FULOKOJA-2024
FEDERAL UNIVERSITY, LOKOJA, KOGI STATE, NIGERIA-CONFERENCE 2024
The Proceeding of 29th Multidisciplinary Academic Conference, Hummingbird Publications and Research International on African Creativity towards Sustainable Development Goals: Multidisciplinary Approach. Vol. 29 No. 1, 29th-31st January, 2024 at Federal University, Lokoja, Kogi State, Nigeria.

SPEED-BASED RELAY SELECTION IN VEHICLE-TO-VEHICLE (V2V): A REVIEW

ABDULSALAM ONIMISI MUSA; NATHANIEL SALAWU; & ABUBAKAR SADDIQ MOHAMMED
Department of Telecommunications Engineering, Federal University of Technology, Minna, Niger State

Abstract
Vehicle-to-vehicle (V2V) communication holds immense potential for improving road safety and traffic efficiency by enabling information exchange between vehicles. However, reliable data transmission in dynamic traffic environments poses significant challenges. This study explores speed-based relay selection as a novel approach to enhance V2V performance. In contrast to traditional methods focusing on signal strength or distance, this approach prioritizes faster vehicles as relays, aiming to reduce latency and improve reliability. While promising, speed-based selection faces challenges like accurate speed estimation, temporal variability, and scalability. Future research directions include advanced speed estimation techniques, adaptive selection strategies, robust security and privacy mechanisms, scalable algorithms, and energy-efficient protocols. By addressing these challenges and actively pursuing further research, speed-based relay selection can revolutionize V2V communication, paving the way for a safer and more efficient future of transportation.

Keywords: V2V communication, Device-to-Device (D2D, Speed-Based Relay Selection

Introduction to the Study.

Vehicle-to-vehicle (V2V) communication refers to the wireless transmission of information between vehicles on a road network. It is an important technology that aims to improve road safety and traffic flow by allowing vehicles to communicate with each other in real-time. V2V communication enables vehicles to exchange information such as speed, position, and acceleration data, which can be used to avoid accidents, reduce traffic congestion, and enhance traffic efficiency (Gould and Brown, 2023). However, V2V communication faces several challenges, such as poor range and line of sight limitations, high mobility of vehicles, and interference from surrounding vehicles and other wireless devices. One of the most significant issues in V2V communication is the selection of a suitable relay node to forward the information to the destination node (Nguyen *et al.*, 2023; Roger *et al.*, 2022). This selection process can determine the quality and reliability of the communication channel and the performance of the entire V2V network.

To address this challenge, various relay selection algorithms have been proposed in the literature. These algorithms use factors such as distance, signal-to-noise ratio, and link quality to select the best relay node. However, these algorithms have limitations, as they do not consider the moving speed of vehicles, which has a significant impact on the quality of the communication channel (Alnasser *et al.*, 2022). To overcome this limitation, this study proposes a speed-based relay selection system for V2V communication networks. The system uses the vehicles' moving speed as the primary factor to select the best relay node. It is expected that the proposed system will improve the quality and reliability of the communication channel and enhance the performance of the V2V network.

Statement of the Research Problem

Despite the potential benefits of V2V communication, the effectiveness of the technology is limited by factors such as signal propagation, interference, and network architecture (Plascencia *et al.*, 2023). Conventional relay selection methods only consider factors such as signal strength, which may not always lead to the best result (Shukla, 2023). Speed-based relay selection, on the other hand, takes into account the speed of the relay nodes, which can improve the performance of V2V communication in terms of latency, reliability, and cost (Zhou *et al.*, 2018). However, there is a lack of theoretical frameworks and simulation studies on speed-based relay selection systems for V2V communication networks. Therefore, the research problem is to develop a theoretical framework for a speed-based relay selection system and evaluate its performance using simulations.

Justification of the Study

V2V communication has the potential to improve traffic efficiency, reduce accidents, and increase road safety. However, the effectiveness of V2V communication is limited by factors such as signal propagation, interference, and network architecture (Singh *et al.*, 2022). One of the major challenges faced in V2V communication is relay selection, which involves selecting the best relay node to transmit the information from the source to the destination (Alotaibi and Mouftah, 2017).

