Scalable Computing: Practice and Experience, ISSN 1895-1767, http://www.scpe.org

Volume 25, Issues 5, pp. 3903–3924, DOI 10.12694/scpe.v25i5.3037

NEXT-GENERATION CONNECTIVITY: A HOLISTIC REVIEW OF COOPERATIVE NOMA IN DYNAMIC VEHICULAR NETWORKS FOR INTELLIGENT TRANSPORTATION SYSTEMS

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Abstract. Intelligent Transportation Systems are witnessing a paradigm shift with the integration of Cooperative Vehicular Networks. The transformations in Intelligent Transportation system in the realistic scenario has posed many research challenges to be addressed. This paper explores a profound survey on impact of vehicles' mobility within the context of real-time scenarios in Cooperative vehicular networks. The dynamic nature of vehicular mobility introduces unique challenges and opportunities for the design and implementation of cooperative systems. It delves into the key components that play a pivotal role for harnessing the full potential of Cooperative vehicular networks such as C-NOMA, Two-Way relaying, cluster formation and collaborative decision-making algorithms for improving latency, link reliability, cluster formation, and interference reduction etc. This paper outlines few surveys on each amalgamated technologies in Vehicular communication and conclude with the research problems in ITS due to vehicles mobility for real time scenarios.

Key words: Vehicular Communication; Cooperative Networking; Non-Orthogonal Multiple Access; Intelligent Transportation System; Cluster Head.

1. Introduction. Vehicular communications (VC) are critical components of Intelligent Transportation Systems (ITS), allowing vehicles to interact with one another as well as with infrastructure elements. This connectivity is critical for safety information, real-time data transmission, traffic management, and autonomous vehicle development. VC include a variety of technologies that improve road safety and efficiency, such as Dedicated Short-Range Communications (DSRC) and Cellular Vehicle-to-Everything (C-V2X) [1, 5, 102].

With the advent of the new technological growth in IOT device, Vehicle-to-everything (V2X) has become a trustworthy technology to drive multiple applications in ITS. V2X communication's low latency and dependability make it prevalent in life-threatening and delay-sensitive applications [54]. Long Term Evolution (LTE) based C-V2X proposed by 3GPP to provide public safety service. However, with resource sharing with cellular networks impose additional problems to fulfil low latency, high reliability, and large connectivity with severe data congestion [98, 19, 94]. Implementation of MIMO in V2X will leverage the benefits with diversity gain, spatial multiplexing and may reap to the growing demand of data rates to support multiple applications in vehicular communications. Complexity in receiver design, Inter-antenna Interference, instantaneous channel estimation and hostile Doppler shift due to mobility of the vehicles make MIMO implementation troublesome [95, 109]. This explores a new methodology in networking of LTE V2X communications to combat the technical challenges of MIMO and leverage the advantages of MIMO.

Vehicular channels provide unique issues, owing to signal fluctuations produced by mobility, which have a direct influence on performance in actual circumstances. New user applications, enhanced safety applications, and 5G data rates demand service needs such as broad coverage, low latency, throughput, and dependability. Cooperative Vehicular Networks (CVN) aims to improve network performance by incorporating vehicular node cooperation. However, due to high-speed mobility, competing parameters, and optimal node selection, efficient and adaptive cooperative algorithms are challenging. Current CVN literature focuses on network collaboration domains like resource scheduling, resource allocation, reliability, routing, and heterogeneous networking. Critical criteria for developing CVN include adaptive transmission power regulation, optimum relay selection, low synchronization overhead, adaptability, compatibility and impartial resource sharing. The future research

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Table 1.1: Nomennclature

Acronym	Meaning
AODV	Ad-hoc On-demand Distance Vector
AODV	Ad-hoc On-demand Distance Vector
AWGN	Additive white Gaussian noise
AF	Amplify and Forward
BS	Base Station
C-NOMA	Cooperative Non-orthogonal Multiple Access
CH	Cluster Head
CVN	Cooperative Vehicular Networks
C-V2X	Cellular Vehicle-to-everything
CoV	Cooperative Vehicles
CSI	Channel State Information
CRB	Cooperative relay broadcasting
CM	Cluster member
DSRC	Dedicated Short-Range Communications
DCVN	Heterogeneous cooperative vehicular networks
DMCNF	Distributed multi-hop clustering method
DF	Decode and Forward
DL	Downlink
FD	Full Duplex
3GPP	Third Generation Partnership project
GEC	Generous cooperative
HD	Half Duplex
ITS	Intelligent Transportation System
ISI	Inter Symbol Interreference
IQI	In-phase/quadrature phase imbalance
IoT	Internet of Things
LTE	Long Term Evolution
MIMO	Multiple-Input-Multiple-Output
MAC	Medium Access Control
MA	Multiple Access
NOMA	Non-orthogonal multiple access
OMA	Orthogonal multiple access
OPA	Optimum Power Allocation
PDMA	Pattern Division Multiple Access
PA	Power Allocation
PAPR	Peak-to-average-power ratio
PSIC	Perfect Successive Interference Cancellation
RSU	Road Side Unit
RS	Relay Selection
SIC	Successive interference cancellation
SNR	Signal to Noise Ratio
SINR	Signal-to-Interference Noise Ratio
SC	Supervisory Coding
SCMA	Sparse Code Multiple Access
SM	Spatial Multiplexing
SER	Symbol Error Rate
SOP	System Outage Probability
TWR	Two-Way Relaying
UL	Uplink
VANETS	Vehicular Adhoc Networks
VC	Vehicular Communications
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
VoI	Vehicle of Interest
TM	Throughput Maximization
OM	Outage Minimization
RE	Reliability Enhancement
UM	Utility Management
IM	Interreference Minimization
PO	Power Optimization
SM	SNR Maximization

Table 2.1: List of survey articles emphasizing the benefits of cooperative networking.

S.No	Benefits	References
1	Upsurges the spectral efficiency and utilization of bandwidth	[30]
2	Delivers diversity gain	[62]
3	Mitigate the complications in employment of MIMO	[33]
4	Enhances throughput with QoS	[15]
5	Mitigates impairments like channel fading and path loss	[76]
6	Provides energy efficiency based on relay location	[103]
7	Reduces interreference	[104]
8	Delivers communication reliability due to multiple paths	[12]
9	Minimizes implementation cost and improves coverage area	[87]
10	Decreases outage probability	[92]

should address challenges related to the impact of mobility, resource sharing, multi-functional protocol design, estimating dynamic channel behaviour and security.

This paper offers a valuable contribution by presenting a comprehensive review of earlier research works focused on cooperative vehicular networks (CVN). Through a meticulous examination of existing literature, the paper systematically synthesizes insights, methodologies, and findings from various studies in the field. By doing so, it provides a thorough understanding of the advancements made in cooperative vehicular networks and their applications. Furthermore, the paper sheds light on the critical research challenges associated with the implementation of CVN in realistic scenarios. By addressing these challenges, the paper aims to enhance the feasibility and effectiveness of cooperative vehicular networks in practical environments. Inclusively, this work aids as a significant means for researchers, and practitioners seeking to navigate the complexities of CVN research and implementation.

The rest of the paper is organized as follwos: Section 2 briefs about cooperative communication and emphasizes on the requirements, challenges and effects of dynamic nature of vehicles in vehicular networks. Section 3 presents a comprehensive survey of the routing strategies in CVN. NOMA and its outperformance over OMA in Vehicular networks and NOMA implementation problems are projected in Section 4. Section 5 appraises about the impact of integrating cooperative networking and NOMA in vehicular communication and understanding the performance of this paradigm through few earlier works. Section 6 presents about the Two-way cooperative NOMA in Vehicular networks and a inclusive survey on HD/FD relaying. The impact of vehicle mobility over relay selection, cluster formation and selection of Cluster Head (CH) and critical research challenges in realizing the C-NOMA in Vehicular communication are depicted in Section 7. Section 8 concludes the paper.

