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ORIGINAL RESEARCH ARTICLE

Wireless sensor network based V2V connectivity in VANET

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ABSTRACT

When it comes to vehicular ad hoc networks (VANETs) and vehicle-to-vehicle (V2V) communication, wireless sensor networks (WSNs) are crucial for enhancing vehicle connectivity. An essential technology that enables vehicle-to-vehicle networking is IEEE 802.11p. This research presents a novel method for improving V to V interaction through the use of wireless sensors networks (WSNs), which overcomes limitations such as limited data transmission capacity and dynamic network topologies. The optimal data exchange rate can be determined by implementing rate adaptation algorithms, which take channel characteristics like data losses into account. The incorporation of sensors in automobiles establishes a decentralized network that enables the instantaneous conversion of data, encompassing traffic locations, road dangers, and vehicle positions. WSN-based V2V networking facilitates the creation of intelligent transportation networks, enabling vehicles to make educated decisions by exchanging information. The purpose of this research is to enhance the creation of modern connectivity systems using VANET and examine the results through effective simulation using NS2.35.

Keywords: rate adaptation; vehicle-to-vehicle safety communications

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1. Introduction

VANET, short for Vehicular Ad Hoc Network, was first established in the early 2000s. It is a type of network that enables communication between vehicles via mobile ad hoc networks. These networks are built by automobiles and allow them to share information with each other[1]. It has been demonstrated that both edge equipment coexists in VANETs to ensure safety on the road, road side infrastructure, and navigation. VANETs are a revolutionary concept in intelligent transportation systems, designed to tackle the emerging issues of contemporary road networks. These networks are purposefully designed to enhance communication between vehicles, establishing a dynamic and integrated automotive ecology[2].

To improve drivers' understanding of their surroundings, reduce traffic congestion, and prevent accidents. The exchange of information is made possible by utilizing specialized short-range communication protocols like DSRC and LTE-V2X[3]. This establishes a network where cars serve as both recipients of data and intermediaries for transmitting it. Wireless sensor networks, or WSN for short, are being included into vehicle ad hoc network (VANETs are networks). Wireless sensor networks (WSNs) provide a network of strategically positioned sensors in vehicles to enable uninterrupted communication[4,5]. The objective of this integration is to enhance safety, optimize efficiency, and enhance overall communication among vehicles in dynamic conditions[6].

The implementation of wireless sensor network (WSN) represents a notable progress in V2V safety communications. WSN is a dynamic adaption method that distinguishes and reduces data loss rates, guaranteeing prompt and secure information sharing among vehicles. This will be achieved by strategically placing sensors and utilizing sophisticated information fusion techniques. This integration provides valuable insights on possible breakthroughs in vehicle communication and safety.

2. Literature review

Ma et al. identify to find the delay and transmission acceptance rates for interstate safety applications in automobile ad hoc network was put up by in the proceedings of mobile networking for automotive environments. To assess how well the V2V activities in the DSRC system worked on highways, an analytical and simulation-based study was carried out[7].

Khabazian and Ali designed an article called "A model for the performance and connectivity in vehicular ad hoc networks." Taking user mobility into account, the researchers examine the statistical traits of the connection in VANETs[8].

Sadeghi et al. introduced the "Advantageous utilization of media in multirate informal networks". Using the Potential Auto Rates (OAR) protocol to its full potential in high-quality channel optimization is the primary goal of this research[9].

Xia et al. proposed the "Model-tree-based rate adjusting scheme for automotive networks". The study looks into MTRA, a self-adapting model-tree rate adaptation system. This method can make real-time adjustments to the data rate and forecast the packet error rate. When it comes to automobile networks, MTRA is superior than other rate adaptation algorithms[10].

Liu et al. proposed the "GERA: Generic rate adjustment for vehicular networks." Using data on context and signal intensity, the paper presents GERA, a novel rate adaptation system that accurately assesses channel conditions. It outperforms traditional rate adaptation algorithms in real-world driving scenarios and achieves higher data transfer rates[11].

