RELAY BASED OPTIMIZATION OF ENERGY CONSUMPTION IN MULTI-HOP COOPERATIVE CELLULAR COMMUNICATION

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in

Electronics and Communication Engineering

By

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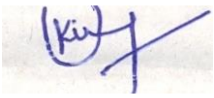
DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Relay Based Optimization of Energy Consumption in Multi-hop Cooperative Cellular Communication",** in fulfillment of degree of Doctor of Philosophy (Ph. D.) is outcome of research work carried out by me under the supervision **Dr. Krishan Kumar**, working as Professor, in the Electronics and Communication Engineering of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled **“Relay Based Optimization of Energy Consumption in Multi-hop Cooperative Cellular Communication”** submitted in fulfillment of the requirement for the reward of degree of **Doctor of Philosophy(Ph.D.)** in the department of Electronics and Communication Engineering, is a research work carried out by Mr. Kiran Uppula Registration No.: 41900740, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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ABSTRACT

With the advances in communication equipment's and Internet of Things (IoT) in intelligent transport systems, Vehicular Ad-hoc Networks (VANETs) has been dramatically gaining tremendous important in modern wireless communications. VANET developed as another form of Mobile Ad-hoc Networks (MANETs) developed to support vehicular communication. The technical standards for research and implementation were standardized by third generation partnership project (3GPP) provided Long Term Evolution (LTE)-based cellular V2X. Initially VANET was developed to support provide driver's assistance applications like road safety, reduce traffic congestion, geographic location information and to optimize the traffic flow. With increase in the road traffic and the hours spent during driving, information dissemination, large content transmission, use of multimedia services and its applications is gaining incredible importance in modern communications. As per the World Road Statistics, road fatalities are expected to become the world's fifth-largest killer by 2040, i.e. thousands of times more than terrorism or rail/air accidents.

Designing and implementation of VANET needs many challenges to be addressed like vehicle mobility, dynamic changing topology, varying vehicle speed, erratic drivers behavior, road topology and multipath fading etc. The unreliable link connectivity makes it even complicated in designing and implementation in realistic situations. Hence dedicated research addressing these challenges to provide an efficient communication is necessary. There are many limitations in VANET and challenges have to be solved in order to provide reliable services in a network. Hence, reliable and stable routing is one of the major issues in VANET. To alleviate the impact of these limitations and improve the reliability, most of the researchers had proposed integration of cooperative networking with vehicular communication. This paradigm where other vehicles helping in content transmission is referred to as Cooperative Vehicular Networking (CVN). Extensive research is carried in implementation of cooperative communication in cellular networks, but due to the dynamic and unpredictable nature of VANETs still there is inevitability to overcome

the limitations for effective implementation. Identification of vehicle as a cooperative node, multi-hop clustering, and reliable routing with less transmission delay are few of the challenges which need further attention.

In most of the earlier research, it was demonstrated that multi-hop cooperative networking will improve diversity gain, coverage area and throughput. But the implementation of multi-hop networking comes at the cost of multiple relay selection, clustering and transmission delay. Motivated by the above problem, this thesis presents an over view of relay selection algorithms, optimization of multi-hop and relays between source to destination using genetic algorithms like optimized Swarm Intelligence based routing in VANET. Hence, in this research a hypothesis is proposed with new Dimension-based Cat Swarm Optimization (D-CSO) algorithm and Best Fitness-derived Crow Tunicate Swarm Optimization (BF-CTSO) algorithm. The performance of the proposed Swarm base optimization techniques is proved superior to existing standard genetic algorithms depicted in the literature.

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INTRODUCTION

1.1 Introduction

Ad-hoc networks, wireless technology advancements, and the automobile sector have all contributed to the emergence of vehicle networks. Moving cars, Road Side Units (RSUs), and people using communicating tools comprise these networks. Vehicle networks may be set up in locations including highways, cities, and rural areas. Vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and Vehicle-to-Pedestrian (V2P) are three basic situations for vehicle communication [1]. Figure 1.1 depicts the VANET in broad strokes. The most widely utilized technologies are Long-Term Evolution (LTE) [5], Dedicated Short-Range Communications (DSRC) [2]/IEEE 802.11p [3], and IEEE 1609 group of standards [4].

In [6], respectively, some of the major technological advancements that have shaped the contemporary auto industry and vehicular networks are discussed. With these vehicles as networks proliferate, new standards for services including safety warning, traffic nursing, lane shifting, and junction supervision, will be imposed [7]. In terms of latency, throughput, and dependability, these apps place various service demands on the network. With high mobility of vehicles, the unpredictability in channel behavior, and link stability are a few of the significant difficulties that vehicular networking must overcome. Many researchers proposed integration of cooperative communication with vehicular networks to mitigate the effect of these hitches. In cooperative networking, neighboring vehicles might work together to improve communication by broadcasting overheard messages. This communication approach, in which other cars assist in transmission, is known as cooperative vehicular networking (CVN).

A. Cooperative Communication (CC)

It is a novel technique that can enable effective spectrum utilization by taking use of the signals broadcast benefit of eavesdropping the information transferred from source to destination.[8] defines cooperative communication as "the processing of overheard information at the surrounding nodes and retransmission towards the target to create spatial variety". Cooperative communication can help achieve more geographical diversity, reduced communication delay, improved throughput, flexibility to topological changes, and less interference [9]. With the above listed characteristics, CC technology has the potential to significantly improve the performance of vehicle networks.

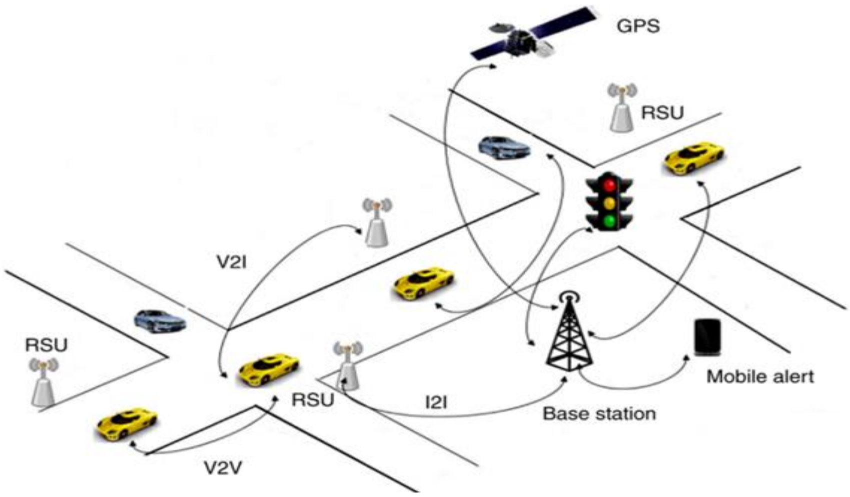


Figure1.1. VANET Architecture depicting various scenarios.

B. Cooperative Vehicular Networking (CVN)

Cooperative communication in vehicle networks, like other wireless networks, has been exploited to provide different enhancements, such as spectrum efficiency, better reliability, and decreased latency [10]. This integrated system aids neighboring vehicles to collaborate with one another by mutual exchange of statistics at different tiers of the network, providing several transmission options for strong communication. Vehicles can communicate with one another unswervingly or with the support of roadside setup. A helper node or relay node is a vehicle node that assists the transmitter node in transmitting its data. The cooperating vehicle is labelled as “relay node”. The relay node can operate in a variety of transmission modes, including Amplify-and-Forward (AF), Decode-and-Forward (DF), Compress-and-Forward (CF), and Store-Carry-and-Forward(SCF) are all methods of forwarding data. [11] provides an overview of numerous solutions for cooperative communication in vehicle networks.

Figure 1.2 depicts a simplified instance of CVN in which collaboration is accomplished in several ways. For example, as shown in Figure 1.2a, a vehicle can help other vehicles with failing direct transmissions. Similarly, a vehicle can assist other vehicle information through RSU or vice versa, if the second vehicle is out of the range of RSU (Figure 1.2b). Figure 1.2c the involvement of vehicle node and RSU in relaying to mitigate the packet loss. For example, if a source RSU fails to deliver a packet to the intended vehicle, the unsuccessful packet is sent to the neighboring RSU through the backhaul wired connection. The neighboring RSU relays the packet to any favorable vehicle that is travelling towards the intended destination.

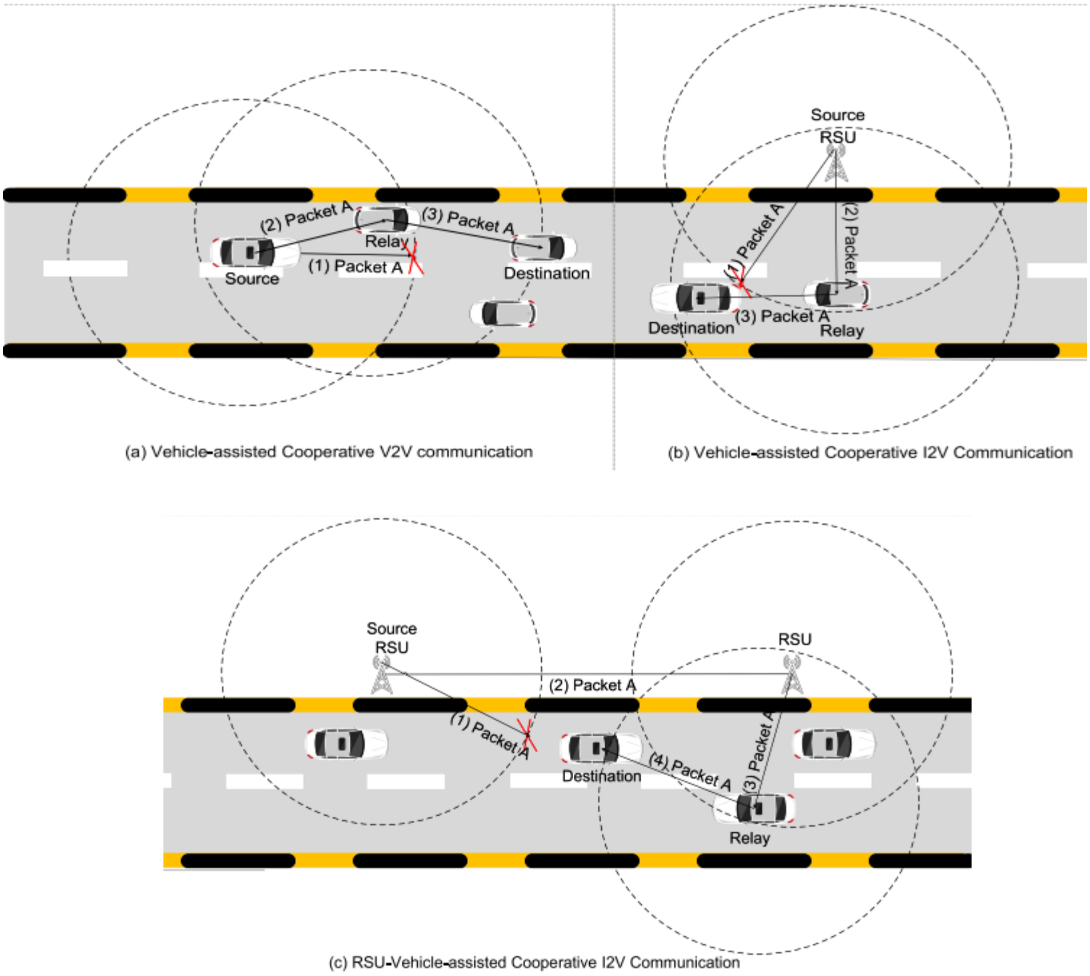


Figure1.2. Illustration of Cooperative Networking in Vehicular Networks.

1.2. VANET Features and Challenges

VANET's capabilities and qualities set it apart from other Ad-hoc networks. Some VANET properties, such as large network size, rapid node speed, and constant mobility, make node connection challenging to sustain. However, in addition to vehicular communication and safety, additional functions like access to multimedia, data transfer and are provided for the convenience [12]. It is critical to describe the primary issues that influence VANET. Some of the most significant technological perception difficulties are mentioned below: Signal Fading: Objects like as buildings and other cars in the path of two connecting vehicles on a road might operate as an impediment and create a network signal shortfall [13].

1] Bandwidth Limitation: The unavailability of a controlling management device, such as a router, for supporting transmission among the nodes is one of VANET's major issues. As a result, productive bandwidth use becomes critical in VANET [14].

2] Smaller Diameter: The partial network coverage of a VANET results in poor connection in node connectivity. As a result, maintaining a network topology for a node for an extended period of time is impractical. As a result, the current VANET routing algorithms are unsuitable for networks with higher diameters [15].

3] Security and Privacy: Due to broadcast, receiving information from a truthful sender is a critical problem in VANET [16]. All of this introduces additional obstacles to VANET communication. Further research and novel solutions are required to assure the appropriate performance to produce efficient security, infrastructure and services. Authenticity, driver secrecy, and availability are still issues that must be addressed with VANET security. Insubstantial, ascendable authentication frameworks are unable of defend vehicular nodes from neighboring attackers who can infiltrate networks using false identities, identifying suppressing attacks, fabricating, altering, or replaying legitimate messages, revealing spoofed GPS signals, and preventing misinformation from entering a vehicular network. These types of assaults are currently being investigated. The overhead due to reliable broadcasting in vehicular communication also led to further issues. This may include selecting the next forwarding node and maintaining vehicle communications. Furthermore, because broadcast messages do not employ Request to Sender/Clear to Sender (RTS/CTS) message exchange as used by IEEE 802.11 [3], they leave or join a group and have hidden terminal difficulties.

4] Self-governing and Infrastructure-less Network: VANETs are made up of autonomous system vehicle nodes connected by wireless networks that lack infrastructure and centralized management. VANET nodes move at random, arranging themselves freely; as a result, the wireless topology of a network changes fast and unexpectedly. A collection of vehicle hosts with wireless network interfaces forms transitory networks in VANETs, which lack permanent infrastructure and centralized administration. A VANET is an infrastructure-free network in which network vehicle nodes dynamically establish routes among themselves to temporarily transfer packets.

VANET is a particular Ad-hoc network of moving automobiles called nodes that allows them to share information without relying on permanent infrastructure. VANETs are self-organizing communication networks where, automobiles act like servers and clients to share information. The vehicles function as mobile nodes in VANET, a subtype of MANET. Vehicles in a VANET are wirelessly connected as an autonomous system using peer-to-peer communication. VANETs differ from MANETs in several ways, including dispersed communication, random mobility, self-organizing capabilities, restrictions on various route patterns, and unrestricted network size. The hard aspects make creating more efficient routing protocols more attractive [17].

Real-time communication research on VANETs enables distributed applications across vehicle nodes in places with no infrastructure. In VANETs, cluster-based routing is important for applications that demand improved routing and scalability to 1000s of vehicles. Techniques based on location increase routing performance in a variety of mobility circumstances. Due to mobility improper architecture, the connectivity among the node is for short time interval. VANET security varies from that of wireless and wired networks. Infrastructure in wired networks contains distinct functional components like hosts and routers to transceiver and route determination respectively.

5] Multi-hop Routing: Developing MANET and VANET technologies will enable network-centric communications. Many mobile nodes connect with one another using single-hop or multi-hop routing protocols. Despite the fact that VANET is a classified MANET scenario, its nodes create a highly dynamic network with node density that can be dense or sparse. Furthermore, because car radios have a restricted radio range, communication takes place via multi-hop routing methods. Based on vehicle position, speed, and trajectory, urban VANETs determine route quality characteristics [18].

According to the pertinent viewpoint analysis, the services of the VANET are defined based on the networking, infrastructure, topology and the requirements. The "one-to-one," or point to point, and "one-to-zone" (route referred to location dependent broadcast) routing algorithms are discussed. In carry and forward relaying, the VANET unicast routing with multi-hop transmission is used to transfer data from source to destination. In multi-hop networking, known as multi-hop forwarding, uses intermediary vehicles in a route to transport data from source to destination as quickly as feasible. A carry-and-forward strategy involves source vehicle carrying data packets for as long as feasible to decrease the number of information packets. The delivery delay-time cost in wireless multi-hop transmission is lower than the carry-and-forward approach.

Multi-hop networking facilitates to transmit the data packets between nodes until the information reaches the destination. The infrastructure domain enables access to Internet services, Internet nodes, and servers. It enables wireless multi-hop communication between two nodes (unicast employing 'greedy forwarding') as well as efficient data packet broadcasting across geographical areas (Geocast) [19]. VANETs allow cars to exchange information (such as the existence of traffic congestion or an accident) via multi-hop broadcasts via intermediate relaying forwarders. However, the efficiency of such multi-hop broadcasts is hampered by difficulties caused by high vehicular mobility and poor V2V radio propagation circumstances. This raises the likelihood of discovering a multi-hop linked path with a communications overhead to the end destination.

6] Dynamically Changing Network Topology: VANET has a dynamic topology and operates without infrastructure. Transportation network communication and routing are difficult because to their short communication lifetime, high-speed vehicles, unexpected node density, topology changes, and metropolitan environment features. Because to its dynamic topology, the risks of disconnection are significant. Due to these many dynamic impairments, the designing of the VANET with reliable communication had dragged attention to overwhelmed the challenges. In VANETs, high mobility causes frequent network segmentation and route disconnection, necessitating re-computation of topological information. Based on the literature survey and the algorithms developed by researchers, authors in [20] summarized different classifications of routing in VANET.

Because of the extremely dynamic nature of topology, designing effective VANET routing protocols is a difficult issue. In VANETs, the routing protocols are mainly classified as into: topology-based routing protocols and position-based routing protocols. Each node in an Ad-hoc network updates the routing table on a regular basis through broadcast or as new information becomes available, ensuring routing table consistency with the Ad-hoc network's constantly changing topology. The routing table element of each mobile node changes constantly to conform to the dynamically changing topology of an Ad-hoc network. Once the consistency level is attained, routing information advertising should be frequent or swift to guarantee that a mobile node in a dynamic Ad-hoc network can always identify other mobile nodes. The most difficult difficulties in VANET are high mobility and frequent network topology modifications. When cars alter their velocity and lanes, the network architecture of VANETs changes. These are not pre-planned and are dependent on drivers and road conditions.

7] Network Scalability: Scalability is a critical quality of large, particularly distributed, networks and systems. The selection of new nodes or termination of existing nodes in the networking or routing should be manageable without effecting the performance is terms of speed or other parameters is called scalability. The vehicles participating in routing effect the network performance in terms of delay, overhead and congestion. Scalability is also affected by protocol design.

Many base stations are strategically placed around a city to facilitate Ad-hoc network routing scalability while ensuring internet access. These allow nodes to communicate via multi-hop pathways. However, there are additional issues like as high node mobility, signal attenuation, and network scalability. With 750 million cars on the road worldwide every day and no global authority to oversee them, network scalability becomes a question mark. The operation of very sparse and severely overloaded networks is an issue inherent in VANET implementation. Current techniques do not handle scalability difficulties thoroughly since they only address sections of the problem. Large networks have good scalability, although network delays and overhead emerge when clusters form in mobile VANETs [21]. Because VANETs may contain several vehicles, protocol techniques must be scalable and economical in terms of mobility management-related overhead. Unfortunately, deterioration as connection possibility rises is a trait prevalent in topology protocols, making scaling challenging. In [22], authors demonstrated the trade-off between the scalability and capacity of VANETs with number of nodes and their distribution in the network.

8] Bandwidth Limitation: Unlike topology protocols, in position-based protocols the route are developed only when desired for transmission, this protocol avoids most of the route maintenance and significantly reduces the BW utilization and control overhead in VANETs. This assures data transmission while utilizing a large amount of bandwidth. The updates are made on a regular basis, independent of bandwidth limits, network congestion, or network size. The disadvantage of such systems is that they impose unnecessary processing limits on the network. Due to a shortage of capacity, that was already pushed to the maximum. Furthermore, when node density grows, so does message transmission, resulting in increased bandwidth usage.

Wireless connections have lesser capacity than cable lines due to bandwidth limits. Wireless communication throughput is impacted by fading, noise, and interference. Mitigation of challenges in V2V and heterogeneous vehicular communication has been a predominant area of today's research for many industries and academicians. Thus, ranking is vital because it allows the most important data to be conveyed while adhering to bandwidth limits [14]. Due to bandwidth limits; a vehicle may not be able to transmit all of its information. To minimize bandwidth utilization, the amount of reports transmitted by a vehicle is decided. Intuitively, if the transmission size is too tiny, bandwidth is wasted, and report distribution worsens.

The following factors make it difficult to facilitate vehicle communication and construct an efficient VANET routing protocol: signal fading caused by obstructions (buildings), bandwidth limits, vehicle mobility, and speed that is reliant on traffic signs and other signals. As a result, this technique varies from typical forwarding in that the sender does not indicate the destination. Depending on the demand and availability of bandwidth problems in VANET, information is disseminated here.

9] Error-Prone and Shared Channel: VANET issues needs be at most concentrated to reduce and provide better performance by ensuring efficient routing, security, and QoS. Dynamic nature in VANET networking leads to ineffective QoS, error-prone resource sharing , restricted resource availability, and insecure medium. Similar to MANETs, VANET also suffers from error-prone due to channel impairments in transmission like pathloss, interference, multipath fading, noise, repeated route interruptions and attenuation. In [23], author proposed cross layer protocol design to handle the challenges of VANET under multiple objectives. The radio channel is a means for broadcasting. Radio waves suffer from attenuation, multipath propagation, and interference as they travel over a wireless medium (from other wireless devices in the vicinity). A channel with a large number of wireless channels is prone to errors. When a protocol is developed without considering faults, its performance degrades during real-time deployment.

A node placed beyond the normal transmission range may not receive lengthy data frames, but it will get short RTS packets without problems. This occurs because real wireless radios do not adhere to unit-disk assumptions, resulting in VANET routing issues.

10] Location-Dependent Contention: Although wireless channels fluctuate in time and place, data transmission rates in VANETs must be adaptive. Location-based services are constructed on top of a push-pull information paradigm based on two previous situations. To begin, regional transit stations provide access to information such as parking zones, gasoline stations, entertainment venues, restaurants, and stores. Second, a vehicle equipped with a Global Positioning System (GPS) allows the incorporation of geographical positions in many practical services for user value-added benefits. The location information of other vehicles can be used as one of the metrics to improve connectivity and resource sharing.

Many applications and services in VANETs use GPS receivers to assume a node's information at a real-time position. However, as VANETs approach critical regions based on localization systems, GPS hitches and glitches may not be robust for many applications. As a result, novel localization approaches are required to overcome GPS limitations [24]. As a result of great mobility of cars and the regularly changing road conditions, VANET channel conditions are very dynamic. Transmitting vehicles modify the transmission parameters such as transmit power, data rate etc as per the channel conditions & location to improve the QoS. VANET enables entities to create a key agreement mechanism and exchange the secret session key, which ensures data security and integrity. It provides authentication while broadcasting as well as in high-contention contexts such as VANETs [25].

11] Energy Efficiency: Vehicle transmitter power control is a tool for balancing network connection and reducing inter-vehicle interference. The energy efficiency of VANETs is not a concern since cars are considered to have infinite energy reserves, i.e., the vehicle's battery. As a result, despite the availability of several research in this field, VANET nodes have practically infinite power for communication via the battery included in them.

A two-tier data delivery technique is used to improve VANET energy competence. The energy efficiency can be improved with proper scheduling of the routing and RSU. A scheduler and implementation of relaying and underlay wiring and assess to close proximity vehicles will increase the overall energy efficiency. Access point power regulations are investigated in [26]. A scheduler capable of meeting the communication needs of cars in close proximity to an AP while conserving energy consumption via AP power regulation is being investigated.