2. Cooperative Communication. Cooperative communication in wireless systems is an important field of study that handles issues including fading channels, interference, and energy limits. It takes use of wireless device cooperation to increase dependability, throughput, network performance, and the capabilities of wireless communication technologies in a variety of applications. Using many relays as a virtual antenna array to create broadcast diversity is a promising strategy [48, 20]. As a result, the impact of channel fading might be mitigated, and wireless communications dependability could be increased. Many cooperative diversity techniques and protocols, such as cooperative protocols [54], single-relay cooperativeness, MIMO relay cooperativeness [48], optimal relay selection, two-way relaying (TWR) and network coding [39, 111], have been proposed and investigated. Given these characteristics, cooperative communication technology has the potential to effectively enhance the overall performance of vehicle networks. Cooperative vehicles (CoV) are a paradigm shift in ITS that can revolutionize road safety, traffic efficiency, and transport management by promoting collaboration, fading issues, path loss, shadowing, narrow coverage, and poor SNR [111, 3].

2.1. Requirements for Cooperative Vehicular Networks. CVN is unique in facilitating vehicular node interaction. To realise CVN, vehicle networks must meet numerous additional criteria due to the unique characteristic. These are some of the main needs.

2.1.1. Adaptive Transmission Power Control. V2V and V2I communication quality changes with time and space [25]. Vehicle speed additionally exacerbates the problem. Thus, CVN need adaptive transmission power control techniques. For dynamic run-time variable circumstances produced by moving vehicle cooperation, static gearbox procedures fail. Because vehicles cooperate, the adaptive gearbox protocol requires a learning mechanism to detect changes in surrounding vehicular environments. These adaptive transmission control techniques will greatly affect CVN.

2.1.2. Optimal Cooperative Relay Selection. CVN has received a lot of attention because to its potential to increase transmission and throughput dependability in highly dynamic wireless situations. In most CVN, relay notes a pivotal role in delivering the packets towards the destination. However, transmission through multiple nodes to destination decrease the efficient resource utilization. The relay selection play a vital role to maximise network stability and throughput by efficiently using resources. Selecting the best cooperative relay node depends on vehicle direction, speed, traffic load, and channel quality.

2.1.3. Minimal Coordination Overhead. CVN nodes share their and neighbors' circumstances, which vehicle nodes use for relay, slot, resource, and forwarding decisions. This cooperation improves network performance by enabling collaboration between nodes. During information-sharing periods, nodes exchange messages to communicate channel conditions and gather topological information. To minimize duplicate transmission, an ideal relay node must be chosen among viable options. This minimizes coordination overhead and efficiently uses short-term resources.

2.1.4. Responsive Cooperative Transmission. CVN improves network speed and packet transmission reliability. However, cooperation techniques may influence neighbouring and collaborating relays. Cooperation with other relays requires to contemplate its self-transmissions besides resource restrictions. The participating node should also handle neighbouring node communications. The stages of node cooperation should be structured such that cooperative transmissions do not impair the performance of the collaborating node and its neighbours.

2.1.5. Equitable Resource Distribution. When considering transmission dependability, it is crucial to also prioritise fair resource allocation. Ensuring equitable allocation of resources to all participating nodes is crucial for optimising the performance of vehicular networks. Previous studies have investigated wireless network fairness in various aspects, such as bandwidth allocation [35], channel assignment [56], and power control [38]. Ensuring equal bandwidth and power usage for each node is of utmost importance, as fair resource distribution is vital. It is crucial to ensure fair distribution of resources to prevent resource hunger, which is why equitable resource allocation is necessary for the CVN.

2.2. Open Research Challenges. Research on cooperative vehicular communications focuses on developing robust protocols for dynamic situations and addressing mobility-induced performance deterioration, highlighting the need for compatibility with vehicle manufacturers.

2.2.1. High Speed Mobility. High-speed mobility in vehicular networks poses a significant challenge to the reliability of communications, introducing temporal variability that complicates traditional solutions. Despite efforts leveraging MIMO technology, cooperative relay and MIMO approaches still face hurdles in adapting to dynamic vehicular environments. The ever-changing network architecture further complicates relay node selection, necessitating agile techniques based on relative mobility speeds to address this challenge effectively. To tackle these obstacles, there is a pressing need for innovative relay selection methodologies capable of real-time adaptation to evolving network topologies. These techniques must navigate the complexities of high-speed mobility, considering factors like varying topography and rapid fading. By developing such adaptive protocols, we can enhance the dependability of vehicular communications, ensuring robust connectivity in dynamic automotive settings.

2.2.2. Multi-Objective Protocols. In the realm of Cooperative Vehicular Networks (CVNs), the predominant research paradigm tends to centre on singular parameters, often neglecting the inherent variability within vehicular network environments. Protocol design necessitates a comprehensive consideration of diverse factors, encompassing aspects such as latency, throughput [83], fairness [58], and energy efficiency [80]. Nonetheless, crafting protocols that effectively reconcile these disparate objectives poses a formidable challenge, owing to the inherent conflicts and trade-offs inherent in such endeavours.

2.2.3. Estimating Channel State Information. Channel State Information (CSI) holds paramount importance in wireless systems, particularly for facilitating real-time cooperative networking. However, the real-time estimation of CSI presents a formidable challenge, primarily attributable to the dynamic nature of channel conditions and the rapid mobility characteristic of vehicular environments. Researchers may leverage principles from related domains to formulate estimation algorithms aimed at addressing this challenge [51].

2.2.4. Optimal Cooperative Relay Selection. The investigation delves into the complexities surrounding the selection of an optimal relay node to mitigate data collision and transmission redundancy effectively. Considerations include factors such as vehicle speed, direction of motion, channel quality, and traffic density. Findings from this study hold promise in informing the development of refined solutions for cooperative relay selection, offering valuable insights to propel further research. Moreover, the dynamic nature of automotive environments, marked by substantial vehicle movement, is demonstrably linked to adverse effects on network performance, underscoring the significance of these observations.

1. **Packet Loss Rate**: During congestion or fast changes in vehicle placements, the packet loss rate in highly mobile vehicular networks can be quite substantial, sometimes even exceeding 20%.
2. **Latency**: The latency in cooperative vehicular networks can vary significantly due to vehicle movement. In situations where there is heavy traffic or frequent lane changes, the latency can exceed 100 milliseconds, which can potentially compromise the real-time aspect of safety-critical systems.
3. **Fluctuations in Throughput**: The performance of vehicular communication systems can vary due to changes in the channel caused by vehicle mobility. During busy periods with a lot of movement on the roads, data speeds can decrease significantly, going from 1 Gbps to below 100 Mbps.
4. **Link Availability**: Link availability in vehicular networks can drop significantly in situations involving fast-moving vehicles, tunnels, or obscured line-of-sight circumstances, potentially reaching as low as 50%. This reduces the chances of establishing ongoing communication connections.
5. **Handover Frequency**: Due to the movement of vehicles in and out of communication ranges, frequent handovers are often required in cooperative vehicular networks. In busy urban areas, vehicles frequently change hands, causing signal overhead and disruptions.
6. **Network Density**: In intense traffic areas, network density may reach more than 1,000 vehicles per square kilometre. High density in communication channels may aggravate interference, contention, and collisions.
7. **Network Partition**: Occasionally, there may be instances where the network becomes temporarily divided due to sudden shifts in vehicle positions, resulting in certain groups of vehicles being isolated from the rest of the network. These partitions can cause significant disruptions to the flow of data, lasting for extended periods of time.
8. **Vehicle geographical Distribution**: Vehicles in cooperative networks have a non-uniform geographical distribution. Congestion in certain regions, such as junctions or highway on-ramps, may result in localised performance reduction.
9. **Effect on Safety Applications**: Mobility-induced performance loss might be especially worrisome in safety-critical cases such as collision evasion. In such cases, the success rate of timely warnings might fall below 90
10. **Impact on Traffic Management**: Due to the reliance on real-time data from vehicles, the effectiveness of traffic flow control and congestion management in cooperative traffic management could be hindered by concerns related to performance caused by mobility.
11. **Autonomous Vehicles Face Difficulties**: Autonomous vehicles rely significantly on cooperative communication. Vehicle mobility-induced performance deterioration might complicate autonomous decision-making and coordination, compromising safety and efficiency.