Punal et al. proposed the paper "RFRA: Random forests rate adaptability for vehicular networks". Using the AI algorithm Random Forests, the researchers investigate the rate adaptation approach for vehicle networks. Particularly when it comes to propagation properties, RFRA outperforms other learning-based techniques[12].

Wong et al. introduced the "Robust rate adaptation in 802.11 radio networks". A new Robust Rate Adaptation Algorithm (RRAA) is proposed after the authors examine the current 802.11 rate adaptation rules. With an improvement in throughput of up to 142% across the board, RRAA outperforms three well-established rate adaption methods[13].

Cao et al. focused on the performance of vehicle-to-vehicle (V2V) communication adopting the Dedicated Short Range Communication (DSRC) application in periodic broadcast mode. An analytical model is studied and a fixed point method is used to analyze the packet delivery ratio (PDR) and mean delay based on the IEEE 802.11p standard in a fully connected network under the assumption of perfect PHY performance. With the characteristics of V2V communication, develop the Semi-persistent Contention Density Control (SpCDC) scheme to improve the DSRC performance. The simulation results show that the packet delivery ratio in SpCDC scheme increases more than 10% compared with IEEE 802.11p in heavy vehicle load scenarios. Meanwhile, the mean reception delay decreases more than 50%, which provides more reliable road safety[14].

Garcia et al. discussed about the Third Generation Partnership Project (3GPP) Release 16 5G NR V2X standard for V2X communications, with a particular focus on the sidelink, since it is the most significant part of 5G NR V2X. The main part of the paper is an in-depth treatment of the key aspects of 5G NR V2X: the physical layer, the resource allocation, the quality of service management, the enhancements introduced to the Uu interface and the mobility management for V2N (Vehicle to Network) communications, as well as the co-existence mechanisms between 5G NR V2X and LTE V2X. Review the use cases, the system architecture, and describe the evaluation methodology and simulation assumptions for 5G NR V2X. Finally, provide an outlook on possible 5G NR V2X enhancements, including those identified within Release 17[15].

Cao et al. analyzed the parameters of Semi-Persistent Scheduling (SPS) used for Basic Safety Messages (BSMs) scheduling in NR-V2X Mode 2 from an Age-of-Information (AoI) perspective, to explore the freshness of BSMs. We first present an analytical model to illustrate that Resource Reservation Interval (RRI) is the SPS parameter which significantly impacts the AoI performance. Subsequently, investigate the expected peak AoI (PAoI) performance with respect to RRI values under different vehicle densities. A Monte Carlo simulator is then utilized to verify the results obtained in the analytical models. Numerical results show that the optimal RRI values in SPS, which minimize the expected PAoI of the vehicular network, can be obtained based on different vehicle densities accordingly[16].

Problem identification

1) Restricted scope: One of the primary obstacles is the constrained range of the Bluetooth sensors. This can lead to complications regarding the extent and dependability of the network, particularly in more expansive regions. Moreover, wireless connectivity in VANETs can be influenced by interference and transmission attenuation, especially in urban settings with skyscrapers. These elements can influence the whole efficiency and efficacy of the V to V connectivity.
2) Privacy concerns: The continuous sharing of knowledge in VANETs, such as location and speed data, gives rise to privacy issues. Safeguarding the confidentiality of individuals' personal information while maintaining efficient communication is a substantial obstacle.
3) Service quality concerns: Ensuring high-quality service (QoS) in VANETs, especially for time-sensitive applications, can be difficult due to fluctuations in network conditions.
4) Dependencies on infrastructure: VANET applications may require the utilization of roadside facilities such as curbside units, which might affect the scalability and implementation of VANETs in some areas.

