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A NOVEL PROTOTYPE OF VEHICLE WARNING SYSTEM FOR VANET SAFETY APPLICATION BASED ON RASPBERRY PI

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Abstract. *In order to cope with challenges in road transport, physical developments or public improvements could no longer be the only solution. It requires the support of information technology. Information technology allows element in the road transport systems such as road, traffic light, message signs to be intelligent with the aid of computer technology (microchip and sensor) to communicate with each other via wireless technology. The aim of our research was to develop a vehicle warning system to improve road safety and evaluate its message delivery performance by making a comparison of the result of OLSR and BATMAN-adv routing protocols. This system consists of communication systems between vehicles using wireless IEEE 802.11n integrated with Raspberry Pi and provided the program to send and receive messages. The result obtained in this research is a prototype vehicle warning system that allows each vehicle within a specific range can exchange information.*

Keywords: Intelligent transportation system, Vehicle warning system, Vehicular ad hoc network

1. **Introduction.** The number of vehicles continues to grow each year, and the high level of mobility of users having the possibility of the traffic accident is enormous. Based on the report of 2015 road safety by the World Health Organization (WHO), which represents information from 180 countries, the number of death due to traffic worldwide has reached 1.25 million every year [1]. The increasing number of traffic accidents indicates that safety on the road is increasingly questionable.

World Health Organization (WHO) [2] proposes several ways to reduce the number of road accidents such as building the infrastructure of secure road, improving safety standard on the vehicle, and educating road users to have safety insight. Moreover, other efforts which can be used are the application of information and communication technology in the sector of transportation and road, for example utilizing the technology of Intelligent Transportation System (ITS) has been growing in the last decade. Through ITS technology, road users will get more information from the transportation network and traffic condition in real time. Moreover, this system can help control the flow of traffic, improve security and comfort and can minimize human error [3]. Implementation of service of emergency message inter-vehicles on the road is one of the ways to build a good transportation system that can provide control in the transportation system and handle problems that occurred on the road.

Currently, operating emergency light and siren on emergency is still the primary choices for service vehicles such as ambulance, police and fire brigade, as the device gives emergency alert around them. Without emergency light and siren, ambulance, fire brigade will be difficult to penetrate the heavy traffic lane. A siren is a tool that allows the travel of

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special vehicles in the traffic jam [4]. However, the use of siren that is always turned on will result in noise that potentially affects driver's comfort as well as increasing anxiety and stress at patient side. A number of solutions have been proposed to overcome the shortcoming of the use of siren on the road, such as applying the inter-vehicle communication system to disseminate warning of emergency service vehicles, so it will be able to replace the use of the siren. It can also be used to send a warning message on the road.

A case study of a prototype of emergency vehicle applications has been presented by Buchenscheit et al. [5]. The emergency vehicle warning message is sent using wireless communication to provide better and faster services to the patients. This prototype is developed based on U2VAS [6]. It is a Java framework for real-world experimentation platform for VANETs. For the test and implementation of the prototype, they used the conventional notebook.

The Vehicle Safety Communications (VSC) project introduces various vehicular safety (and non-safety) applications by wireless communications (either vehicle-vehicle or vehicle-infrastructure), estimates the potential benefits and defines their communications requirements of communication [7]. The specific communication requirements for emergency vehicle warning include communication from vehicle to vehicle, one-way communication, point-to-multipoint communication, transmission mode: event-driven, and data to be transmitted and received: position, vehicle status, vehicle description, time.

In the context of Vehicular Ad hoc NETworks (VANETs), several works have been devoted to the problem of safety message dissemination (for example, [8-10]), and models of connectivity have been proposed. Based on the integration of various wireless communication technologies, Jeong et al. [11] proposed a novel hybrid system in which the combination of cellular network and Wi-Fi Direct supports V2V communication. A similar project, involving using ZigBee for connecting roadside sensor network application has been proposed in [12]. In order to optimize the dissemination of messages in V2V communications, some of the routing protocols are designed. In [13-15], the authors study the performance of the routing protocols for VANET.

Although many types of vehicle warning systems have been introduced, to the best of authors' knowledge there is no study of its implementation on the embedded system platform. Therefore, we aim to design and implement vehicle warning systems on the microcomputer of Raspberry Pi. Thus, we compare the routing protocol of OLSR and BATMAN-adv for VANETs with different vehicle speed.