Conventional relay selection methods only consider factors such as signal strength, which may not always lead to the best result. Speed-based relay selection, on the other hand, takes into account the speed of the relay nodes, which can improve the performance of V2V communication in terms of latency, reliability, and cost. The proposed system will provide a better understanding of the performance of speed-based relay selection and its impact on V2V communication networks.

Overview of Vehicle-to-Vehicle Communication Systems.

Vehicle-to-vehicle (V2V) communication is a type of wireless network in which vehicles can communicate directly with each other to exchange information. V2V communication has the potential to improve traffic efficiency, reduce accidents, and increase road safety by exchanging real-time information between vehicles on the road.

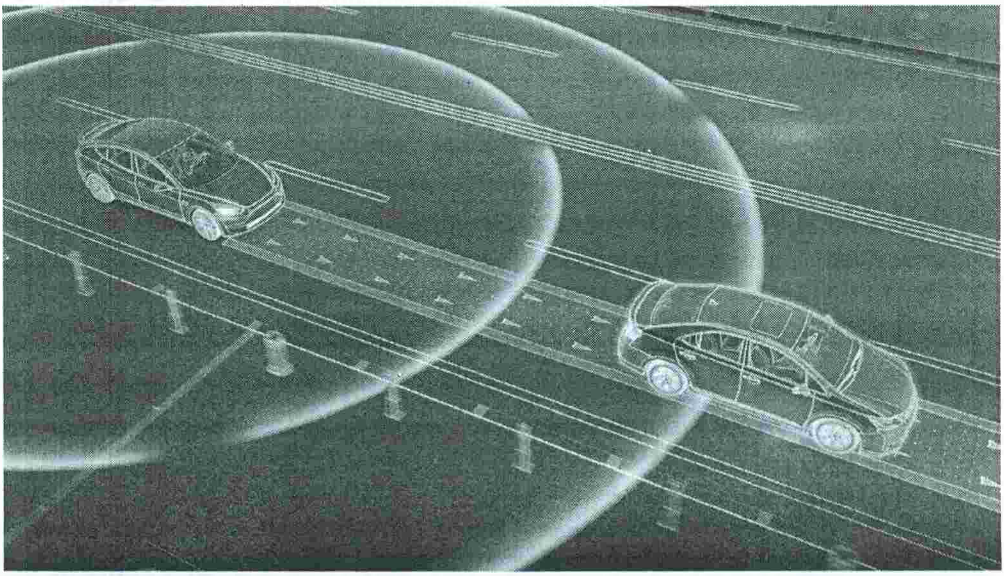

Figure 1: V2V communications

V2V communication systems typically use a combination of technologies such as Bluetooth, Wi-Fi, or cellular networks to create an ad-hoc network among vehicles on the road. Information exchanged between vehicles can include the vehicle's speed, position, acceleration, heading, and intent, which can be used to warn other vehicles of potential hazards, improve traffic efficiency, and prevent accidents (Zadobrischi and Damian, 2021). V2V communication systems face several challenges, such as ensuring the security of communication channels, managing the large volume of data exchanged between vehicles, and dealing with varying road conditions and traffic conditions.

Relay Selection

Relay selection is an important technique used in V2V communication networks to improve network performance by selecting the best relay vehicles for forwarding data packets. Relay vehicles are selected based on various factors such as signal strength, proximity, and available bandwidth. There are several relay selection techniques that can be classified into two categories: channel-based and signal-based relay selection (Kadhim and Jabbar, 2021; Raziah *et al.*, 2021).

Channel-based relay selection

This technique selects the relay nodes based on the channel conditions such as the signal-to-noise ratio (SNR) and signal-to-interference ratio (SIR). The selection criteria can be based on minimizing the packet loss and delay or maximizing the capacity and throughput of the network (Afzal *et al.*, 2018). Channel-based relay selection techniques can be further classified into three categories: distance-based relay selection, beamforming-based relay selection, and channel state information (CSI) based relay selection. Distance-based relay selection selects the relay node closest to the source and destination nodes (El-Zahr and Abou-Rjeily, 2022). Beamforming-based relay selection uses directional beams to improve the channel conditions between the relay and destination nodes. CSI-based relay selection selects the relay nodes based on their real-time channel state information.

Signal-based relay selection

This technique selects the relay nodes based on the quality of the received signal at the relays. Signal-based relay selection can be classified into two categories: coding gain-based relay selection and information gain-based relay selection (Alabed *et al.*, 2021). Coding gain-based relay selection selects the relay node with the highest coding gain, which is the signal-to-noise ratio (SNR) at the destination divided by the SNR at the relay node. Information gain-based relay selection selects the relay node with the highest amount of information at the destination.