1.3. Cooperative Networking

CC has been shown to be a promising approach for maximizing the benefits of MIMO in wireless communications. Cooperative communication is being used in various systems due to its decreased complexity at the physical layer, increased capacity, speed, and network coverage [30]. Adopting cooperative relays with a single antenna might restrict the diversity with many antennas at the devices. There are no extra infrastructural requirements for implementing vehicle communication. Despite these benefits, numerous problems remain unresolved for using the technology in a realistic environment. Communication that is cooperative.

Cooperative communication relays exhibit egoistic, supportive, and cooperative behavior. In this work, *R* node is considered to be egoistic if it can't participate in cooperation between *S* and *D*. If it provides aid in unidirectional, it is said to be supportive behavior. If the *R* node offers bidirectional assistance to all linked nodes in the network, it is referred to as a cooperative node. During the collaboration, the *R* node can communicate its own data while also assisting in the transfer of data from other nodes.

Few significant criteria to consider while constructing cooperative networking are resource allocation and relay selection [31]. The system's performance improves with diversity when cooperative relays are used. Figure 1.3 displays a straightforward cooperative network with a source (*S*), a single relay (*R*), and a Destination (*D*). Two phases help us better understand cooperative communication. The *S* broadcasts the information to the *R* and *D* during the first phase. The *R* retransmits the information to the *D* in the second phase. This second broadcast can help to offset any problems in the *S*-*D* channel.

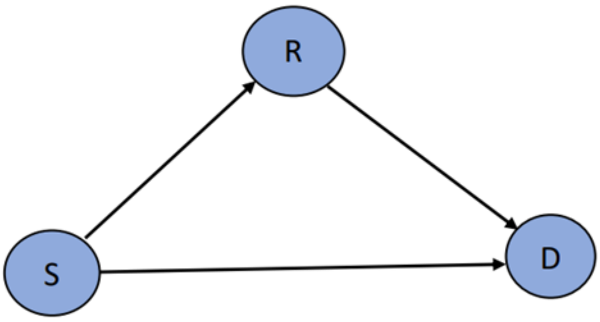


Figure1.3. Cooperative strategy

1.3.1. Cooperative Relaying Protocols

Relay protocols manage data processing in cooperative communication. They vary depending on the relay's distance from the *S* and *D* nodes, its mobility, light-of-sight and nonline-of-sight situations. The relaying protocols are classed as fixed or adaptive based on the preceding parameters [32].

Because of stationary relay and when there is no additional relay selection, resource allocation and channels are predefined in fixed relaying between source and relay. In-spite of its simplicity, though *S* and *D* have tolerable channel conditions, intrusion of *R* reduces inefficiency in resource utilization.

I] Amplify and Forward Relaying (AF)

In this relaying protocol, the *R* node sends the scaled version of *S* information to the *D* [33]. The noise present is additionally enhanced automatically by Amplify and forward relaying. This relaying system lowers transmission time while not increasing circuit complexity. If noise amplification dominates the source information, the system's performance suffers.

II] Fixed Decode and Forward Relaying

The *R* is referred to as a regenerative node in this relaying protocol because the received broadcast information of phase-I is decoded and retransmitted to the *D* [33]. The impact of the noise generated at the *S* and *R* during transmission is mitigated with decoding of information signal [34]. Though relaying decreases noise, if the decoded signal contains erroneous bits, the R node begins retransmission from the *S node*, increasing system time and complexity. In [35] hybrid DF scheme addresses DF's retransmission constraints. The spectral efficiency constraint in fixed relaying is overcome by the use of adaptive relaying protocols, in which the relay selection and protocol vary adaptively with the system needs [35].

1.3.2. Necessity for Relay Selection

In cooperative communications, *R* selection is critical since inefficient relays can contribute to performance deterioration [36]. To increase dependability and reachability, the *R* node provides an alternate technique to carry the *S* information, as depicted in Figure 1.4. The best relay selection implies a reduction in system power consumption, throughput, and outage likelihood [37]. According to the associated literature, relay selection is divided into two categories: centralized relay selection and dispersed relay section system.

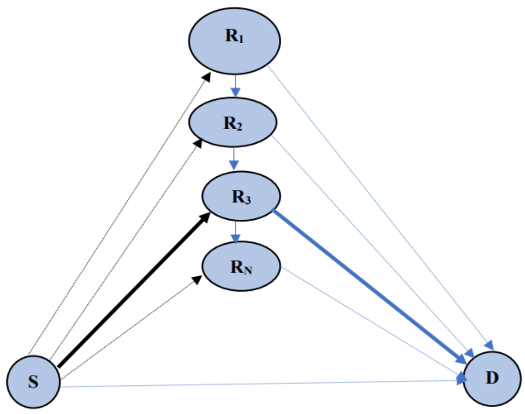


Figure 1.4. Selection of Relay node in CC

In distributed *R* selection, each *R* node have the option of participating in communication or not based on the control information shared between the relays [37]. [38] suggested a relay selection technique based on perfect channel state feedback (CSI). Many studies presented various relay selection methods based on SNR, throughput, energy efficiency, relay position relative to the desired nodes, and so on. The majority of distributed relay selection methods were classified as simple, based on set priority and outage probability. In contrast, in centralized relay selection, the optimal relay is chosen based on a variety of criteria, but the choice is made by the system's base station or access point[38].

1.4. Next hop Selection Algorithms

In cooperative networking, the selection of the next hop is critical in transferring information from one relay to another until it reaches its *D*. The authors provide many routing strategies depending on various metrics and situations. The physical implementation of MANETs and VANETs affects the multi-hop selection scenarios. The strategies are classified as below.

1.4.1 Distance Based Multi-hop

This type of next hop strategies in VANET are mostly determined by the geographical location and network structure of the relays. It is used for selecting the next hop relay and routing to the *D* in order to mitigate difficulties and improve performance. Greedy forwarding algorithms are commonly employed in distance-based route finding techniques. The greedy algorithm chooses the next hop relay based on its geographical proximity to the *D*. If the relay does not know the geographic position of the *D*, it will choose the next hop relay that is the furthest away from the relay. In a few furthest next hop routing methods, the *R* node selects whether or not to cooperate depending on its distance from the preceding relay hop and the threshold value.

1.4.2 Best Quality Link

To accommodate realistic circumstances, the next hop relay or node can be chosen based on the connection quality and channel conditions. Because they take channel circumstances into account, they outperform greedy or farther next hop selection. This sort of next hop strategy is based on connection quality, distance from the next hop, and power received from the beacon signal. End-to-end latency is increased by these techniques.

1.4.3 Most Demanding Node

These algorithms preferred particular nodes to forward messages based on node location, adjacent traffic, and geographical relevance. In a VANET, this form of routing and next hop selection is utilized to transmit urgent warning messages and security alerts. This sort of algorithm provides a low mistake rate and a high level of security. However, identifying such nodes based on priority on various criteria causes significant overall network latency.

1.4.4 Probability Based

Packets are routed to the next hop with a specified probability in this style of routing. This approach is used to reduce packet rebroadcasting. The probability can be calculated dynamically based on channel circumstances, network density, or node location, or it can be fixed for a specific period of time.

1.4.5 Backbone Node

The current network infrastructure will serve as Backbone nodes. Roadside units, particularly in VANETs, can operate as backbone nodes, forwarding information. Cluster-based routing algorithms or trajectory-based routing protocols are used. These infrastructure backbone nodes are used to compute the path to the *D* or to pick the next hop by reducing the needed overhead caused by beacon signal exchange. However, fewer calculations are required to determine the appropriate next hop or trajectory in order to retain dependability and reduce overall network latency.

1.4.6 Stochastic Method

The next hop in this strategy is chosen at random from a set of surrounding nodes. It might be based on either the transmitter or the receiver side. The transmission has a low chance. The link's dependability cannot be guaranteed, and the likelihood of successful packet transmission is minimal. Because there are no computations, this approach has little overhead and has a short transmission latency in the system.

1.4.7 Counter Based

This approach is employed at the node, where a counter counts the amount of messages received. When the node gets a message, it sets the backoff timer, and if the node receives the same message again before the time of forwarding, it stops the message forwarding. This approach is typically utilized in low-overhead geographic broadcast routing protocols. Backoff time is influenced by a variety of factors, including the node's geographical position. It may also be used to plot a path to your goal.

1.4.8 Distance to Mean

In contrast to distance-based strategies, the distance to mean technique is a receiver-based method in which the receiving node determines whether or not to advance the pack based on the relative nodes distance and the spatial mean of previous node forwarding information. The calculated mean value is compared to the threshold across many parameters. Metrics reachability, bandwidth usage, and network latency, this strategy outperforms the distance-based method.

1.5. VANET Routing Protocols

It is the technique of disseminating a message through a network while effectively utilizing network resources. In contrast to MANET, the routing effectiveness of the VANET is controlled by a variety of factors such as vehicle speed, mobility, link dependability, and interference. Aside from them, geographical location, such as urban, rural, and highways, plays an important influence in optimal routing. As a result of the dynamic nature of VANETs, various issues in routing must be addressed. The majority of VANET routing protocols may be derived from MANET standard routing protocols [20].

Routing protocols are standards or algorithms that help to guide information flow in the most efficient way feasible. Some standard routing protocols have been developed for

VANET routing setups. Routing protocols in VANET are classed based on a variety of parameters such as Quality of Service (QoS), resource availability, network architecture, information dissemination type, and so on [20]. They are divided into five categories, as follows:

- Geographic/Position based routing protocol
- Topology based routing protocol
- Broadcast based routing protocol
- Geocast based routing protocol
- Cluster based routing protocol

They are basically classified as Transmission Strategies and Routing Information strategies based on a review of the literature [40]. For effective routing in our proposal, Swarm intelligence-based Routing Information-based Protocol are developed. We may further divide the information-based routing protocol into two categories. In topological routing, every node in the VANET is conscious of the network topology, but in position-based routing protocol, every node is aware of its location. Table 1.1 depicts the comparison of these routing strategies.

Table 1.1 Depicts the comparison of these routing strategies

VANET Routing Protocols	**Methods**	**Strength**	**Limitation**	**Observation**
TOPOLOGY BASED ROUTING	Packet forwarding is used to store the links information in the routing table	Source to destination shortest route	Overheads are more	Best suited for Mobile Ad-hoc Networks
		Message support for broadcast, multicast and unicast	Discovered routes and delay maintenance	Work best for small networks
		Less utilization of resources	Failure in discovering the complete path	
		Beacon less	Flooding unnecessary	

		Saves bandwidth		
GEOGRAPHIC BASED ROUTING	Beaconing	Creation and maintenance of global routes are not required	Obstacles in highway scenarios	Suitable for VANET; research needs to be done for sparse network and dense network
	Information of vehicle's position in a network	More stable in the high mobility environment	Issue of deadlock at Server's location	
	Global positioning	More fitting for distributed network nodes	Failure of position services in absence of satellite signals	
		Minimum overhead		
		Much scalable		

1.5.1. Topology Based Routing Protocol

In these protocols, every node in the VANET is conscious of the network topology. To move data from source to *D*, a routing table with link information is utilized. According to Figure 1.5, the topology-based routing protocol is divided into three groups.

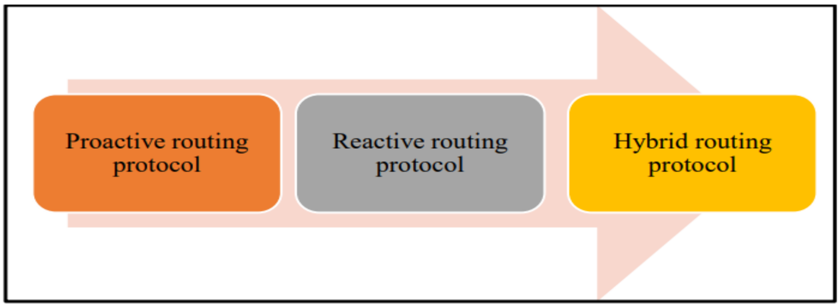


Figure 1.5. Categories of Topology based routing protocols

1.5.1.1. Proactive Routing Protocols

In this routing system, each node uses the routing table and information from other nodes. The routing table is updated on a regular basis depending on the exchange of routing tables with other nodes, and the path to the target node is assessable in advance from any node [41]. It selects the best feasible route to the *D* using the shortest path algorithm, distance vector, and link state approach.

a**) Destination Sequence Distance Vector (DSDV)**

The routing table, as stated in proactive routing protocols, stores routing information and is frequently updated from neighboring nodes. As a routing approach to the target node, it employs the shortest path technique and the distance vector strategy. The table provides information about all of the nodes. The route information along with sequence of nodes to be considered will be broadcasted by the *D* node. However, as the network grows, the exchange and updating of routing tables adds more overhead. The frequency with which the routing table is updated determines the dependability of the route link. Randomized Destination Sequence Distance Vector (R-DSDV) was utilized to address the congestion control problem caused by table information interchange, however DSDV provides less overhead than R-DSDV [42].

b) Optimized Link State Routing Protocol (OLSR)

This approach makes use of the routing table's link state information, which is updated on a regular basis with topological changes with respect to the time. The routing table update aids in determining the nodes information involving in cooperation and data transmission. This protocol is best suited for low-latency dynamically fluctuating networks. Because of the flow of control signals between nodes, this protocol is limited due to network congestion. As a result, a few researchers introduced the Hierarchical Optimized Link State Routing (HOLSR) protocol to offer the hierarchy design with many networks while supporting some low bandwidth applications [43].

c) Fisheye State Routing Protocol (FSR)

The routing table in the FSR protocol is also changed based on information updated from neighboring nodes. The entities were transmitted at various frequencies by the *D* node. The information from the farthest node is delivered at a low frequency, while that from the nearest node is relayed at a high frequency. As a result, this protocol cannot guarantee the entities transmitted at lower frequencies. As the network grows in size, so does the routing table size, and the information for the furthest node may become erroneous [44]. FSR completes all routing nodes, but because the *D* node is outside the scope of the *S* node, the furthest node information may be incorrect.

1.5.1.2. Reactive Routing Protocols

This protocol refreshes route information as well as maintains the route without adding overhead. It sends the route request prior to connection setup to discover a new path to the target. Because of moving vehicles, this protocol is best suited for networks with dynamic topologies [41]. This protocol is also known as the On-Demand routing protocol since it begins the request and confirms the route depending on demand whenever a new route is required. Some of the reactive routing techniques examined and described in this literature study include:

a) Ad-hoc On-Demand Distance Vector (AODV)

This strategy was designed for MANETs, but it also works well for VANETs [45]. It is a source routing protocol that employs sequence numbering as well as hop-to-hop routing. It is started if a new single route must be discovered because the present route does not exist or fails. The broadcasting request plus the delay caused by existing route failure cause huge delays, and the request's redundancy may cause a broadcast storm problem in the network. This eventually leads to inefficient network bandwidth and resource use. Despite the benefits, experts advise improving the AODV protocol to meet the needs of the VANET scenario [43].

b) Ad-hoc On Demand Multipath Distance Vector Routing (AOMDV)

It is an improved version of the AODV routing protocol. This protocol discovers all potential multiple routes from source to D whenever a new single route is identified and updates the table. When compared to AODV, it performs better. Even if a single route breaks during transmission, the information can be diverted through other pathways due to many routes. Only after all multiple routes fail to convey information will a fresh route discovery be begun. This strategy decreases the network's broadcast storm problem while increasing bandwidth efficiency. This protocol is particularly suited for large, dense, and dynamic networks [46].

c) Dynamic Source Routing Protocol (DSR)

This protocol is a type of multi-hop routing protocol that is used to find and manage routes. It is a protocol with several hops. Any relay that requires a new route makes a request to both the source and intermediary nodes. All nodes broadcast the request message to the D, and the modified path data are saved in the source routing table for future use. If the route fails, the source broadcasts a route error message, and the source begins the search for a new route. The DSR protocols are appropriate for stationary networks but are ineffective for VANETs owing to high network sizes and changing network topologies caused by vehicle movement. Routing message exchanges increase network overhead as the network grows in size.

d) **Temporally Ordered Routing Algorithm (TORA)**

It is a scattered strategy protocol suits well for multi-hop routing. The routing information in this protocol adapts to network changes and does not use shortest path routing. The route to the *D* is designated by the *S* node. Because the request message is just from the *S node*, this strategy has very little network overhead. The TORA algorithm is best suited for stationary networks but not for dynamic routing in VANETs [47].

1.5.2. Position Based Routing Protocol

It is a routing technique that is based on the geographical position of the nodes in the network. This protocol does not consider the network address, but rather the geographic location to transport information to the *D*. It employs a GPS system to determine the position of the node in relation to the *S node*. The location information of the *D* is contained in the packet header of the information packet; therefore no additional cost is required for routing via the intermediate nodes. This reduces the finding and maintenance of the route and allows for direct transmission. This approach minimizes transmission latency while also requiring less sophisticated implementation [122]. In comparison to topology-based routing protocols, this protocol is appropriate for large networks such as VANETs.

1.5.2.1 Delay Tolerant Network Protocol (DTN)

Routing protocols for VANETs must address unique characteristics such as unstable connections, inevitable delays, huge networks, bandwidth constraints, and high mobility, among others. This protocol employs a store and forward system, in which all odes cooperate and forward packets when they come within transmission range. This strategy may improve redundancy for stored packets, but it ensures packet delivery to the target [123].

1.5.2.2 Non-Delay Tolerant Network Protocol (Non-DTN)

It operates depending on the location of the *D* and closest nodes. This does not necessitate any routing table maintenance at the nodes and places no focus on connection breaking between the nodes. If a connection breaks, packets are sent by close neighboring nodes assuming there are enough nodes accessible in the network. This protocol focuses on sending packets to nearby cars, which makes it unsuitable for VANETs as vehicles may or may not have close neighboring nodes [124]. Although this protocol reduces network overhead and frequent retransmission requests, it suffers from performance deterioration due to a lack of reliable routing information. Because VANETs are like Gaussian distributions, they are analyzed using a variety of metrics such as shortest path, clustering coefficients, node distribution, traffic density, and trajectory, among others. The low density VANET appears to be a tiny work network with limited connection that cannot fully benefit from its advantages [125]. Most studies employ forward construction speed profiles to acquire information about node distribution to analyze vehicle density in metropolitan areas.

1.5.3. Hybrid Routing Protocols

The hybrid protocols in VANET are created by combining the features of proactive and reactive routing methods. This protocol goal is to decrease overhead and delay in discovery of the routs in on-demand routing methods. The whole network is segmented into zones for easy maintenance and a dependable routing system. The node divides the network into inner and outside zones, with proactive routing protocols doing routing maintenance in the inside zone and route discovery techniques reaching the outer zone [48]. Hybrid protocols are likewise unsuitable for dynamic networks such as VANETs.

1.5.3.1. Zone Routing Protocol (ZRP)

As previously stated, the network region is divided into inner and outside zones depending on criteria such as signal strength, vehicle speed, density, and so on. The inner and outside zones have separate routing, with the interior zone using proactive routing and the outer zone using reactive routing. The internal and outer zones are separate yet operate under the same ZRP. This makes routing and management easier and more pleasant, with less transmission latency. The key drawback of this protocol is that it acts as proactive routing protocols for big size zonal regions while acting as reactive routing protocols for small zones [48]. Because of its huge network and changing topologies, this protocol is also unsuitable for VANET. To address the shortcomings of hybrid routing protocols, the inventors of [49] created a Buffer and Switch (BAS) road-based routing protocol. Another Buffer and Switch (BAS) approach was also proposed by the researcher. This protocol takes into account road-to-road routing rather than node-to-node routing techniques. This protocol is heavily reliant on road topology, which differs depending on geographic area such as urban, rural, and highways. Due to the extreme mobility of the vehicles, this protocol may cause transmission delays and packet loss.

Table 1.2 Comparative study of VANET routing protocol

Parameter	Position based	Geocast based protocol	Proactive protocol	Reactive protocol	Cluster based protocol	Broadcast based
Scenario	Urban	Highway	Urban	Urban	Urban	Highway
Recover Strategy	Carry and forward	Flooding	Multi-hop forwarding	Carry and forward	Carry and forward	Carry and forward
Requirement of Digital Maps	NO	NO	NO	NO	YES	NO
Realistic Traffic Flow	YES	YES	YES	YES	NO	YES
Requirement of Virtual Infrastructure	NO	NO	NO	NO	YES	NO
Method to Prior forwarding	Heuristic Method	Wireless multi-hop forwarding	Wireless multi-hop forwarding	Wireless multi-hop forwarding	Wireless multi-hop forwarding	Wireless multi-hop forwarding

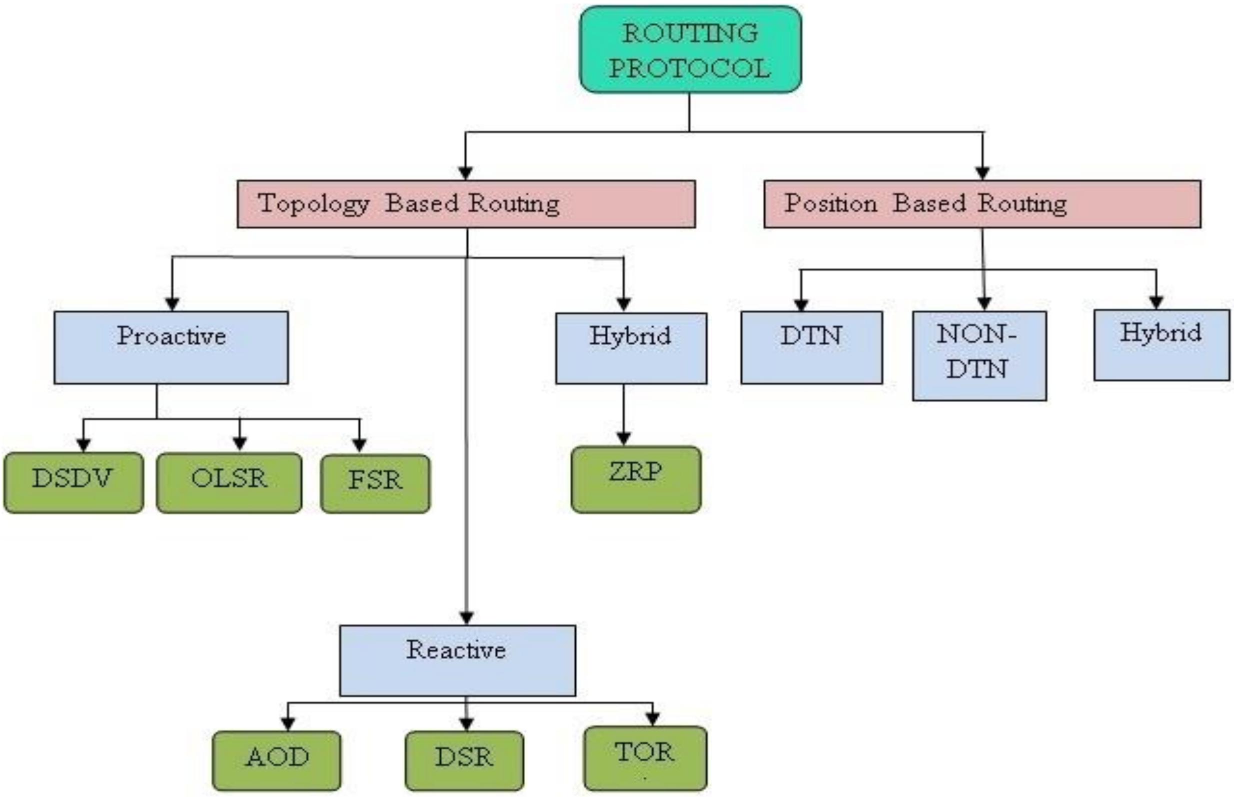


Figure 1.6. Classification of VANET standard routing protocols

1.6. Motivation for Work

Multi-hop cooperative vehicular communication has the potential to increase coverage, improve throughput owing to optimal multi-hops, and energy efficiency. The Outage probability of a system using multi-hop in Nakagami fading channels in [27] the authors analyzed the overall outage with implementation of multi-hop networking.