In addition, in the proposed system we evaluated the broadcast of messages from vehicles with varying mobility speed. We also investigated the performance of our vehicle warning system considering the successful packet delivery, end-to-end delay, and the number of packets sent.

2. **Research Methods.** In this section, we present a methodology for the development vehicle warning system for VANET safety application that aims to support an intelligent transportation system. This research was built by utilizing the device of the embedded system and wireless devices as a medium of message delivery on the street. The deployment service of warning message on the road is used to inform critical matters to help the smoothness of the journey and improve safety as shown in Figure 1.

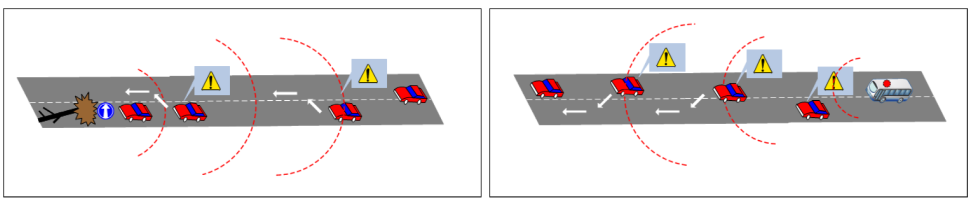

FIGURE 1. Prototype warning and emergency scenario

This vehicle warning system is designed as a solution to the emergency vehicle to replace the use of sirens which in turn will provide a better and saver emergency warning signal on the road. This automatic system which uses a minicomputer of Raspberry Pi as the embedded system operates in wireless communication of IEEE 802.11n. Communications can only be done one way from the transmitter device (mounted on the emergency vehicle) to the receiver that is installed on a public/private car.

The vehicle warning system device is designed in two main parts: sender and receiver. Both are based on embedded system using Raspberry Pi as a communication tool and data processing information. The two parts are the basis for the inter-vehicle warning system for the driver on the road. Figure 2 depicts the whole block diagram of the design of system hardware.

FIGURE 2. Block diagram of vehicle warning system

2.1. **The transmitter section.** The transmitter section serves to send message/warning information when an emergency condition is on the ambulance, police or firefighter to other vehicles in the road, or it can also be used to provide information about the incident on the street so another driver on the highway can be anticipated.

For the transmitter section, there is a minicomputer Raspberry Pi equipped with wireless connection IEEE 802.11n technology that has been installed of the Raspbian operating system and added with LCD interface to run the application of emergency message. These transmitters are installed in vehicles of emergency service such as ambulances, police or firefighter. The sender display of emergency message is shown in Figure 3.

FIGURE 3. Display of emergency message sender application

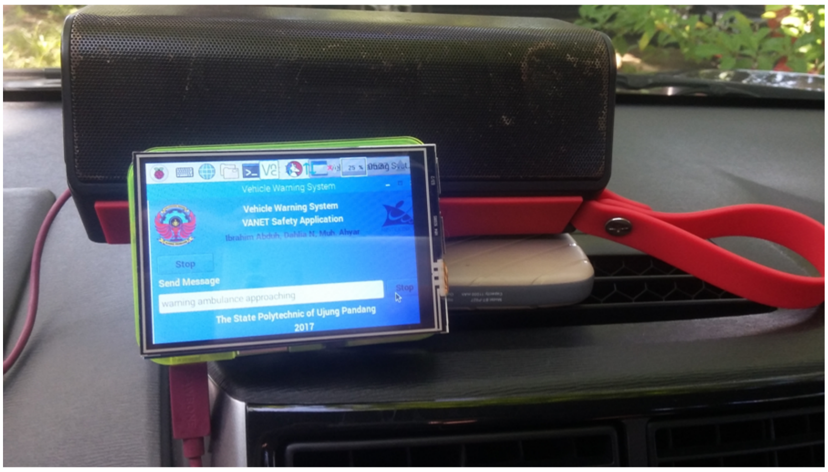

FIGURE 4. Display of emergency message receiver application

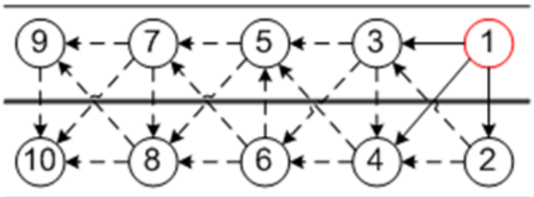

FIGURE 5. The mechanism of sending messages with a multi-hop mechanism

2.2. **The recipient section.** This is the part that serves to receive messages from the transmitter. It also consists of an embedded system in the form of minicomputer of Raspberry Pi which has been added part of the interface in the form of speaker and LCD, whose function is to produce a sound as a sign to the driver whenever getting the message from the transmitter and display the information to the LCD. The device is placed in a public/private vehicle to warn the driver that an emergency vehicle is approaching. The display of the receiver of the emergency message is shown in Figure 4.