3. Proposed methodology

The system architecture of the proposed sensor network wireless Based V2V Connection is illustrated in **Figure 1**. For this work, it is assumed that each car has the capability to get its precise location using a GPS device. Neighboring cars share positions through V2V communications. Consequently, every vehicle has the ability to compute the distances between all adjacent vehicles and the state of traffic at the application layer[17–20].

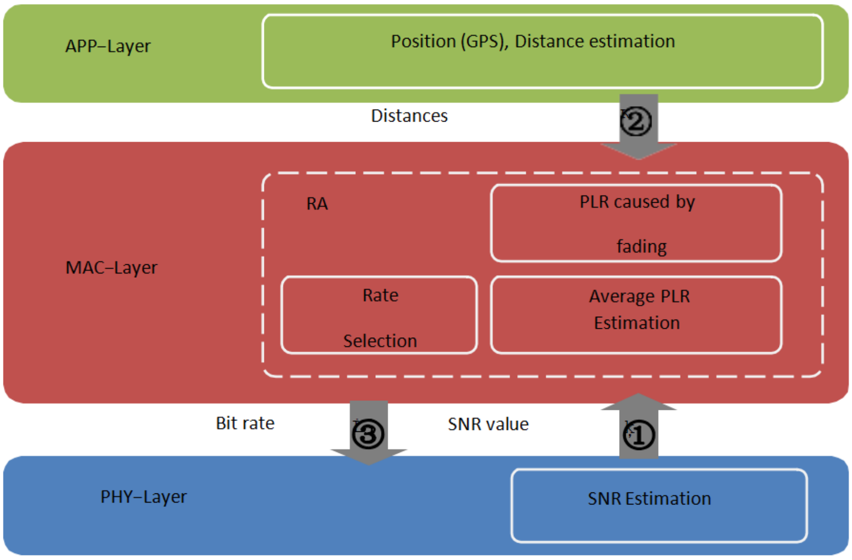


Figure 1. Proposed system architecture.

3.1. Application layer

The application-layer the VANET protocols should be developed utilizing overlay phases rather than relying on earlier examinations[21]. The proposed overlay standard differs significantly from the aforementioned research in a number of important respects. To improve the dependability of package delivery, we first set up overlay organizations to maximize the organizational redundancy of preexisting businesses. In the event that the main way is either unavailable or overloaded, this article presents an overlay-based approach that attempts to redirect packages via a different path[22,23].

In addition, application-layer overlay networks are build using preexisting VANET routing protocols, which means that these protocols are superimposed on top of hidden direction conventions. All of these things make it easier to take use of the current VANET standards' strengths while mitigating their weaknesses through the suggested layer structures.

3.2. Media access control (MAC) layer

The MAC layer is responsible for managing the flow of data and multiplexing on the transmission channel, whereas the LLC layer conducts same tasks for the logical connection, including EtherType and 802.1Q VLAN tag.

Collectively, these two sublayers constitute layer 2 of the OSI model. The use of LLC is mandatory for the implementation of other IEEE 802 physical level standards, but it is not necessary for IEEE 802.3 implementations. In the latter case, the frames are considered "raw" to address compatibility issues. Within the hierarchical structure of the IEEE 802 and OSI models.

3.3. Estimation of average PLR

When assessing the overall dependability of single-jump broadcast, the PLRAVG within the security range (Lsr) on a designated hub is used as a parameter. The receiver often estimates the loss of a parcel when in unicast mode and relays this information to the sender in the acknowledgement frame. Keep in mind that the sender can't receive any channel details from the receiver when in broadcast mode and that there is no acknowledgments (ACK) mechanism either[24]. A model-based technique is used to evaluate the average PLR to tackle this issue. The chance of a package going missing between the specified origin point and a receiver at an angle r is

$$p(r, \mathrm{Sth}) = \mathrm{P}\{\mathrm{SINR} < \mathrm{Sth}\} \quad (1)$$

where SINR is determined as

$$\begin{aligned} \text{SINR} &= \text{P}\{(\text{Pr}(r)/I(\text{r}) + \text{WN}) < \text{Sth}\} \\ &= \text{P}\{(\text{Pp}(r)\text{Ps}/I(r) + \text{WN}) < \text{Sth}\} \\ &= \text{P}\{\text{Ps}(r) < (\text{Sth}(I(r) + \text{WN})/\text{Pp}(r)\} \end{aligned} \quad (2)$$