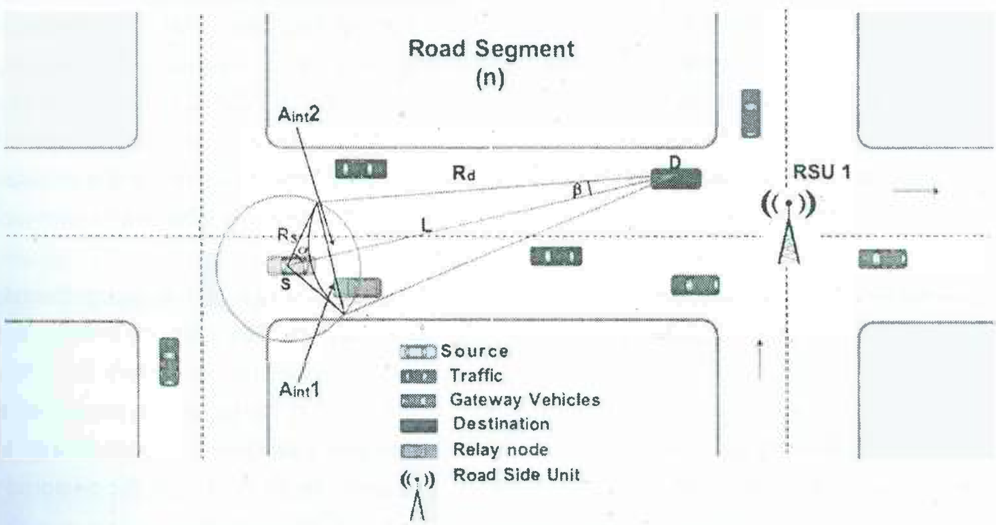

Fig 1: Network model for selecting relay node for path estimation

Review of Related Studies

A range of relay selection algorithms have been proposed to address V2V challenges, but they often overlook the impact of vehicle speed on communication quality. Alnasser *et al.* (2022) introduces a QoS-balancing algorithm that considers channel capacity, link stability, and end-to-end delay, significantly improving PDR and delivery ratio. The study proposed an Analytic Hierarchy Process (AHP)-based algorithm for optimal relay selection in Vehicle-to-Everything (V2X) communications, specifically in the context of Device-to-Device (D2D) relay nodes. Eshteiwi *et al.* (2019) presented a V2V full duplex amplify-and-forward (AF) cooperative wireless network model with two vehicular relay selection schemes. The analysis considers Nakagami-m fading channels in both line-of-sight (LOS) and non-line-of-sight (NLOS) scenarios, incorporating independent vehicle displacement between lanes. The system performance was comprehensively studied across fading severity, threshold, self-interference, number of lanes, vehicle intensity in each lane, and inter-vehicle spacing. The paper positions itself as a benchmark for evaluating the evolving V2V full duplex relaying in cooperative wireless networks, offering insights into performance metrics under diverse scenarios.

Cui *et al.* (2022) proposed a relaying-based information routing solutions with a K-means-type algorithm and an on-request relay selection method in a vehicular ad hoc network (VANET). The authors introduced base station and/or core network-aided relay selection with vehicle maneuver considering power consumption for addressing NLOS signal attenuation. Simulation results demonstrate the performance gain on system throughput, latency, and packet received rate by comparing with the state-of-the-art and non-relaying scenarios in realistic V2V scenarios with NLOS signal dissemination.

Lohat *et al.* (2023) considered the issue of efficiently transmitting service messages in the Internet of Vehicles (IoV) network using a proposed fractional mayfly optimization algorithm (FMA) to select the relay vehicle and cooperative vehicle for transmitting service messages from the RSU through the process of I2V and V2V scheduling. The study aims to improve the channel quality indicator (CQI), delay, distance, packet delivery ratio (PDR), and throughput in the IoV network. The proposed scheduling method is evaluated and compared to other methods by simulation, which shows significant performance improvement.

