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An Intelligent IoT-Based System for Real-Time Emergency Detection and Reporting in Passenger and Cargo Vehicles

I Made Dharma Adnyana*, I Made Cahyana Wiryanata, Komang Reni Virginia
Politeknik Transportasi Darat Bali, Indonesia
Email : *dharmaadnyana49922@gmail.com*

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Corresponding Author

ABSTRACT

Emergencies while driving often result in losses and even fatalities due to delays in information and handling provided by related parties. One of the parties affected by this is the user of passenger cars and goods. Therefore, it is important to design an emergency reporting system that utilizes advances in IoT technology, which in this study is focused on vehicles, cars, passenger cars, and goods to increase effectiveness and efficiency in the handling process. This study uses a literature study method where data collection is carried out systematically, objectively analytical, and critical from secondary data in the form of books, articles, journals, internet sites, final projects, and others that are relevant to obtain the necessary data. This emergency reporting system utilizes Internet of Things (IoT) technology with ESP8266 microcontroller as a data processor. The emergency detection indicators that are used as inputs come from sensor components such as tilt sensors, fire sensors, limit switches, emergency buttons, and GPS as data providers of the location of the incident. The microcontroller will process the data and output an "Accident Message" or "Emergency Message" via Telegram to relevant parties such as the police, nearby hospitals, clan services, and fire departments. In addition, the microcontroller also activates CCTV that has been connected to related party applications so that it allows for rapid monitoring and response in accordance with SOPs. It is hoped that the design of this tool can contribute to improving and supporting the development of technological innovations in the field of land transportation, especially related to the comfort and safety of vehicle users.

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INTRODUCTION

The frequency of traffic accidents in Indonesia is an urgent issue that requires attention. The Traffic Corps (Korlantas) compiled data on traffic accidents in Indonesia in the period from January 2024 to the end of October 2024 showing that more than 220,647 accidents occurred, with the death toll reaching 22,970 people. The main factor that affects the high number of accidents is the driver negligence factor. This can be in the form of fatigue while driving or lack of attention to the condition of the vehicle used, as well as inadequate road conditions are additional factors that contribute to increasing the number of these accidents. However, it is possible that there are also indications of dangerous situations such as beheadings, which will obviously threaten the life of the driver. This high number not only causes material losses, but also causes significant social and economic impacts (Fathurrahman et al., 2011).

One of the biggest challenges in dealing with accidents is the delay in incident reporting. Not only accidents, indications of delays in handling can also occur in emergency conditions while driving. For example, the driver or passenger experiences pregnancy contractions, heart attacks, strokes, or other acute medical conditions, when the flow conditions are jammed or obstructed so that

the vehicle cannot move. Here, there is often inefficient coordination between the police and hospitals which results in delays in responding to incidents and even people who are at the scene of the incident have difficulty reporting the accident to the authorities quickly and accurately. The main reason is the lack of effective reporting options. So that people spread accident information through social media, which obviously does not always work.

Delays in medical treatment have a significant impact on accident victims on the patient's recovery rate. This is strengthened by several studies. Delay in treatment if it is more than 30 minutes can increase the likelihood of complications up to 40%. (Yani et al., 2024) The measure used as an indicator in a patient's recovery rate is the time it takes for a patient to recover from his condition after receiving treatment (Sendoh et al., 2023).

The best treatment time is the first 4 minutes if the accident victim has an injury to the head. If the treatment is delayed for more than 30 minutes, the success rate in the rescue is only about 20%

Due to the lack of information obtained by the hospital, the hospital often has to wait for information from the victim's family or the authorities. This can be very detrimental to the victim and can allow complications and death, especially for victims who have experienced severe trauma (Melani et al., 2024).