In VANETs implementation of Cooperative networking with multi-hop by optimally selecting the relays in each hop will eventually leads to a better performance. However, multi-hop cooperative VANETs need a path management and relay selection technique, as well as additional latency. [28] the authors presented the effect of a central control and a distributed control over relay selection with the help of CSI knowledge and the technique is called Last-n-hop selection.

The intricacy of the relay selection methods that necessitate the use of a Central Controller is quite high. The controlling station monitors the CSI of all network links to select the best link and modify all the relays to participate and help in data transfer. The estimation and evaluation of CSI is a complex and time-consuming process. The channel estimation and latency in information transmission should be less than channel coherence time. An further challenge is that the CSI of all network links is necessary before the intended route can be determined. Despite the fact that various works have presented unique channel estimate approaches for multi-hop relay cooperative networks, getting CSI for all connections is a time-consuming task. This means that for fast fading channels with less coherence time needs relay selection at multiple intervals. This multiple relay selection makes it difficult to transmit data continuously, resulting in degradation of throughput. As a result, a strategy to optimize the number of multi-hop and relays between source and destination vehicles is required.

1.7. Contribution of this Works

Motivated by the above-mentioned advantages of multi-hop implementation in cooperative VANET and its implications over the performance of system, this work contribution is summarized in this thesis as follows.

1. The first effort is meant to construct a network and algorithm for minimum number of multi-hops and relays using novel Dimension-based Cat Swarm Optimization (D-CSO) method for improving the performance in throughput and outage probability by resolving the multi-objective.
2. To investigate the effect of proposed intelligent swarm-based multi-hop selection model over convergence, statistical, throughput, and outage probability.
3. The Best Fitness-derived Crow Tunicate Swarm Optimization (BF-CTSO) method is used to preference the best multi-hop relays in a cooperative VANET to address multi-objective functions.
4. The ideal relay selection reduces communication delay and network energy consumption while increasing throughput with a faster convergence rate.

1.8. Thesis Outline

The projected work in this thesis is an outcome of the work carried out on multi-hop cooperative vehicular networks. The following paragraphs emulate a synopsis of each chapter. The thesis is organized into six chapters and which elucidate introduction to the considered system to research finding for the proposed aim in the cooperative vehicular networks. Motivated by the research gaps formulated from the literature review, the projected work is an outcome of the work carried to fulfill the objectives extracted from motivation of the thesis.

Chapter 1: This chapter provides basic introduction to cooperative communication and its implementation in vehicular communications under 5G. The integration of cooperative networking and its implications, advantages and disadvantages are further cited. The VANET features and challenges are listed in detail to summarize the research gap and motivation to carry this research work.

Chapter 2: A literature survey of cooperative communications and a brief introduction to background subjects related to our work such as relaying selection techniques and algorithms, next-hop selection, routing protocols and Swarm optimization in VANETs.

Chapter 3: The performance analysis of Proposed Dimension-based Cat Swarm Optimization (D-CSO) algorithm in CVN is presented for optimal relay selection and number of muti-hop reduction.

The research paper " Throughput and Outage Probability-aware Intelligent Swarm-based Multi-hop Selection in Vehicular Network". This was published in Cybernatics and Systems: An International Journal(SCI), volume 53, August-2022.

Chapter4: In this chapter a Hybrid Heuristic optimal relay selection approach for energy efficient multi hop CVN is presented and is carried out through the multi-objective function regarding link reliability, energy consumption, outage probability, mobility factor, and transmission delay of the system.

The research paper "An Hybrid Heuristic optimal relay selection strategy for energy efficient multi hop cooperative cellular communication" This was published in Ad-hoc Networks, Publisher: Elsevier(SCI), volume 140,March-2023.

Chapter 5: This chapter presents the assessment of optimal relay selection in multi-hop with secrecy capacity. The simulation results of the proposed algorithm are analyzed by throughput, transmission delay, estimating outage behavior, convergence and runtime for three scenarios.

The research paper "An Hybrid Heuristic optimal relay selection strategy for energy efficient multi hop cooperative cellular communication" This was published in Ad-hoc Networks, Publisher: Elsevier(SCI), volume 140,March-2023.

Chapter 6: In this chapter,summeraize the conclusion of the proposed alogortihms by comparing with the existing algortihms in the literature.

CHAPTER-2

LITERATURE SURVEY

CHAPTER-2

LITERATURE SURVEY

This survey provided a clear understanding of the methodology used as well as the limitations of previous routing protocols, which were designed to find and maintain routes to Ds by taking into account a number of metrics such as power limitation, bandwidth limitation, node mobility, geographic location, congestion, delay, and distance, among others.

2.1 Literature Survey on Existing Work Related to Multi-Objective Metric in CVN

This section explores contemporary study techniques on cooperative transmission using few similar approaches, as well as the merits and limitations of such investigations. This method's superiority was established by comparing it to the stated baseline techniques.

2.1.1. Routing Strategies in CVN

The authors of *H. Bhayani et al*. used the car driver navigation approach to determine the *D* in a distributed real-time setting. It is used to determine the best route, road conditions, and to validate the data source [50]. Similar to how the driver's search for a location is not linked to any other device, the author advocated security using an anonymous credential.

The authors of *C. Crespo et al*. used WiMAX technology to measure inter-vehicular interaction [51]. The WIMAX mesh framework's performance has been evaluated using OPNET simulations. The integrity with WiMAX in this study utilized the portable routing algorithms significance with Optimized Link State Routing (OLSR) protocols and Ad-hoc On-Demand Distance Vector (AODV). *G. H. Raisoni et al*. developed a swarm-based intelligence-based method with two distinct parameters to shorten journey time [52]. In the first factor, the suggested algorithm used green traffic signaling period to offer traffic-free vehicle travel. It insisted on green traffic signal duration, which creates a traffic-free channel for vehicle travel. The second aspect combines preventative traffic signals with a modified Ant Colony optimization approach to decrease vehicle waiting time.

ACO and DSR are also regarded routing algorithms in terms of stable routing in VANET situations *S. K. Routray et al*. [53]. In VANET, an ACO-based routing system distributes highway links for eco-friendly routing. The authors of *M. Y. Elnainay et al*.

investigated the influence of feedback and cost updating approaches on resolving the shortcoming of VANET [54]. Link reliability and dependability are two metrics utilized in VANETs for effective routing.

The authors of *S. Ur Rehman et al*. presented a Generic algorithm application for VANET to achieve higher bandwidth efficiency and location aware data flow routing [55]. To solve the 2-lane problem in VANET sensor-based networks, the authors *P. Mohan Khilar et al*. of presented an Integer Linear Program, which was later extended to Center-PSO to perform cross-layer design in hybrid networks in [56]. The *A. Khattab et al*. authors suggested a double-head clustering technique for appropriate Cluster Head (CH) and implemented the Trust dependent Ant Colony Routing for real-time position update and trust value of cars in highway scenarios VANET (TACR) [57]. When it comes to routing overhead, the simulation results show that TACR outperforms the Mobility-aware Ant Colony Optimization Routing (MAR- DYMO) method.

The review in *M. Venkatanaga et. al* revealed the application of bio-inspired routing algorithms in VANET, which reduces network impairments and delivers resilient performance in bigger networks by decreasing complexity and packet error rate [58]. In *E. N. Onwuka et al*., the author suggested an improved Genetic Algorithm-based Routing Optimization Technique (IGAROT) for route optimization that surpasses optimum relay selection using the K-Means clustering technique [59].Motivated by the historical history of an age, the authors of *M. Khalilian et al*. suggested a novel metaheuristic Giza Pyramids Construction (GPC) algorithm that was population-based [60]. The author investigated the influence of the algorithm on optimization approaches, strategies that may be taken from optimum routing, and technique integration.

In *X. Chen et al*. the GPRS connection dependability is improved by using Greedy Parameter Stateless Routing (GPSR-R) [61]. When compared to standard GPRS, the modified approach improves performance and packet delivery ratio. However, due to calculating delays and extensive computations, this approach is not chosen in time-constrained applications. In *B. Ramakrishnan et al*. determined to achieve transmission targets of network as primary objective [62]. A routing system is encompassed to facilitate efficient channel distribution. The routing protocol used a tree-based topology to provide efficient routing across networks. Authors improvised the protocol for tree routing by introducing an efficient, optimized method. A unique Genetic Whale Optimization Algorithm

(GWOA) was employed to choose main stream link for transmission. The Modified Cognitive Tree Routing Protocol (MCTRP) was incorporated in the proposed system. Proposed routing technique distributed spectrum to satisfy the need for optimal channel use, minimized inherent latency, and maximized transmission efficiency. While estimating using conventional procedures, they used channels efficiently and cut overhead.

The authors *Lin S.S et al*. offers a vehicle Ad-hoc network clustering strategy based on the passive clustering process used in mobile Ad-hoc networks [63]. According to the authors, the suggested strategy creates stable clusters with a long lifespan, resulting in respectable routing performance. Three phases make up the recommended plan of action. The finding of routes, setting up of routes, and data transfer fall under this category. This study's main focus is on choosing qualified people for the gateway and cluster head (CH) jobs. The route discovery will then use these nodes to relay the routing information. The appropriateness of a node to serve as the cluster head is determined by metrics. These three factors are node degree, communication burden, and connection longevity. Geographical routing methods are better suited for VANET because of its GPS-like capabilities and unlimited battery life. The GPSR is a geographical routing protocol based on a greedy approach proposed by *Wattenhofer. R et al*. With the hope that this passing on may discover a route to the target, it transfers the packets to the neighbours [64]. Due to the driver's behaviour, changing topology, node speeds, and density in a VANET, the protocol directs packets to the region's perimeter when there are no near neighbours. In a road or highway situation, the network topology is determined by the road layout. Due to connection problems, the packet may end up in a low-density area as a result of GPSR's greed.

The *Yoo, J et al.* outlines a VANET routing plan depending on the number of vehicles on the road. It creates a path for reliable V2V communication in a city context by taking into account realistic density information. The road information and beacon messages are used by neighbouring nodes to calculate density. It guarantees the shortest end-to-end latency and offers the most effective communication path. [65]. Scalability and interoperability are the two most important problems with VANET routing technologies. To provide QoS for diverse VANET applications, effective dissemination and routing protocols are necessary. VANETs cannot use the routing protocols created for MANETs. Research has been done in this area to ensure connection dependability. A scheme is proposed by *Jamalipour, A et al*. it uses the knowledge of the vehicle heading to anticipate the connection breaking before it occurs. By grouping the vehicles according to their velocity vectors, the suggested approach offers route durability and stability. [66].

A Reliability-Based Routing Scheme for VANET (AODV-R) proposed by *Ni, Q et al*. [32] uses their route reliability definition and link reliability model to modify the AODV routing protocol in order to offer QoS in a highway scenario. The network's RREQ message serves as the foundation for AODV route construction. The node that gets the RREQ message forwards it and stores the information about the previous hop. Using the path discovered from earlier hop records, a node sends a route it discovers to the source node using route request-reply (RREP)[67]. A route error message (RERR) also informs the source node of a broken connection if it occurs. The AODV regularly transmits HELLO messages to check on the status of the link. With regard to node coordinates, speed, direction, and connection dependability, the proposed technique adds five new fields to the RREQ message. More field link reliability is added, and the RERR and routing table are also expanded. In order to deliver accurate routing, the AODV-R leverages these data during the route discovery process.

A hybrid location-based Ad-hoc routing (HLAR) scheme to handle the scalability issue was proposed by *Malaney. R et al*. This protocol combines the positive aspects of reactive topology-based routing with topographical routing. When topographical data is not available, the reactive version of HLAR is enabled. The simulations are used to assess network overhead and scalability performance [68]. *Liu et al*. Depending on destinations and neighbour node positions, in presented a stable direction based routing (SDR) that broadcasts the RREQ packets in a certain direction. It lessens flooding and its detrimental impact on the network. By evaluating link stability and marking pathways with path stability and expected expiration time, it also offers stable links for propagation. While determining a route, it takes the vehicle's direction of travel into account. The protocol chooses stable links as a route and forecasts the length of the journey. [69].

The SDR decreases network time by choosing a reliable route and decreases flooding by employing directed broadcasting of RREQ. SDR is a hybrid topological and geography-based routing protocol that, at the expense of additional computing effort, eliminates the congestion issues associated with topology-based routing and the link instability issues associated with geographical routing. Continuous calculations and upkeep for connection stability might slow down a network. The second issue is that RREQ broadcasting results in congestion, albeit at a lower level than topology-based routings.

2.1.2. Relay Selection Strategies in CVN

Zhao et. al adapted [33] concept as the Optimal Power Allocation (OPA) method for All Participate Amplify and Forward (AP-AF). With his idea, the author demonstrated that in a multi-relay situation, this technique may minimize outage probability and SER. However, when a high number of relays were used, the performance of cooperative communication declined. The method's limitations were minimized by using Selection-based amplify-and-forward (S-AF) in conjunction with OPA algorithm, in which only the best *R* is meant to cooperate [40].

Aggelos, et al. suggested an Opportunistic relaying (OR) strategy which did not take power allocation at *R* nodes into account [40]. To address the constraints of the OR method, *Qiu, P. et al*. introduced Power-Aware Relay Selection (PARS) technique, in which OPA was utilized to minimize transmitted power by evaluating channel strength at relays [70]. According to the authors' findings, the combination of PARS with the OR scheme increased network longevity. The suggested approach failed to solve the issues that arise when time runs out at many relays and introduced complexity due to CSI estimate of all connections. Kyu-Sung et al. presented Switch-and-Examine-node-selection (SENS) in multi-hop relay protocol technique to alleviate the drawbacks of this approach. The link SNR threshold data were utilized to choose a relay. The chosen relay will cooperate until the link SNR value falls below the threshold. This system proved to be less complicated than the OR scheme, and it consumes less power because all relays must be in the listening state. The switching idea introduced with SENS allows for relay switching depending on channel deterioration.

Nosratinia, A. et al. proposed an opportunistic routing strategy to reduce the information latency and transmission delay between cooperative relays [71]. This is accomplished by requiring imperfect CSI feedback. They went on to investigate the trade-off between diversity multiplexing and band width resource allocation between source and collaborating nodes. The overall power consumption in this suggested system is higher since all of the *R* nodes were designed to be in listening mode and decode the source information.

To address the shortcomings of the preceding system, *Win, M. Z. et al.* suggested an opportunistic AF relaying with feedback [72]. ARQ is coupled with OR in this technique for feedback from the *D* node, significantly reducing overhead. Only when the *D* is unable to decipher the source information will the selected relay participate.

Syue, S.J. et al. describe a "Geographic information based relaying selection" technique in which the best relay from a group of relays is chosen based on geographical information [73]. Relay clusters were constructed, and data transmission had a lower likelihood of symbol mistake (SEP). Despite benefits such as lower overhead and higher spectral efficiency, this approach struggled in relay selection since each relay location's information was required. Nash equilibrium under stocastic technique was developed for DF cooperative netwrking by *Nayak. A et al*. for relay selection and extact OP behaviour was adopted for multi relay system [74]. A full-duplex store-carry-forward strategy is proposed in *Ni, Q., and Leung et al.* for distributing maximum information to the destination vehicle in the unexposed area by leveraging the relay's capability for concurrent information transmission and reception [75]. The primary intension of proposing is to reduce the power allocation based on link capabilities.

The authors of *S. M. Yiu et al*. introduced a novel way to clustering Mobility Based with Cluster Head algorithms [76], where distinct clustering methods features, objectives, methodology, various performance metrics employed, and barriers are briefly reviewed. It was fascinating to discover which ideas from general public networks were most effective. Location information of nodes in multi-hop cooperative networks should not be compromised at the expense of message security and integrity. According to the suggested algorithm, there is an improvement in vehicle local awareness, and the information exchange provides an update of the information of neighboring cars, which aids in extending the hops until the target D is achieved. A novel cooperative strategy was proposed by *Ismail, M.H et al.* in which algorihm was proposed for relay selction under realistic senario (Unnammed Aerial Vehicles) considering Nakagami-m short-term static fading channels [77]. The vehicular communication model was investigated with cooperative networking in *Zhou, Y. et al.* . The optimal relay selection was computed based on incremental security metric in both the phases using Adaptive Optimal Relay Selection (AORS).

DF relaying protocol helps is successful transmission of information from source to destination with the help of decodable relays. *Madani, M.H. et al.* also proposed multiple relay selection approach with diversity gain with the aid of residual energy and instantaneous CSI to overcome improper resource utiliozation [78]. With CSI and residual energy power resource allocation stratagem with distributed join is proposed for multi-hop relaying cellular networks by *Hong, J.I., Xi et al.* With reference to finite-state Markov chain of first order, state transition of varying channels are expressed [79].

A fuzzy logic-based routing method with authentication capability for VANETs is introduced by *.Lago and S. S. Yang et al*. Vehicles were grouped in this case utilising an efficient tactic [80]. Furthermore, secure information frames were used in an authentication strategy based on the Message Authentication Code (MAC) and symmetric key cryptography. A method for VANETs has been developed in [80]. A game theory-based technique was used for clustering of vehicles and identification of cluster head (CH). This approach reduce the complexity of regular updation of information for cluster peeformance enhancements. Clusters based on the social nature of automobiles were implemented using the K-means algorithm.

2.1.3. Relay Selection Based on Threshold Metrics

Alouini, M. S. et al. presented Output-Threshold MRC (OT-MRC), in which the *D* node adaptively cartels all signals received from and compares the computed SNR to a predetermined Threshold SNR [81]. *W. Su, K. & J. Ray Liu et al*. presented the following 2-phased multiple relay selection technique [82]: The relays evaluate their received signal intensity to a preset threshold in the first phase, and the best relay is chosen in the second phase. The author illustrated the improvement in the suggested strategy by comparing it to a no-threshold scheme. The fixed threshold in this approach is independent of channel conditions, and the number of channel estimates rises as the selected relays fulfil the threshold criterion.

Giannakis, G. B et al. introduced a Link-Adaptive-Relaying (LAR) method to attain complete diversity in DF relaying schemes, in which the relay sends the power with regard to the channel (link) SNR [83]. Authors evaluated the proposal for both uncoded and coded networks. This approach had demonstrated resistance to feedback and quantization problems. Using a power scaling factor, the authors observed an improvement in average bit error probability. *Fettweis, G. et al.* proposed an optimization technique for relay selection using threshold by evaluating the power scaling factor between *S* and *R* [84].

Yanikomeroglu, H. et al. investigate the impact of using several antennas in immovable dispersed nodes and with relays engaged in collaboration [85]. In his investigation, he proved that relays with many multiple antennas provide better performances than the relays with few antennas. *Thompson, J. S. et al.* presented SNR-based relay selection with an appropriate threshold determined by averaging the SNRs from the *S* to the *D* and the *R* to the D [86] . Only condition-satisfied relays will send information to the D under this scheme. This technique's performance was calculated to minimize the average BER. *Wilson, S. G. et al.* evaluated the impact of diversity order in un-coded system, by using adaptive DF relaying with a condition over adaptive threshold over average SNR [87].

Young-Chai Ko et al. introduced a suboptimal relay selection based on threshold, where from the group of relays, the *R* having highest SNR compared to the predefined threshold was selected to transmit destinations [88]. This proposal reduces the overall power consumption in comparison to OR and the BER performance was analyzed at the low SNR regime. The BER performance in low SNR regime is assessed to see if it improves over the OR approach. *Thompson, J. S., et al.* investigated the effect on BER with selective digital relaying based on SNR [89]. In their proposal, authors examined the influence of instantaneous SNR of *S-R*, *R-D*, *S-D*, and average SNR information at relay in the first phase, and the results show that the relay performance improves when it knows the instantaneous SNR value of *S-D*. In the second section, the authors suggested a hybrid scheme in which digital relay selection is paired with a detection approach, and the writers absorbed the performance gain with the hybrid technique over the first portion.

Tsiftsis, T. et al. developed a Generalized Selection Combining with an Absolute Threshold (AT-GSC) [90]. It was a hybrid strategy that combined Minimum Selection (MS) and Normalized Threshold Selection (NTS). Relay selection technique in this scheme was based on threshold, and it is noticed that the channel conditions are taken into account while determining the ideal relay selection threshold.

Liu, K. H. et al. resented double testing of threshold error detection approach to improve the end-to-end performance of decode-and-forward relaying [91]. *K. J. Ray Liu et al.* during retransmission from the *R*, the link quality of the *S-R* and *R-D* is assessed. *Tellambura, C. et al.* examined end-to-end performance with optimal threshold at *S-R* connection, whereas Ban et al. implemented the optimal threshold at *R-D* connection. As a result, error propagation is limited. In *Tellambura, C. et al.* based on the threshold at the *D*, they proposed Output Threshold Multiple Relay Selection (OT-MRS) approach for huge CN [92]. When evaluating at the *D*, orthogonal channeling and maximum ratio combining (MRC) are taken into account. When compared to single-relay- selection schemes and generalized-selection-combining (GSC), the suggested system demonstrated equivalent performance improvement.

The relay selection technique based on the SNR was investigated by *Taiyi, Z et al*. [93]. *Kyu-Sung et al.* proposed approach was based on threshold-based relay selection scheme [70]. Based on the threshold, the authors *Win, M. Z. et al.* expressed a closed form expression of OP. The proposal was observed to reduce the number of channel estimates and provide the similar variety of OR systems [72]. *Tellambura, C. et al.* proposed hybrid relay selection technique based on threshold, where AF and DF relaying operation was selected based on error detection and SNR threshold [92]. The relay whose instanton SNR value is larger than the threshold is deemed to be a DF relay, while the others are AF relays. In DF, Convolutional coding was implemented at *S*, and FER metric was used as a performance indicator. This model was used to determine average FER expression at high SNR using hybrid relay selection.

Nam, S. S. et al. created an Adaptive-Threshold-based Relay-Selection Scheme (ATRS) in which the *R* is chosen from a group of relays based on SNR threshold and calculated instantaneous SNR between *R* and *D* [94]. *Thompson, J. S et al.* suggested relay selection techniques in which the source chooses the relay and the D chooses the relay [86]. In contrast to [86-91] propose no control message exchange in the relay selection process, which reduces complexity and power consumption. *Mohamed-Pour, K. et al.* introduced "switch-and-stay partial-relay selection" (SS-PRS), in which authors calculated OP and average BER [95]. The authors discovered that the outage probability is nearly same to that of the PRS method, but the complexity is lower. The incremental relay combining with output threshold was proposed by *Ju, M. et al.* (IRC-OT) [96]. Multiple relay selection is used with incremental relaying (IR) in this technique to attain spectral efficiency and diversity gain in CN. When compared to only incremental relaying, the authors exhibited a gain in spectral efficiency and BER performance with reduced system complexity. *Liyanapathirana, R. et al.* suggested relay selection "Distributed Switch-and-Examine Combining based on Threshold (DSEC-T) [97]. In the proposed technique, the *S*-*R* links SNR were examined, and the *R* was selected if SNR is below the threshold. AF relaying is used to forward the information from *S* to *D*. This concept combined the switch-and-examine combining strategy of *Alouini, M. S. et al.* with threshold-based relay selection to create a hybrid model [98].