3. Routing Strategies. CVN routing systems must develop pathways that fully leverage the accessible forwarding relay selections in every hop in order to enhance transmission performance. Current cooperative vehicular networking research initiatives attempt to achieve a variety of goals, including throughput maximisation, power allocation optimisation, transmission outage minimising, reliability enhancement, utilisation maximisation, and reservation slot collision minimization. Researchers are researching several techniques of constructing cross-layer routing to suit this need.

In [31], the authors put forward a proposal for VANET cross-layer routing that focuses on cooperative networking and finding a balance between end-to-end dependability and gearbox power consumption. The optimisation focuses on achieving two main objectives: ensuring high dependability while staying within gearbox power limits, and minimising power consumption. Nevertheless, the solution overlooks the possibility of co-channel interference from different source-destination pairs, which could potentially impact the performance of the protocol.

The VANET cross-layer routing technique optimizes wireless channel performance and overpowers unreliability [20]. Route detection and administration are done via AODV protocol. A relay selection method maximizes throughput, using predicted connection time and SNR. A MAC protocol extends route duration for stability. However, this assumes every vehicle is connected to RSU, increasing deployment costs.

By implementing cooperative forwarding and utilising network coding, the number of retransmissions can be significantly reduced [45]. The study in [111] introduced a cooperative forwarding system based on network coding, utilising a master/slave network topology paradigm. The master node selects the forwarding slave relay node based on trajectory, constancy, and proximity. The packet is encoded using linear network coding, incorporating slave addresses in route replies and updates.

The researchers in [69] proposed a network coding-aided scheduling technique for cooperative data dissemination systems. Vehicles exchange data via V2I and V2V channels, with each sending and receiving heartbeat messages to announce existence, update RSU, and switch operating modes. The proposed caching technique maximizes network coding effect, improving service performance but potentially cumulative latency for each packet. Authors in [72] proposed a bandwidth-optimized distribution technique for heterogeneous cooperative vehicular networks (DHVN), allowing quick data distribution and adapting to road design. The protocol improves packet retransmission and uses a store and forward technique to alleviate disconnections.

In [123], proposed an ungraceful cooperative strategy that uses forwarding probability with the aid of node position to decide next-hop transmission, reducing coordination overhead but requiring global positioning system information, potentially unavailable in tunnels. In [91] authors studied bidirectional cooperative V2V performance in vehicle abetted and RSU aided scenarios, using relay node location without channel status information. Authors in [37] investigate the influence of rate and gearbox range on CV critical systems, using a model to measure network performance. In [18] author also examined the combined impact of cooperation, interference, and channel fading in a Nakagami fading channel model.

A novel cooperative communication technique uses V2V, V2I, and mobility to increase vehicular network capacity. The disc model utilised in it omitted communication fading and interference, which may not suit the actual circumstance. This research synthetically analyses CVN network capacity using the highway scenario and variable communication scene fading. Using an analytical framework, a bottleneck expression of gearbox capacity is generated, and a newton iteration approach yields the estimated ideal cooperative vehicular ratio.

A dual segment generous cooperative (GEC) routing scheme is suggested [65]. A cooperative watchdog paradigm reduces false alerts and improves misbehaviour detection. The GEC routing protocol has several components that find cooperative pathways and distribute traffic. GEC design involves route finding and maintenance. The three steps of route discovery are neighbour sighting, erudition relay metric, and cooperative relay selection. Route recovery begins when a node gets a route error report. Link failure deletes the route from the routing database. The suggested technique separates troublesome vehicles, minimising end-to-end time. However, the suggested method lacks service diversity, which is essential for meeting traffic needs.

A novel network coding-aided scheduling technique is proposed to investigate the features of cooperative data dissemination systems [10]. In this setup, Vehicle-to-Infrastructure (V2I) communication channels facilitate the exchange of data between Roadside Units (RSUs) and passing vehicles, while Vehicle-to-Vehicle (V2V) channels enable vehicles to communicate cached data with nearby peers. The proposed solution comprises three phases: firstly, each vehicle transmits and receives heartbeat messages to announce its presence and gather information about nearby nodes. In the second phase, vehicles update their own and neighbouring

Table 3.1: List of review articles on routing strategies with multiple metrics

Research Articles	TM	OM	RE	UM	IM	PO	SM
Q. Zhang et. al. [120]	✓	×	×	×	×	×	×
M. Hempel et.al [127]	✓	×	×	×	×	×	×
Y. Cui et. al. [121]	✓	×	×	✓	×	×	×
W. Wang et.al [126]	✓	✓	×	×	×	×	×
T. Tang et. al. [128]	✓	×	×	×	×	×	×
H. Li et. al.[61]	×	×	×	×	×	×	×
C. Li et.al. [17]	×	×	×	✓	✓	×	×
A. Zafar et.al. [122]	✓	×	×	×	×	×	×
H. Yan et. al. [16]	×	✓	✓	×	×	×	✓
T. Zhang et. al.[45]	✓	×	×	×	×	×	×

vehicles status information to the RSU. Finally, in the last phase, all vehicles switch operating modes based on RSU scheduling. To optimize the network coding effect, a caching method is recommended. While the suggested network coding-assisted data distribution enhances service performance, it may also lead to increased hop-to-hop latency and packet latency.

To improve broadcast reliability, propose cooperative relay broadcasting (CRB) to rebroadcast neighbouring source node packets [10]. A two-state Markov chain-based optimisation framework and channel prediction technique are also presented. The optimisation framework limits CRB performance, while the channel prediction algorithm selects the optimal relay node. CRB facilitates proactive cooperative choices to send packets before expiration.

Node mobility and V2V/V2I communications have been studied to optimise throughput [17]. The authors suggested a V2I communications technique for the Vehicle-of-Interest (VoI) to obtain information from RSU while in coverage. After outside infrastructure transmission range, the VoI uses V2V communications to receive data via relay nodes. Data transmission under cooperative communication techniques is investigated using an analytical approach. In [16], the study proposed a cooperative communication method that maximizes throughput by utilizing V2V and V2I communication, mobility, infrastructure, and vehicle collaboration. It develops an analytical framework and close-form expression for feasible throughput.

4. NOMA in Vehicular Networks. Powered by the increasing spread of Internet-enabled smart devices and creative apps, sophisticated new services accelerate 5G network development needing new MA approaches. To reduce access collisions in V2X environments, novel multiple access techniques like SCMA, PDMA, and NOMA have been projected to enhance bandwidth efficiency and massive connectivity [84, 23].

Non-orthogonal multiple access (NOMA) is a trustworthy solution for 5G networks, offering increased spectrum efficiency, throughput and balanced user fairness [26], figure 1 depicting the downlink and uplink NOMA in cooperative vehicular networks. Unlike the standard orthogonal multiple access (OMA) system, the NOMA approach enables numerous users to share time/frequency radio resources while differentiating users based on power levels [32, 105]. Implemented in power domain and code domain, NOMA combines multiple users and uses channel gain differential for better performance. Successive interference cancellation (SIC) aids in signal discrimination [68].