An online reporting and notification system has been introduced by the police to improve transparency, efficiency, and accountability in handling accidents and criminal cases. The hospital also has procedures for receiving and following up on emergency reports, including accidents and criminal incidents, through the Integrated Emergency Management System (SPGDT)(HARTONO 2020). However, not everyone has access to or can use the internet, so online news may not reach all levels of society. Some regions may not even have the necessary technical infrastructure to support online reporting systems. The lack of resources and technology to handle online reports is a problem faced by certain hospitals. In some cases, employees may not be fully aware of the importance of accident reporting, leading to incomplete or delayed reporting. This leads to a lack of integration between the hospital system and the police (Santoso, Pramono, and Persada 2019), which slows down the flow of information and rapid response. In many cases, especially if it involves multiple parties, the reporting officer actually performs very slow, complicated, and time-consuming processing work. Indonesia's police and hospital reporting systems through online portals have been designed to improve efficiency and transparency, but there are still some shortcomings that raise public suspicion and insecurity about the reporting process.

In an effort to solve these problems, Internet of Things (IoT) technology seems to be a possible solution. IoT can be developed for real-time monitoring and reporting of incidents through smart devices accompanied by sensors (Nassreddine, El Arid, and Nassereddine 2024). Various applications, including transportation systems take advantage of this technology. Network-based communication systems can play an important role in IoT technology including the efficiency of vehicle monitoring and accident incident response. The presence of sensors on vehicles can signal sudden changes in acceleration, impacts, and other abnormal conditions to indicate an impending accident or danger (Simran, Sinha, and Peter 2022). By automatically sending data to the control center, IoT networks enable faster response times.

The implementation of an IoT-based system for incident reporting will also help address the issue of reporting delays. By utilizing applications, IoT systems provide a quick and easy means for the public to report incidents (Pradana 2021), so that authorities can take the necessary actions. Furthermore, the hope for a better road safety ecosystem in Indonesia requires the participation of stakeholders such as the government, police, and technology companies.

Therefore, the development of an Internet of Things (IoT)-based emergency notification system is a very important innovation to improve the efficiency and effectiveness of response and

security to emergency situations. With the development of this system and the application of technology, it is hoped that it can improve the efficiency and effectiveness of handling so that it can save more lives and reduce the negative impact of reporting delays in the future.

Passenger cars and goods were chosen as the target for the installation of the emergency reporting system design in this study because passenger and freight cars have a high level of mobility, so the potential for accidents and emergencies in this type of vehicle is relatively high. In addition, robbers often choose freight cars as the target of their actions considering the valuable cargo they carry. To avoid this from happening, the emergency reporting system is very appropriate to be applied to this type of vehicle.

RESEARCH METHOD

This research applies a literature study method, where the activities carried out are related to the method of collecting library data, taking notes, and reading. The management of research data is carried out carefully and in-depth in a systematic, objective, analytical, and critical manner with the aim of obtaining data on the design of IoT-based systems on the emergency reporting mechanism on passenger cars and goods. The data obtained and analyzed are secondary data in the form of various research results such as books, articles, journals, internet sites, final projects, and other relevant ones. Salimnahdi. The awareness that knowledge will continue to develop as the times change and progress is the basis for this literature review. Practice in the field will be very helpful and have a reference with the help of theoretical references as the foundation of theories that have been collected by means of literature study research (Aditya Putri et al., 2020; Aryana, 2021; Yunus Saputra, 2017).

RESULTS AND DISCUSSION

In designing the creation of an IoT-based emergency reporting system, ESP8266 microcontrollers were used. To program this microcontroller requires Arduino IDE (Integrated Development Environment) software. The programming language used in this software is the C language. The design block diagram of the device of an IoT-based emergency reporting system can be seen in figure 1.

