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Research Article

Vehicle To Vehicle Communication through VANET using Cognitive Radio Technology for Enhanced Spectrum Sensing

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ABSTRACT

As vehicles become more intelligent and connected, the ability for them to communicate directly with each other—known as vehicle-to-vehicle (V2V) communication—is becoming essential for safer and more efficient roads. Cognitive radios are capable of scanning their environment to detect unused spectrum, or "spectrum holes," allowing vehicles to exchange data without interfering with other devices. This dynamic spectrum access is especially useful in crowded traffic scenarios where reliable communication is critical. Our system is designed to transmit key information such as speed, engine temperature, and the distance to nearby vehicles—all in real time. The system is designed to continuously monitor and share key data from each vehicle, such as speed, engine temperature, and the distance to nearby vehicles. A simulation that replicates real-time communication between vehicles is uses in this. The results were promising—vehicles using cognitive radios were able to exchange information quickly and reliably, with fewer delays and better spectrum efficiency compared to traditional methods. A prototype is also used, where it helps vehicles share accurate information with each other without causing confusion or picking up unwanted signals and ensuring that cars can exchange critical data accurately, without adding noise or errors, helping drivers stay informed and make better decisions on the road.

Keywords: Traffic Optimization, Road safety, Enhanced Spectrum, Vehicle, Vehicle Communication, Cognitive Radio Frequencyg.

INTRODUCTION

In today's increasingly connected world, where devices, people, and systems are constantly communicating, the volume of data being exchanged is growing rapidly [1]. Managing this surge effectively is becoming a major challenge, and emerging technologies like Cognitive Radio (CR) offer promising solutions. CR has the potential to make communication systems more efficient by increasing capacity, reducing delays, and improving energy use [5]. These networks are designed to be adaptive, allowing wireless devices to sense their environment and adjust their communication in real time. This capability is especially valuable in Vehicle-to-Vehicle (V2V) communication, where vehicles need to exchange information instantly and reliably to ensure safety and improve driving decisions. As transportation becomes more integrated with smart technology, how we travel is changing dramatically [4]. Vehicles, being one of the most common spaces we spend time in, have become a major area of focus for wireless communication development. The IEEE 802.11p standard was created to support V2V and Vehicle-to-Infrastructure (V2I) communication using Dedicated Short-Range Communication (DSRC) in the 5.9 GHz frequency band. This allows cars to share data quickly and directly without needing a central network, which is vital for time-sensitive features like collision avoidance and emergency braking alerts [3][12]. However, the technology has some limitations, particularly its range—usually between 300 meters and 1 kilometer—which may lead to inconsistent connectivity in areas with poor infrastructure [16]. Because of this, alternative solutions like Cellular V2X (C-V2X) are gaining interest for their extended range and improved reliability. This research explores how cognitive radio can be used to

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enhance V2V systems. It begins with a review of current research on V2V communication using cognitive technologies, followed by a proposed method that incorporates CR features such as spectrum sensing, channel selection, noise analysis, and signal optimization to ensure efficient and safe data exchange between vehicles. The goal is to demonstrate how CR can improve the reliability and performance of vehicular networks by reducing interference, avoiding data collisions, and enabling vehicles to share accurate, real-time information even in complex environments.

LITERATURE SURVEY:

Vehicle-to-Vehicle (V2V) communication systems have advanced rapidly, especially with the introduction of cognitive radio technology to solve communication challenges in vehicle networks. For example, [1] proposed a method that forms clusters of vehicles based on their speed and location, helping improve how data is shared. Building on this idea, our system uses cognitive radio to manage spectrum access more effectively, improving how communication resources are used. In [2], researchers worked on improving road safety by sending real-time collision warnings between vehicles. However, their system depends on fixed communication channels. Our approach improves reliability by using cognitive radio to find and use the best available channels on the fly. Delays in message delivery, especially in heavy traffic, were the focus of [3]. Our system helps reduce these delays by using cognitive radio to quickly sense and switch to better spectrum channels, enabling faster communication.The protocol introduced in [4] reduces message congestion in vehicular networks. While their work focuses on simplifying communication, our system takes it further by using cognitive radio to adapt to real-time changes in the communication environment, especially in crowded areas. Study [5] explored how combining cognitive radio with multiple radio technologies can improve bandwidth use and reduce interference. We use a similar method to maintain strong, clear signals even in high-traffic zones.Another important aspect is how movement affects signal quality. [6] simulated this using the Doppler effect. Our MATLAB simulations also consider vehicle motion and Doppler effects to ensure that signals remain clear when vehicles are moving fast. Accurate vehicle positioning is also critical. In [7], GPS and sensor data were combined to improve positioning accuracy. Our system uses this type of data to make sure vehicles can exchange information accurately and in real time. Study [8] showed how V2V communication can reduce accidents and increase highway capacity. Their system used sensors for crash avoidance. Our approach adds cognitive radio to send timely and reliable data, improving both safety and traffic flow.In [9], the benefits of V2V communication in smart transportation systems (ITS) were discussed, like real-time road condition alerts and traffic updates. We expand on this by using cognitive radio to improve spectrum use and communication reliability in ITS environments.Lastly, [10] looked at the IEEE 802.11p standard, which has issues with channel access in busy areas. Our system solves this by using cognitive radio to dynamically manage the spectrum, ensuring better performance even when traffic is dense.Overall, integrating cognitive radio into V2V systems helps solve key issues like limited spectrum, interference, and slow data transmission—leading to safer, faster, and more reliable vehicle communication.