NOMA, unlike OMA, offers fewer system delays, improved dependability, higher transmission rates, and lower-cost service needs [119]. Traditional OMA methods assign orthogonal radio resources to multiple users, but they don't always reach the sum-rate capacity of multiuser wireless networks. NOMA can fully utilize its capacity by surpassing OMA with power domain multiplexing at the transmitter and SIC at the receivers [97].

To demonstrate the mathematical link between NOMA and OMA, we use SNR expressions to characterise the two-user downlink performance. h_s and h_d depict the channel coefficients of $V_S$and V_D . At RSU $\rho\left|h_s\right|^2 < \left|h_d\right|^2$ represent transmit SNR, then throughput of OMA can be articulated for as [75].

$$R_{V_S}^{OMA} = \beta log_2\left(1 + \frac{\alpha_{V_S}\rho}{\beta}\left|h_S\right|^2\right)$$

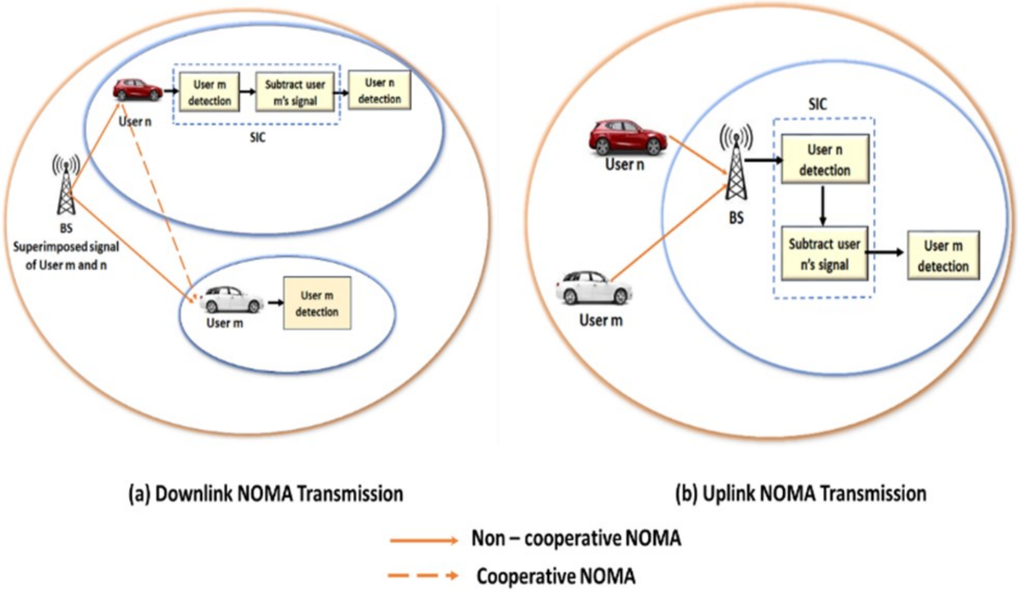

Fig. 4.1: Downlink and Uplink NOMA in CVN.

and

$$R_{V_D}^{OMA} = (1-\beta)log_2\left(1+\frac{\alpha_{V_D}\rho}{1-\beta}\left|h_d\right|^2\right)$$

where α_{Vs} and α_{VD} are power allocation coefficients of with a condition of $\alpha_{Vs}+\alpha_{VD}=1$ and β is resource allocation coefficients. The throughput of V_S and V_D in NOMA are given as [75].

$$R_{V_S}^{OMA} = log_2\left(1+\frac{\rho\alpha_{V_S}\left|h_S^2\right|}{1+\rho\alpha_{V_D}\left|h_S^2\right|}\right)$$

and

$$R_{V_D}^{NOMA} = log_2\left(1+\alpha_{V_D}\rho\left|h_d\right|^2\right)$$

When we have $|h_d|^2 < |h_s|^2$, NOMA outperforms over OMA in sum throughput when adequate channel differences pertain between the two users.

4.1. Benefits of NOMA in Vehicular Networks.

Enhanced Spectrum Efficiency. Uplink NOMA can attain capacity constraints, but OMA methods are often suboptimal. However, when the quality of received signals of two vehicles are large, vehicle throughput fairness is meagre. The border of NOMA rate pairs in the downlink is outside the OMA rate zone. OMA can reach cumulative capacity in multi-path fading channels, but NOMA is optimum [49].

Massive Connectivity. By utilising non-orthogonal resource allocation, NOMA enables the support of a larger number of users or vehicles compared to OMA. This allows for excellent performance even in overloaded scenarios, despite the constraints of existing resources and scheduling limitations [49].

Low transmission latency and signalling rate. Traditional OMA with QOS requirements entails scheduling requests to base stations, leading to significant delay and expensive signalling costs. This is particularly problematic for large connections in 5G. However, certain NOMA uplink methods do not require dynamic scheduling, resulting in grant-free transmission, which can significantly reduce latency and signalling costs.

Table 4.1: List of survey articles on NOMA with various performance metrics

Research Articles	US	PA	FA	CN	MN	UN	SDN	EPN	HN
S.Han et. al [26]	✓	×	×	×	✓	✓	✓	×	×
F.Cui et. al [13]	✓	✓	✓	✓	✓	✓	×	×	✓
J.Choi et. al. [32]	×	×	✓	✓	✓	✓	×	×	×
E.Hossain et. al. [4]	✓	✓	×	×	×	×	×	×	✓
S.Kwak et.al. [49]	✓	✓	✓	✓	✓	✓	×	✓	✓
D.I.Kimetal et.al. [99]	✓	✓	×	✓	✓	✓	×	✓	×
Z.Ding et. al. [93]	✓	✓	×	✓	×	×	×	×	×

Fairness. NOMA empowers individuals with limited abilities. It is possible to achieve a desirable equilibrium between user fairness and performance. In this study, we will delve into the intricate NOMA fairness methods, such as intelligent power allocation (PA) policies [92, 73] and the cooperative NOMA scheme [100].

4.1.1. Ultra-high Connectivity:. The 5G system will connect billions of IoT smart devices [70], and NOMA, with its non-orthogonal properties, provides an efficient design option for conventional OMA.

4.1.2. Compatibility:. NOMA leverages the power-domain as ”add-on” strategy for any current OMA technologies like TDMA/FDMA/CDMA/OFDMA. Given the maturity of Superposition coding and Successive Interference Cancellation procedures practically NOMA might be combined with aforementioned multiple Access techniques.

Non-Orthogonal Multiple Access (NOMA) technology represents a versatile 5G technique renowned for enhancing spectral efficiency and reducing latency in wireless communication systems [57]. In the realm of Vehicle-to-Everything (V2X) services, NOMA is harnessed to mitigate resource collision and achieve high throughput transmission even under resource constraints. Furthermore, NOMA finds application in vehicular networks to minimize latency and bolster reliability [29]. Leveraging NOMA-based broadcasting introduces a hybrid architecture alongside power control mechanisms tailored for participating vehicles [28]. Additionally, NOMA-spatial modulation (NOMA-SM) augments bandwidth efficiency and alleviates wireless V2V scenarios [6]. By employing power allocation algorithms with opportunistic constraints, NOMA systems hold the potential to enhance V2X network performance [49].

4.2. Implementation Challenges of NOMA. Nonetheless, some outstanding concerns must be solved before NOMA may be used in vehicle contexts.