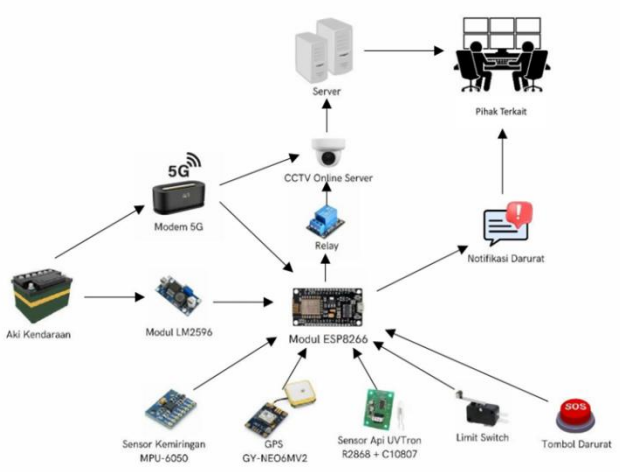

Figure 1. Device Design Diagram Blocks

Component explanation

1. **IoT (Internet of Things)**

   In the modern wireless telecommunications scenario, the Internet of Things (IoT) has become a new paradigm that is rapidly taking over. The Internet of Things (IoT) allows and even

allows some objects to communicate without the help of intermediaries such as humans by simply transmitting data over a Wi-Fi network. IoT in its ability to share data with real objects can be advantageous in terms of distance control (Kusumawati et al. 2017). There are three fundamental layers in the IoT realm, including the network layer (data transmission), the application layer (data storage and manipulation) and the perception layer (detection) with technology that focuses on NFC, RFID and Wireless Sensor Node (WSN) (Atzori, Iera, and Morabito 2010). The concept of IoT plays a very important role in technological advances and aspects of daily life and even the impact it has is quite significant.

2. Microcontroller

A microcontroller is a component in the form of a processor whose interest is focused on controlling. Microcontrollers are created with the same components as computers, only they are much smaller in size. A program created by a programmer will give commands to the computer (microcontroller) to perform complex tasks as the programmer wants (Devianto & Dwiasnati, 2018).

3. Module ESP8266

Espressif Chinese manufacturer created a Wi-Fi module ESP8266 that supports the use of TCP/IP. AI-Thinker, the third-party manufacturer of this module, released the ESP-01 module in 2014. The AT-Command configuration is used by this module. Low prices, low power usage, and small dimensions attract many developers to develop further. With the release of the software development kit (SDK) in October 2014, more developers will be able to develop this module. The form factor 2x4 DIL module ESP-01 measures 14.3 x 24.8 mm and requires 3.3 volts of power. NodeMCU ESP8266 v0.9 has 4MB of RAM, 11 GPIO pins, 2 pairs of UART, 1 ADC pin, 2.4GHz, Wi-Fi and is capable of WPA/WPA2 support. NodeMCU has the ability to be programmed in the LUA language, and the Arduino IDE makes it possible to do so in the C language (Yuliansyah et al., 2016; Fajar Wicaksono, 2017).

4. 5G Technology

5G technology, also known as 5G networks, was created to improve the 4G LTE network and have higher speeds. The channel characteristics are very different on different frequency bands, especially on higher frequency bands. This technology uses radio waves to transmit documents or data where radio waves can be divided into multiple frequencies. Some of the goals of the 5G network include reaching a data rate of 1 millisecond, being able to connect to equipment such as cars, phones, and household appliances, and obtaining higher speeds than 4G (Anggraini & Back, 2021).

5. Internet modem

Demodulation Modulation stands for the word modem. The function of the modem is to convert digital signals into analog signals (sound signals) and vice versa, from analog signals (sound signals) to digital signals. The speed at which the modem transmits data is measured in bits per second (bps), or bits per second. A modem is a two-way communication device that allows the transmission and reception of an internet network to a computer or mobile device. This device is essential because it allows every device connected to it to receive and transmit high internet frequencies. The types of modems can be classified into two namely internal and external modems. External modems connect to computers via USB or serial

cables, while internal modems are designed to be installed directly on a computer's motherboard or CPU (Fahrudin, 2019; Squirt, 2021).

