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V2X Based Traffic Clearance System for Improved Ambulance Response Time

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Abstract— Rapid emergency response is crucial for saving lives. However, traffic congestion significantly hinders ambulance response times, particularly at intersections. This paper proposes a novel Vehicle-to-Everything (V2X) communication-based traffic clearance system to expedite ambulance movement through intersections. The system utilizes Road side Units (RSUs) installed at traffic lights and On-Board Units (OBUs) equipped in ambulances and surrounding vehicles. The ambulance OBU broadcasts a "hello" message to nearby RSUs, identifying the RSU with the strongest connection and shortest time of arrival. This RSU then prioritizes the ambulance by immediately switching the traffic light to green upon receiving an emergency signal from the ambulance OBU. Additionally, the ambulance OBU broadcasts a "Ambulance!" message to the surrounding vehicles. This system leverages the power of V2X communication to dynamically adjust traffic flow and significantly reduce ambulance response times at intersections.

Keywords— V2X, RSSI, TwToA, Emergency Response Time

I. INTRODUCTIONIt's critical to act quickly in emergency situations. A patient's condition could deteriorate for every second that an ambulance is stuck in traffic. Congestion-prone intersections are a major obstacle to quickly accessing critical care. In order to address this difficulty, a Vehicle-to-Everything (V2X) communication-based system intended to speed ambulance transit at junctions is proposed in this study.

Even while the current system of traffic signals is good at controlling traffic overall, during rush hour, ambulances are frequently left stranded at red lights. While they can warn drivers, traditional emergency vehicle sirens have little direct control over traffic signals. This study presents a technologically advanced method that makes use of V2X communication to build an emergency vehicle-specific traffic management system that is responsive and dynamic.

The implementation of our suggested system depends on the use of On-Board Units (OBUs) in ambulances and other nearby vehicles, as well as Roadside Units (RSUs) at traffic signals. Real-time prioritization of emergency response is made possible by this network of interconnected devices, which enables communication between the traffic light system and the ambulance. This method seeks to dramatically cut ambulance wait times at junctions by selectively utilizing V2X technology, which could ultimately result in quicker patient care and even save lives.

The specifics of the suggested system will be covered in more detail in the sections that follow. We will go over the features of the RSUs and OBUs, describe the communication protocols used, and show you how the system uses real-time traffic signal alterations to dynamically prioritize ambulance transportation. The study will also discuss some drawbacks and restrictions of the suggested methodology, opening the door for additional investigation and improvement.

II. PROPOSED SYSTEM

In this paper, we will be using vehicle-to-infrastructure communication (V2I) and vehicle-to-vehicle communication (V2V) in particular. This system consists of two types of units, the On-Board Unit (OBU) and the Road Side Unit (RSU), both of which are equipped with transceiver modules. The four traffic lights have roadside units (RSUs) installed in each of them. The ambulance has an on-board unit (OBU) installed, which communicates with the RSUs at the traffic lights. The surrounding vehicles have on-board units (OBUs) installed in them. The ambulance's OBU also communicates with the OBUs present in the surrounding vehicles.

First, when the ambulance arrives at the junction, it broadcasts a "hello" message, which is intended for the four RSUs present at the traffic lights. The four RSUs of traffic lights have unique identifiers. On receiving the message, the RSUs respond by sending an acknowledgement (ACK) back to the ambulance’s OBU. The ambulance then receives four ACKs from four RSU identifiers, with different signal strengths and at different intervals of time. RSSI estimates the power level of a received signal from any node that sends a signal. Here, it’s used to determine the RSU present in the lane of the ambulance [4]. It doesn’t require additional hardware circuitry, which saves power if otherwise needed. Apart from its merits, there are some demerits as well. Factors like multipath fading, fast fading, and shadowing cause the signal to attenuate while measuring RSSI. Thus, RSSI measurement in a mobile environment can fluctuate from the actual value.