- Error Propagation in SIC: In NOMA systems, SIC is the primary mechanism for detecting users. However, one major disadvantage of adopting SIC is the inter-user error propagation problem, which spreads from one user to the next since a judgement mistake results in deducting the incorrect remodulated signal from the composite multiuser signal, resulting in residual interference. The majority of extant NOMA research contributions are predicated on the premise that the SIC receivers are capable of completely cancelling the interference. In reality, because to faulty PA and inadequate channel decoding, this assumption cannot be easily met in practise. Several academics have acknowledged the obscurity of error propagation concerns and explored the impact of faulty SIC on uplink NOMA.
- NOMA Channel Estimation Error and Complexity: Channel estimation plays a pivotal role in NOMA systems compared to OMA, inaccurate channel estimates lead to muddled user collation and poor power control, both of which impact the accuracy of SIC decoding. The channel estimate diverges with numerous parameters and is always a critical challenge to achieve perfect estimation in practical scenarios.

In addition to the aforementioned implementation challenges, NOMA encounters several additional limitations. Due to NOMA's utilization of multiple access at variable power levels, the received signal intensities exhibit variability, presenting additional hurdles for effective analog-to-digital (A/D) conversion. While robust signals necessitate a wide voltage range, ensuring correct quantization at low levels demands high-resolution ADCs for weaker signals. However, employing ADCs with both attributes proves impractical due to cost and system complexity constraints, inevitably leading to quantization errors. Balancing performance and complexity becomes paramount, necessitating a suitable trade-off consideration.

Another significant challenge in NOMA, often overlooked in prior research, is accurate synchronization. Achieving complete synchronous transmissions proves unattainable in practical scenarios due to the dynamic mobile environments of users, especially evident in uplink NOMA transmission. Addressing synchronization difficulties can be approached through two strategies: proposing precise pilot designs to minimize time synchronization errors and exploring novel asynchronous communication techniques. In a recent study [40], researchers proposed an innovative integrated circuit (IC) approach for asynchronous NOMA-aided orthogonal frequency multiplexing systems, highlighting the significant impact of relative time offsets among interfering users on system performance.

Moreover, NOMA encompasses various additional features such as reference signal design, channel estimation, and Channel State Information (CSI) feedback mechanisms, which bolster performance even in the presence of substantial cross-user interference. Resource allocation signaling is adept at accommodating diverse NOMA transmission modes, while extending NOMA to massive Multiple-Input Multiple-Output (MIMO) systems and other MIMO configurations promises optimal performance. Furthermore, efforts are underway to mitigate the peak-to-average-power ratio (PAPR) in networks with multiple vehicular networks, underscoring NOMA's ongoing evolution and its potential to address a multitude of challenges in wireless communication systems.

5. Cooperative NOMA in Vehicular Networks. NOMA-based transmission has less coverage than OMA-based transmission since each NOMA user is only assigned a portion of total transmit power. One successful strategy to broaden the coverage of NOMA-based transmission is to include cooperative techniques into NOMA networks, resulting in cooperative NOMA networks [67].

Cooperative communication has been a significant focus of study in the past due to its potential to enhance network coverage, throughput, and transmission reliability. By leveraging spatial diversity gain to counteract the effects of wireless fading, cooperative communication offers promising benefits [104].

The fundamental idea behind cooperative communication is to incorporate additional nodes that can assist in facilitating communication between the source and destination. By leveraging its geographical diversity advantage, combining data from various sources enhances the reliability of the destination's reception.

5.1. C-NOMA Networks with Relay and User Assistance. C-NOMA network research may be split into two groups with the aid of nature of collaboration. As illustrated in Figure 5.1a, is based on dedicated relay cooperation, in which specialised relays are installed to aid communication between the source and NOMA consumers [79].

The Figure 5.1b collaboration involves NOMA users with robust connections acting as relays to help those with deprived connections. According to the NOMA principle, strong users must decode frail users' information before decoding their anticipated information [79]. When they correctly discover weak users' information, they can assist them.

Integrating cooperativeness with NOMA can enhance system efficiency and dependability. Users with superior channel conditions may decode messages for others using the C-NOMA technique, which exploits prior knowledge in NOMA systems [33]. When users have superior channel conditions, short-range communication technologies such as Bluetooth and ultra-wideband may set up cooperative conversations. There are two parts to C-NOMA: transmission and collaboration, with NOMA users receiving superposed messages

$(N-1)$ time slots make up the cooperation phase. In the i^{th} time slot, where $1 \leq i \leq (N-1)$, the user from $(N-i+1)^{th}$ broadcasts the combination of the messages from $(N-1)$ C-NOMA achieves the greatest variety gain for all users by adjusting power allocation factors based on local channel circumstances. However, it is costly due to serial message retransmissions. C-NOMA provides user coupling with the aid of separate channel gains, reducing system complexity. Optimum power allocation strategies further improve the performance [42, 60, 73].

C-NOMA transmissions offer several key advantages over conventional NOMA transmissions, including:

- Low System Redundance: When dealing with weak signals, the DF protocol makes intellect since SIC algorithms in NOMA can decipher user messages. It is possible to remodulate and retransmit them from locations that are closer to the intended recipients.

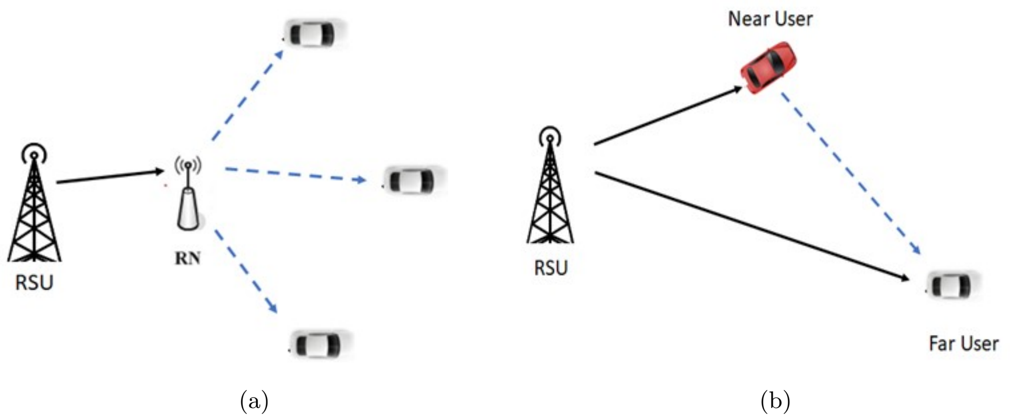

Fig. 5.1: Cooperative NOMA Networks (a) Relay-aided C-NOMA Network, and (b) User-aided C-NOMA Networks

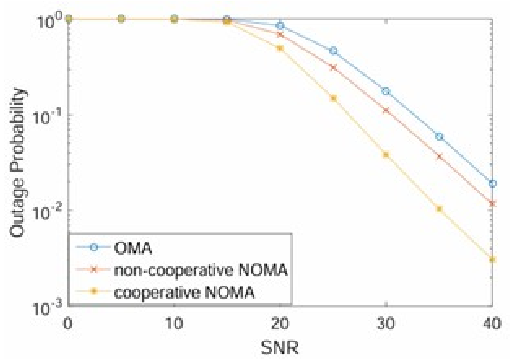

Fig. 5.2: Performance comparison between cooperative NOMA and non-cooperative NOMA.

- Greater fairness: C-NOMA improves the reliability of weak users, increasing fairness in transmission, especially when the weak user is near the cell's edge with reference to the BS [100].
- Higher diversity gain: This C-NOMA serves as a linchpin for superior performance in dynamic and challenging vehicular communication environments. Through NOMA, multiple users can simultaneously transmit and receive data within the same time-frequency resource, fostering a cooperative environment that significantly enhances diversity gain. This heightened diversity gain translates into improved reliability and robustness, crucial elements for vehicular networks where communication channels are inherently volatile and prone to fluctuations. By leveraging the capabilities of NOMA to efficiently manage multiple connections, vehicular networks can achieve unparalleled diversity, enabling seamless communication even in scenarios with fading channels or challenging propagation conditions [70].

