Journal of Physics: Conference Series

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To cite this article: A Bhawiyuga *et al* 2017 *J. Phys.: Conf. Ser.* **801** 012085

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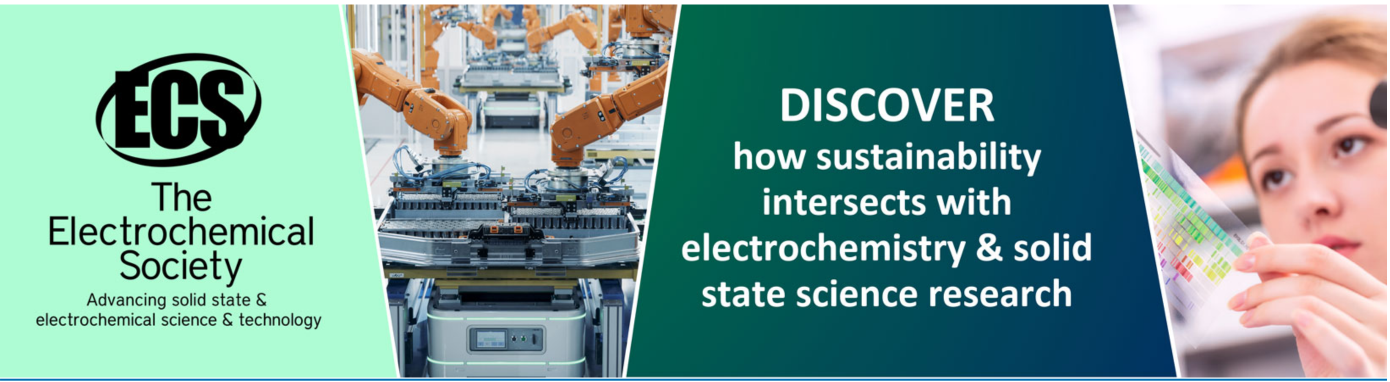

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A Wi-Fi based Electronic Road Sign for Enhancing the Awareness of Vehicle Driver

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Abstract. Reducing the road accident rate is one of the city goal in the area of transportation. One of the effort to reach that goal is done by deploying various signs across the road. However, the role of those road signs can be diminished once the vehicle drivers intentionally or unintentionally disobey the rule indicated on those signs. In order to increase the awareness of the driver, we can employ the vehicular network concept in which a vehicle can communicate with another vehicles or with the infrastructure installed along the road. For realizing that idea, we propose the implementation of communication equipped road sign system which consists of two components: Road Side Unit (RSU) module deployed at road sign and On Board Unit (OBU) module deployed at each vehicle. In our proposed scheme, both of the devices communicate each other through the widely-used Wi-Fi protocol (IEEE 802.11n) operating in ad-hoc mode. While a OBU equipped vehicle is moving towards the communication range of RSU, it will make an association to a predefined wireless ad-hoc network. Once it is associated, the OBU can receive message broadcast by the RSU. Upon reception, OBU display alert message indicating that the vehicle is approaching a road sign. From performance testing we observe that the proposed system can give relatively good service the vehicle moving as fast as speed 90km/h with the distance as far as 90m.

1. Introduction

In recent years, there exists an increasing trend of road accident in Indonesia. According to Indonesian Statistics Board (BPS), the road accident rate in Indonesia increases from 108.696 cases in 2011 to 117.949 cases in 2012 [1]. There are several factors that contribute to those increase such as the lack of proper road facilities and the human error factor. As the amount of car and motor in the road rises, this worrying trends is predicted to continue in upcoming years.

One of the effort to reduce the amount of road accident is done by deploying the road sign [2]. There are various kind of deployed road sign including the red-green light signal in junction, crossing pedestrian sign, maximum/minimum speed sign and no turn left/right sign. Those kind of road signal are important for both managing the road traffic and reducing the road accident rates. However, the role of those various road signs may be diminished once the road users disobey the rule indicated to those road sign both intentional and unintentional. Therefore, we think that it is an important problem to improve the awareness of driver on the road towards the existence of deployed road signs.

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In literature, there have been several works to cope with aforementioned problem. In [3], the author proposed a traffic sign recognition system through image processing by capturing the sign with camera and then, by utilizing the classification method, it can perceive the meaning of a sign and give an early information to the driver. Since those proposed systems utilize the camera, its performance may highly depends on the amount of lighting in those specific road segment. By realizing the problem in previous work, one of the solution is proposed by incorporating communication between the deployed road signal and the driving entity. In [4, 5], authors proposed the design and prototype of a road sign delivery system using RFID. Since it utilizes the wireless communication, the proposed system does not be affected the lightning problem as in the image processing solution. However, the communication range of the RFID may limit the functionality of proposed system. Therefore, we may require a wireless communication method with longer transmission range and reasonable delay.