Given that Ps is modeled by an average deviation of a zero-mean log-normal distributed $\sigma 1$ and $\sigma 2$, we can conclude that

$$\text{pf}(r, \text{Sth}) = \{\Phi(\ln[\text{Sth}(I(r)+\text{WN})/\text{Pp}(r)])/\sigma 1,\ \text{d0} \le r \le \text{dc} \quad \Phi(\ln[\text{Sth}(\text{I}(r)+\text{WN})/\text{Pp}(r)])/\sigma 2,\ r > \text{dc}\} \quad (3)$$

Φ is the total capacity for appropriation of the normal typical appropriation.

$$\text{PLR}_{\text{AVG}} = 1/n \sum_{k=1}^{n} (rk, Sth), rk \le Lsr, \quad (4)$$

The number of automobiles inside the designated hub's security zone is represented by *n*, while the distance between the designated hub and the kth hub is denoted by *rk*. Our goal is to replicate this model using the SINR2P LR capabilities and calculate the average loss of path ratio (PLRAVG). Nevertheless, measurements on the real testbed are required to ascertain the precise boundaries of SINR2P Lf in devices.

3.4. Prediction of the channel's state

The Transmission Losses Ratio (PLR), which is affected by channel blurring, is used as a measure to assess the channel's effectiveness, as seen in PLRF Advertising. This article describes how to weaken a mobile channel's transmission with little interference. Our comparative analysis is centered on the 802.11p norm, while Shankar's estimations depend on the 802.11a standard[25–27]. This is the only difference between our two analyses, but they are otherwise identical. The picture shows the scenario. The TX hub will intermittently exchange WSMP messages throughout the probe.

The car is drawing near the TX hub before turning away from it to become the RX hub. When in motion, the car will stop for a short while and keep some distance away from the TX hub. We gather GPS data and the strength of the received signal. As the distance increases over time, **Figure 1** shows the growth of the power level obtained and PLRF advertisements. It can be shown that the amount of power received varies between 4 and 6 dB, with rare maxima reaching 10 to 12 dB, based on this observation. At a respectable distance, the PLRF propagation fluctuation is smooth[28–30].

According to the findings, the influence of substantial scale obscuring on the obtained power intensity components may be captured by distance. Because of the strong correlation between PLR and signal-to-noise ratio (SNR), the distance may be used as an accurate measure of PLR enhancement. Our goal in the preceding sentence is to use the range data to determine the development of PLRF.

By employing the same methods as a standard PLR assessment, we may determine the PLR resulting from the blurring of a central point located at a distance r from the designated central point. Under these circumstances, there is no external agent causing interference, resulting in the typical blockage power $I(r)$ being zero.

Thus, the probability of loss due to channel blurring is reduced.

$$\begin{aligned} \text{pf}(r, \text{STh}) &= \text{P}\{\text{SNR} < \text{STh}\} \\ &= \text{P}\{\text{Pr}(r)/\text{WN} < \text{Sth}\} \end{aligned} \quad (5)$$

Then, we have

$$\text{pf}\,(r, \text{Sth}) = \{\ \Phi(\ln[\text{Sth WN}/\text{Pp}(r)]/\sigma 1),\ \text{d0} \le r \le \text{dc}, \quad \Phi(\ln[\text{Sth WN}/\text{Pp(r)}]/\sigma 2),\ r > \text{dc} \quad (6)$$

