token must be configured for traffic light device reading. For ensure that server-side tracking service and its remote token really work as expected, HTTP API must be tested using common web browser. Server-side server should reply with some sets of json record about emergency vehicle entity include latitude and longitude position.

![Emergency vehicle access token configuration and testing](image)

**Figure 6.** Emergency vehicle access token configuration and testing

For real environment testing, emergency device and traffic light device have been placed in two different location as shown in image below. Traffic light device as no moving device was assigned with static latitude and longitude. While emergency vehicle device keeps moving towards traffic light device through the main road.

![Emergency vehicle access token configuration and testing](image)

**Figure 7.** Emergency vehicle access token configuration and testing
Emergency vehicle device will continuously send its position to tracking server. When the traffic light device starts running, it will first connect to GPRS network and remote tracking server. It usually takes 5 seconds to 10 seconds for good cellular network condition. The tracking server replies with session information. Traffic light device then queries the emergency vehicle device’s position through tracking server. And measured their distance based on haversine formula [5]. When the distance is within specified range for example 20 meters to 50 meters, then the traffic light device will turn the green light on, this will allow emergency vehicle device to passed the road.

Figure 8. Measured distance between traffic light device and emergency vehicle device

4. Conclusion
Based on this research, latitude and longitude position data, actually from any GPS device (for example emergency vehicle device), can be accessed from microcontroller platform (for example traffic light device) using GPRS connection through HTTP request. Traffic light device has been successfully read emergency vehicle device’s location data and measured their distance. In good condition of GPRS network, this process finished in about 1-2 seconds, which showed as offset Time in figure 8. The measured distance is used to determine whether and when did the emergency vehicle device allowed to pass the road.

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