In contrast to the suggested work of *Ko, Y. C. et al.* devised a sub-optimal relay selection system in which the relay selection is created on the switching threshold when end-to-end SNR is greater than the switching threshold [99]. According to simulation findings of *Zummo, S. A. et al.* it attained better, low channel estimation, Bit Error Probability (BEP) and low power consumption at relays compared to other strategies [100]. The error in channel estimation is investigated in AF CN based on threshold-based detection by *Abuzaid, A. et al.* [101]. A hybrid system was developed by *Wang, H., & Lin, X. et al.* by merging generalized relay selection scheme with threshold based diversity combining [102]. The performance of DF networks was evaluated by *Aydın, E. et al.* [103] with MRC and threshold-based relay selection technique. created an optimal threshold-based relay selection technique based on cooperative MRC for DF networks. The authors took into account the Nakagami-m fading distribution between the *S, R* and *D.*

To reduce the self-interference, a hybrid CN is proposed by *Wang, C. X. et al.* [104] by integrating the concepts of decode AF relaying with incremental relaying which was projected by *Duy and Laneman et al.* [105]. Based on channel quality between the nodes, the selected relay will either transmit the source information or remain quiet. Based on the SNR, the relay can operate as DF or AF. The suggested system's performance was evaluated using resource allocation (Power), relay placement, and SNR threshold with regard to Outage Probability. For outage and BER performance, the performance of incremental DF relaying (IDF) and incremental selective DF (ISDF) is examined. *Balasaraswathi, M. et al.* created a DF-based multi-relay selection strategy [106]. This approach exploits threshold to address the limits of mistakes in the selection combining scheme at relays. As the number of relays rises, the efficiency of picking the optimal relay diminishes. This approach was created to analyze the error rate using flat fading channels. According to the findings, instantaneous SNR has a significant influence on the chance of symbol mistake (SEP).

In *Kumar, V. J. S. et al.* advocated combining selection with complete CSI in DF networks [107]. The effect of detection errors on the system performance is evaluated and concluded that suggested selection combining method outperformed standard Selection Combining (SC) strategies in terms of symbol error probability (SEP).In *Hwang, D., et al.* [108], enhanced the ATRS strategy presented by *Mohamed-Pour, K. et al* . to enhance performance of the CN with limited feedback [95]. Relays that require more feedback are removed, and just 1-bit feedback is utilized to evaluate performance.

In *Kaya, H. et al.* proposed Selective Cooperative Non-Orthogonal Multiple Access (NOMA) based on threshold to overcome propagation problems and boost data dependability in cooperative NOMA-based networks (TBS-C-NOMA) [109]. The far end users at the cell edge will get information from the near end users based on the signal to interference noise ratio. The source's power communicated to far end and near end consumer’s changes with distance from the source. This method has been shown to decrease error propagation and increase system performance. To reduce the interference at the relay, successive interference cancellation was applied. In *Kaya, H. et al.* improved on the TBS-C-NOMA scheme by analyzing outage probability and ergodic capacity [109]. For symmetric and non-symmetric cooperative systems, the authors developed closed form formulas for outage probability and ergodic capacity. Non-orthogonal multiple access, joint power allocation, and thresholding enhanced BER and ergodic capacity performance.

Nagarajan et al. suggested DF relaying protocol-based multiple relay selection. By employing an ideal threshold at the relays, this technique gets beyond the selection combining scheme's detection error constraints. Nevertheless, when more relays are added to the network, it becomes less effective to locate the ideal relay for data forwarding. The error rate of the multiple relay DF method in a flat Rayleigh fading environment was investigated by the authors. The results of this investigation show that the symbol mistake probability is influenced by the instantaneous SNR threshold at the relays [110]. *Dayanidhy & Kumar,* suggested combination of complete CSI and selection. This method addresses the performance reduction in multi-relay DF networks brought on by detection failures. In comparison to the traditional Selection Combining (SC) procedures, the suggested selection combining scheme in this work has increased symbol error probability (SEP) [110]..

S.S. Nam et al. The ATRS system developed by Park et al. (2011) was expanded, and the SER performance based on restricted input was analyzed. The expanded ATRS plan put up by *S.S. Nam et al.* (2018) counteract the performance deterioration caused by the type II relay environment's rejection of the superior relay to destination connections owing to minimum feedback by increasing the feedback data rate by one bit [94]. *Ferdi Kara et al.* To increase data dependability and address the problem of error propagation in the traditional cooperative NOMA-based network, Threshold based Selective Cooperative Non-Orthogonal Multiple Access (TBS-C-NOMA) was developed. If the signal to interference plus noise ratio (SINR) is above the threshold in this system, the cell edge user will get the forwarded signal from the user close to the base station, preventing error propagation [109].

Ferdi Kara et al. examined the TBS-C-NOMA system presented by Ferdi Kara et al [109]'s outage probability and ergodic capacity. The authors used the ergodic capacity and outage probability closed form formulations to symmetric and asymmetric channel circumstances in this study. Moreover, a compromise between BER performance, outage, and ergodic capacity has been established. Both BER and ergodic capacity performance are improved by the combined power allocation and threshold selection suggested in this study [110].

2.1.4. Impact of Relay Selection in Energy Harvesting in CVN

In *Binod Kumar Singh et al.*, suggested an unique "Quantum Atom Search Optimization combined with Blockchain assisted Data Transfer (QASO-BDT) strategy" for relay node selection that included security-derived data transmission [111]. This approach has 03 phases: registration, clustering, and transmission. Initially, to register the node a capillary gateway was utilized. During the clustering phase, the cluster head was selected and an enhanced multi-objective clustering strategy to frame several clusters. Lastly, the QASO as transmission phase for multi-hop broadcast using optimum relay node selection, and system security was assured by executing a blockchain-based transaction. The proposed work evaluated parameters like lower energy value and throughput, as well as ensured security compared to traditional techniques

In *Kaiyu Li et al.* studied novel Energy Harvesting-Wireless Sensor Networks (EH-WSN) for energy-efficiency by combining optimizing the relay selection and power resource distribution technique [112]. It indicates the objective of EH-WSN is to enhance the energy efficiency of each clustered node. Impact of the cooperation is analyzed with energy sustainability for relay node. Authors, associated an online optimization issue with a reduction in the computational complexity required to find near-optimal solutions. Using a performance evaluation of typical running utility and transmission power allocation, the developed model recognized the exceptional efficiency. In addition, the suggested approach for joint optimization outperformed previous applications.

In *Y. Yao et al.* , proposed Energy Awareness Optimal Relay Selection (EAORS) design for defining the number of minimal relays by implementing a weighted objective function for energy consumption for cooperative and in both the cooperative transmission and spectrum sensing to reduce Bit Error Rate (BER) [113]. It emphasizes the relative comparison between energy economy and estimation accuracy, and it applies a weighted convex objective function for relay numbers. They discovered a solution to the nonlinear convex problem of identifying the optimal relays. This methodology proved the model's energy consumption analysis efficiency.

In *Y. Wang et al.,* saw development of the "double auction theory" to solve finest relay design problem [114]. Authors concentrated on boosting the efficiency of users at cell-edge by improving energy efficiency. The evaluation findings indicated that the effectiveness of EE-MWM was analyzed using criteria like OP, network capacity and energy efficiency. Using traditional estimation techniques, our model enhanced the performance of CVN. In *Hashem Kalbkhani et al.* proposed cooperative multicast D2D communication with NC with relays functioning as femtocell base stations [115]. With resource allocation like power and relay selection, this method emphasized energy efficiency. The proposed model provides a novel method for network-coded cooperative D2D transmission that greatly outperforms previous strategies in terms of energy efficiency and estimate of spectral efficiency.

In *WANG Ying et al.* introduced a unique cooperative network system proposing energy-efficient relaying methods based on the use of relays with irregular traffic [116]. Using this proposal, the overall energy consumption has been computed. Authors proposed a "Joint Uplink and Downlink Relay Selection" (JUDRS) technique to reduce overall energy consumption through relay selection efficiency. Further, they explored energy-efficient zones and identified the best relay location for irregular traffic networks. Further, experimental findings demonstrate that the proposed method significantly improves energy economy when computing the best mean selection compared to past previous finest inferior channel selection strategies. It used the relative comparison of Diversity-Multiplexing. Number of participating terminals in this network was completely spatially dispersed using the suggested strategy.

In *Jianshan Zhou et al.* proposed an auction-based method for relay selection in cooperative networking. Consequently, determined the value of 03 players [117]. This approach presents centralized "Predicted Mobility Based Profitable Relay Selection Algorithm (PMPRSA)" for selecting a relay based on the random waypoint mobility model and auction theory. Experimental investigation demonstrated that it improved data transfer rates and identification of best relay. In *Jianshan Zhou et al.* a bio-inspired unicast routing system for VANETs. The subsequent hops were selected using the method of cellular attractor selection [118]. Using routing response packets, the author built an unique routing protocol that was utilized to change a complicated dynamic platform. The multi-attribute decision-making strategy was used to limit the number of intrants for subsequent hop selection. In conclusion, actual evidence demonstrates its better performance.

In *Hassaan Khaliq Qureshi et al.* examined distributed information estimate challenges. Existing network-assisted applications such as minimization, node localization, and dispersed surveillance are included into system [119]. Numbers has been offered as constraint with finite states and a probability. To minimize the energy comsuption by wireless devices the authors of *Ilhan et al*. proposed energy minimization stategies using game theory approach for heterogeneous networks (HetNets) with cooperative networking [120]. The minimal relaying was considered as programming and the selection of the relay as the solution of the programming. The optimal relay selection problem is addressed by *F.B.*, *Radwana et al*. for leveraging the connectivity with other users and user interface to improve cooperative multi-hop D2D communications [121]. With a novel strategy, this model has addressed the aforementioned issue. Users were chosen based on the constructed social correlations, with relays with a stronger social association being prioritised.

Table 2.1. Merits and limitations of few cited approaches in CVN

Citations	**Approach**	**Merits**	**Limitations**
Binod Kumar Singh et al. [111]	QASO-BDT	• Minimized transmission delay and energy consumption. • Improved throughput and durability of node lifespan.	• Not suitable for dynamic MANET.
Kaiyu Li et al.[112]	Joint-optimization algorithm	• Efficient optimal relay selection is achieved and improves efficiency.	• OP is unsolved in this proposal.
Y. Yao et al. [113]	Compressed sensing	• Explored better relative comparison between energy efficiency and accuracy.	• Increases overhead.
Y. Wang and C. Wang et al. [114]	EE-MWM	• Energy consumption is reduced at source and relay nodes and provided	• Need to enhance performance while correlating a relay with

		improved efficiency.	one CEU.
Mahrokh G. Shayesteh et al. [115]	Monte Carlo simulation	• Enhances spectral and energy efficiency in heterogeneous networks. • Minimizes femtocell networking interference.	• Complexity increases in estimating perfect CSI.
WANG Ying et al.[116]	JUDRS	• Enhanced energy efficiency for the proposed design.	• Performance degradation with increased transmission error rate.

2.2 Research Gaps

2.2.1. Routing Strategies in CVN

Different routing techniques were proposed by many authors in literature, and through survey it is found that VANETs routing poses many challenges due to dynamic changes in topology. Few strategies address the routing impairments by considering the frequent routing table up-dation at the cost of increase in overhead. The packet loss ratio, retransmission requests and latency are ignored in most of the works. The CH selection did not considered the relative mobility with respect to the other nodes in the cluster to increase the routing stability. Most of the proposals either considered stationary vehicles are vehicles with minimum speed which is not always suitable in VANETs real-time scenarios.

2.2.2. Relay Selection Strategies in CVN

In the aforementioned literature works, it is observed that relay selection was confined to only one hop and the power allocation or resource allocation to the relays was ignored. The position of the relay and mobility effect in relay selection was avoided for reduced computational complexity. Cluster formation and intereference among the relays and multi-hop selection is also neglected. Stationary relay selection does not suit for VANETs, where the dynamic behaviour impose multiple challenges in relay selection.

2.2.3. Relay Selection based on Threshold metrics

In this section, it is observed from literature survey that, threshold based relay selection was proposed by many authors either for relay selection, power allocation, outage and capacity, interference and transmission energy. The SNR in the broad cast phase was evaluated based on the threshold, but in realistic scenarios dynamic behavior pertains to the continuous time varying channels which was ignored in many works. The multi-objective threshold would have been a better solution for the optimization of energy consumptions.

2.2.4. Impact of Relay selection in Energy harvesting in CVN

In the aforementioned works, many authors projected their strategies for energy harvesting. After survey it is observed that few strategies are suitable for only MANETs and can be implemented for VANETs due to dynamic behavior of vehicles. In some works they did not consider the changes in the CSI, and its effect over the performance is not considered, the correlation between the relays was missing and which lead to the link failure, computational complexity in estimating CSI, relay selection lead to decrease in latency.

2.3. Objective of the work

The aim of this proposed research work is to minimizing the total energy consumption in Multi-hop cooperative network. Hence, the proposed strategy encompasses with below objectives:

1. To propose a closed form expression for the minimum number of multi-hops required between the source and destination for the expected target throughput and outage probability.
2. To propose a dynamic relay selection and optimum relays selection in cluster hop to increase link reliability and reduction in the overall energy consumption of the system.
3. Optimization of energy consumption in the above proposals by considering mobility factor, transmission delay and outage probability.
4. To validate or testing of proposed method with simulation software / MATLAB and compare with the energy reduction techniques in multi-hop cellular communications.

2.4. Conclusion

In this chapter a deep insight on the literature survey and observations are projected to formulate the research problem as projected in chapter-1. The implementation of cooperative communication in VANETs leverages many networking benefits like coverage area improvement, energy efficiency and spatial diversity at the cost of many challenges when implemented in practical scenarios. In addition, mobility of vehicles, dynamic behavior of channels, traffic density, lane dynamics, geographical area impose further challenges to researchers to develop an efficient system.

Literature survey on Routing strategies, relay selection, clustering and multi-hop networking and their impact on the energy optimization are discussed in this chapter. It is observed in many works that, energy optimization strategies are proposed based on any one or two metric and they ignored the mobility factor and relativeness among the relay vehicles. Few of the strategies-imposed control overhead and increased the computation complexity and end-to-end relay. Motivated with the above presented research gaps, chapter 3,4 and 5 presents the work carried out in mitigating the challenges in relay selection and energy optimization with multi-objective functions.

CHAPTER-3

INTELLIGENT SWARM BASED MULTI-HOP SELECTION

CHAPTER-3

INTELLIGENT SWARM BASED MULTI-HOP SELECTION

3.1. Introduction

Cooperation has emerged as a critical standard for increasing spatial diversity in Vehicular Ad-Hoc Networks (VANET). As a result, implementing cooperative networking has resulted in better network solutions for improving VANET efficiency in terms of specific constraints such as outage probability (OP), energy efficiency and network capacity. The agenda of this research was to create an optimized model for relay selection and to optimize the number of multi-hops to resolve multi-objective function between the source and destination vehicles with throughput and OP. For optimization, a new Dimension-based Cat Swarm Optimization (D-CSO) algorithm was proposed, to achieve better fairness and convergence rate.

With the introduction of the Internet of Things (IoT) in VANETs in recent years, it has been observed that many telemetry applications ranging from entertainment to safety-oriented time constraint applications can be explored [62]. VANET is a combination of many wireless static and moving devices that link vehicle-to-vehicle (V2V), Road-Side Access Points (RSU) to vehicles, vehicle-to-infrastructure (V2I) and communications [122]. Channels in VANET suffer from any impairment caused by dynamic behavior, time delay effects, multi-path propagation, interference, and limited link reliability due to vehicle mobility. A thorough investigation of diversity is required for the successful implementation of the communication system. Cooperative communication has been proposed as a new standard in several communities to improve wireless relay transmission performance through cross-layer physical layer implementation. As a result, it is regarded as the best solution for mitigating fast signal fading issues [123]. As a result, relay selection using a heuristic-based algorithm is used to solve problems with throughput and OP in VANETs.

The objective of the chapter

- To design an optimization model for reducing the number of multi-hops in cooperative VANETs to attain better convergence and fairness between source and destination vehicles.

- To resolve multi-objective functions with throughput and OP by minimizing the number of relays with D-CSO algorithm for proposed cooperative VANETs.
- Intelligent Swarm-Based Multi-hop relay selection strategy implementation to improve convergence analysis, OP, throughput and statistical analysis in VANETs.

3.2. System Model and Cooperative Mechanism in VANETs

This segment briefly presents a system model to demonstrate the performance improvement with the proposed algorithm in cooperative VANET via convergence and statistical analysis.

3.2.1 System Model

While considering the active eavesdropper in the system, a time division multiplexing is considered with several Decode-and Forward (DF) relay cooperative vehicular to the vehicular communications system. Proposed system model is depicted in Fig. 3.1, which includes a pair of vehicles that use time division multiplexing and use the Decode and Forward (DF) relaying protocol. As a result, each relay is assumed to decode and re-encode the information before forwarding it to the destination.

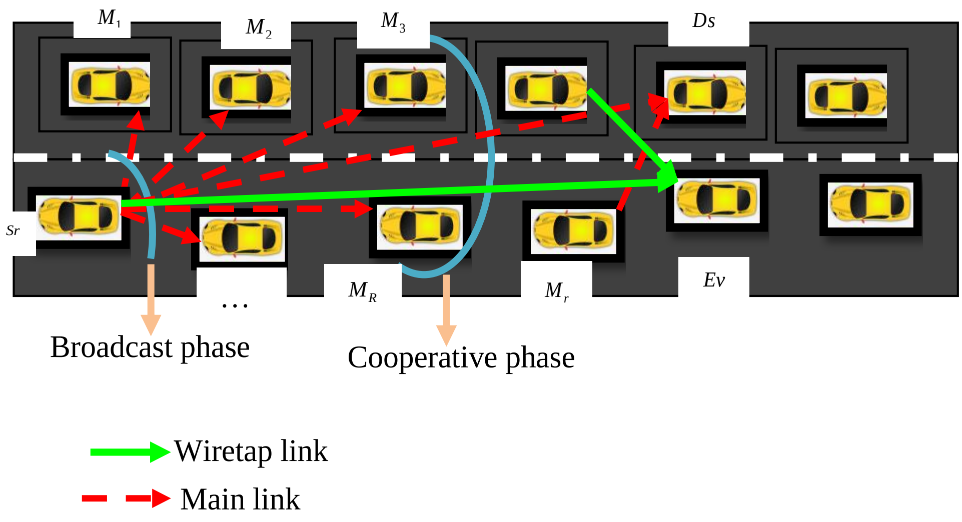


Figure 3.1. The cooperative networking in VANET

All vehicles (source node S_r, R- relay nodes where $(M_1, M_2, \cdots, M_R)$, destination D_s, and eavesdropper E_v) are assumed to have a single antenna and to be in half-duplex mode, which means they cannot transmit and receive at the same time. It is also assumed in the system modelling that few direct paths exist between the source and the eavesdropper and the destination. Founded on CSI of wiretap channels, accurate channel state information is estimated. In general, CSI exists in two states: either the transmitter is aware due to feedback or CSI is only available at receiver nodes. All channels between the source, relays and destination are considered to be Rayleigh distribution with quasi-static flat fading of variance σ^2_{BcTn} and zero mean.

Information transmitted by source will be encoded as a codeword $A \in \mathrm{A}^b$ in the wiretap channel using codebook, example an input alphabet of length b is denoted as A^b . The source broadcasts their secret information with unit power a in the first time slot, and transmitted power is denoted as P_{Sr}. In this phase, the authorized nodes' received signals can be denoted as follows:

$$z_{Ds} = \sqrt{P_{Sr}} h_{SrDs} a + b_{Ds} \tag{3.1}$$

$$z_{M,r} = \sqrt{P_{Sr}} h_{SrM,r} a + b_M \tag{3.2}$$

At the different relays and the destination, the Additive White Gaussian Noise (AWGN) is symbolized as b_{Ds} and b_M power of η_0. In broadcast phase, the relay node Ev wiretaps from source and the received signal can be expressed as:

$$z_{Ev} = \sqrt{P_{Sr}} h_{SrEv} a + b_{Ev} \tag{3.3}$$

In Eq. (3.3), b_{Ev} represents AWGN noise. The two cooperative phases are executed distinctly in cooperative communication for finding their security capabilities individually. For security capacity evaluation in broadcast phase, it should be considered that source transmits information to many relays. Selective combining is used to find the channel capacity at both relay and destination as shown in Eq (3.4).

$$\zeta^r_{SC} = \log_2\left(1 + \kappa_1 \left|h_{SC,r}\right|^2\right) \tag{3.4}$$

$$h_{SC,r} = \max\left\{\left|h_{SrDs}\right|^2, \left|h_{SC,r}\right|^2\right\} \tag{3.5}$$

Where, $\kappa_1 = \frac{P_{Sr}}{\eta_0}$. In addition, Eq. (3.6) expresses the wiretap channel's capability.

$$\zeta_{SE} = \log_2\left(1 + \kappa_1 \left|h_{SE}\right|^2\right) \tag{3.6}$$

Security capacity is defined as a difference between the capabilities between main and wiretap links [116]. Eq. (3.7) depicts, relay security capacity in first phase of cooperation.

$$\zeta_{SS}^{BP,r} = \left[\zeta_{SC}^{r} - \zeta_{SE}\right]^{+}$$
$$= \left[\log_2 \frac{1+\kappa_1 |h_{SC,r}|^2}{1+\kappa_1 |h_{SE}|^2}\right]^{+} \quad (3.7)$$

The functional representational of expression $[a]^{+} = \max(0, a)$.

3.2.2. Cooperative Mechanism

The relay node transmits a signal with power P_r to evaluate the security in the cooperative phase, the signals received at Ev and Ds are expressed as

$$z_{MDs,r} = \sqrt{P_r}\, h_{MDs,r}\, a + b'_{Ds} \quad (3.8)$$

$$z_{MEv,r} = \sqrt{P_r}\, h_{MEv,r}\, a + b'_{Ev} \quad (3.9)$$

In Eq. (3.8) and (3.9), AWGN at Ev and Ds with similar power of η_0 being embodied as b'_{Ds} and b'_{Ev}, correspondingly, which primes the security capacity of the cooperative phase is framed in Eq. (3.10), where $\kappa_2 = \frac{P_r}{\eta_0}$.

$$\zeta_{SS}^{CP,r} = \left[\log_2\left(\frac{1+\kappa_1 |h_{SrDs,r}|^2 + \kappa_2 |h_{M_r,Ds}|^2}{1+\kappa_1 |h_{SE}|^2 + \kappa_2 |h_{M_r,Ev}|^2}\right)\right]^{+} \quad (3.10)$$

When relay node is in cable of recovering the source information, the relay in participation is said to be inactive. Lower security capability in both cooperative phases of transmission results in overall security capability between source and destination.

$$\zeta_{SS}^{r} = \frac{1}{2}\min\left\{ \left[\log_2\left(\frac{1+\gamma_{SC}^{r}}{1+\gamma_{SE}^{r}}\right)\right]^{+}, \left[\log_2\left(\frac{1+\gamma_{SrDs}+\gamma_{MDs}^{r}}{1+\gamma_{SE}+\gamma_{MEv}^{r}}\right)\right]^{+} \right\} \quad (3.11)$$

In Eq. (3.11), $\gamma_{MEv}^{r} = \kappa_2 |h_{MEv,r}|^2$, $\gamma_{MDs}^{r} = \kappa_2 |h_{MDs,r}|^2$, $\gamma_{SE} = \kappa_1 |h_{SE}|^2$, and $\gamma_{SC}^{r} = \kappa_1 |h_{SC,r}|^2$. $\frac{1}{2}$ is the above equation is used to represent two slots to send secret message. A Generalized representation of "Optimal Relay Selection" (GORS) strategy is resulting from Eq. (3.12).

$$\zeta_{SS}^{GORS} = \frac{1}{2} \max_{r \in \{1,..,R\}} \left\{ \min \left\{ \zeta_{SS}^{BP,r}, \zeta_{SS}^{CP,r} \right\} \right\} \quad (3.12)$$

However, due to miscellaneous inducers and defaulters, the security can be reduced due to the overall security can be devastated with dripping at every phase or secret information leakage in multiple phases. Two different constraints are framed to address the security issues in GORS, when the source and destination links are weaker or stronger compared to $Sr - M_r, r = 1, \cdots R$ links.