At last, the PLR brought about by blurring is given as

$$\text{PLRF Promotion} = 1/n \sum_{k=1}^{n} pf(rk, Sth), rk \leq Lsr \tag{7}$$

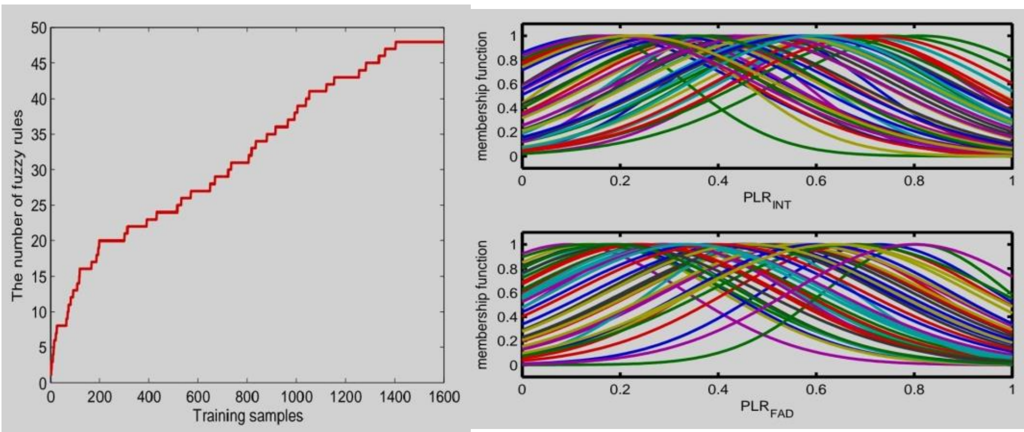
Consider the labeled hub as having a safety range of *n* automobiles, and the distance between the *k*-th hub and the one marked hub as *rk*. To determine how much parcel damage occurs in the simulation model due to blurring, we use the Dis2P LR capability. For tasks to be executed on actual devices, precise determination of the boundary setting is required[31].

3.5. Rate selection method

By using the average power line rate (PLRAVG) and the power line rate resulting from channel blurring (PLRF Promotion), we can calculate the power line rate due to impedance (PLRINT). Thus far, we can distinguish PLRF Marketing and PLRINT from that broader category of PLR. This subsection will comprehensively present the calculation for rate determination, taking into account both PLRF Promo and PLRINT. Due to the lack of precise assessment of the advantages of PLRF Enhancement and PLRINT, we employ a fuzzy logic approach to address this issue. The Fluffy hypothesis is effective in presenting inaccurate information. However, devising a strategy for organizing the elements of enrollment data factors and fluffy rules is a challenging problem, particularly in the field of vehicular management. The variations in traffic concentrations and channel circumstances result in a vast number of combinations[32].

Self-Sorting out follows. **Figure 2** shows the preparation cycle of SOFNN (a) the growth of fuzzy rules (b) input membership functions. SOFNN, or fuzzy brain organization, is able to autonomously construct roles and fuzzy rules in addition to using fuzzy logic for issue description. We can maximise the benefits of PLRF Marketing or PLRINT (from 0 to 1) by modifying traffic population density, thermal bruit authority, and security distance.

After that, we record the maximum data transfer rate in every test after running comprehensive simulations utilizing several data sources (PLRF In and PLRINT). Three thousand two hundred similarities have been found between the information being provided and the output. In order to prepare the SOFNN, a grand total of 1600 data points are utilized.



(a) **(b)**

Figure 2. The preparation cycle of SOFNN **(a)** the growth of fuzzy rules; **(b)** input membership functions.

A total of 45 fluffy standards have been established, resulting in each one having 45 participation capabilities. It is evident that the data rate reaches 3 Mbps when the P LRF Promotion increases and the PLRINT decreases. In this situation, the primary consequence is the blurring of the channel[33,34].

Because of this, we have to go with a reduced data rate so we can survive the bad channel. Nevertheless, it is observed that the data selected frequency tends to grow with increasing PLRINT. An increase in PLRINT suggests that the automotive organization is experiencing a greater variety of effects.