Fortunately, in recent years, the researchers are actively involved in the research topic related to the road safety using relatively long range wireless communication between entities on the road called vehicular network. In short, vehicular network is a subset of wireless network that allows a vehicle to communicate and exchange information's with its nearby vehicles called vehicle to-vehicle (V2V) communication or with the deployed road infrastructure called vehicle-to-infrastructure (V2I) communication [6, 7, 8]. By utilizing the exchanged information, each vehicle can detect its surrounding environment and react accordingly while an endangered situation happened [10, 11]. With its ability, we believe that the vehicular network can be one of the promising solution for helping the driver to be aware toward the road signs. In addition, we can see the vehicular network as a part of the whole integrated smart city solution, especially in the area of transportation [9].

In this paper, we propose the implementation of communication equipped road sign system which consists of two components: Road Side Unit (RSU) module deployed at road sign and On Board Unit (OBU) module deployed at each vehicle. The prototype of both modules are built in Raspberry Pi equipped with wireless dongle while the communication between those two entities are performed using IEEE 802.11n protocol. In this case, both the RSU module and its OBU counterpart operates in ad-hoc mode. While a vehicle equipped with OBU is moving towards the communication range of RSU, it will make an association to the predefined wireless ad-hoc network. Once it is associated, then the OBU can receive the road sign information broadcast by the RSU. Upon receiving that information, the OBU module shows up an alarm notification to the driver indicating that the vehicle is approaching a road sign together with a certain signal. Notice that, for carrying a specific information of a road sign with a minimal packet size, we define custom Ethernet frame with customizable payload.

The remainder of this paper is organized as follows. In section 2, we describe architecture of system. Based on this architecture, in section 3 we present the implementation of our proposed system. The feasibility testing results are then discussed in section 4. Finally, we conclude our paper at section 5.

2. System Architecture

Fig. 1(a) illustrates the architecture of the proposed system. Our system consists of two main components: the sender module deployed at road sign and receiver module deployed at each vehicle. Notice that according to vehicular network specification described in Section 1, the sender module acts as Road Side Unit (RSU) while the receiver module acts as the On Board Unit (OBU). Both of OBU and RSU communicate each other using IEEE 802.11n with ad-hoc mode. We choose the ad-hoc mode rather than management mode since this kind of mode does not require additional handshaking time as if we utilize the management mode.

The mechanism of proposed system can be described with block diagram in Fig. 1(b). While a vehicle equipped with OBU is moving towards the communication range of RSU, it will make an

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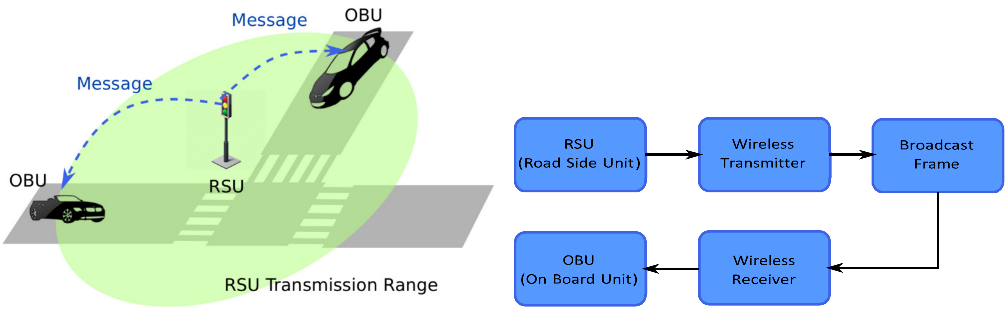
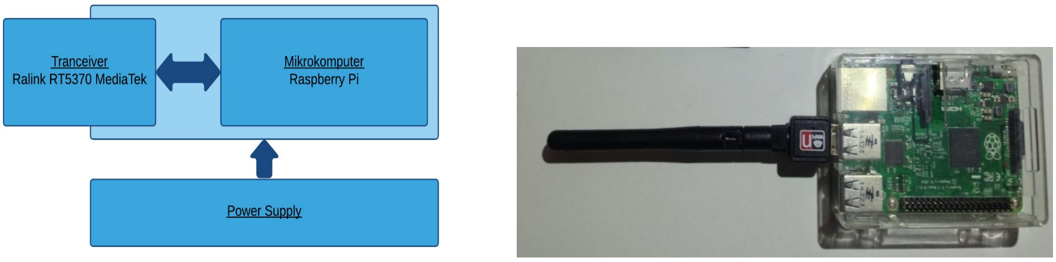
association to the wireless ad-hoc network with predefined ESSID. Once it is associated, then the OBU can receive the road sign information broadcast by the RSU. Upon receiving



(a)Systemarchitecture (b)Blockdiagram

Figure 1. System architecture and block diagram.