The GORS security capacity can be computed as

$$\zeta_{SS,1}^{GORS} = \frac{1}{2} \max_{r \in \{1,..,R\}} \left\{ \min \left\{ \zeta_{SS}^{SrM,r}, \zeta_{SS}^{CP,r} \right\} \right\} \quad (3.13)$$

In Eq. (3.13), $\zeta_{SS}^{SrM,r} = \left[\log_2 \left(\frac{1+\gamma_{SrM}^r}{1+\gamma_{SE}} \right) \right]^+$ and $\gamma_{SrM}^r = \kappa_1 \left| h_{SrM,r} \right|^2$. In initial case, secure capacity of the GORS" is alike to the maximum R secrecy capacities [124]. Similarly, for the next case, the secure capacity can be computed from Eq. (3.14), where, ζ_{SS}^{SrDs} is used to represent instantaneous secrecy capacity at the D_s through S_r.

$$\zeta_{SS,2}^{GORS} = \frac{1}{2} \max_{r \in \{1,..,R\}} \left\{ \min \left\{ \zeta_{SS}^{SrDs}, \zeta_{SS}^{CP,r} \right\} \right\} \quad (3.14)$$

In Eq. (3.14), $\zeta_{SS}^{SrDs} = \left[\log_2 \left(\frac{1+\gamma_{SrDs}}{1+\gamma_{SE}} \right) \right]^+$ is alike to the maximum $R -$ secrecy capacities.

The GORS strategy takes advantage of these two conditions; relaying reduces transmission efficiency by a factor of half while also improving the wiretap link relative to the primary channel. The CSI is estimated at transmitting and receiving node in each phase, it is used for best relay selection. Overall CSI can be accessed by receiver nodes and the source node can broadcast the secret message at a predetermined rate $\Re_{SS}$. Furthermore, decisions about the direct link's ability to recover the source message are made at the destination, as shown in Eq. (3.15).

$$\varepsilon : \zeta_{SS}^{SrDs} < \Re_{SS} \quad (3.15)$$

The adaptive relaying is obtained by solving the preceding equation and the best relay is chosen to maximize the secure capacity, failing which the source node transmits a new secret message. This is referred to as AORS. In order to resolve the complexity described in Eq. (3.16) and increase spectral efficiency, incremental relaying is used. The technique of incremental relaying is employed.

$$\zeta_{SS}^{SrDs} < \left[\log_2 \left(\frac{1+\kappa_1 \max_{r\in\{1,..,R\}} \left\{ \left| h_{SrM,r} \right|^2 \right\}}{1+\kappa_1 \left| h_{SrEv} \right|^2} \right) \right]^+ \tag{3.16}$$

Can be simplified as per [113].

$$\psi : \gamma_{SrDs} < \max_{r\in\{1,..,R\}} \gamma_{SrM}^{r} \tag{3.17}$$

AORS is designed to maximize secrecy capacity while satisfying the ψ by implementing the incremental selection of minimal relay.

3.3. Optimal Relay Number Selection Model in VANETs

In this session, the proposed D-CSO algorithm for the minimal relay selection for VANETs is presented.

3.3.1 Relay Selection Strategy

In order to improve communication performance, D-CSO is utilized to identify the appropriate relay in proposed VANETs in which a discusses about overall relay selection strategy is projected. Control module and transmission module are considered in this approach. Source determines whether or not the buffer is empty during control module consideration. If it is empty, it remains idle; otherwise, the source node broadcasts control frames for transmission known as handshake messages. The destination node responds with Inertial Measurement Unit (IMU), GPS assistance and differential GPS information to the source node after receiving the beacon signals. The number of cooperative relays depends on the distance between the source and destination nodes.

In transmission module, source transmits the information frames via omnidirectional broadcast, while the destination precisely decodes the data frames. During the next Automatic Repeat Request (ARQ) round, source sends a new data frame. In alternative situation, after the destination assesses the ARQ round *q*; the destination calls for retransmission or feedbacks negative acknowledgment, if the assessed value falls below the higher value. In retransmission stage DF relaying with *p* relays among *r** set is used to decode the source information. When the ARQ *p*=0, the Sr retransmits the information frame. Similarly, *p* relays will not retransmit until destination is reached or until they receive an acknowledgment from the *D*.

3.4. Proposed D-CSO Based Relay Selection

This algorithm is used for relay selection because it has several features that improve the efficiency of VANETs.

The number of alterations and transformations in the dimensions in the boundary limit [0,1] is defined by Count of Dimension Change (CDC) strategy in CSO algorithm [125]. The ratio of best fitness to the weak fitness solutions is used in CDC. With better calibration between the evaluation and exploitation stages, CSO can obtain more accurate solutions. CSO [125] is chosen in this work because it meets the ability to resolve the premature convergence problem. Based on the best and weak solutions are used in evaluation of CDC which is used in the proposed D-CSO algorithm. With reference to the cat fitness, location DS with velocity and flag, the cat will be in either seeking or tracing mode. As number of operational cats is an important metric, the count of cats is computed after every iteration and the result is saved in memory. The number of cats is calculated after each iteration within boundary limits and saved in memory at the beginning and resultant number of cats at end of iteration. In [126-127], authors projected solutions to achieve a better solution with D-CSO.

Based on the boundary limits [0,1], maximum ration is used to categorize the cats. Category specific fitness function is used to assess the fitness of cat and the cat with best fitness is selected and details are saved in memory. Based on the mixture ratio, the cats are either distributed in seeking mode or tracing mode. The process continuous till the conditions is met, if not the process repeats multiple times.

"Seeking Mode": With the assistance of metrics like Seeking-Memory-Pool (SMP), Self-position-consideration (SPC) and Seeking-Range-selected dimensions (SRD), seeking mode is stated as resting time of the cats. The number of alterations in dimensions can be computed with SRD. The candidate cat among the cats and their location and dimensions information can be retrieved from SMP. The metrics that are use under seeking mode of CSO are:

The updated position of the cats CT_j are used generate multiple copies of SMP. The dimensions of the CDC can be evaluated as

$$CDC = \frac{fit(k)}{worstfit(k)} \tag{3.18}$$

To nullify the old position status, the SRD values are updated periodically as denoted in Eq. (3.19).

$$Y_{kdsnew} = Y_{kdsold} * (1 + rn * SRD) \tag{3.19}$$

Where, *m* represents arbitrary value ranging between [0,1], *k* represents the number of cats, Y_{kdsold} and Y_{kdsnew} indicate current location and next location of cats and d_s indicate dimension.

The fitness value is used to determine the location of all search agents and consider any location as next location of cat., based on the higher fitness value derived from Eq. (3.20) the cat is selected.

$$\rho = \frac{|fit_i - fit_c|}{fit_{\max} - fit_{\min}} \tag{3.20}$$

The probability is considered as 1 for every candidate whose fitness is found to be identical. To reduce the objective, it is considered as either $fit_c = fit_{\max}$ or else $fit_c = fit_{\min}$ for $0 < i < k$.

"Tracking Mode": It mimics cats' tracing behavior. Initially, velocity values are assigned at random in the entire vicinity of the cat's location. However, the velocity values for the next steps must be updated. Cat position and the velocities across all paths in the vicinity can be expressed in Eq (3.21).

$$\vartheta_{j,ds} = \vartheta_{j,ds} + rs_1 cn_1 (Y_{best,ds} - Y_{j,ds}) \tag{3.21}$$

As the movement increases, the velocity rate increases proportionately. The updation of location CT_j is then accordingly using Eq (3.22).

$$Y_{j,ds} = Y_{j,ds} + \vartheta_{j,ds} \tag{3.22}$$

With the fitness value from the seeking and tracing mode, CDC updates the D-CSO algorithm. This further leads to minimal value and quicker convergence rate for minimal relay selection in VANETS. Algorithm-1 flow and the strategy is depicted below for the proposed algorithm.

Algorithm 1: Proposed D-CSO
Determine cat population and constraints
Frame the fitness of whole solutions
Compute CDC based on the current fitness and vilest fitness solutions using Eq. (3.18)
Find the distance covered accurate and current search agents and average distance
Assessment of cats according to the fitness function
It CT_j is in the seeking mode
Solution update by Eq. (3.19), according to seeking mode
else
Solution update by Eq. (3.22), based on tracing mode
End if
Reallocate "the number of cats and allotted them into tracing mode through mixture ratio and assign others to seek mode"
End for
End while
Compute fitness of all solution
Elevate best fitness value
end while
Return accurate solutions

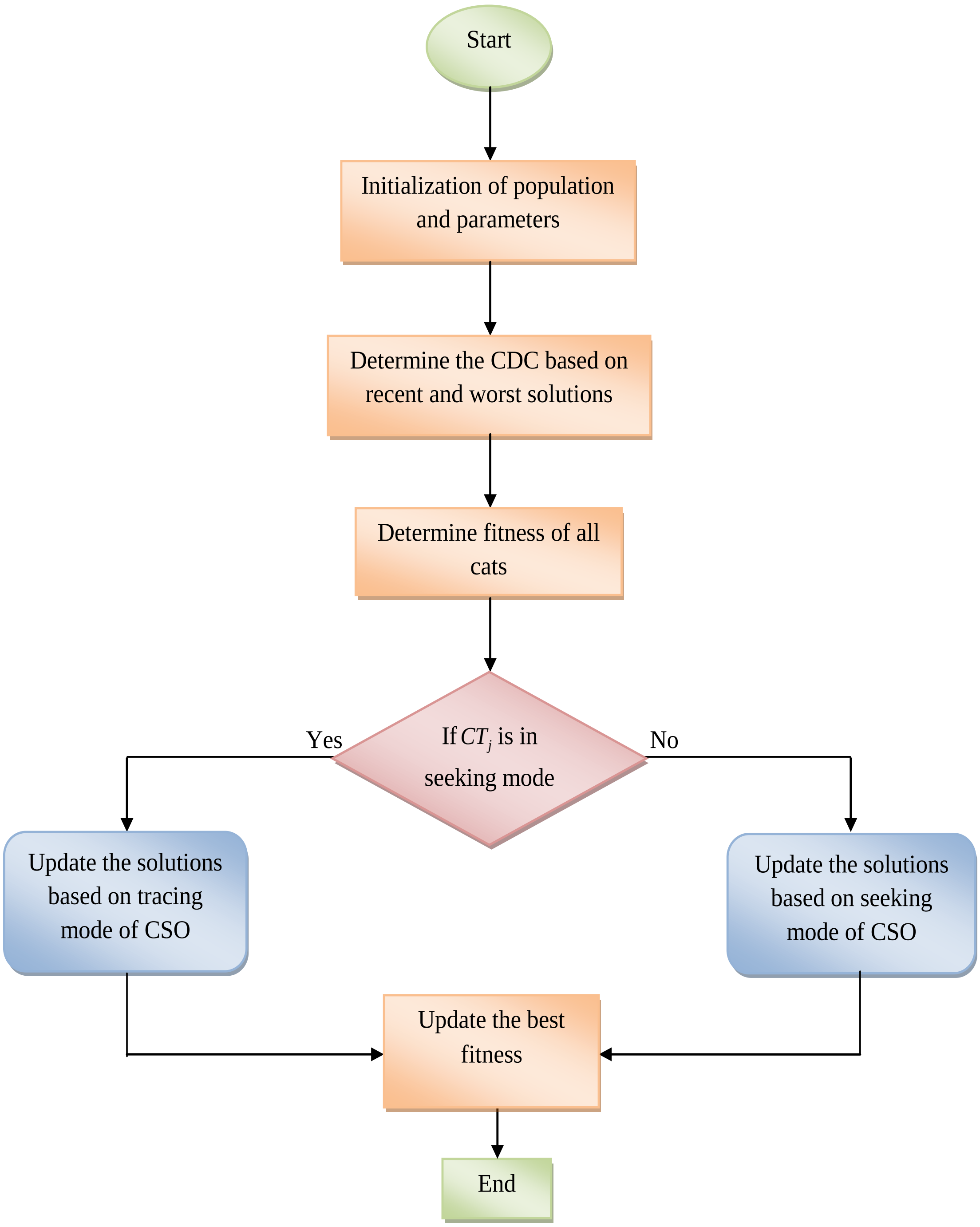


Figure 3.2. Flow chart of proposed algorithm

3.5. Proposed Relay Selection with OP and Throughput

3.5.1 Proposed Relay Optimization

The D-CSO method optimizes relays in planned vehicular networks by addressing fitness functions like outage probability reduction and throughput maximization (Th). Figure 3.3 shows the relay selection solution encoding before and after optimization.

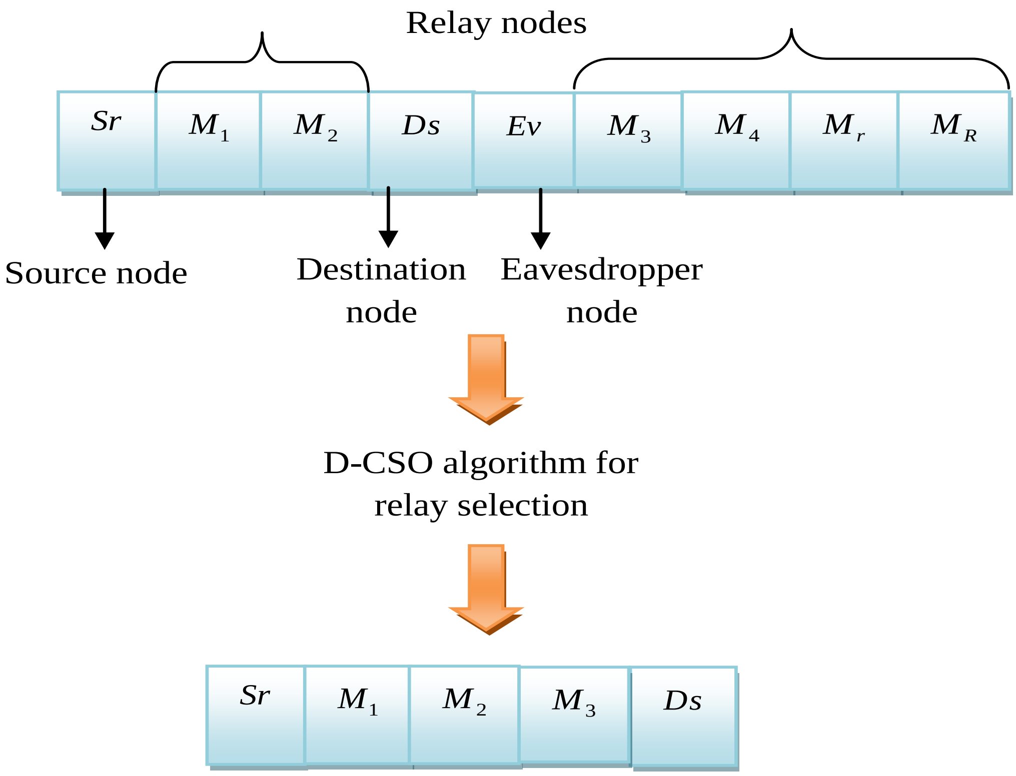


Figure 3.3.Optimum relay selection with encoding under proposed algorithm

Proposed algorithm used to perform multi-hop selection, which eliminates unnecessary relay nodes from networks. This algorithm is used to select minimum number of relays and multi-hops to resolve multi-objective functions in the VANETS. The presented approach's primary application is derived from Eq (3.23).

$$fit = \arg\min_{\{M_r\}} \left(OP_{out} + \frac{1}{Th} \right) \tag{3.23}$$

The optimal relays under the cooperative aide are also termed as mean relays ($M_r \in [1,R]$) selected with the proposed algorithm to enhance the VANET efficiency by minimizing intricacy.

3.5.2 OP Computation

Assume the data link has a "outage probability" of and a signalling rate of rt, and the transmitted signal has a "Signal-to-Noise Ratio (SNR)" of γ, as shown in Eq (3.24).

$$\begin{aligned} OP_{out} &= OP\{J(a;b|\,fh) < rt\} \\ &= OP\{\log_2(1+\gamma|\,fh|^2) < rt\} \end{aligned} \tag{3.24}$$

Where, fh represents fading coefficient and b as received signal. The OP of links between S, R and D in the q^{th} ARQ are expressed as $SrM_{out,q}$, $SrMDs_{out,q}$ and $SrDs_{out,q}$, correspondingly.

$EX\left[\left|fh_{ij,q}\right|^2\right]$ represents the expectation function of fading coefficients between i and j nodes and $d_{ij}^{-\beta}$, where β represents the pathloss. The outage is computed considering Nakagami-m short-term static fading channel.

For expression simplification, $d_{M_1Ds} \neq d_{M_2Ds} \neq \cdots \neq d_{M_RDs}$ and $d_{SrM_1} = d_{SrM_2} = \cdots = d_{SrM_R} = d_{SrM}$ are considered.

The OP of the source relay failed link for ARQ round is given as:

$$\begin{aligned} OP\left(SrM_{out,q}\right) &= \prod_{us=1}^{q} OP\left\{\log_2\left(1+\gamma\left|fh_{SrM,us}\right|^2\right) < rt\right\} \\ &= \prod_{us=1}^{q} OP\left\{\omega_{SrM,us} < \varepsilon\right\} \\ &= \prod_{us=1}^{q} DF_{\omega_{SrM,us}}(\varepsilon) \end{aligned} \tag{3.25}$$

The OP of the p relays which could not transmit the source information to destination till q^{th} ARQ round can be expressed as

$$\begin{aligned} OP\left(SrMDs_{out,q}\right) &= \prod_{us=1}^{T_M^p} OP\left\{\log_2\left(1+\gamma\left|fh_{SrDs,us}\right|^2\right) < rt\right\} \cdot \\ &\prod_{vs=T_M^p+1}^{q} OP\left\{\log_2\left(1+\sum_{t=1}^{p}\gamma\left|fh_{M_tDs,vs}\right|^2\right) < rt\right\} \\ &= \prod_{us=1}^{T_M^p} OP\left\{\omega_{SrDs,us} < \varepsilon\right\} \cdot \prod_{vs=T_M^p+1}^{q} OP\left\{\sum_{t=1}^{p}\omega_{M_tDs,vs} < \varepsilon\right\} \end{aligned} \tag{3.26}$$

Eq. (3.27) depicts the failure or outage of q^{th} ARQ round transmission links from source to destination.

$$\begin{aligned} OP\left(SrDs_{out,q}\right) &= \prod_{us=1}^{q} OP\left\{\log_2\left(1+\gamma\left|fh_{SrDs,us}\right|^2\right) < rt\right\} \\ &= \prod_{us=1}^{q} OP\left\{\omega_{SrDs,us} < \varepsilon\right\} = \prod_{us=1}^{q} DF_{\omega_{SrDs,us}}(\varepsilon) \end{aligned} \tag{3.27}$$

$DF_A(a)$ represents the CDF of the term A, where $\varepsilon \,\hat{=}\, \frac{2^{rt}-1}{\gamma}$.

The power density gain matrix can be simple represented as:

$$\omega_{MDs} = \begin{bmatrix} \omega_{M_1Ds,1} & \omega_{M_1Ds,2} & \cdots & \omega_{M_1Ds,Q} \\ \omega_{M_2Ds,1} & \omega_{M_2Ds,2} & \cdots & \omega_{M_2Ds,Q} \\ \vdots & \cdots & \cdots & \vdots \\ \omega_{M_RDs,1} & \omega_{M_RDs,2} & \cdots & \omega_{M_RDs,Q} \end{bmatrix}_{R\times Q} = \omega_{M_tDs,vs}$$

$$W_{SrM} = \lfloor \omega_{Sr,1}, \omega_{Sr,2}, \cdots, \omega_{Sr,Q} \rfloor_{1\times Q} = \omega_{SrDs,us}$$

$$W_{SrDs} = \lfloor \omega_{SrDs,1}, \omega_{SrDs,2}, \cdots, \omega_{SrDs,Q} \rfloor_{1\times Q} = \omega_{SrM,us}$$

T_M^p defines the *p* relays in VANETS that can decode the information frame in the first ARQ round. And the probability of those p relays can be computed as:

$$OP\left(T_M^p = t\right) = \binom{R}{p}\left[OP\left(SrM_{out,t-1}\right) - OP\left(SrM_{out,t}\right)\right]^k \cdot OP^{(R-k)}\left(SrM_{out,t}\right) \tag{3.28}$$

This expression represents the *p* relays out off *R* which cannot decode the information frame until *t*th ARD round. $\omega_{ij,q}$ represents the Gamma random variable." $\left(o_{ij}, \frac{\Omega_{ij}}{o_{ij}}\right)$ is denoted as. The overall *p* is evaluated with CDF which is not equal to the OP computed from the Gamma arbitrary terms (o_t , Ω_t, where *t* = 1,2,…,*p*) with $OP\left\{\sum_{t=1}^{p} \omega_{M_tDs,vs} < h\right\}$. The PDF and CDF of X ($X = \sum_{t=1}^{p} \xi_t$) is given as:

$$df_X(x) = \prod_{t=1}^{p}\left(\frac{o_t}{\Omega_t}\right)^{o_t} GF_{\delta,\delta}^{\delta,0}\left[\exp(-x)\Big|_{\lambda_\delta^{(2)}}^{\lambda_\delta^{(1)}}\right] \tag{3.29}$$

$$DF_X(x) = \prod_{t=1}^{p}\left(\frac{o_t}{\Omega_t}\right)^{o_t} GF_{\delta+1,\delta+1}^{\delta+1,0}\left[\exp(-x)\Big|_{\lambda_\delta^{(2)},0}^{\lambda_\delta^{(1)},1}\right] \tag{3.30}$$

Meiger-G function (GF) [131] is figured in Eq. (3.31) .

$$GF_{po,qo}^{ks,ls}\left[\mu\Big|_{\lambda_\delta^{(2)}}^{\lambda_\delta^{(1)}}\right] = GF_{po,qo}^{ks,ls}\left[\mu\Big|_{ys_1,ys_2,\cdots,ys_{qo}}^{x_1,x_2,\cdots,x_{po}}\right] = \frac{1}{2\pi i}\int_{Ch} \frac{\prod_{j=1}^{o}\Gamma\left(ys_j - su\right)\cdot\prod_{j=1}^{R}\Gamma\left(1 - x_j + su\right)}{\prod_{j=o+1}^{qo}\Gamma\left(1 - ys_j + su\right)\cdot\prod_{j=R+1}^{po}\Gamma\left(x_j - su\right)}\mu^{su}\,dsu \tag{3.31}$$