Linsalata *et al.*, (2023) proposed a proactive relaying strategy that uses environment information to predict dynamic line of sight maps, maximizing network connectivity. Roger *et al.* (2022) introduced a context-aware antenna selection procedure to enhance communication in 5G systems, while Nguyen *et al*, (2023) analyzed the impact of big vehicle shadowing on V2V communications and proposes relaying schemes to improve message dissemination performance. These studies collectively highlight the potential of these strategies in overcoming the challenges of V2V communication.

Challenges in V2V Communication

Communication networks, especially vehicle-to-vehicle (V2V) communication networks, are complex and dynamic systems where various challenges and limitations affect their performance (Nguyen *et al.*, 2023). Some of the most significant challenges and limitations in V2V communication networks include:

Interference

In V2V communication networks, the signals can be attenuated or distorted due to interference from other signals or sources. This can lead to the degradation of the signal-to-noise ratio, causing errors or data loss, which can affect the reliability of the communication.

Interference in V2V communication networks can lead to several issues, such as data loss, delay, and reduced coverage area, which can have significant consequences for road safety and traffic management (Plascencia *et al.*, 2023). Therefore, it is critical to develop effective interference mitigation techniques, such as frequency hopping, carrier sense multiple access/collision avoidance, and adaptive power control, to address the interference problem in V2V communication networks.

Latency

The latency in V2V communication networks can be affected by various factors, such as the communication protocol, the network infrastructure, and the location of the vehicles. High latency can cause a delay in the delivery of the communication messages, which can be critical in emergency scenarios (Li *et al.*, 2020).

To reduce latency in V2V communication networks, various techniques can be used, such as channel allocation based on delay requirements, priority-based scheduling, and adaptive power control. It is also important to monitor and optimize the network infrastructure to ensure that it can support the required service level agreement (SLA).

Security

Security is a critical aspect in Vehicle-to-Vehicle (V2V) communication networks, as it ensures the confidentiality, integrity, and accessibility of communicated data. Security threats in V2V communication networks can lead to several issues, such as data theft, spoofing attacks, and confidentiality breaches, which can have significant consequences for road safety and traffic management (Twardokus and Rahbari, 2023).

Power consumption

Power consumption is an important aspect to consider in V2V communication networks, as it ensures the optimal performance of the communication devices used by the vehicles. Power consumption can be affected by various factors, including distance, signal quality, transmission frequency, data rate, and communication protocol (He *et al.*, 2023).

Frequency allocation

In V2V communication networks, the frequency allocation is a significant challenge due to the limited spectrum available for communication. This can limit the number of vehicles that can communicate simultaneously and affect the reliability of the network (Mura *et al.*, 2022).

Speed-based relay selection in V2V (Vehicle-to-Vehicle)

Speed-based relay selection in Vehicle-to-Vehicle (V2V) communication is a dynamic and adaptive approach aimed at enhancing the reliability and efficiency of data transmission among vehicles on the road. In V2V communication, vehicles exchange critical information for purposes such as collision avoidance and traffic coordination, selecting an optimal relay vehicle based on its speed becomes crucial for maintaining a robust communication link.