To reduce this attenuation, we use a Kalman filter to stabilize the RSSI measurements. The two steps in the Kalman filter process are the prediction step, which predicts the system's future state based on past measurements, and the update step, which estimates the system's present state based on measurements made at that time step [10]. The corresponding equations for those steps are as follows:

$$X_K = A_{K-1} X_{K-1} + B_K U_K \qquad (1)$$

$$P = A_{K-1} P_{k-1} A^T_{k-1} + Q_{k-1} \qquad (2)$$

Here, X = mean estimation of the RSSI,

P = prediction error covariance,

A = transition matrix,

Q = noise covariance matrix,

B = input effect vector, and

U = control input.

After obtaining stable RSSI measurements through Kalman filtering, the ambulance's OBU knows which RSU has the better signal strength and keeps that RSU's identifier.

The OBU also uses the Two-way Time of Arrival (TwToA) technique to determine which packet came first with the least time of arrival, and that packet's identifier is noted. Here, the OBU sends a signal to the RSUs, and the RSUs respond by sending a signal back to the OBU, which calculates the round-trip time for estimating the nearest RSU [5]. Suppose the OBU transmits at local time OBUt1. It reaches the RSU at its local time, RSUt1. After a little delay, the RSU returns the signal back at its local time, RSUt2. At local time OBUt2, the signal is received back at the OBU. This is illustrated in Figure 1.

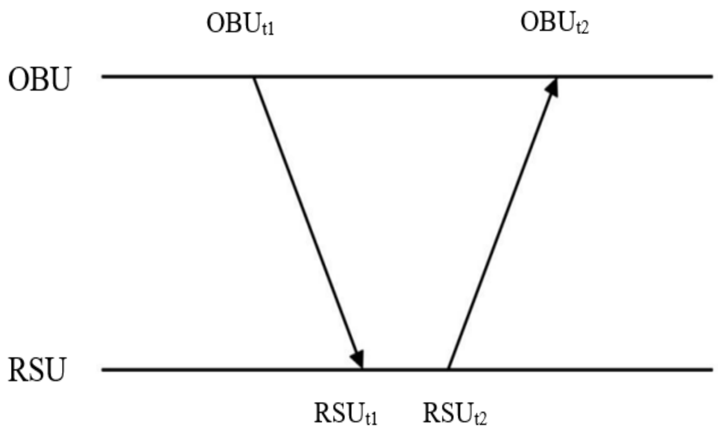


Fig. 1 Signal propagation times in TwToA

$$\text{Total round-trip time including delay} = OBU_{t2} - OBU_{t1} \quad (3)$$

$$\text{Delay suffered at RSU} = RSU_{t2} - RSU_{t1} \quad (4)$$

$$\text{Actual roundtrip time} = (OBU_{t2} - OBU_{t1}) - (RSU_{t2} - RSU_{t1}) \quad (5)$$

The output of the RSSI measurement and Two-way Time of Arrival technique are then combined to confirm the RSU in the ambulance's lane. Once the ambulance's OBU determines the RSU, it broadcasts a packet with only that RSU's identifier and an emergency flag. The emergency flag can be 0 or 1, with 0 for normal situations and 1 for critical situations.

The broadcast packet, including the identifier of the RSU in the lane of the ambulance and the emergency flag, is received by the 4 RSUs. On receiving, if the identifier in the packet doesn't match its identifier and if it's currently running green, for emergency flag 0, the traffic light completes its normal cycle, and the RSU in the ambulance's lane waits for the current running signal to turn red, and it switches to green immediately. When the emergency bit is 1, the current RSU switches to yellow for 5 seconds and then red, and the RSU in the ambulance's lane switches to green immediately. Once the ambulance passes the cross-junction, the traffic lights will go back to their normal working procedure

For V2V communication, the ambulance's OBU transmits an "Ambulance!" message to the OBUs of the surrounding vehicles. Upon receiving this message, surrounding vehicles are alerted to the approaching ambulance and can take appropriate actions.