PROPOSED METHODOLOGY

The proposed system uses a Cognitive Radio (CR)-based communication model to make Vehicle-to-Vehicle (V2V) communication smarter and more efficient. Each vehicle is equipped with a cognitive transceiver and a set of sensors that monitor important factors like speed, temperature, vibration, alcohol levels, distance from nearby objects, and tire pressure.This sensor data is transmitted in real-time using the best available radio-frequency channels, thanks to the system's ability to dynamically switch between channels. By doing this, the system avoids interference and makes the most efficient use of available bandwidth.To keep the data organized and trustworthy, every vehicle is assigned a unique identifier. So, for instance, if Vehicle 1 (V1) receives information from Vehicle 2 (V2) and Vehicle 3 (V3), it can clearly identify the sources as V2d and V3d — where 'd' stands for their unique addresses.This setup allows vehicles to continuously share and receive real-time updates about traffic conditions, road status, and the operational state of nearby vehicles. By having a complete and constantly updated view of their surroundings, vehicles can better anticipate potential hazards and respond proactively to avoid them. Thanks to cognitive radio, communication stays smooth and uninterrupted, even in areas with heavy network traffic, as the system can bypass congested channels. Altogether, this intelligent and collaborative communication system enhances road safety, reduces the risk of accidents, improves traffic flow, and creates a safer, more informed driving experience. A simple work flow is shown in Fig.1 .

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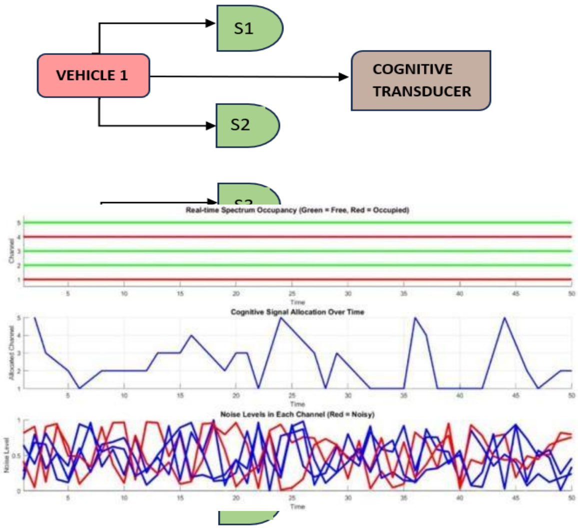

Fig. 1. Block Diagram of V2V using Cognitive Radio Frequency

RESULT AND DISCUSSION

The proposed Cognitive Radio (CR)-based V2V communication system was evaluated using MATLAB simulations and a hardware prototype. The simulations showed that CR-enabled vehicles could dynamically identify and switch to vacant channels more efficiently shown in Fig.2.

Fig. 2. Bandwidth selection of cognitive radio Frequency

This led to improved signal clarity, reduced latency, and better reliability, especially in high-density traffic scenarios. Techniques like matched filter detection shown in Fig. 3 with BPSK and Power Spectral Density (PSD) analysis confirmed the system's accuracy in detecting available channels, ensuring consistent communication even under high mobility and Doppler effects.