4. Results and discussion

This section clearly discusses the performance evaluation of the proposed approach. The evaluations are carried out based on the packet loss ratio and the data rate selection metrics. In comparison to other systems, the full DCC approach attained minimal packet loss rate (**Figure 3a**). On the other hand, there are temporal fluctuations in the complete DCC reliability curve. Compared to the full DCC standard, LORA’s PLRAVG is somewhat higher, but its adjustments are more gradual. Also, at the most busy part of the main street, LORAwold/DCC-TDC’s dependability drops dramatically. The full DCC convention displays a large variety of bundle deferral durations over an extended amount of time, as seen in **Figure 3b**. Also, that three seconds is far from the ideal delay. To meet the needs of security-related uses, the latency of different algorithms is always less than 100 ms. The frequently obtained clusters of all automobiles within the selected hub’s safe range are shown in **Figure 3c**. The total amount of the LORA program assemblies, at different densities, is clearly much closer to ten packets per second. On the other hand, when traffic isn’t too heavy, the entire DCC conference is worth a lot more than when it’s jammed. In addition, moves are a part of the overall trend of the DCC conference. The simulation findings demonstrate that wireless sensor network (WSN) based vehicle-to-vehicle (V2V) Connectivity in vehicular ad-hoc networks (VANET) outperforms both LORA and DCC approaches. The conclusive findings demonstrate that the DCC approach surpasses the existing method in terms of efficiency.

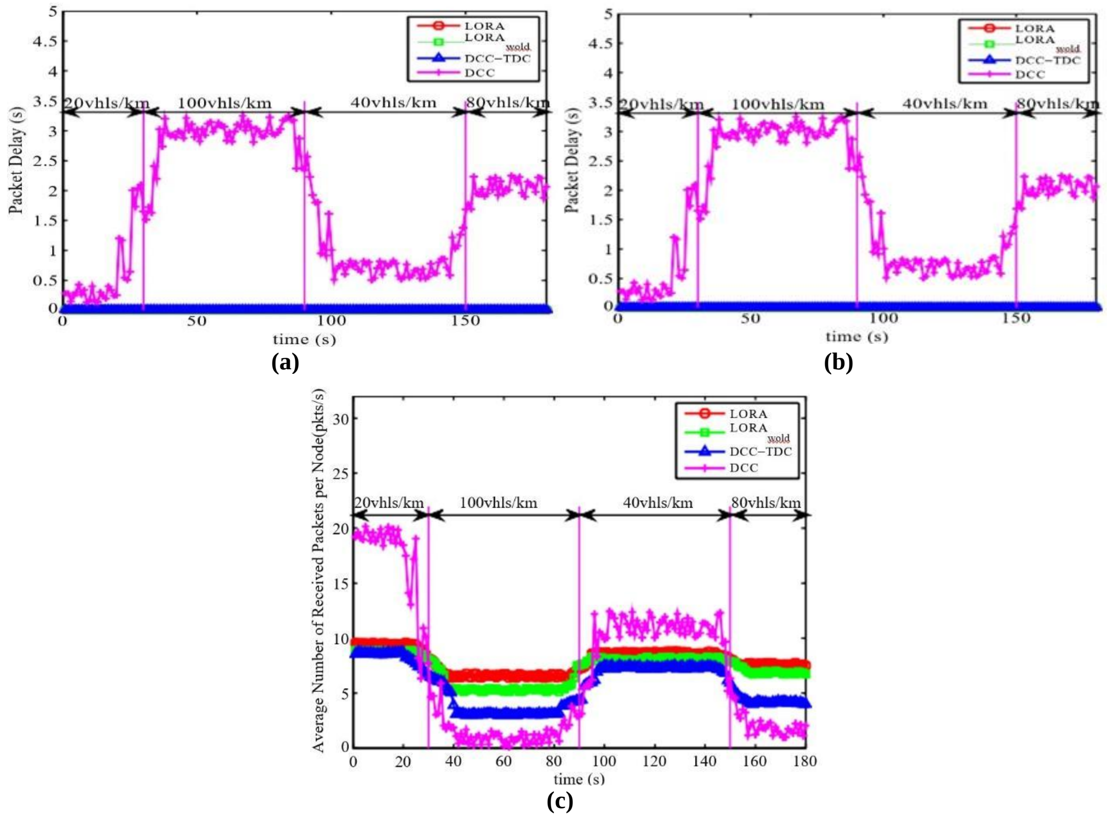
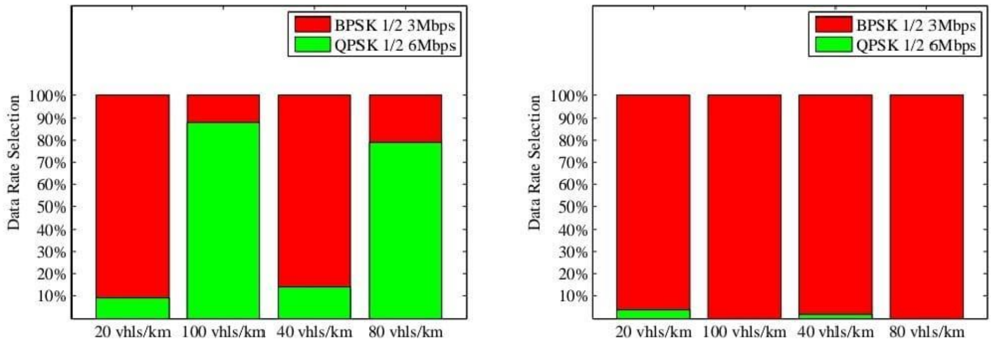