$\delta = \sum_{t=1}^{p} o_t$ represents an integer value. To consider the relative size an integral path is denoted by Ch, where is the relative size of the limitations, an integration is considered for *Ch*. The Gamma function is deduced from the aforementioned equations as $\Gamma(\cdot)$, Where, $\lambda_\delta^{(1)}$ and $\lambda_\delta^{(2)}$ are given as:

$$\tilde{\lambda}_{\delta}^{(1)} = \overbrace{\underbrace{\left(1+\frac{o_1}{\Omega_1}\right),\cdots,\left(1+\frac{o_1}{\Omega_1}\right)}_{o_1},\cdots,\underbrace{\left(1+\frac{o_p}{\Omega_p}\right),\cdots,\left(1+\frac{o_p}{\Omega_p}\right)}_{o_p}}^{\delta} \quad (3.32)$$

$$\tilde{\lambda}_{\delta}^{(2)} = \overbrace{\underbrace{\left(\frac{o_1}{\Omega_1}\right),\cdots,\left(\frac{o_1}{\Omega_1}\right)}_{o_1},\cdots,\underbrace{\left(\frac{o_p}{\Omega_p}\right),\cdots,\left(\frac{o_p}{\Omega_p}\right)}_{o_p}}^{\delta} \quad (3.33)$$

Furthermore, $\Omega_t \neq \Omega_q (t, q = 1,2,3,\cdots, p, t \neq q)$ in Eq. (3.33) depicts the average power. The PDF of the sum *p* of random variables in Rayleigh fading channel can be obtained.

$$df_X^{Rayleigh}(x) = \frac{1}{\prod_{t=1}^{p}\Omega_t} GF_{p,p}^{p,0}\left[\exp(-x)\middle| \begin{matrix} 1+\frac{1}{\Omega_1},\cdots,1+\frac{1}{\Omega_1} \\ \frac{1}{\Omega_1},\cdots,\frac{1}{\Omega_1} \end{matrix}\right] \quad (3.34)$$

It can be further enhanced through the Meijer-G identity and can be expressed as

$$df_X^{Rayleigh}(x) = \sum_{t=1}^{p}\left(\prod_{su\neq t}\frac{\frac{1}{\Omega_{su}}}{\frac{1}{\Omega_{su}}-\frac{1}{\Omega_t}}\right)\frac{1}{\Omega_t}\exp\left(-\frac{x}{\Omega_t}\right) \quad (3.35)$$

3.5.3 Throughput Computation

This metric is the average number of frames successfully transfer in unit time. Whereas, the steady state probability is defined as the initial point with mean Discrete Time Markov Chain (DTMC). π_{Sr} depicts stable probability of initial state, and $\pi = (\pi_{Sr}, \pi_1, \cdots, \pi_{DF})$ represents steady-state distribution of the 3-D DTMC model. The throughput is dependable on Q and R binary functions, where it can be articulated as $\begin{cases} \pi \cdot PO = \pi \\ \sum \pi = 1 \end{cases}$ and OP represents transition probability of one step and expressed as $\left[(Q+1)+R\sum_{i=1}^{Q-1} i\right]\times\left[(Q+1)+R\sum_{i=1}^{Q-1} i\right]$. Throughput (*Th*) can be evaluated as

$$Th = \pi_{Sr}(Q,R) = \frac{1-FErr(Q,R)}{fh(Q,R)} \quad (3.36)$$

$fh(Q,R)$ denotes a binary function of (Q,R) and $FErr(Q,R)$ represents frame fault rate and can be computed as:

$$FErr(Q,R)=\begin{cases} OP_{SrM_{1,0,0}} \cdot OP_{M_{1,0,0}DF} \\ + \sum_{p=1}^{R} OP_{SrM_{1,p,0}} \cdot OP_{M_{1,p,0}DF}, & Q=2 \\ Eq.(39), & Q \geq 3 \end{cases} \tag{3.37}$$

$$fh(Q,R)=\begin{cases} 1+OP_{SrM_{1,0,0}} + \sum_{p=1}^{R} OP_{SrM_{1,p,0}}, & Q=2 \\ Eq.(40), & Q \geq 3 \end{cases} \tag{3.38}$$

$$\begin{aligned} FErr(Q,R) &= \\ & OP_{SrM_{1,0,0}} \cdot \prod_{i=1}^{Q-2}\left[OP_{M_{i,0,0}M_{i+1,0,0}}\right] \cdot OP_{M_{Q-1,0,0}DF} \\ & + \sum_{p=1}^{R} OP_{SrM_{1,p,1}} \cdot \prod_{i=1}^{Q-2}\left[OP_{M_{i,p,i}M_{i+1,p,i+1}}\right] \cdot OP_{M_{Q-1,p,Q-1}DF} \qquad Q \geq 3 \\ & + \sum_{p=1}^{R} \sum_{T_M^p=2}^{Q-1} \left(\begin{array}{c} OP_{SrM_{1,0,0}} \cdot \prod_{i=1}^{T_M^p-2}\left[OP_{M_{i,0,0}M_{i+1,0,0}}\right] \\ \cdot OP_{M_{T_M^p-1,0,0,}M_{T_M^p-1,p,1}} \\ \cdot \prod_{i=T_M^p,\, j=1}^{i=Q-2,\, j=Q-T_M^p-1}\left[OP_{M_{i,p,j}M_{i+1,p,j+1}}\right] \cdot OP_{M_{Q-1,p,Q-T_M^p}DF} \end{array} \right) \end{aligned} \tag{3.39}$$

$$\begin{aligned} fh(Q,R) = & \; fh(Q-1,R) + OP_{Sr_{1,0,0}} \cdot \prod_{i=1}^{Q-2}\left[OP_{M_{i,0,0}M_{i+1,0,0}}\right] \\ & + \sum_{p=1}^{R} OP_{SrM_{1,p,1}} \cdot \left[OP_{M_{i,p,j}M_{i+1,p,i+1}}\right] \qquad Q \geq 3 \\ & + \sum_{p=1}^{R} \left(\begin{array}{c} \sum_{T_M^p=2}^{Q-1} OP_{SrM_{1,0,0}} \cdot \prod_{i=1}^{T_M^p-2}\left[OP_{M_{i,0,0}M_{i+1,0,0}}\right] \cdot \\ OP_{M_{\left(T_M^p-1\right),0,0}M_{T_M^p,p,1}} \\ \prod_{i=T_M^p,\, j=1}^{i=Q-2,\, j=Q-T_M^p-1}\left[OP_{M_{i,p,j}M_{i+1,p,j+1}}\right] \end{array} \right) \end{aligned} \tag{3.40}$$

Substituting Eq. (3.37) with Eq. (3.40), Eq, (3.36) explores throughput.

3.6. Results

In this section, clear details of simulation parameters under consideration and observations from the MATLAB for the proposed algorithm are projected.

3.6.1 Investigational Setup

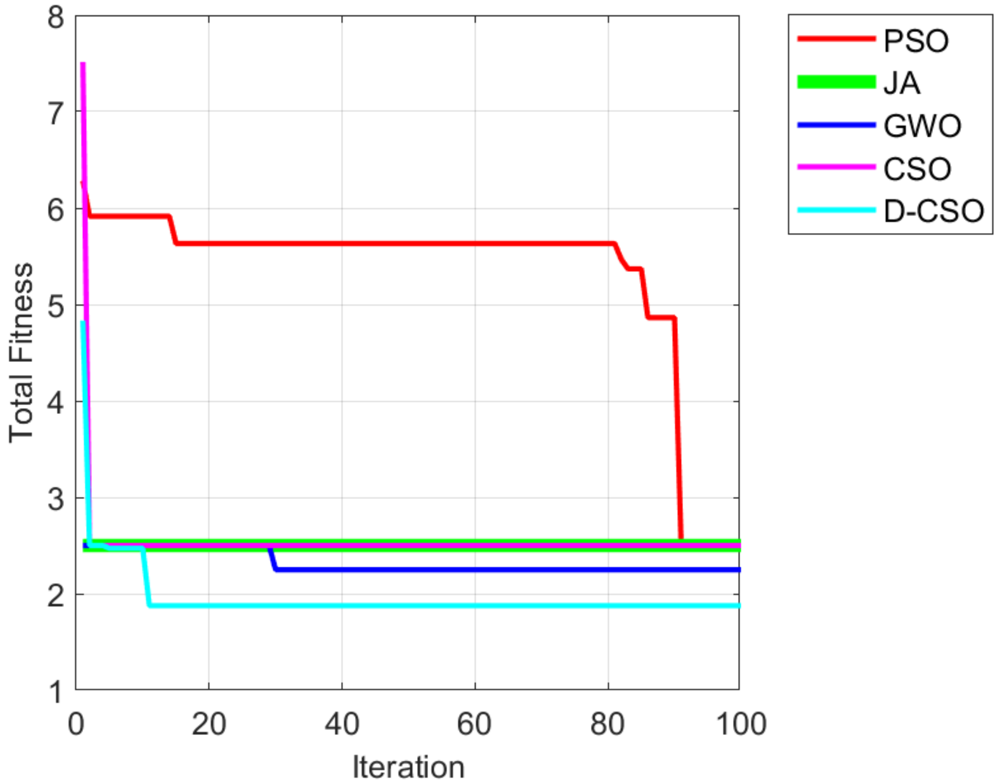
The proposed algorithm for multi-hop selection in VANETs is analyzed using MATLAB software tool, and it is compared with prevailing empirical algorithms such as Particle Swarm Optimization (PSO) [129], Jaya Algorithm (JA) [128] proposed a powerful optimization algorithm for constrained and unconstrained optimization problems, focusing on achieving the best solution without any algorithm-specific control parameters, Grey Wolf Optimizer (GWO) [130] algorithm mimicked the social hierarchy and hunting behavior of grey wolves, and CSO [125]. The performance metrics like convergence, throughput, OP and statistical analysis was computed for three cases with different number of nodes as [50, 100, and 150].

Table 3.1. Parametrs used for simulation

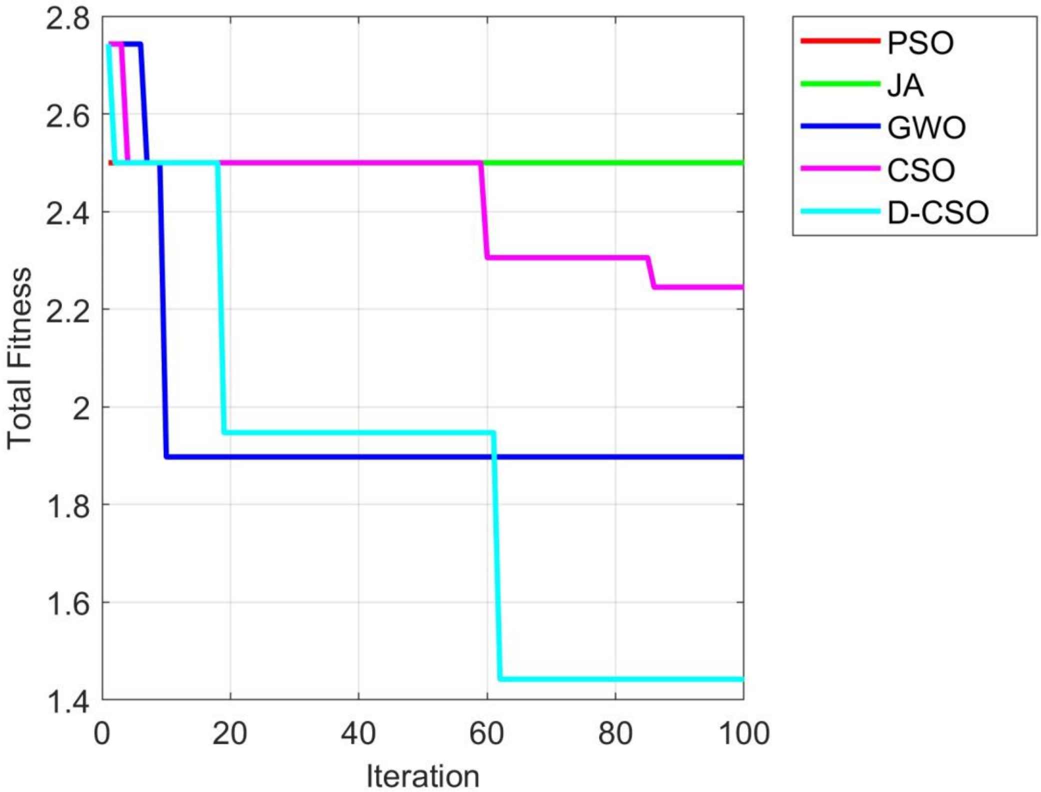
S.no	Parameters	Symbols	Values
1.	No. of Nodes	M	[50, 100, 150]
2.	No. of relay nodes	R	50
3.	Instantaneous SNR	γ	105dB
4.	OP of the data link with a signalling rate	rt	0.50 bits/slot/Hz
5.	No. of population	N_{pop}	10
6.	Vicinity of antenna	-	1000 m
7.	No. of Antennas	-	01
8.	No. of frames	P	05 frames/second
9.	Binary function	Q	02, 03
10.	No. of iterations	Max_iter	100

3.6.2. Convergence Evaluation

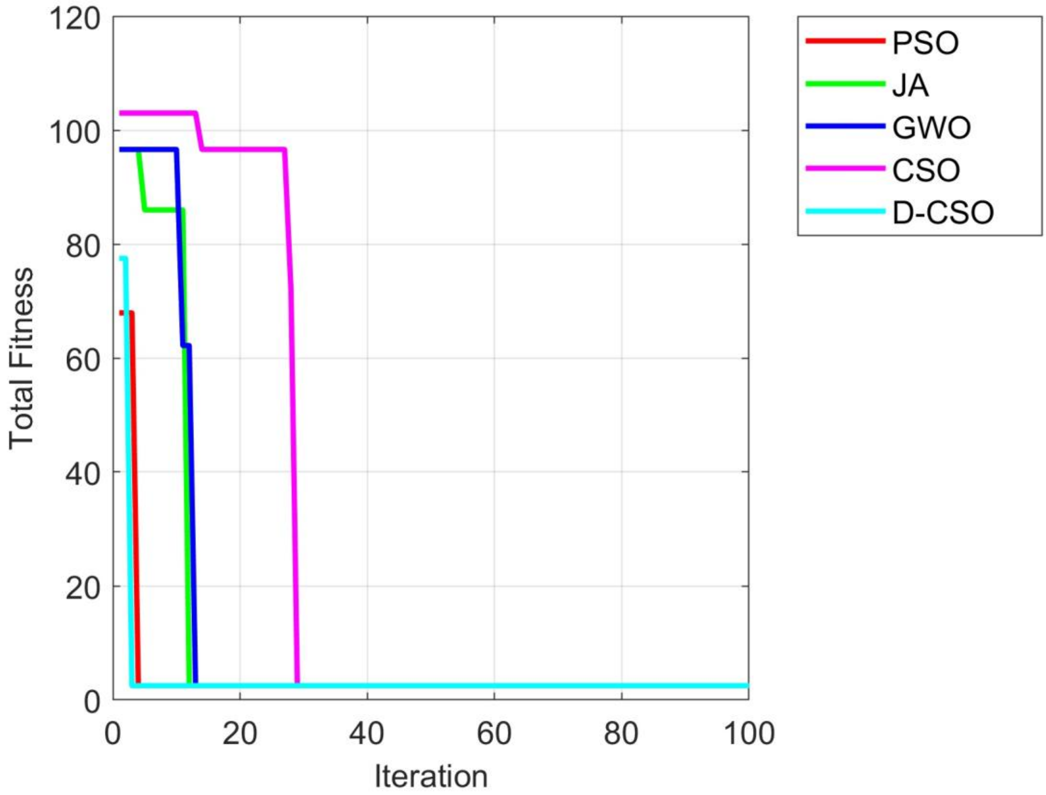
This evaluation for the different number of nodes under the proposed algorithm is depicted in Figure 3.4. Proposed algorithm had shown D-CSO observes the peak fitness rate in the first iteration of case one compared to other algorithms. Whereas, D-CSO identifies minimum cost function with better performance at the tenth iteration. In Case two, peak fitness rate is minimized at 60th iteration by improving the performance rate. And in Case three, the D-CSO has peak convergence rate at minimum rates. According to the investigation, during the 100th iteration of case one, the proposed algorithm had shown 28%, 25%, 18%, and 28% better than the PSO, JA, and JA-CSO.



(a) Case One



(b) Case Two

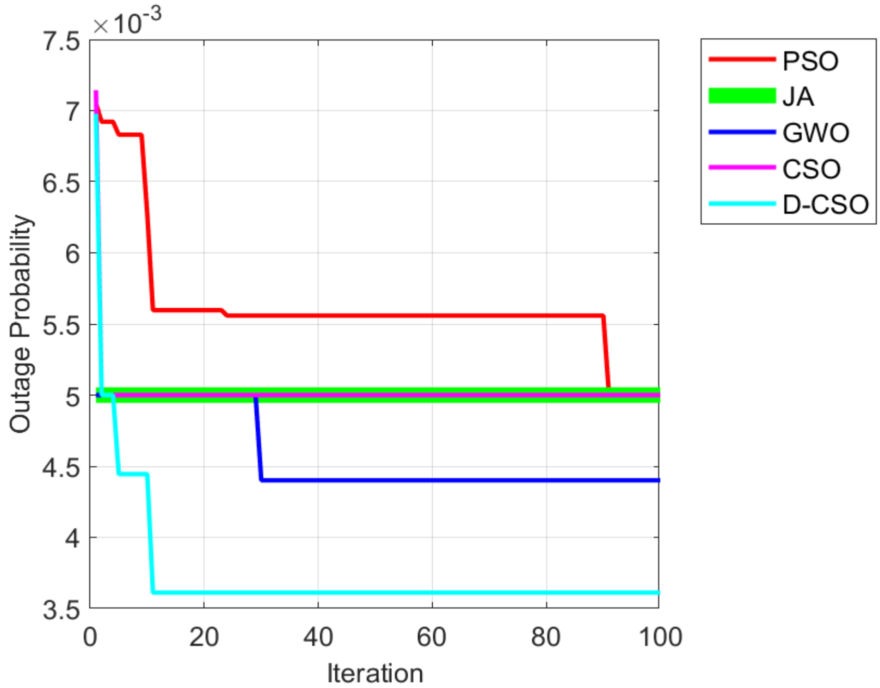


(c) Case Three

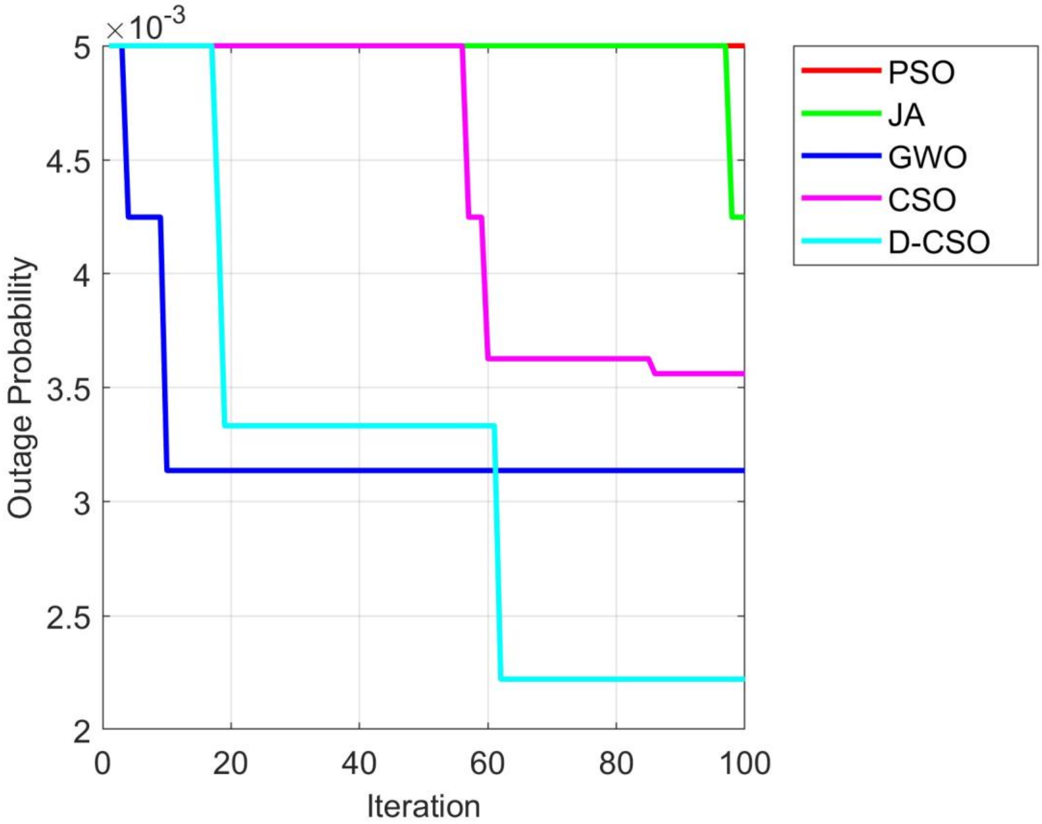
Figure 3.4.Convergence evaluation of proposed algorithm with various empirical algorithms for (a) Case One, (b) Case Two, and (c) Case Three.

3.6.3. Analysis of OP

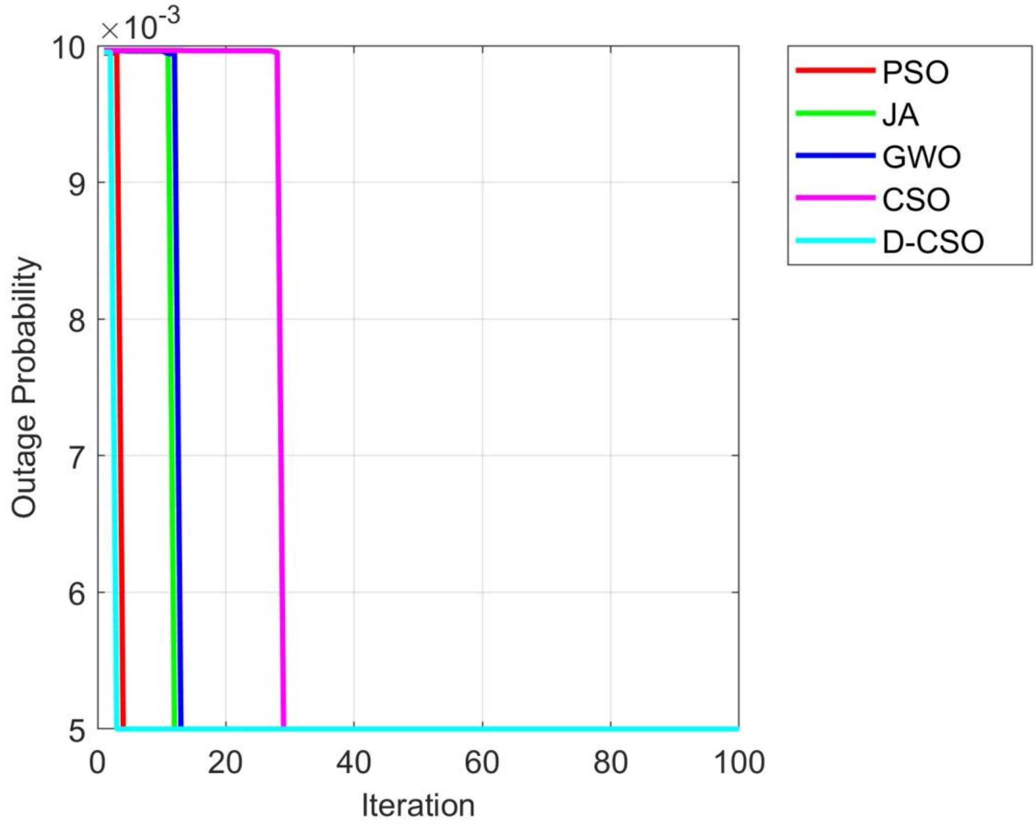
The proposed multi-hop selection in VANETS is analyzed with OP for three cases as shown in Figure 3.5. D-CSO maximizes performance by minimizing OP. In the first example, the D-CSO method achieves the least rate with better performance at 10^{th} iteration. In case two, the proposed algorithm performance was better in 60^{th} iteration. Following that, however, the proposed model outperforms others in terms of consistency. D-CSO also notices improved performance in Case three initial iterations. All other algorithms, on the other hand, perform similarly.