6. Simcard

SIM (Subscriber Identity Module) cards are formed from Microprocessors, ROMs, and RAMs which are then combined into a single unit called ICC-ID (Integrated Circuit Card Identifier). MCC (Mobile Country Code), MNC (Mobile Network Code), and card number/number serial determine the identity of this ICC card. SIM cards are used for user authentication within GSM networks. Providers that release SIM cards in the form of IMSI also contain the country code (International Mobile Subscriber Identity), Ki identity (the term for authentication key), commercial radio lines in the form of TMSI or Temporary Mobile Subscriber Identity, and LAI for the last area accessed by the user. In addition, the SIM Card also contains the MSISDN (Mobile Subscriber ISDN) number and the Ki identity (the term for personal identity key). TMSI and LAI data always change depending on where the mobile device is in the telecommunication network used. At first, the size of a SIM Card was the same as a credit card, but with the advancement of technology, the size of the SIM Card also became smaller as the size of the mobile phone got smaller. The third generation of SIM cards, called Micro-SIM, began to be known to the public along with the launch of Apple's iPad products. Even the fourth generation of SIM cards, Nano-SIM, has appeared today. Nano-SIM is 30% smaller than Micro-SIM and 15% thinner than Micro-SIM, with a thickness of 0.7 mm. The study also mentioned that Nano-SIM allows manufacturers to provide more space for additional components in mobile phones, such as memory cards or larger batteries. Thus, Nano-SIM reduces the need for larger batteries. When a mobile phone or smartphone product is released, the small size of the Nano-SIM affects the thickness of the product (Casey & Turnbull, 2011) (Prayudi & Rifandi , 2013).

7. CCTV online server

Digital video camera devices known as CCTV (Closed Circuit Television) were created to distribute signals to monitor screens in a certain room or location with the aim of monitoring the situation and conditions in that place. CCTV is usually used to monitor public areas. Initially, the display from the CCTV camera was only transmitted to a specific monitor room via cable and monitored directly by the operator or security officer because the image resolution was still low. However, the impact of the rapid development of technology today, many types of CCTV cameras have implemented more sophisticated systems. Currently, digital CCTV camera systems can be operated and controlled through a computer or mobile phone, and as long as there is an internet connection or GPRS, users can view from anywhere and at any time (Adriansyah & Rizki , 2014).

8. MPU-6050 tilt sensor

The MPU 6050 is an inverse IC chip with an integrated gyro sensor and accelerometer. Accelerometer components are applied to obtain measurements of gravitational acceleration, acceleration of motion, and acceleration. To measure the angle of inclination, the accelerometer can only work when it remains static. Often, the incorporation of one or more gyros and a combination of data is used to calculate the angle in order to obtain an accurate angle of inclination. Based on the principles of angular momentum, gyros are devices that can be used to maintain or measure orientation. MPU6050 serves as a dreadmill balance. The process of working is that the microcontroller obtains data from the angle of the gimbal's tilt,

which then processes the data and ensures that the gimbal remains balanced (Stuttgart , 2016) (Donkey , 2020).

9. **Limit switch**
   A limit switch is an electromagnetic device that can change the position of the terminal contact with the actuator lever from normally closed (NC) to normally open (No) and vice versa. Limit switches are sensors and are very important for process control because they have several functions that are providing inputs to the process and from the outside environment, changing physical information such as the position of electrical signals, and connecting with physical variables in known processes, resulting in its electrical signals being processed to see and control processes (Hutajulu et al., 2021) (Riswan et al., 2010).