(a) Block diagram of OBU/RSU (b) Hardware implementation

Figure 2. OBU/RSU block diagram and implementation.

that information, the OBU module shows up an alarm notification to the driver indicating that the vehicle is approaching a road sign together with a certain signal. Furthermore, in order to reduce the size of message, instead of using the standard TCP/UDP/IP packet, we utilize the custom Ethernet frame with customizable frame type and payload.

3. Implementation

In this section we present the implementation of both RSU and OBU modules. The implementation is performed in both hardware and software part.

3.1. *Hardware Implementation*

Fig. 2 shows the block diagram of the hardware for both OBU and RSU. In general, the hardware part consists of two main components: processing and communication part. For processing part, we utilize microcomputer entitled Raspberry Pi Model B with 900 Mhz Quad Core CPU, 1 GB RAM, 4 USB ports and 40 GPIO pins. The Raspberry Pi is chosen since it provides enough computation power with the low power consumption. For the RSU part, the power consumption of the hardware can be an important issue since it can be deployed on the road with insufficient source of power. To perform the communication, processing part is equipped by the low cost IEEE 802.11n dongle with 2dBi internal antenna, -70+/-1dBm receive sensitivity, and 15+/-1dBm transmit sensitivity. The assembled hardware consisting of processing and communication part is shown in Fig. xxx.

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3.2. Software Implementation

For the software part, we utilize Python based Scapy framework to develop the application for both RSU and OBU part. Scapy itself is a framework for developing a network-based application [12]. With Scapy, we can send and sniff the packet, create a frame with custom payload and decode the incoming packet. Those features are important since we employ Layer 2 broadcasting to reduce the overhead in upper layer. Moreover, since each road sign may have different signal, its payload content can also be different.

```
class Infra (Packet) :
name = ”Test”
  fields _desc = [ LongField (”time” , 1) , LongField (”lon” , 2) ,
  LongField (”lat” , 3) , ShortField (”msg” , 0) ]
while (True):
   curr _time = time . time ()
  lon , lat , max _speed = 129.231212 , 30.1213234 , 60
  frame=Ether (dst=”ff:ff:ff:ff:ff:ff ” , type=0x8088)/ Infra (
      time=curr _time , lon=lon , lat=lat ,  msg=max _speed)
  sendp(frame , iface=”wlan1”)
```

Listing 1. Source code of RSU Application

Listing 1 shows the main code of application in RSU part. At first, we define the class containing all information that would be broadcast to all nearby vehicles. For example, we define the message for maximum speed road sign containing several fields including the current time, position of road sign in longitude/latitude format and the allowed maximum speed at that road segment. At next, the Ethernet frame with frame type **0x8088**. Since the RSU should send the frame to all OBUs connected to the similar ad-hoc network, the destination address is set to Layer 2 broadcast address **FF:FF:FF:FF:FF:FF**.

```
def packets (pkt) :
   if pkt.haslayer(Ether) :
    if pkt.type == 0x8088:pack = Infra(pkt.load ) print str(pkt.type )+’
      ’+str (pack.time )+’ ’+str (pack.lon )+’ ’+str (pack.lat )+’ ’+str
      (pack.msg)
 sniff ( iface=”wlan1” , prn = packets )
```

Listing 2. Source code of OBU Aplication

In the other side, the code of application in OBU part is shown in Listing 2. We first define the callback function which will be called once OBU receives any frame from outside. The callback function is then specified as a parameter of sniffing process performed by the **sniff()** function. The **sniff()** itself is a blocking function which means that its following code will not be executed until a frame received. Upon reception of a frame, it then checks whether the frame is Ethernet with type **0x8088** as predefined in RSU or not. If so, it then prints frame information including: source address, type and message.

4. Performance Testing

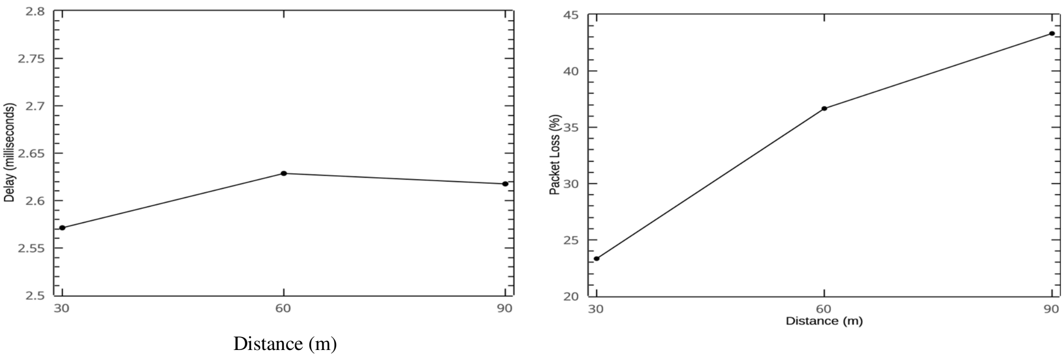
In this section, we present the performance testing result of our proposed system. We first present the testing environment and then, we shows the performance result and analysis.