Figure 3. The results of comparison with traffic density dynamic, **(a)** PLR AVG; **(b)** packet delay; **(c)** average no of received packet, the results of comparison with traffic density dynamic.

At varying traffic concentrations, **Figure 4a** shows the LORA data rates and **Figure 4b** shows the LORAwold rate of data. LORAwold uses the PLRAVG as its only metric for determining the information rate. In most cases, it assumes poor channel quality and hence cannot reliably identify if the decreased effect is caused by an upper limit of 3 Mbps, even though it modifies the data rate depending on fluctuations in the level of signal. This observation illustrates the need of the misfortune separation component in LORA for accurate data rate selection in an environment with high interference. The simulation findings demonstrate that wireless sensor network (WSN) based vehicle-to-vehicle (V2V) Connectivity in vehicular ad-hoc networks (VANET) outperforms both LORA and DCC approaches. The final findings demonstrate that the suggested approach achieves greater data transmission rates compared to existing methods. Based on thorough evaluations and research, LORA surpasses other plans in terms of reliability, performance, and stability.



(a) **(b)**

Figure 4. Data rate selection with the traffic density dynamic **(a)** data rates of LORA; **(b)** data rates of LORAwold.

5. Conclusion

Therefore, this study examined and applied a network of wireless sensors (WSN) that utilizes vehicle-to-vehicle (V2V) connectivity in order to calculate automated systems for transportation in road side contexts. Additionally, a simulated analysis was conducted using scientific models for dedicated short distance communications to automobiles with safety connection in the surrounding environment. The implementation findings demonstrate that networks of wireless sensors (WSNs) are well-suited for achieving higher levels of accuracy, packet delivery ratios, and data transfer rates. Furthermore, this study yielded further insights on road side safety, such as low energy consumption, extensive range connectivity, dependability, blind spot alerts, backwards and forwards collision data, ideal speed guidance, and accident particulars.

Author contributions

Conceptualization, RU and MP; methodology, NKS; software, BGMB; validation, SG, TM and RSS; formal analysis, PES; investigation, NKS; resources, TM; data curation, RSS; writing—original draft preparation, RU; writing—review and editing, MP; visualization, NKS; supervision, PES; project administration, RSS. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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