(a) Case One



(b) Case Two

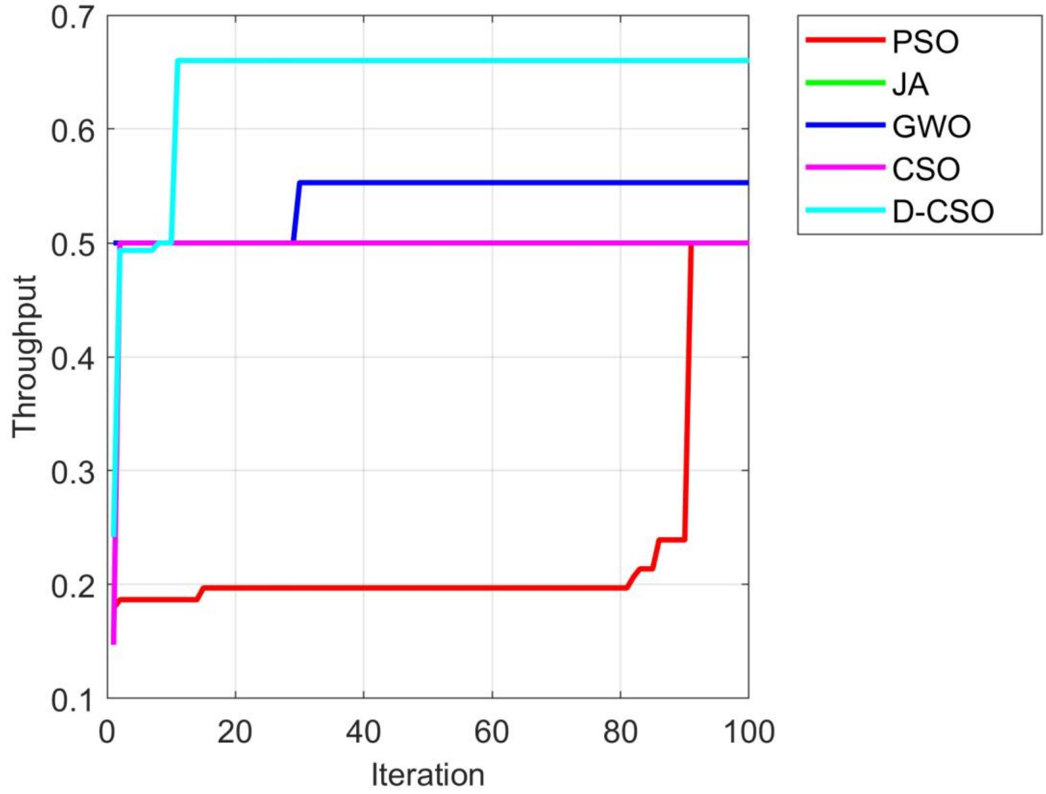


(c) Case Three

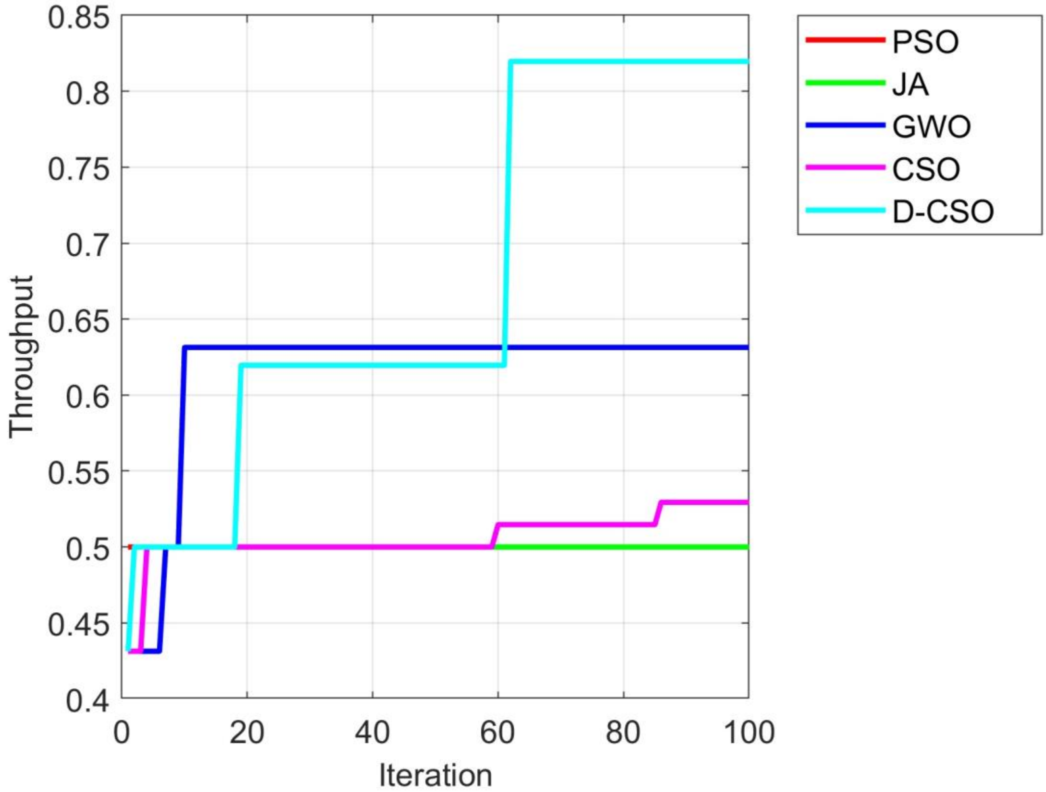
Figure 3.5. OP analysis of proposed algorithm with various empirical algorithms for (a) Case One, (b) Case Two, and (c) Case Three.

3.6.4. Analysis of Throughput

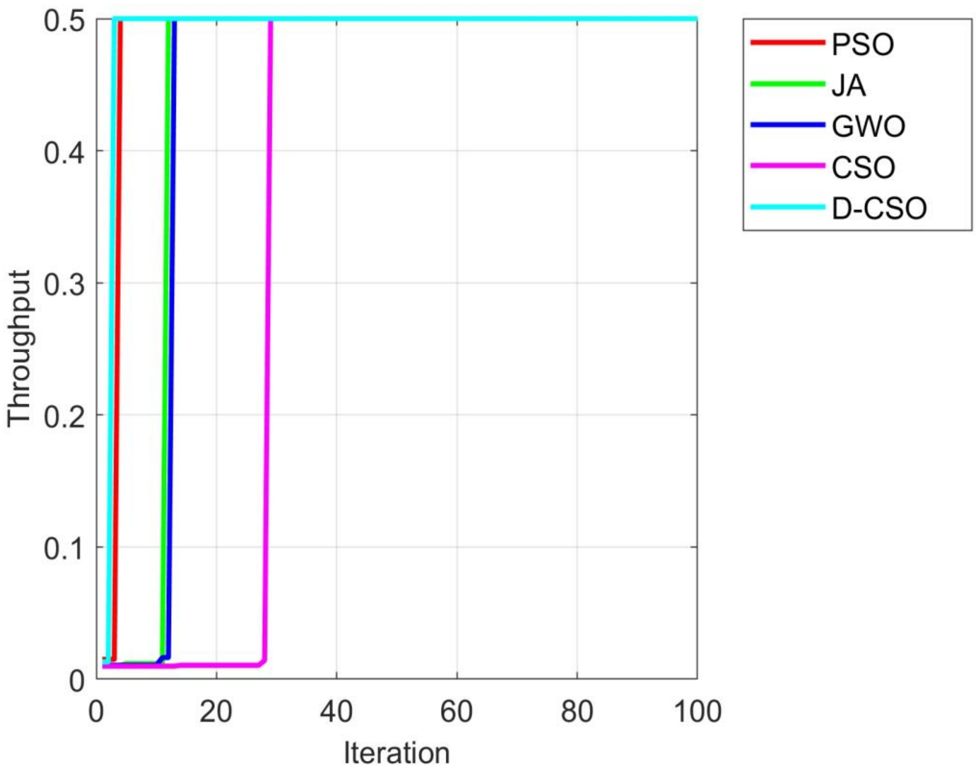
Performance evaluation of proposed algorithm with throughput for three cases is depicted in Figure 3.6. The peak D-CSO rate increases the throughput efficiency of the proposed algorithm. As a result, the tenth iteration of test case one, the superior performance compared to other algorithms is obvious. In case two, finest performance of the proposed algorithm is 60^{th} iteration, and subsequent analysis reveals consistent and remarkable performance. The third test scenario achieves the best performance on the third iteration, after which all algorithms perform similarly. In the 100th iteration of test case three, the D-CSO approach outperforms PSO, JA, GWO, and CSO by 28%, 64%, 28%, and 50%, respectively. As a result, the proposed D-CSO has depicted improved performance over other previous techniques.



(a) Case One



(b) Case Two



(c) Case Three

Figure 3.6. Throughput analysis of proposed design with various empirical algorithms in (a) Case One, (b) Case Two, and (c) Case Three.

3.6.5. Statistical Analysis

The statistical assessment values of the proposed design in VANETs over other algorithms are depicted in Table 3.2. The mean is the average value of the best and worst values and the median is referred to as the center point of the best and worst values whereas the standard deviation is represented as the degree of deviation between each execution". The performance of the suggested D-CSO is correspondingly secured at 88.6%, 67.6%, and 78% more advanced than the PSO, GWO, and CSO for test case 1. Similarly, while taking test case 2, the performance of the suggested D-CSO is correspondingly secured at 81%, 43%, and 83.3% more advanced than the JA, GWO, and CSO. Likewise, for test case 3, the outperformance is noticed by D-CSO-based multi-hop selection in vehicular networks.

Table 3.2. Statistical assessed values of proposed design with different empirical algorithms.

Algorithms	**Standard deviation**	**Best**	**Worst**	**Mean**	**Median**
Field Case 1					
Ref. [129]	5.3	2.5	6.2	0.9	5.6
Ref. [128]	2.5	2.5	2.5	0.0	2.5
Ref. [130]	1.9	1.8	4.8	0.3	1.8
Ref. [125]	2.5	2.5	7.5	0.5	2.5
D-CSO [proposed]	2.3	2.2	2.5	0.1	2.2
Field Case 2					
Ref. [129]	2.5	2.5	2.5	0.0	2.5
Ref. [128]	2.5	2.5	2.7	0.04	2.5
Ref. [130]	1.8	1.4	2.7	0.3	1.9
Ref. [125]	2.4	2.2	2.7	0.1	2.5
D-CSO [proposed]	1.9	1.9	2.7	0.2	1.9
Field Case 3					
Ref. [128]	12.1	2.5	96.6	7.5	2.5
Ref. [130]	3.9	2.5	77.5	0.5	2.5
Ref. [125]	29.4	2.5	103	3.5	2.5
D-CSO [proposed]	13.1	2.5	96.6	9.2	2.5

3.7 Conclusion

In this chapter, D-CSO algorithm is used as an minimization technique for cooperative VANET to selecting optimal number of multi-hops between the sender node and destination node. To improve the performance of proposed design, multi-objective metrics like outage probabilty and throughput are used to find an optimal soulution in selecting hops or relays. The performance of proposed algorithm is evcaluated on the aforementioned multi-objectiv functions and observed that it outperformed about 36%, 42%, 25.2%, and 36% better than PSO, JA, GWO, and CSO, respectively, at the 100th iteration. When compared to other heuristic algorithms, D-CSO demonstrated superior performance in all three test cases. D-CSO, on the other hand, achieved the same results in both test cases 2 and 3 using other algorithms

CHAPTER-4

HEURISTIC OPTIMAL RELAY SELECTION STRATEGY

CHAPTER-4

HEURISTIC OPTIMAL RELAY SELECTION STRATEGY

4.1 Introduction

Due to the battery limitations in the user devices, achieving effective communication and reliability had become some of the most important paradigms in relay networks. Fifth Generation (5G) networks include cooperative Vehicular networks (CVN), which concentrate on improving data rate, network reliability, network capacity, and spectrum efficiency. Recent research examines the selection of relays in automotive communication networks. The base station (operator) chooses the relay for each user in order to decrease expenses by increasing data transfer speeds and decreasing overall transmission power. When picking a relay, the advantages or utilities provided by three players, including the relay, the mobile user, and the operator, are examined.

Traditional methods for selecting relay nodes are hampered by issues such as lower network lifespan, latency, higher energy usage, and collusion attacks. Both energy economy and capacity are essential for wireless networks of the future generation. A hybrid heuristic technique is utilized to develop a novel multi-objective resultant energy efficient relay selection in multi-hop CVN in order to overcome these challenges. For low-latency probability-based multi-hop broadcasting, standard methods are used. The key drawbacks of cellular communication are the difficulty in designing an efficient multi-hop communication strategy, which produces hidden node difficulties, a loss in vehicle speed, and a lack of infrastructure in network architecture.

In light of this, the purpose of this work is to present a hybrid optimization model for choosing the minimal number of multi-hops in CVN. A multi-objective function that takes into account connection dependability, energy efficiency, OP, mobility factor, and transmission delay to precisely choose the number of hops or relays. Hybrid algorithm in conjunction with Best Fitness-derived Crow Tunicate Swarm Optimization (BF-CTSO) algorithm is anticipated to be the most significant technique to minimize multi-hops between source and destination in CVN. Based on simulation findings, the suggested energy-efficient CVN beats conventional techniques.

Currently, smart devices are widely employed, especially in automotive infrastructure, where they cannot fulfil the requirement for massive data transfers. Even though data transmission speeds have grown dramatically compared to the prior generation network, there is an increase in demand for value added services and data rates that has lately been addressed as a significant obstacle. Consequently, implementation of cooperativeness in wireless network mitigates the limitations of using multiple antennas by improving diversity, network capacity and coverage. The intermediate vehicles termed as relay nodes facilitate to improve the communication between intended source and destination. In order to boost network capacity and coverage, for instance, static relays are deployed deterministically in diverse locations like building or high geographical locations. In real-time applications, however, there are several instances in which it is required to deliver outstanding performance to customers.

Nodes with mobility are further cost-effective compared to static relays under distributed networks, since fixed nodes do not offer assured service under non-uniform conditions. Hence more research has to be emphasized on wireless networks with moving relays [131]. In order for individuals to comply, however, several incentives and rewards must be offered. As vehicle users function as relays, they behave stationary or move randomly in any direction [132]. Further, a substantial number of users may serve as relays to finish the broadcast. However, the precise selection of relays is very crucial for efficient delivery of packets.

Relay as an intermediate virtual node supports broadcasted source node information to destination. The security from active hacked nodes using a cryptographic technique is an important key management system. In MIMO, security induces complex mathematical computations, to leverage these complications cooperative networking has become a promising solution. Employment of security protocol in the network improve the secrecy capacity of cooperative network. AF and DF are relaying techniques mostly used to address many channel varying issues in network. The most difficult aspect is choosing an efficient or better node to maximize performance. Hybrid relaying strategies are recently proposed, in which each relay node makes its own judgment over its realistic relayed nodes. Transmission techniques based on cooperative beam forming are utilized to minimize overall energy usage [133]. Beam forming and spatial diversity improve the throughput and decrease the outage at the cost of increased power consumption, which further need an attention to be addressed [134].

Efficient selection of relay strategies is necessary for improved energy efficiency and throughput of cooperative networks. Due to the fact that relays take more energy and system resources a tradeoff limitation should be considered. As a consequence, assessing whether a two-hop communication is essential is the most important aspect of the relaying system. In order to maximize the collaboration characteristics for the whole system or the user [135], it is also required to choose a relay from among various possibilities. Recent research has examined relay selection at length. The wireless communication system is expanding quickly, yet physical restrictions provide obstacles. In general, battery capacity, channel fading, and restricted bandwidth are the most challenging aspects of research that must be addressed. Cooperative communication is a more prevalent method for enhancing the data transmission capacity of wireless networks and extending battery life. Energy losses must be avoided with efficient data transmission with best selected relay [136]. This works aims to present an unique multi-hop technique with relay selection strategies, especially for VANETs using a hybrid empirical approach.

This study explores on following points:

- Conduct novel research on multi-objective multi-hop cooperative networking via a hybrid empirical technique to optimize energy-efficient relay selection performance with minimal route damage.
- Deploy the BF-CTSO heuristic method, which combines the Crow Search Algorithm (CSA) and the Tunicate Swarm Algorithm (TSA) techniques for choosing minimal relay nodes and improve performance in CVN.
- To design the multi-objective functional cooperative networking utilizing a variety of metrics including link reliability, mobility factor, energy consumption, OP, and latency. To decrease energy usage, a multi-objective function is generated.
- Conventional techniques were used to verify the effectiveness of multi-hop cooperative networking model using different metrics. The outcome study illustrates both the successes of the proposed over other methods.

4.2. A Hybrid Heuristic Method for Energy-Efficient Relay Selection in Multi-hop CVN

This segment provides a comprehensive explanation of a breakthrough BF-CTSO algorithm and an overview on selection of relay node in CVN.

4.2.1 Relay Scheme Selection for Multi-hop CVN

In this constructed multi-hop CVN model, suitable relays are selected using a innovative BF-CTSO algorithm to maximize transmission efficiency and security capacity. Two-Round Relay Selection (2-RRS) is considered to be idle , in which a cluster of relays capable of decoding the source data is selected in the early phase. As a consequence, in the first round of selection, the captured data are sent to the target through an accurate relay. Typically, relay selection needs two modules, including a controlling and transmission module. The control module is verified by the source node to check whether it is idle before transmission, otherwise, the source node broadcasts control frames containing handshake messages to continue the conversation. With position algorithms are used by the destination to inform the location to the source node. The cooperation nodes are selected based on the "distance between the source and the destination".

In addition, the source node sends the information frames with omnidirectional broadcasting, while the receiver decodes the data frames precisely. During the next Automatic Repeat Request (ARQ) cycle, the source node sends the information frame. In contrast, the target node assesses the ARQ round *rq*. If value is maximum, messages are resent or a negative response is sent to the destination, and *rq* is set to 0.

In retransmission of information frame, $tp-$out-of $re*$ relays decode under DF mode. In subsequent ARQ cycle $tp=0$, the information frame is retransmitted from source node; otherwise, it is disseminated to the destination via $tp-$relays where $re=1,2,3,\cdots,tp$. This retransmission occurs until a positive acknowledgment from the destination is received.

4.2.2 Hybrid BF-CTSO Algorithm

In CVN, the BF-CTSO approach is developed to select minimum multi-hop relays to resolve the multi-objective function. The best relay architecture decreases delay and network energy consumption while simultaneously boosting throughput and convergence rate.

This algorithm was constructed using TSA and CSA methods. According to current research, TSA offers several advantages, including efficient mathematical computations and reduce difficulty as well as robustness related results. This work used CSA to solve TSA restrictions and gain a quicker convergence rate because to its simplicity of implementation, effectiveness in creating plausible solutions, and superior convergence rate. This algorithm also addresses the convergence and optimum challenges, resulting in enhanced growth.

Conventional TSA algorithm is updated by merely taking initial and secondary speeds along with an arbitrary number. The initial and secondary speeds are depicted as $Z_{\min}$ and $Z_{\max}$, and, which fall within the boundary limits of [1,4]. The fitness metric help to successfully update solutions. Eq. (4.1) and Eq. (4.3) reflects social pressures among search individuals.

$$\vec{F} = \frac{\left[Z_{\max} - Z_{\min}\right]}{Fs(j)} \tag{4.1}$$

If $\vec{F} \leq Fs_{best}(j)$ it verified, TSA will update the search personnel; if not, CSA will upgrade using the specified BF-CTSO method.

TSA [137] is a bio-inspired meta-empirical minimization method inspired by the swarming behavior of tunicate jet populations during feeding and navigation operations. Tunicates are bioluminescent sea organisms that produce a faint blue and green light. Each tunicate is very small in centimeters. TSA demonstrates its capacity to resolve engineering design challenges and standard optimization procedures. Tunicate has the ability to identify food in the water. However, they are unaware of the location of the food in the investigation area. For this goal, swarm intelligence and jet propulsion serve as models. To mimic the jet propulsion constraint, a tunicate must satisfy three conditions: elimination of conflicts between search people, migration to the location of optimum search individuals and in proximity to the ideal search agent. By updating the positions of additional search agents, the optimal solutions are discovered via swarm behavior. Here are provided three mathematical modelling cases.

(i) "Evading the fights between search agents": It is used to evaluate the behavior of search agents position using the vector $\vec{S}$ specified in Eq. (4.2).

$$\vec{S} = \frac{\vec{V}}{\vec{F}} \tag{4.2}$$

$$\vec{F} = \left[Z_{\min} + a_1 \cdot Z_{\max} - Z_{\min} \right] \tag{4.3}$$

$$\vec{V} = a_2 + a_3 - \vec{W} \tag{4.4}$$

$$\vec{W} = 2 \cdot a_1 \tag{4.5}$$

The constants in the aforementioned conditions are denoted as a1, a2, and a3 and fall within the interval [0, 1], whereas the ocean's water flow is defined as $\vec{W}$, the social forces among search agents are described as $\vec{F}$, and the gravitational force is indicated as $\vec{V}$.

(ii) Location of best candidates: Later eliminating discriminations between search persons, the people are advanced in search space to the position for ideal neighbors by computing the distance between food source and search candidates as explained and stated in Eq. (4.6).

$$\vec{B} = \left| \vec{Y} - c_{rn} \cdot \vec{Z}_{tuni}(j) \right| \tag{4.6}$$

The position of the food source, and a random numerical will be in the range of [0, 1].

(iii) "Convergence towards the best candidate": Identifying best candidate or food supply by keeping their location as equivalent in Eq. (4.7).

$$\vec{Z}_{tuni}(j) = \begin{cases} \vec{Y} + \vec{S} \cdot \vec{B} & if\ c_{rn} \geq 0.5 \\ \vec{Y} - \vec{S} \cdot \vec{B} & if\ c_{rn} < 0.5 \end{cases} \tag{4.7}$$

The new location of tunicates due to the relocation of their food supply is denoted as $\vec{Z}_{tuni}(j')$.

(iv) "Swarm behavior": Eq. (4.8) depicts the expression for behavior of Swarm algorithm.

$$\vec{Z}_{tuni}(j+1) = \frac{\vec{Z}_{tuni}(j) + \vec{Z}_{tuni}(j+1)}{a_1 + 2} \tag{4.8}$$

The eventual position will be selected by chance inside a cone or cylinder specified by the tunicate's location.

CSA then updates the search people in the established BF-CTSO algorithm once $\vec{F} > Fs_{best}(j)$ has been verified.

CSA [142] is a "population-based strategy" inspired by the cognitive behavior of crows, and it examines the notion of storing the crows' surplus food in safe locations so they can get it when needed. This algorithm demonstrates competitive performance by producing better outcomes when compared to conventional methodologies. Crows (corvids or crow family) are clever birds with a voracious appetite, as they vie for the best food sources. In addition, corvids monitor other birds in order to discover where they keep their food, which they then take without their awareness. They then defend themselves against other birds. To formulate CSA, a significant number of its characteristics must be studied. They are able to recall where they hide, follow other crows or birds when doing crimes, and use probability to avoid detection while stealing.