4.1. Testing Environment

During the test, we place the RSU node in the junction and let the vehicle equipped with OBU to go on the road segment near that junction. The OBU node is moved along the road with following scenarios:

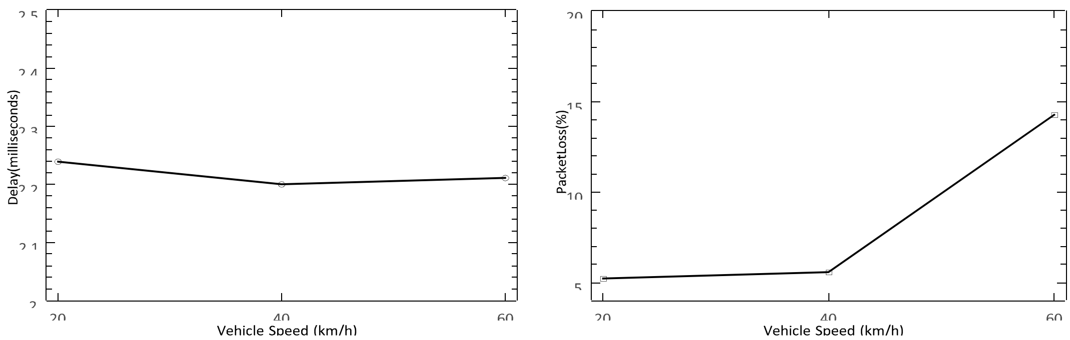
(i) The OBU moves along the road with various speed i.e. 10, 20, 30, 40km/h to measure the impact of vehicle speed on the performance of proposed system.

(ii) The OBU stop at various distance from the RSU i.e. 50, 100, 150m to measure the impact of OBU-to-RSU distance on the performance of proposed system.



(a) Delay (b) Packet loss

Figure 3. Delay and packet loss from different distance parameter.



(a) Delay (b) Packet loss

Figure 4. Delay and packet loss from different speed parameter.

For each of the scenario, we measure the performance of proposed system in term of delay (in milliseconds) and packet loss (in percent). In addition we also perform preliminary testing to measure the average communication range from RSU to OBU.

4.2. Testing Result

Fig. 3 (a) and (b) show the delay in milliseconds and packet loss in percent from different distance parameter respectively. From Fig. 3(a) we observe that the delay seems to increase a little bit as the distance increases. However, with average delay 2.61ms, if the vehicle is moving with the speed as fast as 100km/h or 30m/s and the RSU-to-OBU distance is as close as 30m, the message can still be delivered. On the other side, from Fig. 3 (b) we realize that the packet loss tends to significantly increase as the RSU-to-OBU distance increases. This trends can be happened due to the impact of wireless signal attenuation in which the transmission signal decreases as the transmitter-receiver distance increases.

We next examine the impact of vehicle speed to the performance of proposed system in term of delay and packet loss. Fig 4 (a) and (b) show the delay and packet loss from different vehicle speed parameter with fixed starting distance i.e. 60m respectively. From Fig. 4(a) we observe that the vehicle speed seems to have a little impact to the delay. On the other side, the packet loss significantly increases as the vehicle speed increases. This different pattern happened due to the utilization of non-reliable frame transmission in which the loss packet will not be retransmitted if the frame dropped, however, if the frame is successfully received, its delay is relatively small.

In the end, from overall results, we can observe that the proposed system is feasible enough to be implemented in road segment to vehicle signal delivery since the RSU is statically placed and its state shift can be predicted, and therefore, each vehicle may only need to receive the message at least once.

5. Conclusion

In this paper, we presented the implementation of a Wi-Fi-based electronic road sign for enhancing the awareness of vehicle driver. The proposed system consists of two components: The Road Side Unit (RSU) placed at road sign and the On-Board Unit (OBU) placed in the vehicle. While the OBU equipped vehicle is moving toward the RSU, it makes an association with the RSU through a predefined ad-hoc Wi-Fi connection. Once it is associated, OBU can receive the custom Ethernet frame broadcast by RSU containing specific road sign information. Upon reception, the OBU can show an alert message to the driver. From the performance testing we show that the proposed system is feasible enough to be implemented.

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