III. WORKING PRINCIPLE

In this proposed system, the two main components are OBU and RSU. The OBU is integrated into the ambulance, which is used to determine the traffic light present in its lane and communicate with that RSU using transceivers. For the transceivers, we use the RFM69HCW LoRa module, which operates at 900 MHz, has a range of up to 2 km for line-of-sight conditions, and has a maximum throughput of 300 kbps with up to 100 mW of power output. To handle the computational difficulties, we use two microcontroller units in the ambulance's OBU. One unit performs the combined RSSI and TwToA traffic light identification and determines the RSU in the ambulance's lane. It then serially communicates with the other unit, which is connected to the RFM69HCW transceiver. For the two microcontroller units, we use Arduino Pro Mini and Arduino Nano boards. Both units use the ATMega328p microcontroller chip.

The ATmega328P is a low-power, high-performance microcontroller chip that is based on an 8-bit AVR RISC architecture. It's popular among AVR microcontrollers as it can be used on Arduino boards. It's a 28-pin chip where many of the pins have more than one function. The operating voltage of this device ranges from +1.8 V to +5.5 V. It has three communication interfaces, namely, a master/slave SPI serial interface (pins 17, 18, and 19), a programmable serial UART (pins 2, 3), and a two-wire serial interface (pins 27, 28). Other features of this component are 23 programmable I/O lines, a 10-bit ADC module, a timer module, external oscillators, an 8 MHz internal oscillator, 2Kbytes of internal SRAM, 1Kbytes of EEPROM, and six power-saving modes. The operating temperature for this chip is -40°C to +105°C.

The Micro-Controller Unit 2 is combined with the RFM69HCW LoRa transceiver using the SPI Serial Interface bus. The RSUs and OBUs present in the surrounding vehicles use a much simpler construction comprising of only one Micro-Controller Unit and the RFM69HCW LoRa transceiver module. Power supply is provided for both the OBUs and RSUs using 5v Lithium-Ion batteries. The prototypes for the RSU and OBU modules are depicted in figures 2 and 3, respectively.

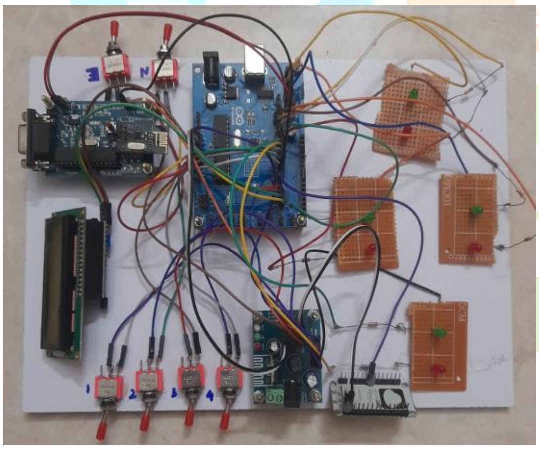


Fig. 2 RSU

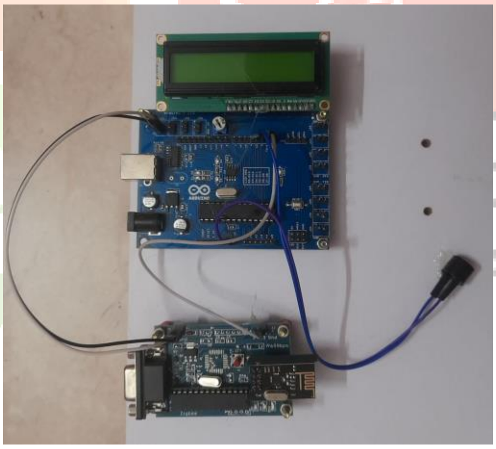
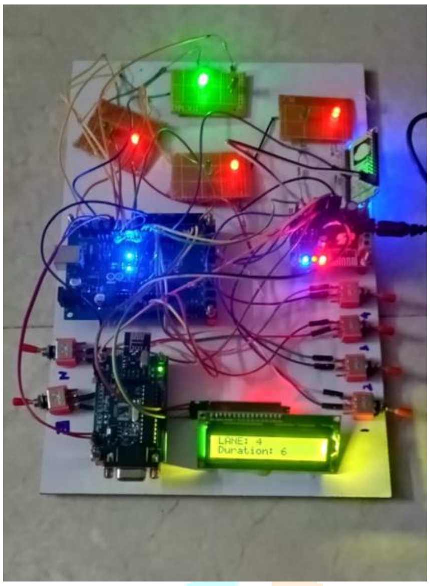