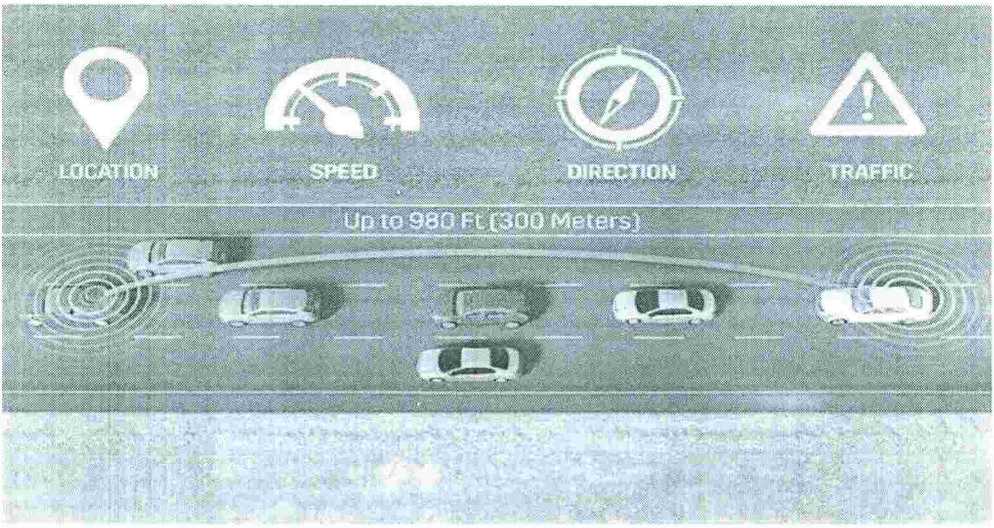

Figure 3: V2V communication scenario

In a speed-based relay selection approach, the relays are selected based on the speed of the vehicles. In other words, faster vehicles are more likely to be chosen as relays, as they can more easily intercept the data packets and forward them to the destination. This approach is motivated by the fact that V2V communication is often used for emergency messages or time-sensitive data, and the faster the data can be transmitted, the more likely it will arrive in time.

To implement a speed-based relay selection scheme, the speeds of the vehicles in the network are estimated using various techniques such as GPS or radio-based methods. The estimated speeds are then used as input to a utility function that evaluates the performance of each vehicle as a relay based on its speed. The vehicle with the highest relay utility is selected as the best relay for the transmission.

While speed-based relay selection can be an effective approach in some scenarios, it also has some limitations. For instance, speed can change rapidly, and the performance of the selected relay may vary considerably over time. In addition, the selected relay may not be able to receive the data due to physical obstructions or interference from other vehicles. As such, there is a need for more robust and adaptive relay selection strategies in V2V communication.

Challenges of Speed-based Relay Selection

The use of speed-based relay selection in V2V communication has several challenges that need to be addressed for its effective implementation. These challenges include:

Speed Estimation

The speed-based relay selection approach requires the accurate estimation of the speeds of vehicles in the network. However, this is a challenging task due to noisy speed measurements obtained from GPS or radio-based methods (Ghaffarpasand *et al.*, 2022). Furthermore, vehicles may not always have access to GPS or other speed estimation methods, which may result in inaccurate speed estimates.

Temporal Variability

The speeds of vehicles in the network can change rapidly due to traffic conditions, weather, and other variables. This temporal variability can impact the performance of speed-based relay selection, as the selected relay may not always be the best option for a particular transmission.

Interference and Obstructions

V2V communication relies on line of sight transmission, which can be easily blocked by physical obstructions such as buildings and other vehicles. These obstructions can affect the performance of speed-based relay selection, as the selection of a relay that has a better line of sight may be more reliable (Tan and Chung, 2021).

Scalability

V2V networks can be very large, with hundreds or thousands of vehicles, and scaling the speed-based relay selection approach can be a challenge due to the computational complexity and information exchange overhead required.

Energy Efficiency

V2V communication requires vehicles to keep their radios in active state to receive and transmit data, which can significantly impact the energy efficiency of the network. It is important to ensure that the deployment of speed-based relay selection does not further impact the energy efficiency of the network (Xu *et al.*, 2023).

Conclusion:

This research comprehensively explored the potential of speed-based relay selection as an innovative approach to enhance V2V communication performance. While conventional methods primarily focus on factors like signal strength and distance, incorporating vehicle speed adds a crucial dimension to optimize data transmission. By prioritizing faster moving vehicles as relays, this approach promises faster delivery of critical information, reduced latency, and improved network reliability.

Recommendations

Building upon this study, future research can delve deeper into specific areas to refine and optimize speed-based relay selection:

Advanced Speed Estimation

Develop highly accurate and robust algorithms for speed estimation, minimizing relia on potentially unreliable GPS signals and incorporating real-time traffic data.

Adaptive Selection Strategies

Design dynamic and adaptable selection algorithms that respond to changes in veh speed, network topology, and environmental conditions. Consider hybrid approaches combine speed with other relevant factors for even more efficient relay selection.

Security and Privacy

Address potential security and privacy concerns with meticulous data encryption robust authentication mechanisms in the relay selection process.

Network Scalability

Investigate efficient algorithms and protocols to ensure the scalability of speed-based r selection for large-scale V2V networks, minimizing computational complexity information exchange overhead.

Energy Efficiency Optimization

Design energy-efficient relay selection mechanisms that balance impro communication performance with minimal impact on vehicle battery life.

By actively exploring these avenues, researchers can further refine and unlock the potential of speed-based relay selection, solidifying its role as a key driver towards a sa more efficient, and connected future of transportation.