Figure 5.2, shows cooperative NOMA's superior outage probability and diversity increase compared to non-cooperative NOMA and OMA. This strategy enhances transmission consistency, especially for weak NOMA users with deprived channel conditions.

5.2. Survey on C-NOMA:. NOMA achieves the highest diversity order for all users compared to OMA [33]. Many researchers have worked on designing and implementing NOMA techniques and on solving various technological problems associated with those methods. The literature demonstrates that NOMA is compatible with cooperative communication.

In terms of diversity order, NOMA outperforms OMA for all users [33]. Researchers have put lot of effort to develop and apply NOMA approaches, as well as to solve the many technical issues. Research shows that NOMA can work with cooperative communication. A special eminence on the C-NOMA techniques is presented in this treatise.

With NOMA in coordinated direct and relay transmission, the authors of [57] examined the ergodic capacity and outage probability of the system. In a multi-relay scenario, they explored consequences of how relay selection affected system performance and suggested a two-stage max-min method for selecting relays. Presenting a power allocation method and investigating the usage of SIC in decoding user signals, Yang & et al. [113] investigated the outage probability and user rates of a NOMA system with paired users in a non-cooperative uplink scenario.

The study in [114] explored the influence of relay selection on C-NOMA performance. A two-stage RS technique was used to minimize outage probability and maximize diversity. A dual-hop cooperative relaying technique based on NOMA was proposed in [52], involving simultaneous interaction between two sources over the same frequency range. The protocol successfully achieved ergodic total capacity through perfect and imperfect consecutive interference cancellation.

The work presented in [107] investigated the performance of a downlink cooperative relay system using DF and AF protocols across Nakagami-m fading channels. Data decoding order from cell-edge users was determined in the research using statistical CSI. When considering ergodic total rate, the findings reveal that, even when considering near-far effects, the DF protocol performs better than the AF protocol. However, the advantage diminishes with increasing SNR. The study also considers the obsolete CSI effect due to continuous channel fluctuations.

In [115], authors explored two possibilities in their paper. a] Direct connection between BS and Users b] No direct connection. First they investigated ordered users' outage behavior utilizing the AF relaying protocol while there was direct connection between the Base station (BS) and them. Secondly, a new closed-form calculation for the downlink outage probability with stochastically dispersed users was created in the absence of a direct relaying node. The users' diversity orders for the two situations have been determined based on the analysis findings. Furthermore, adopting the NOMA technique rather than the standard numerous Access approach ensures the fairness of numerous users. The suggested system was assessed using just AF, and two-way communication with HD/FD may have enhanced user throughput even further.

In order to improve upon OMA-based methods with regard to outage probability, system throughput, and spectrum utilization, reference [71] suggested a NOMA-based transmission strategy for cooperative spectrum-sharing networks. Under the assumption of a high SNR for the purpose of calculating the outage probability, the research in [74] investigated NOMA-based downlink AF relay networks that had low CSI performance. However, because to fixed-ordered decoding approaches, optimal uplink performance could not be confirmed. In [86], researchers examined NOMA-based single-and multi-vehicle systems fared under multipath fading conditions with and without in-phase/quadrature phase imbalance (IQI). Results showed that IQI effects vary across NOMA users and depend on system characteristics. Higher order users were more susceptible to IQI. The TBS-C-NOMA network enhances data reliability in traditional C-NOMA networks by preventing error propagation [53]. If the SINR is superior than the threshold, the intra-cell user will convey the symbols of the cell-edge user. The optimal threshold value is examined to reduce BEP, with SINR determining relay selection. The authors of [7] introduced a two-way cooperative relay technique that utilizes NOMA for bidirectional communication, outperforming a standard one-way C-NOMA system in terms of outage probability and ergodic rate.

Discussions and Prognosis: In the realm of cooperative vehicular communications, the synergy between Non-Orthogonal Multiple Access (NOMA) and cooperative techniques holds paramount significance for scientific advancements, particularly in scenarios where users are strategically positioned and route loss remains consistent. The interplay between NOMA and cooperative communications serves as a cornerstone for driving scientific contributions forward, offering opportunities to enhance system performance and reliability. While previous research endeavors have delved into the potential performance gains achievable through cooperative approaches, numerous open research challenges persist, warranting further investigation and innovation.

One such challenge lies in leveraging relays to improve reception reliability within NOMA-based networks. Relays introduce an additional time window for signal transmission, potentially bolstering the dependability of reception. However, the effective integration of relays necessitates careful consideration of various factors,

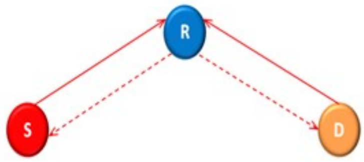

Fig. 6.1: Two-Way Cooperative communication.

Table 6.1: List of Survey articles with two way cooperative relaying

References	No. of users	No. of active relays	Link direction
[100, 112, 59, 85]	1	1	One-way
[119, 43, 110, 101]	2	1	Two-way
[44, 108]	1	2	One-way
[55, 88]	Multiple	1	Two-way

including interference mitigation and resource allocation. In this context, the deployment of full-duplex relays emerges as a promising avenue to address these challenges. By enabling simultaneous transmission and reception, full-duplex relays have the potential to mitigate the need for additional interference management techniques, thereby simplifying network design and enhancing overall system efficiency.

However, the successful implementation of full-duplex relays in NOMA networks requires comprehensive solutions to eradicate interference effectively. Overcoming interference challenges remains a critical research objective, as it directly impacts the reliability and performance of cooperative vehicular communications. Future research endeavors should focus on developing robust interference mitigation strategies tailored to the unique characteristics of NOMA-based cooperative networks. By addressing these challenges, the integration of NOMA and cooperative communications can unlock new opportunities for advancing the reliability, efficiency, and scalability of vehicular communication systems.

6. Two-way Cooperative Networks. The cooperative NOMA treaties use a one-way relay system, while two-way relay (TWR) technology improves spectral efficiency [81]. TWR systems use relays to communicate between nodes, resulting in larger throughput. CNOMA uses full-duplex mode and combines TWR with a suitable technique to improve system spectral efficiency. Two users working in three phases benefit from bidirectional communication in [116] s two-way cooperative relay technique using NOMA, demonstrating superior outage probability and ergodic rate than a one-way C-NOMA system. Hybrid TWRS was established in [8] for compressing data and high spectral efficiency in Network Coding.

Figure 6.1 depicts a system which involves two source nodes broadcasting packets x_1 and x_2 to the relay R, in second phase, R decodes them based on channel gains, and combining them using an XOR operation ($x = x_1 \bigoplus x_2$). The source nodes decode by performing $x_1 \bigoplus x = x_2$ and $x_2 \bigoplus x = x_1$ respectively. This efficiency has led to numerous researches focusing on this system as a promising solution to broaden coverage and deploy the diversity characteristic of wireless networks. The system's efficiency makes it a promising solution for wireless network applications.

Combining TWR with NOMA (TWR-NOMA) can enhance spectrum efficiency and system throughput [8]. Both technologies outperform in boosting spectral efficiency. Analytical and simulation findings show that outage probability converges to an error floor, even with Perfect Successive Interference Cancellation (PSIC), resulting in a zero diversity order, making it logical to combine TWR and NOMA [116].

6.1. Survey on TWR Cooperative NOMA. The majority of C-NOMA treaties concentrated on one directional communication, where messages are sent from the either source to relay and destination or destination to relay and source. Spectrum utilization is limited since communication requires two time slots to reach its target. Optimizing spectral efficiency is achieved by the use of TWR technology [88].