10. **UVTron R2868 + C10807 fire sensor**
    The sensor has a gap spectrum sensitivity of 185–260 nm that uses the mixing effect of gas and the photoelectric effect of metal. A light spectrum cutting filter appears to be unnecessary on this sensor thus distinguishing it from semiconductor detectors and making it easy to use. To make the UVTron sensor connect to the microcontroller, the response signal conditioning circuit must be set to a pulse 7 that can be recognized by the microcontroller in the Signal Processing Circuit section. This circuit regulates the number of pulses produced by the UVTron sensor for 2 seconds, which is then received and processed by the C10807 in the form of pulses 10 milliseconds wide. The output of this 10-millisecond-wide pulse circuit can be connected directly to the microcontroller system, which will detect changes in the input state at an interval of 10ms (Setiawan & Yanto, 2018) (Ananda et al., 2023).
11. **GPS GY-NEO6MV2**
    GPS is a satellite-based navigation system that can show your location and time information in all weather conditions as long as it is within range of at least four satellites. The Ublox NEO-6MV2 is a GPS module that can be used for navigation. This GPS module is manufactured by Ublox AG and uses UART communication with the NMEA 0183 protocol. There are baud rate values of 4800, 9600, and 38400. This module is capable of achieving an accuracy level of about 2.5 meters to 10meters and can provide a voltage between 3.3 to 5 Volts (Düsseldorf & Sumardi, 2014) (Rahman et al., 2019).
12. **Relay**
    A relay is an electronic component consisting of an electronic switch controlled by an electric current. In general, a relay is a switch lever in the form of a wire coil near the solenoid, or an iron rod. Due to the magnetic force that arises on the solenoid when it is subjected to electric current, the contact of the switch will close. The lever will return to its starting position and the switch contacts will reopen when the current is stopped accompanied by a loss of magnetic force. Relays are usually used to drive large currents/voltages using small currents/voltages. (Turang, 2015)

Wiring diagram

To make it easier to design tools, wiring diagrams are needed which can later become a benchmark in the tool manufacturing process. A wiring diagram is a detailed drawing that is used to determine the relationship between each component (Angela et al., 2022). The wiring diagram of the design of this tool can be seen in figure 2.