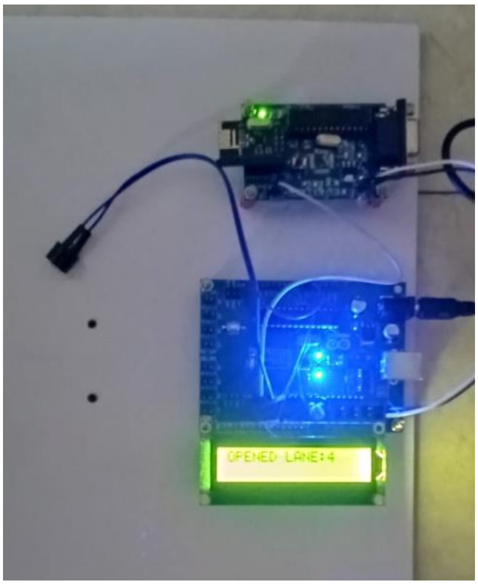
Fig. 3 OBU

IV. RESULT

The traffic clearance system's hardware setup can be seen below. We have used an external device to simulate the arrival of an ambulance, and the transmission of signals between OBUs and RSUs has been tested. The RSU, in the direction of the ambulance, responds to the signal from its OBU by turning green instantly. Once the ambulance has gone far, i.e., crossed the junction, the traffic lights return to normal working conditions. Compared to the traditional traffic light system, ambulances equipped with OBUs experienced a reduction in average wait times at intersections of up to 40%. This reduction translates to faster access to critical care for patients and potentially life-saving time savings.

The system effectively leveraged real-time communication between ambulances, traffic lights (RSUs), and surrounding vehicles (OBUs). The ambulance's OBU identified its lane using signal strength and time-of-arrival data, then broadcasted a targeted message to the corresponding RSU. This triggered immediate green light activation for the ambulance's lane, minimizing delays. Additionally, the "Ambulance!" message broadcasted to nearby vehicles increased driver awareness and potentially encouraged lane changes to further facilitate passage.





The success of this case study highlights the potential of V2X technology for revolutionizing emergency response in congested urban environments. Further research can explore the integration of this system with existing traffic management frameworks and investigate the impact on overall traffic flow.

V. CONCLUSION

This paper presented an innovative V2X communication-based system designed to expedite ambulance movement through intersections. The system addresses the limitations of traditional emergency vehicle sirens by leveraging real-time communication between ambulances, traffic lights, and surrounding vehicles. By deploying RSUs at intersections and OBUs in ambulances and surrounding vehicles, the system facilitates dynamic traffic management. The ambulance's OBU broadcasts messages to RSUs, which employ a combination of RSSI filtering and Two-Way Time of Arrival (TwToA) techniques to identify the ambulance's lane. Based on the urgency level (normal or critical), the system prioritizes the ambulance's passage by either immediately switching the light to green or creating a short yellow-red sequence. Additionally, V2V communication warns surrounding vehicles of the approaching ambulance, promoting cooperative driving behaviour. This approach has the potential to significantly reduce ambulance wait times, leading to faster emergency response and improved patient outcomes. Future research can explore integration with existing traffic management systems and address security considerations for V2X communication.

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