The authors of [47] offered a new method for selecting relays to streamline TWR systems after studying the behaviors of DF relay outages under both ideal and imperfect CSI conditions. The outage behavior of two-way full-duplex DF relay systems on different multi-user scheduling strategies was investigated using CSI and system status information [63]. In [117], evaluated the performance gain and provided an expressions for outage probability, ergodic capacity, and throughput to show the value of with and without direct connection in cooperative NOMA. The work did not specify relay choices, although dedicated relay was explored. Also absent: channel variation effects.

The performance of the C-NOMA system in full-duplex (FD) and amplify-and-forward (AF) modes with a dedicated relay was investigated in a study published in [2]. When compared to the FD decode-and-forward (DF) NOMA methodology, the suggested FD-AF relaying method outperformed in partial self-interference cancellation, according to the simulations. An increase in transmit signal-to-noise ratio (SNR) raises the near user's ergodic achievable rate.

Based on HD/FD in [118], authors developed closed-form methods to calculate the outage probability for two NOMA Relay selection (NOMA-RS) systems. An outage was shown to be less likely in HD-based NOMA-RS with more relays. The researchers postulated that HD-based NOMA-RS systems may provide a diversity order that is precisely proportionate to the number of relays. Nonetheless, NOMA-RS systems based on FD outperformed NOMA-RS systems based on HD in the low SNR range. The investigation did not take mobility, relaying systems, or delay limits into account. A two-way relay NOMA with DF was examined in the study, and for users with imperfect or perfect SIC, the researchers discovered closed-form equations for the exact and asymptotic outage probability in [42]. When dealing with channel circumstances that change over time and impact diversity gain, we ignore the relay selection.

The study in [34] introduced a novel approach for two-user DL and UL transmissions, utilizing a dedicated relay node to assist HD. This approach was compared to traditional one-way relay-based C-NOMA and OMA strategies. Nevertheless, the existence of a dedicated relay remains undefined. In [113], a virtual full-duplex cooperative NOMA scheme and relay selection method were proposed for a downlink two-hop network with multiple HD DF relays. This scheme provides a greater sum-rate compared to regular OMA transmissions and has the potential to improve spectral efficiency when used in conjunction with TWR.

A C-NOMA system for a two-user TWR network (TWRN) was presented in [67, 43], demonstrating a higher sum-rate compared to traditional OMA-based transmission. Unfortunately, no performance evaluation was articulated. A study conducted by experts in the field explored TWRNs that utilize NOMA technology. The study specifically focused on the aspects of secrecy and FD C-NOMA aided TWR systems. Formulas were derived to calculate outage probability, diversity orders, ergodic rates, and system throughput. In certain situations, FD NOMA gearbox demonstrated superior performance compared to HD gearbox.

Numerous multiuser relay networks (UMRNs) have effectively integrated NOMA, including cellular uplink and downlink broadcasts [21, 66, 90] and multi-pair TWRNs. Using rate excruciating and consecutive group decoding, a NOMA multipair TWRN was examined in research that was carried out in [125]. Despite this, a performance analysis was omitted from the research, which found significant decoding difficulty.

7. Relay Selection Strategies in CVN. The issues of routing in automotive networks are far from apparent. The challenge stems mostly from the instability of routing pathways generated by node mobility and network fragmentation. Indeed, the fact that the network has intermittent or partial connection suggests that routing management must vary from topological techniques.

The major routing algorithms for VANETs may be implemented in a diverse context, each with its particular set of characteristics like speed, vehicle density, road layouts, and so on. For example, metropolitan settings are distinguished by a complicated mobility model, high vehicle density, and limited speed, all of which are mostly the result of existing junctions and stop spots. However, the highway and rural settings are distinguished by great distances, making these surroundings less disruptive for radio waves during intervehicle interactions.

Inter-vehicular routing remains a significant difficulty, particularly in urban contexts with high vehicle density and the existence of impediments. The proposed new routing solution must fulfil the needs and characteristics of this kind of environment, whose limits have a significant impact on node mobility and routing performance. As a result of the high mobility of vehicles, the routing route between vehicles may not be guaranteed at all times. Unfortunately, the majority of present protocols fail to adequately assess the impact of potential obstacles that may have an immediate bearing on routing efficiency and, therefore, vehicle communication.

In [62, 124] authors presented a method called Optimal Power Allocation (OPA) for the all-participate-amplify-and-forward (AP-AF) environment. The aim of this method is to minimize the outage probability for multiple relay nodes. The OPA technique was shown to effectively reduce symbol error rate (SER), according to the author's findings. In larger networks, the performance of the AP-AF technique tends to decrease as the number of collaborating nodes increases. This study presents a new approach called selection-based amplify and forward (S-AF), which aims to minimize overhead by choosing the most suitable relay node. This approach combines relay selection and OPA. Unlike [11], this single relay selection does not include relay delay.

The Ad-hoc On-demand Distance Vector (AODV) protocol is used for route discovery and management, with a novel relay selection method aiming to maximize throughput. The cost-based selection criteria consider projected link time and SNR. The relay node decodes frames and sends them in their allocated slot, discarding the rest. A MAC protocol is developed to increase route duration and stability. However, the study assumes every vehicle is directly connected to a Remote Sensing Unit (RSU), resulting in high deployment costs. The study in [31] proposed VANET cross-layer routing via cooperative transmission and a novel route selection method to balance end-to-end dependability with gearbox power consumption. Two optimization issues are created to maximize dependability within transmission power limits and minimize power usage under reliability limitations. The solution assumes one network route and ignores co-channel interference from other node pairs, potentially affecting protocol performance if multiple network paths are active.

The authors in [64] presented an uncoordinated cooperative strategy that uses forwarding likelihood based on node position to decide on the next-hop transmission, reducing coordination overhead but requiring global positioning system information. [38] also presents a cooperative relay broadcasting (CRB) strategy to improve broadcast transmission reliability. The strategy includes a channel prediction technique and an optimization framework based on a two-state Markov chain. The optimization framework constrains CRB performance, while the channel prediction technique aids in selecting the optimal relay node.

The combined impact of user collaboration and dedicated relay cooperation is investigated in [27] for diversity benefit. Adaptive relay selection techniques have the lowest system outage probability (SOP). The relay selection was adaptable based on whether or not the nearby user need assistance. The investigation did not incorporate mobility or channel fluctuations in relay selection, and diversity was calculated based on the number of dedicated relays.

7.1. Mobility effect in clustering of vehicular networks. Clustering is a technique that involves gathering nodes with similar properties, such as destination, direction, and speed, to form distinct virtual sets called clusters. Vehicle mobility in vehicular networks significantly influences cluster formation and maintenance. Each cluster has a cluster head (CH) and several cluster members (CMs), with CH selection influenced by factors like the node's relative average speed. Each cluster has a predetermined size determined by the node's transmission range. Vehicle node clustering can improve communication efficiency in Vehicle Access Control Networks (VANETs) if the clusters are trustworthy and long-lasting.

The mobility effect in clustering may be difficult to achieve for the following reasons:

1. Dynamic Topology: The fast movement of vehicles might generate frequent changes in network topology, resulting in cluster reformation.
2. Cluster Disruptions: Vehicle movement may cause clusters to split apart, making steady and effective communication inside a cluster problematic.
3. Load Imbalance: Vehicle movement might result in an unequal distribution of network load, resulting in performance deterioration in certain portions of the network.
4. Cluster Formation: Vehicle movement might make it difficult to create clusters efficiently and effectively, resulting in inferior performance.