To enable inter-vehicle communication, the routing protocol is required to establish and maintain route among vehicles. The two routing protocols implemented in this system are OLSR and BATMAN-adv. These routing protocols represent proactive routing type protocol based on table driven. In the proactive routing, protocol node continuously maintains up-to-date routing information on every node in the network [16]. This routing protocol is suitable for large network and rapid topology changes like VANET.

This technique successfully overcomes the limitation of distance range of the source sender of the message, mainly due to the use of multi-hop mechanism. In such mechanism an emergency message is sent on the broadcast to the neighbor vehicle that then the message will be forwarded again to another nearby vehicle to a predetermined threshold [17]. The multi-hop scenario can be seen in Figure 5.

The process of sending multi-hop is created using a socket program, which serves resumption UDP packet that has been received prior to an existing network. The program of packet relay is created using C language to enable socket programming in forwarding message from information received.

Figure 6 shows the workflow of the program of the communication system between vehicles to improve road safety for both sender part (Algorithm 1) and receiver part (Algorithm 2).

3. **Results and Analysis.** After the development of the vehicle warning system, we conduct a series of experiments to evaluate the performance of distribution of warning

Algorithm 1: Sender part	Algorithm 2: Receiver part

Hardware initialization
Setup wireless ad hoc mode
Enable routing (OLSR/BATMAN-adv)
Run the sender App
Initialization socket
If (an emergency occurs)
    Create the warning message
    Send the message
End
	Hardware initialization
	Setup wireless ad hoc mode
	Enable routing (OLSR/BATMAN-adv)
	Run the receiver App
	Initialization socket
	While (wait for the message) do
	    Receive the message
	    Display the warning message on
	    LCD and sound the speaker
	    Relay the message
	End

Figure 6. The pseudocode of implementing vehicle warning system for VANET safety application mechanism

message by a vehicle which are sent by broadcasting all of the vehicles. The general overview of our experimental environment is shown in Figure 1. There are six vehicles on the road, one as the sender and another as the receiver based on the application program. Each vehicle is equipped with Raspberry Pi device and using IEEE 802.11n. We have implemented and compared the performance of OLSR and BATMAN-adv as the proactive routing protocols for our implemented model. This experiment is performed by varying average speeds as low, medium and high between the sender and receiver to represent real vehicle operation on urban environment.

3.1. **Message delivery status.** This test scenario aims to find out whether the prototype is capable of being used in a real state of the road. The scenario in this test is the vehicle that is carried by the receiver in front of the sending vehicle, and the distance > 50 meters from the sender. Data collection is done by variation of the speed of sender from 10 km/h-100 km/h. The test result is only the data of the success or failure of the receiver to receive data from the transmitter, at the condition of the transmitter speed when sending data. The performance measurement results are in Table 1.

Table 1. Status of delivery of message between vehicles

No	Speed Sender	Delivery Status
1	±10 km/h	Message sent
2	±20 km/h	Message sent
3	±30 km/h	Message sent
4	±40 km/h	Message sent
5	±50 km/h	Message sent
6	±60 km/h	Message sent
7	±70 km/h	Message sent
8	±80 km/h	Message sent
9	±90 km/h	Message sent
10	±100 km/h	Unsent message

As shown in Table 1 the receiver can still accept the message from the transmitter with the maximum speed of the vehicle being 90 km/h and the distance of over 50 meters.