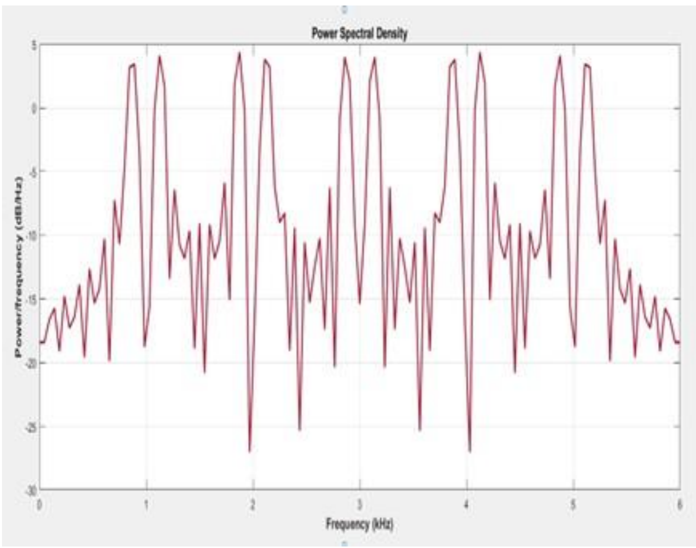

Fig. 3. Spectrum Sensing of unused spectrum

Prototype testing further validated the system, successfully transmitting real-time sensor data such as speed, engine temperature, and proximity. Adaptive techniques like frequency hopping allowed stable communication in

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interference-prone areas. Compared to conventional systems, the CR-based approach delivered lower latency, higher transmission success rates, and better spectrum efficiency. These results highlight CR's potential to enhance V2V communication, particularly in urban traffic and safety-critical applications like collision avoidance and emergency navigation, making it a viable solution for future intelligent transportation systems.

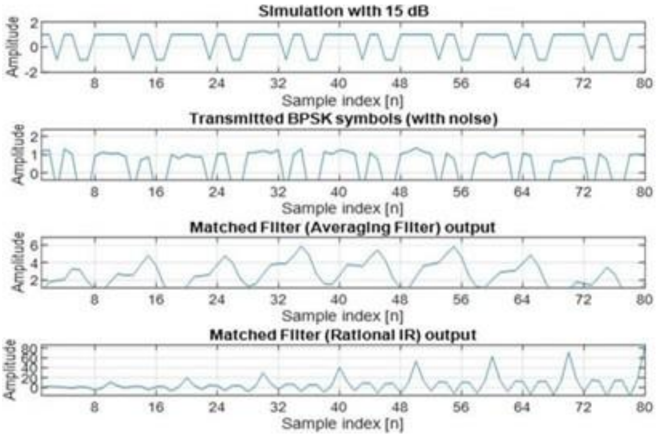

Fig. 6. Spectrum occupancy indicating high and low noises

CONCLUSION

Cognitive radio (CR) technology plays an increasingly important role in advancing Vehicle-to-Vehicle (V2V) communication by enabling dynamic and efficient use of the wireless spectrum. Although its integration into vehicular networks is still developing, CR shows great promise in transforming how vehicles communicate—particularly as the demand for intelligent transportation systems grows alongside a booming automotive market. One major motivation for this advancement is the rising number of traffic-related fatalities, especially those resulting from collisions between emergency vehicles and standard traffic at busy urban intersections. This has led both government agencies and automotive manufacturers to ramp up investments in intelligent communication technologies. Cognitive radio systems improve vehicular communication by intelligently managing the radio spectrum to reduce channel interference and prevent data packet collisions. Each vehicle in the network is assigned a unique identifier, which ensures accurate source recognition and prevents disruption during data exchanges. These vehicles are equipped with sensors that detect obstacles and collect environmental data in real time, enabling informed and timely decision-making.

The system operates through techniques such as frequency hopping, adaptive bandwidth control, and modulation variations (including amplitude, frequency, and phase modulation) to transmit vital information like speed and positioning. To identify which channels are occupied or free, the system employs Binary Phase Shift Keying (BPSK)-based matched filter detection. This method enhances signal clarity by filtering out noise and avoiding false channel detection. Graphical analysis of the system's behavior—such as Power Spectral Density (PSD) plots—illustrates how signal power varies across channels, with active channels (e.g., channels 1, 3, 4, and 5) showing higher energy levels compared to vacant ones (e.g., channel 2). Looking ahead, the proposed design includes a real-time interactive model integrated within vehicles. This model incorporates recursive feedback mechanisms to maintain stable communication and ensure that data is exchanged reliably, without signal loss or interference. As the technology continues to mature, cognitive radio is expected to significantly improve the performance, safety, and dependability of future vehicular communication systems.

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