In order to address these challenges, experts are exploring various approaches aimed at enhancing the stability, efficiency, and scalability of vehicular networks. These efforts involve considering vehicle movement when establishing and managing clusters. The VANET distributed multi-hop clustering method (DMCNF) uses location, speed, position, and direction as input metrics, but one hop neighbor selection increases network time. To address this issue, a new protocol Enhanced DMCNF is being researched in [27], which handles communication between the RSU and stable cluster, reducing cluster overhead.

Rapidly moving vehicles can cause network architecture changes and communication path instability, leading to connection failure [41, 106]. A method utilizing a multi agent system and particle swarm optimization is employed to tackle this problem. This approach utilizes the particle swarm optimization algorithm, a cluster formation process, and a multiple agent-based technique. The input parameters encompass various factors such as simulation time, transmission rate, coverage area, transmission range, node density, and numeral iterations. On the other hand, the output metrics focus on evaluating the throughput, packet loss, routing overhead, and packet delivery ratio. This approach is suitable for networks with average service quality, but performance may suffer when applied to high-quality networks.

The authors in [46] proposes a hybrid dynamic cluster strategy to improve communication reliability in vehicular adhoc networks. This strategy involves creating a stable dynamic topology using agent technology, with key measures including time for cluster creation, cluster head selection, and the total lifespan of the cluster. This approach addresses communication failure as a significant disadvantage. In [82] authors proposed a new strategy for enhancing vehicle network stability using clustering mechanisms, which are influenced by constantly changing topologies. The method uses indicators like received signal strength and identification number metrics. For specific roadside settings, a dynamic mobility and stability-based clustering technique is designed, focusing on vehicle direction, location, and lifespan estimation. The proposed work involves defining clusters, transitioning between states, creating and selecting heads, selecting gateway nodes, and ensuring maintenance. The input parameters consist of various factors such as the vehicle density, road length, hastening rate, slowing rate, proliferation model, numeral reiterations, and mobility model. On the other hand, the output metrics provide insights on clusters, CH length, state variation and clustering competence.

In [22, 24] advocated distributed multi-hop clustering. It passively picks the cluster head after organizing the vehicle using vehicle following. The vehicle following technique reduces cluster formation costs, while passive clustering improves stability. However, it ignores inter-node connection dependability when choosing the next vehicle, resulting in poor cluster reliability. Cluster coverage is improved and VANET cluster heads are reduced when a multi-hop clustering technique is used as opposed to a single-hop clustering method, according to this study. The use of available bandwidth is subsequently enhanced.

The authors in [78] proposed a strategy to enhance vehicle network stability using clustering mechanisms, which are influenced by constantly changing topologies. The method uses indicators like received signal strength and identification number metrics. With a focus on dynamic mobility and stability, a clustering approach is created for certain roadside situations that considers the vehicle's trajectory, location, and predicted lifespan [50]. By using the Ant Colony Optimization algorithm, the best way to transmit data from source to destination may be determined. Cluster heads are built with the highest possible link stability. The assessment metrics under consideration include QoS, network dependability, latency, energy efficiency, and network throughput.

In [96, 36], Trust degrees are utilized in authenticated VANET clustering to select CHs, with direct trust degrees reported by neighbors based on prior experience and indirect trust degrees based on nearby node recommendations. This approach addresses VANET instability caused by fast movement of mobile nodes. The previously labeled efforts generate a large quantity of CH, which degraded the performance. To address this issue, the clustering method incorporates grey wolf optimization. The grey wolf's natural hunting habit is employed to construct efficient clusters, resulting in the optimal number of clusters. The simulation findings give communication quality and a dependable information delivery ratio in VANET.

The study in [9, 89] proposed an efficient route repair approach to improve VANET network performance by combining ant colony optimization with an AODV routing system. This approach improves connection stability, packet delivery ratio, vehicle speed, and network quality. However, cluster head overburdening in cluster-based VANET communication is a problem. The research proposed in [77] a multi cluster head selection method, divided into two sections: hybrid fuzzy multi criteria decision making protocol and fuzzy analytic hierarchy protocol. The tributary topic is intrusion detection, focusing on support vector machine and dolphin swarm optimization. An adaptive updating approach was proposed in [14] to tackle the problem of rising channel traffic and congestion by improving the transmission of beacon signals. The method entails transmitting a beacon message by considering the participation of nodes in the forwarding set and the estimated duration of connection availability. The output metrics consist of packet delivery ratio, control packets, and routing overhead. The projected technique shows promise compared to previous models, but it is still in its early stages and has limited applicability to different mobility paradigms.

Previously, one hop clustering was considered, which reduces coverage and increases cluster heads, impacting network performance and cluster overlaps. Some models overlook VANET mobility features, dynamic topology, and restricted driving direction. Earlier mobility-based clustering algorithms caused network congestion and increased collision rate.

Discussions and Prognosis. In the dynamic landscape of vehicular networks, the deployment of two-way cooperative Non-Orthogonal Multiple Access (NOMA) presents a multitude of intricate research challenges. While this approach holds considerable promise in enhancing both spectral efficiency and reliability, its successful implementation hinges on addressing several critical issues that warrant immediate attention for further exploration.

One of the primary challenges lies in optimizing resource allocation strategies to effectively cater to the diverse and dynamic nature of vehicular communication environments. Given the varying mobility patterns and communication requirements of vehicles, devising adaptive resource allocation schemes capable of efficiently utilizing available resources is essential to ensure optimal network performance. Furthermore, mitigating the impact of fluctuating channel conditions poses a significant hurdle. In the context of vehicular networks, where vehicles are constantly in motion, channel conditions can vary rapidly, leading to fluctuations in signal strength and quality. Developing robust techniques to adaptively adjust transmission parameters in response to these variations is crucial for maintaining reliable communication links.

Interference management also emerges as a critical concern. With numerous vehicles transmitting and receiving data simultaneously in close proximity, managing interference becomes inherently challenging. Effective interference mitigation techniques are necessary to minimize signal degradation and ensure seamless communication within the vehicular network.

Moreover, the integration of cooperative NOMA (C-NOMA) with high diversity gain, stringent latency requirements, and reliability constraints of Intelligent Transportation Systems (ITS) warrants thorough investigation. Balancing the trade-offs between spectral efficiency, latency, and reliability in the context of vehicular communications poses a complex optimization problem that requires careful consideration.

As the automotive industry progresses towards a future dominated by connected and autonomous vehicles, addressing these challenges becomes imperative. Unlocking the full potential of two-way C-NOMA in vehicular communications holds the key to driving advancements in intelligent transportation systems and vehicular communication technologies, ultimately paving the way for safer, more efficient, and smarter transportation systems.

8. Conclusion. This comprehensive survey has shed light on the multifaceted landscape of Cooperative Vehicular Communications in Intelligent Transportation Systems (ITS), emphasizing the pressing research challenges that must be addressed for successful implementation in realistic scenarios. The dynamic nature of vehicular mobility, coupled with the need for real-time communication, link reliability, coverage, interference, and adaptability, presents a complex set of hurdles that demand immediate attention from the research community. According to the comprehensive survey in this paper most of the solutions provided unheeded the influence of mobility in relay selection, and the estimated CSI in relay selection is outdated during data transmission. Future research efforts should prioritize the development of creative solutions that that can effectively connect theoretical frameworks with practical applications, fostering the creation of resilient, efficient, and secure cooperative vehicular systems that can truly transform the landscape of intelligent transportation. It is crucial to tackle these challenges head-on in order to fully unleash the potential of CVNs and create a safer and more sustainable future in transportation.

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Edited by: Rajanikanth Aluvalu
Special issue on: Evolutionary Computing for AI-Driven Security and Privacy: Advancing the state-of-the-art applications
Received: Dec 14, 2023
Accepted: Feb 23, 2024