Additional Considerations

While emphasizing the advantages of speed-based selection, it's crucial to acknowle its limitations and potential drawbacks. Carefully weigh the benefits against poter issues like fluctuating speeds, obstructions, and computational complexity.

Collaborate with experts in various fields, including signal processing, communica engineering, and network optimization, to address various challenges and develop hol solutions.

Conduct extensive simulations and real-world testing to validate the effectivenes proposed algorithms and adapt them to different scenarios and traffic patterns.

By addressing these concerns and actively pursuing further research, the promise of sp based relay selection can be translated into a tangible reality, revolutionizing the lands of V2V communication and shaping the future of intelligent transportation systems.

References

Afzal, M. K., Nam, S.Y., Kim, B. S., & Kim, S. W.(2018). SNR-based relay selection in cooperative wi ad hoc networks. *International Journal of Ad Hoc and Ubiquitous Computing, 28*(1), 45–54. https://doi.org/10.1504/IJAHUC.2018.091571

Alabed, S., Maaz, I., & Al-Rabayah, M. (2021). Improved Bi-directional three-phase single-relay selection technique for cooperative wireless communications. *Computers, Materials and Continua, 70*(1), 999–1015. https://doi.org/10.32604/cmc.2022_.019758

Alnasser, A., Sun, H., & Jiang, J. (2022). QoS-Balancing Algorithm for Optimal Relay Selection in Heterogeneous Vehicular Networks. *IEEE Transactions on Intelligent Transportation Systems, 23*(7), 8223–8233. https://doi.org/10.1109/TITS.2021.3076901

Alotaibi, M. M., & Mouftah, H. T. (2017). Relay Selection for Heterogeneous Transmission Powers in VANETs. *IEEE Access, 5*, 4870–4886. https://doi.org/10.1109/ACCESS.2017.2679606

Cui, T., Sun, C., & Li, L. (2022). Information Relaying Methods in VANET: Algorithms, Standards and Tests. *Applied Sciences, 12*(21), 10748. https://doi.org/10.3390/app122110748

El-Zahr, S., & Abou-Rjeily, C. (2022). Buffer State Based Relay Selection for Half-Duplex Buffer-Aided Serial Relaying Systems. *IEEE Transactions on Communications, 70*(6), 3668–3681. https://doi.org/10.1109/TCOMM.2o22.3166242

Eshteiwi, K., Kaddoum, G., Ben Fredj, K., Soujeri, E., & Gagnon, F. (2019). Performance Analysis of Full-Duplex Vehicle Relay-Based Selection in Dense Multi-Lane Highways. *IEEE Access, 7*, 61581–61595. https://doi.org/10.1109/ACCESS.2019.2903453

Ghaffarpasand, O., Burke, M., Osei, L. K., Ursell, H., Chapman, S., & Pope, F. D. (2022). Vehicle Telematics for Safer, Cleaner and More Sustainable Urban Transport: A Review. *Sustainability, 14*(24), 16386. https://doi.org/10.3390/su142416386

Gould, B. T., & Brown, P. N. (2023). Information design for Vehicle-to-Vehicle communication. *Transportation Research Part C: Emerging Technologies, 150*, 104084. https://doi.org/10.1016/j.trc.2o23.104084

He, Y., Wang, D., Huang, F., Zhang, R., Gu, X., & Pan, J. (2023). A V2I and V2V Collaboration Framework to Support Emergency Communications in ABS-Aided Internet of Vehicles. *IEEE Transactions on Green Communications and Networking*, 7(4), 2038–2051. https://doi.org/10.11o9/TGCN.2023.3245098

Kadhim, D. J., & Jabbar, S. Q. (2021). Proposed different relay selection schemes for improving the performance of cooperative wireless networks. *Telkomnika (Telecommunication Computing Electronics and Control), 19*(4), 1107–1117. https://doi.org/10.12928/TELKOMNIKA.v19i4.18327

Li, Z., Xiang, L., Ge, X., Mao, G., & Chao, H.-C. (2020). Latency and Reliability of mmWave Multi-Hop V2V Communications Under Relay Selections. *IEEE Transactions on Vehicular Technology, 69*(9), 9807–9821. https://doi.org/10.1109/TVT.2020.3002903

Linsalata, F., Mura, S., Mizmizi, M., Magarini, M., Wang, P., Khormuji, M. N., Perotti, A., & Spagnolini, U. (2023). LoS-Map Construction for Proactive Relay of Opportunity Selection in 6G V2X Systems. *IEEE Transactions on Vehicular Technology, 72*(3), 3864–3878. https://doi.org/10.1109/TVT.2022.3217966