3.2. **End to end delay time.** Delay is defined as the time interval from the arrival of an emergency message at the MAC layer up to the successful transmission [18]. Based on the theoretical analysis from [19], we define the delay as:

$$\mathrm{T_{MAC}} = \mathrm{T_{RTS}} + \mathrm{SIFS} + \mathrm{T_{CTS}} + \mathrm{SIFS} + \mathrm{T_{DATA}} + \mathrm{SIFS} + \mathrm{T_{ACK}} + \mathrm{DIFS} \tag{1}$$

where T_{DATA}, T_{ACK}, T_{RTS}, and T_{CTS} are the transmission times for a data, acknowledgment, RTS, and CTS packet, respectively.

$$t = \sum_{i}^{N-1} (T_{MACi} + TP_i) \tag{2}$$

where t = multihop delay; N = hop count; T_{MAC} = MAC delay; TP = propagation delay.

The testing of the speed of delivery and receiver aims to measure how to optimize the speed between the transmitter and receiver in communication wirelessly. The distance that becomes the independent variable is measured from 5-100 meters. In this testing, it will be measured the time required for this prototype to send and receive data using two routing protocols, i.e., OLSR and BATMAN-adv. Scenario performed in this test is a transmitter and receiver that are given the distance between the two then made a delay measurement of the process of the data transmission. The graph shapes for the results of performance measurement can be seen in Figures 7-12.

- **Slow speed**

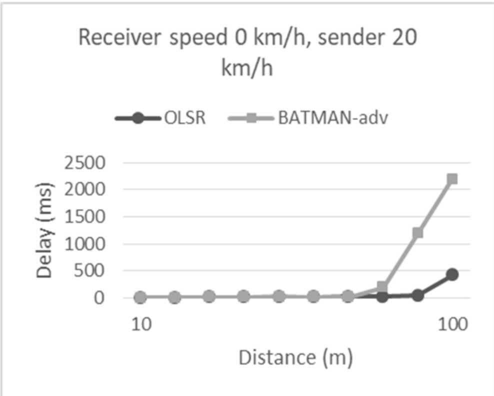

Figure 7. The result of delay testing to the distance with receiver speed not moving while the sending speed is 20 km/h

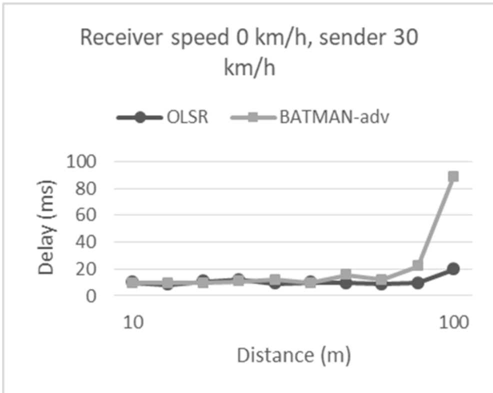

Figure 8. The result of delay testing to the distance with receiver speed not moving while the sending speed is 30 km/h

- **Medium speed**

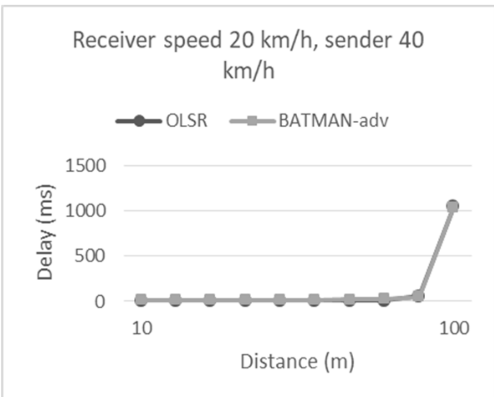

Figure 9. The result of the delay test to the distance with the receiver speed of 20 km/h, while the sender speed of 40 km/h

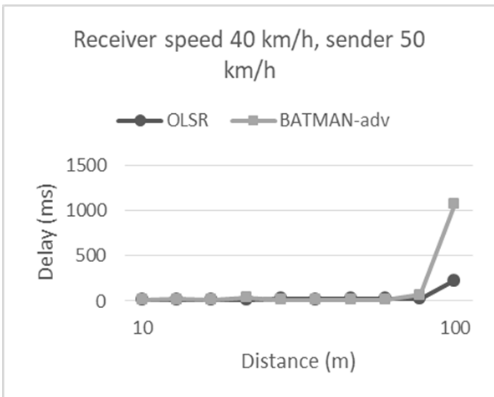

Figure 10. The result of the delay test to the distance with the receiver speed of 40 km/h, while the sender speed of 50 km/h