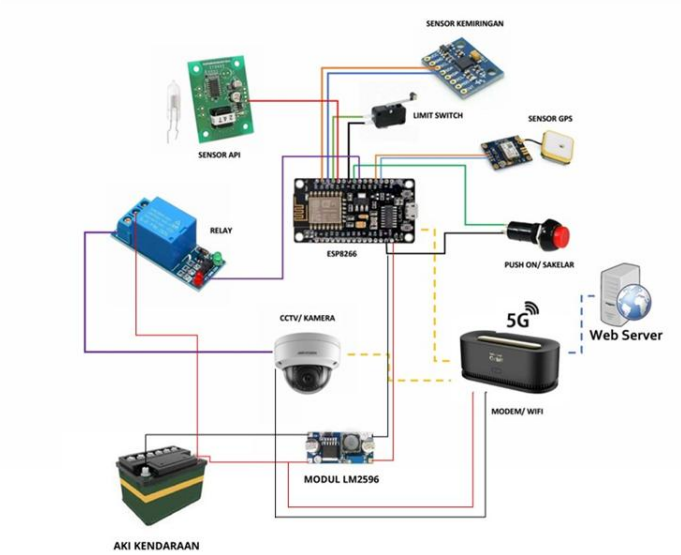

Figure 2. Wiring Device Design Diagram

Working principle of the tool

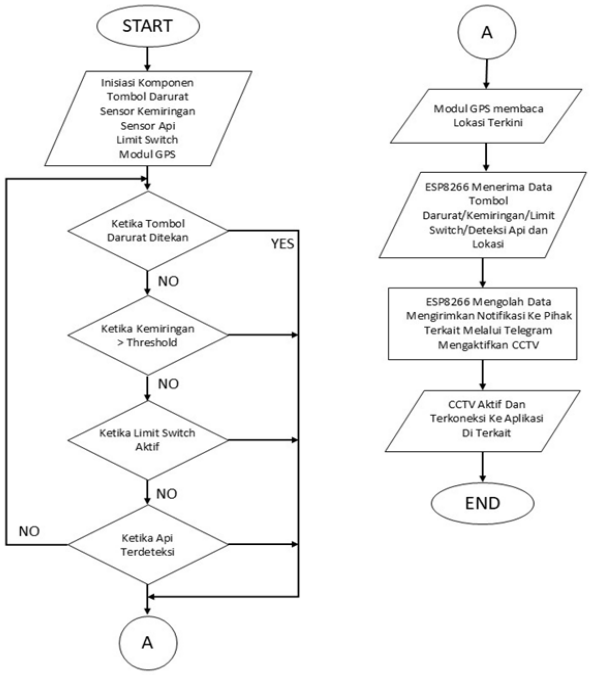

Figure 3. Process Flow Diagram of How The System Works

The working principle of this tool makes use of IoT integration that works by sending data over the internet. The input received by the microcontroller will be processed and produce 2 outputs, namely in the form of notification messages and the activation of CCTV online servers that are connected to related party applications such as the police, nearby hospitals, clan services, and fire departments. Through the information that has been obtained, related parties can take action quickly in accordance with the applicable SOPs.

Figure 3 shows a flowchart of the system's work process based on the components that have been discussed. The five components function as inputs, namely an emergency button that allows the

driver or passenger to report consciously, a tilt sensor to read the state of the motorcycle's slope, a fire sensor as a fire identifier, and a limit switch to identify impacts that cause the airbag to inflate, and a GPS module as a data provider at the scene. It uses ESP8266 microcontroller as a data receiver and processor. ESP8266 process data by gaining internet access through a WiFi modem. The output produced is in the form of Telegram messages sent to related parties containing incident information, including location, time, identity of the owner, and identity of the vehicle. The microcontroller will also activate CCTV connected to the server on the related party application so that the situation can be monitored, the condition of the driver and passengers, and ensure the correctness of the reporting. The microcontroller power source is obtained from the vehicle battery whose voltage has been lowered from 12V to 3.3V using the LM2596 module. (Rizal Mulia & Ikhsan Maulana, 2024) (Chandra São Paulo Farid Hanifan & Elvin São Paulo Sri Sarjana, 2024)
This tool can operate based on two possible circumstances, namely:

1. **Works automatically when the vehicle is in an accident**
   When this happens, the microcontroller will ESP8266 receive input from the sensor. The slope sensor will provide input to the microcontroller if the vehicle's slope has exceeded reasonable limits. This sensor functions when the vehicle is not in its proper position such as upside down or rolling. The fire sensor will provide input to the microcontroller if it detects a fire. This sensor functions when the vehicle is on fire. A Limit Switch is mounted on the airbag that will provide input to the microcontroller in the event of a collision resulting in the airbag inflating. The inputs from the sensor will be processed by ESP8266 microcontroller. The output produced is in the form of "Accident Messages" via telegram sent to related parties and activation of CCTV online servers. (Chandra São Paulo Farid Hanifan & Elvin São Paulo Sri Sarjana, 2024)

2. **Work with human control in the event of an emergency**
   Other emergencies in question such as robbery or beheading, critical patients, pregnant women who are about to give birth, and other circumstances related to safety. When this happens, the driver can press an emergency button which will then provide input to the ESP8266 microcontroller. This microcontroller will process data and produce output in the form of "Emergency Messages" through telegrams sent to related parties and activation of the CCTV online server.

CONCLUSION

The development of the design of this emergency reporting system will have a great impact to increase efficiency and effectiveness in handling an emergency. The integration of IoT technology, which is developing very rapidly, with 5G technology will have a great impact on the realization of this system. Different types of sensors such as fire sensors, tilt sensors, GPS, limit switches are controlled by ESP8266 microcontrollers to process the inpu so that this system can run properly. When the vehicle has an accident, the system is capable of working automatically and in the event of other emergencies, it can be controlled manually. Messages will be sent via Telegram notifications by a microcontroller containing information about the incident, including the time, location, and identity of the vehicle. CCTV will also be activated and directly connected to the related application. It is possible that related parties such as the police, fire departments, and hospitals are able to respond quickly and in accordance with SOPs. To improve emergency response and efficiency in critical situations, the system uses the internet and IoT technology. The design of this system is expected to make a significant contribution to improving the comfort and safety of vehicle users, especially

passenger cars and goods, and supporting the development of technological innovations in the field of land transportation.

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