Lohat, S., Jain, S., & Kumar, R. (2023). Fractional mayfly optimization algorithm-based Infrastructure-to-Vehicle and Vehicle-to-Vehicle scheduling for service message transmission in IoV-fog. *International Journal of Communication Systems, 36*(9). https://doi.org/10.1002/dac.5479

Mura, S., Linsalata, F., Mizmizi, M., Magarini, M., Khormuji, M. N., Wang, P., Perotti, A., & Spagnolini, U. (2022). Spatial-Interference Aware Cooperative Resource Allocation for 5G V2V Communications. *2022 IEEE 95th Vehicular Technology Conference: (VTC2022-Spring), 2022-June*, 1–6. https://doi.org/10.1109/VTC2022-Spring54318.2022.9860812

Nguyen, H. T., Noor-A-Rahim, M., Guan, Y. L., & Pesch, D. (2023). Cellular V2X Communications in the Presence of Big Vehicle Shadowing: Performance Analysis and Mitigation. *IEEE Transactions on Vehicular Technology, 72*(3), 3764–3776. https://doi.org/10.1109/TVT.2022.3212704

Plascencia, E., Guan, H., Chassagne, L., Barrois, O., Shagdar, O., & Căilean, A. M. (2023). A Comprehensive Investigation on Multi-User Interference Effects in Vehicular Visible Light Communications. *Sensors*, *23*(5), 2553. https://doi.org/10.3390/s23052553

Raziah, I., Yunida, Y., Away, Y., Muharar, R., & Nasaruddin, N. (2021). Adaptive relay selection based on channel gain and link distance for cooperative out-band device-to-device networks. *Heliyon*, *7*(7), e07430. https://doi.org/10.1016/j.heliyon.2021.e07430

Roger, S., Martin-Sacristan, D., Garcia-Roger, D., Monserrat, J. F., Kousaridas, A., Spapis, P., & Ayaz, S. (2022). 5G V2V Communication with Antenna Selection Based on Context Awareness: Signaling and Performance Study. *IEEE Transactions on Intelligent Transportation Systems*, *23*(2), 1044–1057. https://doi.org/10.1109/TITS.2020.3019530

Shukla, S. (2023). Target node selection for data offloading in partially connected vehicular ad hoc networks. *International Journal of Ad Hoc and Ubiquitous Computing*, *42*(2), 113. https://doi.org/10.1504/ijahuc.2023.128491

Singh, G., Srivastava, A., Bohara, V. A., Liu, Z., Noor-A-Rahim, M., & Ghatak, G. (2022). Heterogeneous Visible Light and Radio Communication for Improving Safety Message Dissemination at Road Intersection. *IEEE Transactions on Intelligent Transportation Systems*, *23*(10), 17607–17619. https://doi.org/10.1109/TITS.2022.3156119

Tan, H., & Chung, I. (2021). Rsu-aided remote v2v message dissemination employing secure group association for uav-assisted vanets. *Electronics (Switzerland)*, *10*(5), 1–22. https://doi.org/10.3390/electronics10050548

Twardokus, G., & Rahbari, H. (2023). Toward Protecting 5G Sidelink Scheduling in C-V2X Against Intelligent DoS Attacks. *IEEE Transactions on Wireless Communications*, *22*(11), 7273–7286. https://doi.org/10.1109/TWC.2023.3249665

Xu, C., Wang, S., Song, P., Li, K., & Song, T. (2023). Intelligent Resource Allocation for V2V Communication with Spectrum–Energy Efficiency Maximization. *Sensors*, *23*(15), 6796. https://doi.org/10.3390/s23156796

Zadobrischi, E., & Damian, M. (2021). Vehicular communications utility in road safety applications: A step toward self-aware intelligent traffic systems. *Symmetry*, *13*(3). https://doi.org/10.3390/sym13030438

Zhou, Y., Li, H., Shi, C., Lu, N., & Cheng, N. (2018). A Fuzzy-Rule Based Data Delivery Scheme in VANETs with Intelligent Speed Prediction and Relay Selection. *Wireless Communications and Mobile Computing*, *2018*, 1–15. https://doi.org/10.1155/2018/7637059