- **High speed**

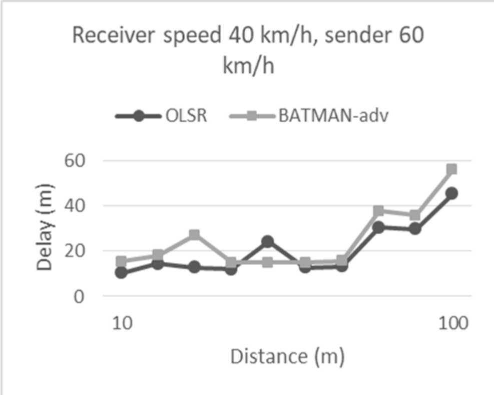

FIGURE 11. The result of the delay test to the distance with the receiver speed of 40 km/h, while the sender speed of 60 km/h

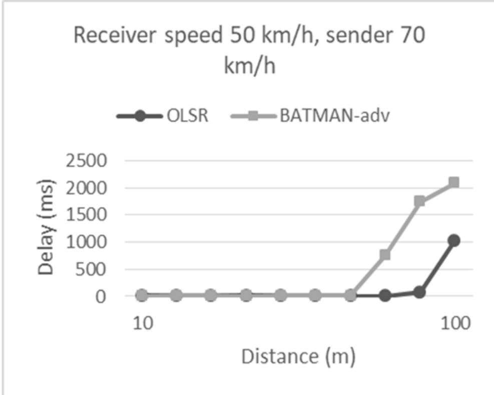

FIGURE 12. The result of the delay test to the distance with the receiver speed of 50 km/h, while the sender speed of 70 km/h

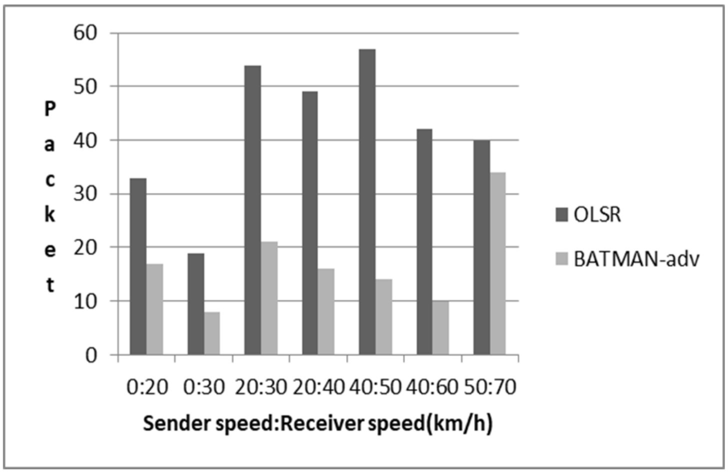

FIGURE 13. Results of testing the number of messages that are successfully sent to the variation of the receiver and the sender speed

Based on the test result, the system can communicate up to approximately 100 meters and the delay tends to increase for every increase in distance. In this case, the more distance will increase propagation which in turn makes a longer delay time. As a result, the delay is more considerable. The influence of speed to delay tends to fluctuate. From the variation of speed and distance scenario that has been done it can be seen that OLSR routing protocol has the lower delay than BATMAN-adv routing protocol.

3.3. **Number of messages successfully transmitted.** In this step, the number of messages successfully transmitted by the moving for a single connection period is measured. The more messages that can be sent have better reliability to avoid losing warning messages. Figure 13 shows the number of messages sent by OLSR and BATMAN-adv routing protocol. It is found that OLSR routing protocol always sends more messages than BATMAN-adv routing protocol in all different speeds of sender and receiver.

4. **Conclusions.** This work presents the implementation of a prototype vehicle warning system for VANET safety application. This system will be helpful for giving an early warning sign to the driver regarding unsafety road condition and also to support emergency vehicles services such as ambulances, police and fire brigade to broadcast danger

warning sign to the driver of the vehicle. The results of the experiment show that our vehicle warning system can send warning message with the maximum speed of the vehicle being 90 km/h. The performance of broadcasting messages for two routing protocols, i.e., OLSR and BATMAN-adv, has shown that the average delay of OLSR is relatively low for a VANET safety application. Likewise, OLSR can send many messages more than BATMAN-adv routing protocol. As future work, we will develop early warning system for road intersections as part of vehicle warning system.

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