To examine the crows in a $dm-$ dimension CSA algorithm is originated and the number of crows is designated by $Z^{i,j}$, where $i=1,2,3,\cdots,Ns$ in which Ns represents number of crows and $j=1,2,3,\cdots,j_{\max}$. Each crow has learned the place of its hiding spot. The position of the i^{th} crow's hiding place at each j^{th} iteration is given by $H^{i,j}$. Throughout each repeat, crows are expected to inspect their hiding place. As a consequence, the crow decides to pursue the crow *k* for finding its hiding spot. Consequently, there are two possible outcomes.

First State: Crow i chooses to pursue crow *k* since he knows where crow *k* is hidden without their awareness. In this situation, Eq. (4.9) expresses the crow's new position .

$$Z^{i,j+1}=Z^{i,j}+rn_i\times lf^{i,j}\times\left(H^{i,j}-Z^{i,j}\right) \tag{4.9}$$

In this case, $lf^{i,j}$ represents Crow *i* flight duration in the j^{th} iteration and an arbitrary integer in the range of [0,1] is termed as rn_i

Second State: The crow *k* is conscious of monitoring of crow *i* and chooses to shield their walloping location from the crow *i* by tricking with moving to a phony location.

A arbitrary number and the awareness probability are used to determine states 1 and 2, which are jointly obtained in Eq (4.10).

$$Z^{i,j+1}=\begin{cases}Z^{i,j}+rn_i\times lf^{i,j}\times\left(H^{i,j}-Z^{i,j}\right) & rn_i\geq\rho^{i,j}\\ Random\,location & else\end{cases} \tag{4.10}$$

$\rho^{i,j}$ represents the probability of crow *i* at *j* iteration.

The BF-CTSO method is implemented by filling search agents which defines the number of retransmissions and initial system settings so can be defined. Finally, the fitness of each search individual is determined. After determining the fitness value, the optimal candidate within the specified search region is identified. Each search agent's position is updated by modifying the value $\vec{F}$ using either the CSA or TSA technique. Change the updated search person who moves outside the confines of a certain search area for update with options available Otherwise, the algorithm is executed.

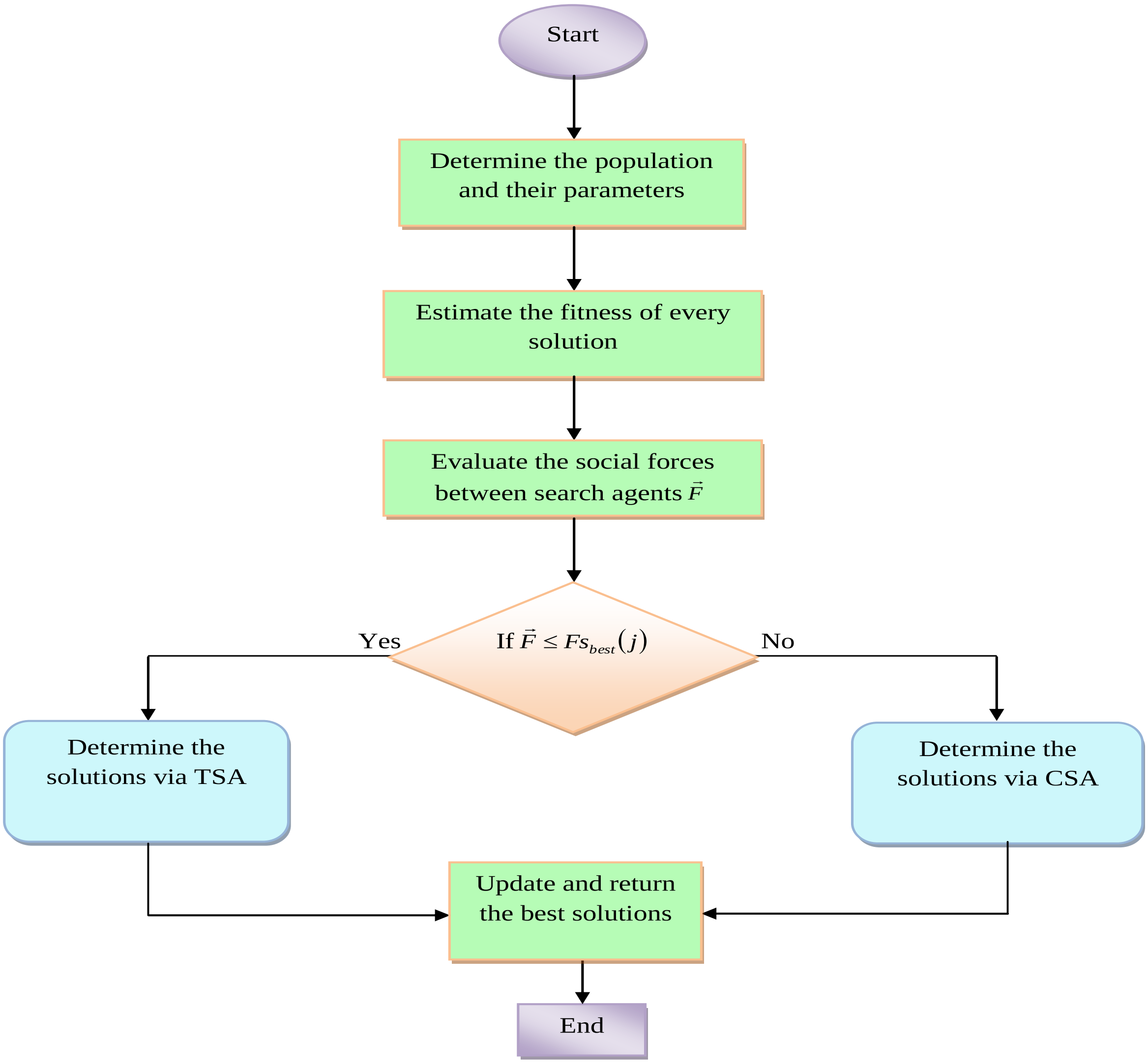


Figure 4.1. Flow diagram of proposed BF-CTSO algorithm

Algorithm 1: Proposed BF-CTSO algorithm
Frame a population of search individuals Authenticate the objective of each every answer Set the social forces among search agents $\vec{F}$ Initialization of the random parameters While $(j < j_{max})$

If $\vec{F} \le Fs_{best}(j)$

Update the solutions using TSA

If $c_{rn} \le 0.5$

Upgrade the search individuals with the help of the first constraint of Eq. (4.7)

Else

Upgrade the search individuals with the help of the second constraint of Eq. (4.7)

End if

Update swarm behavior using Eq. (4.8)

Else

Update the solutions using CSA

If $rn_i \ge \rho^{i,j}$

Update the search individuals using the first constraint of Eq. (4.9)

Else

Update the search individuals using the second constraint of Eq. (4.9)

End if

Verify the feasibility of new positions

Determine the fitness of new solutions

Evaluate the new solutions

$j = j + 1$

End while

End

4.3. Multi-Objective Energy Efficient Relay Selection in Multi-hop CVN

4.3.1 Objective Function on Relay Minimization

In this energy efficiency metric is used to evaluate minimal number of relays in multi-hop CVN. BF-CTSO strategy is proposed to identify minimal number relays for improving performance under different constraints. This is derived by identifying the fitness function for several factors including connection reliability, mobility factor, energy consumption, OP, and transmission delay. Eq. (4.11) computes the objective of the proposed CVN relay selection method.

$$Fs = \arg\min_{\{MR_{re}\}} \left(O_{out} + EC + MOF + Tj + \frac{1}{LR} \right) \tag{4.11}$$

In Eq.(4.11), MR_{re} depicts relays under optimization. The multi-objective functions like OP characterized as O_{out}, energy consumption stated as, connection reliability specified as, transmission delay Tj and mobility factor specified as MOF, and connection reliability specified as.

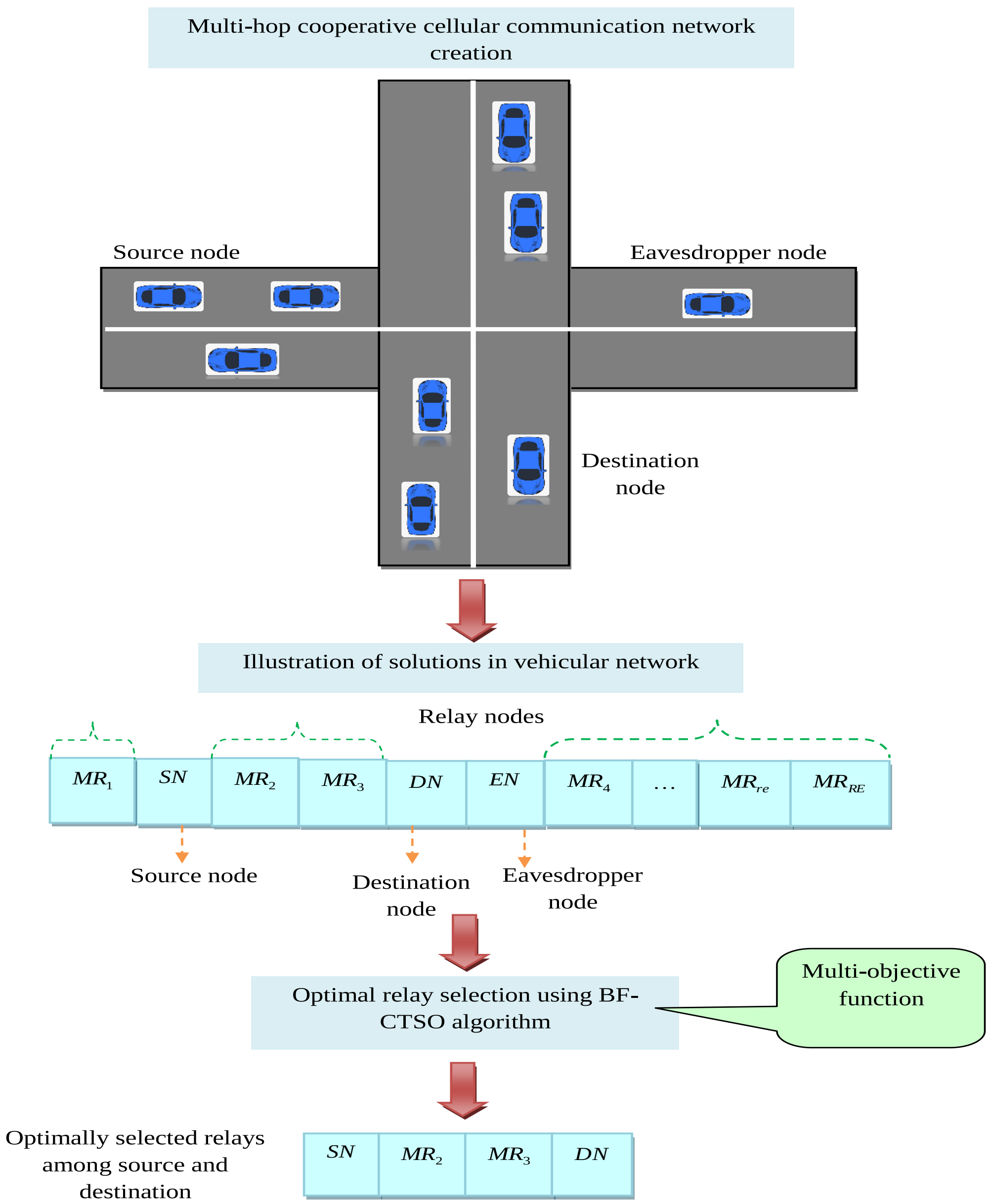


Figure 4.2. BF-CTSO method is used to choose minimal relay nodes in proposed CVN.

This diagrammatic depiction aids comprehension of the cooperative cellular communication model's relay selection process. The basic objective of a CVN is to choose multi-hops between the source and destination using the BF-CTSO algorithm, hence avoiding pointless relay or eavesdropper nodes. Figure 4.2 illustrates the optimal relay node selection for the vehicular network design.

4.3.2 Restraints for Multi-Objective Function

In the proposed system, connection dependability, mobility factor, energy consumption, OP, and transmission delay, are multi-object for the minimum relay selection in multi-hop CVN.

4.3.2.1. Link reliability: "Link reliability" is defined as "the probability that a direct transmission link between two nodes will remain continuously available for a particular time." Eq. (4.12) determines with PDF with respect to time.

$$LR = \int_{ti}^{ti+Ti_{fz}} ff\left(Ti\right)dti \qquad if\ Ti_{fz} > 0 \tag{4.12}$$

4.3.2.2. Average transmission delay: It is the average time taken to transmit a frame. The "average total transmission time per data frame" is how it's characterized. $EP[Tj_{DN}(AL,re)]$ represents the average of random number of times a *re* relays transmits the frame to the destination.

$$Tj\left(AL,re\right) = \frac{\upsilon \cdot EP\left[Tj_{RE}\left(AL,re\right)\right] + EP\left[Tj_{DN}\left(AL,re\right)\right] - EP\left[Tj_{RE}\left(AL,re\right)\right]}{KL} \tag{4.13}$$

$$EP\left[Tj_{DN}\left(AL,re\right)\right] = \sum_{is=1}^{AL} is \cdot \rho r\left(Tj_{DN} = is\right) \tag{4.14}$$

$$\rho r\left(Tj_{DN} = is\right) = \begin{cases} 1-\rho r\left(SNDN_{out,1}\right) & is = 1 \\ \rho r\left(Tj_{DN} = \hat{is}\right) & 2 \le is = \hat{is} \le AL-1 \\ \rho r\left(Tj_{DN} = AL\right) & is = AL \end{cases} \tag{4.15}$$

$$\rho r\left(Tj_{DN} = \hat{is}\right) = \rho r^{re}\left(SNRE_{out,AL-1}\right) \cdot \rho r\left(SNRE_{out,AL-1}\right) + \sum_{JH=1}^{AL-1} \sum_{re=1}^{RE} \rho r\left(Tj_{MR}^{re} = AL - JH\right) \cdot \rho r\left(SNDN_{out,AL-1}\right) \tag{4.16}$$

The $EP[Tj_{DN}(AL,re)]$, represents the not decoding of *re* relay in the AL^{th} ARQ round.

$$EP\left[Tj_{RE}\left(AL,re\right)\right] = \sum_{is=1}^{AL-1} \sum_{re=1}^{RE} is \cdot \rho r\left(Tj_{MR}^{re} = is\right) \tag{4.17}$$

As a result, the average transmission latency in CN may be calculated.

4.3.2.3. Energy consumption Model: It is used to depict the energy consumption evaluation of proposed multi-hop relay selection approach in CVN.

The power used by a node during transmission throughout the whole communication channel is comprised of both circuit power consumption PW_{cp} and transmission signal power PW_{re}. In addition, the data transfer rate helps determine the transmission signal strength PW_{re}. Finally, the total transmission power is computed using the Eq. (4.18).

$$PW = PW_{re} + PW_{cp} \leq PW_{\max} \tag{4.18}$$

Using Eq.(18) depicts available power at relay $PW_{\max}$ is estimated which is used for evaluating energy per bit i.e. energy efficiency. Since all nodes participating in information transfer have different power consumption challenge, it is necessary to measure the energy used by the *S* and *r* nodes, as given theoretically in Eq (4.19).

$$EC = \frac{\left(PW_{re} + PW_{SN}\right)}{LT_{total}} \tag{4.19}$$

Therefore, the minimal relay selection can be derived with energy consumption.

4.3.2.4. OP: The probability of the link failure with target signal rate and SNR is expressed in Eq. (4.20) and measurable in bits/slot/Hz.

$$\begin{aligned} O_{out} &= O\left\{Js\left(bx;by\middle|ht\right) < sr\right\} \\ &= O\left\{\log_2\left(1+\Im|ht|^2\right) < sr\right\} \end{aligned} \tag{4.20}$$

In rq^{th} ARQ $SNMR_{out,rq}$, $SNMRDN_{out,rq}$ and $SNDN_{out,rq}$, represents outages at relay with *ht* as fading coefficients. In addition, OP can be simplified by considering assumptions like $dq_{MR_1DN} \neq dq_{MR_2DN} \neq \cdots \neq dq_{MR_{RE}DN}$ and $dq_{SNMR_1} = dq_{SNMR_2} = \cdots = dq_{SNMR_{RE}} = dq_{SNMR}$, where expectation function is given as $EP[\cdot]$. The expectation of any two node pairs like i_s and j_s can be given as $EP\left[\left|fs_{isjs,qs}\right|^2\right]$ and δ symbolizes pathloss.

Hence link failure or outage in ARQ may suffer and the Eq. (21) determines this behavior.

$$O\left(SNDN_{out,q}\right)=\prod_{ut=1}^{q}O\left\{\log_2\left(1+\eta\left|fs_{SNDN,ut}\right|^2\right)<sr\right\}$$
$$=\prod_{ut=1}^{q}O\left\{\omega_{SNDN,ut}<\varepsilon\right\}=\prod_{ut=1}^{q}HF_{\omega_{SNDN,ut}}(\varepsilon) \quad (4.21)$$

The CDF of the random constraint RV is represented by $HF_{RV}(bx)$, and $\varepsilon \hat{=} \frac{2^{sr}-1}{\eta}$, and the modules of power intensity gain matrixes are expressed as $EW_{SNMR}=\lfloor\omega_{SN,1},\omega_{SN,2},\cdots,\omega_{SN,Q}\rfloor_{1\times Q}$, $EW_{SNDN}=\lfloor\omega_{SNDN,1},\omega_{SNDN,2},\cdots,\omega_{SNDN,Q}\rfloor_{1\times Q}$ and $\omega_{MRDN}=\begin{bmatrix}\omega_{MR_1DN,1} & \omega_{MR_1DN,2} & \cdots & \omega_{MR_1DN,Q}\\ \omega_{MR_2DN,1} & \omega_{MR_2DN,2} & \cdots & \omega_{MR_2DN,Q}\\ \vdots & \cdots & \cdots & \vdots\\ \omega_{MR_{RE}DN,1} & \omega_{MR_{RE}DN,2} & \cdots & \omega_{MR_{RE}DN,Q}\end{bmatrix}_{RE\times Q}$.

The link failure or unsuccessful ARQ round and its behavior is depicted in Eq. (4.22).

$$O\left(SNMR_{out,q}\right)=\prod_{ut=1}^{q}O\left\{\log_2\left(1+\eta\left|fs_{SNMR,ut}\right|^2\right)<sr\right\}$$
$$=\prod_{ut=1}^{q}O\left\{\omega_{SNMR,ut}<\varepsilon\right\}=\prod_{ut=1}^{q}HF_{\omega_{SNMN,ut}}(\varepsilon) \quad (4.22)$$

The failure in the rq^{th} ARQ rounds with *re* relays, as shown in Eq. (4.23).

$$O\left(SNMRDN_{out,rq}\right)=\prod_{ut=1}^{Tj_{MR}^{re}}O\left\{\log_2\left(1+\eta\left|fs_{SNDN,ut}\right|^2\right)<sr\right\}\cdot$$
$$\prod_{vp=Tj_{MR}^{re}+1}^{q}O\left\{\log_2\left(1+\sum_{tj=1}^{re}\eta\left|fs_{MR_{tj}DN,vp}\right|^2\right)<sr\right\}$$
$$=\prod_{ut=1}^{Tj_{MR}^{re}}O\left\{\omega_{SNDN,ut}<\varepsilon\right\}\cdot\prod_{vp=Tj_{MR}^{re}+1}^{q}O\left\{\sum_{tj=1}^{re}\omega_{MR_{tj}DN,vp}<\varepsilon\right\} \quad (4.23)$$

In the first time slot, the information frame $\left(Tj_{MR}^{re}\right)^{th}$ received at *re* relay in ARQ round is given Tj_{MR}^{re}, and it is decoded by the network's $re-$ out-of-neighbor nodes. As a result, the probability Tj_{MR}^{re} is calculated in Eq. (4.24).

$$O\left(Tj_{MR}^{re}=tj\right)=\binom{RE}{re}\left[O\left(SNMR_{out,tj-1}\right)-O\left(SNMN_{out,tj}\right)\right]^{kt}\cdot$$
$$O^{(RE-kt)}\left(SNMR_{out,tj}\right) \quad (4.24)$$

Until re reaches to ARQ round, it does not decode the received frame, The symbol for a Gamma arbitrary constraint with parameter $\left(ot_{isjs}, \frac{\Omega_{isjs}}{o_{isjs}}\right)$ is $\omega_{isjs,q}$. As a result, Eq. (4.24) derives the CDF of the sum of $re-$ independent but not essentially alike to Gamma random variables given the restrictions of $O\left\{\sum_{tj=1}^{re} \omega_{MR_{tj}DN,vp} < lh\right\}$. Furthermore, the PDF and CDF of XH are calculated here using $XH = \sum_{tj=1}^{re} \alpha_{tj}$.

$$hf_{XH}(xh) = \prod_{tj=1}^{re} \left(\frac{ot_{tj}}{\Omega_{tj}}\right)^{ot_{tj}} FG_{\Im,\Im}^{\Im,0}\left[\exp(-xh)\Big|_{\lambda_{\Im}^{(2)}}^{\lambda_{\Im}^{(1)}}\right] \tag{4.25}$$

$$HF_{XH}(xh) = \prod_{tj=1}^{re} \left(\frac{ot_{tj}}{\Omega_{tj}}\right)^{ot_{tj}} FG_{\Im+1,\Im+1}^{\Im+1,0}\left[\exp(-xh)\Big|_{\lambda_{\Im}^{(2)},0}^{\lambda_{\Im}^{(1)},1}\right] \tag{4.26}$$

Here, an integer is given $\Im = \sum_{tj=1}^{re} ot_{tj}$ and the Meiger-G function [129] is denoted in Eq. (4.27).

$$\begin{aligned} FG_{pt,qt}^{kq,lq}\left[\varsigma\Big|_{\lambda_{\Im}^{(2)}}^{\lambda_{\Im}^{(1)}}\right] &= FG_{pt,qt}^{kq,lq}\left[\varsigma\Big|_{yh_1,yh_2,\cdots,yh_{qt}}^{xh_1,xh_2,\cdots,xh_{pt}}\right] \\ &= \frac{1}{2\pi is}\int_{CK} \frac{\prod_{js=1}^{o}\Gamma\left(yh_{jt}-sg\right)\cdot\prod_{jt=1}^{RE}\Gamma\left(1-xh_{jt}+sg\right)}{\prod_{js=ot+1}^{qt}\Gamma\left(1-yh_{jt}+sg\right)\cdot\prod_{jt=RE+1}^{pt}\Gamma\left(xh_{jt}-sg\right)}\varsigma^{sg}\,dsg \end{aligned} \tag{4.27}$$

Considering all elements in the vicinity, the integral route is specified by CK and the Gamma function is denoted as $\Gamma(\cdot)$, $\lambda_{\Im}^{(1)}$ and $\lambda_{\Im}^{(2)}$ are obtained in Eqs. (4.28) and (4.29).

$$\lambda_{\Im}^{(1)} = \overbrace{\underbrace{\left(1+\frac{ot_1}{\Omega_1}\right),\cdots,\left(1+\frac{ot_1}{\Omega_1}\right)}_{ot_1},\cdots,\underbrace{\left(1+\frac{ot_{re}}{\Omega_{re}}\right),\cdots,\left(1+\frac{ot_{re}}{\Omega_{re}}\right)}_{ot_{re}}}^{\Im} \tag{4.28}$$

$$\lambda_{\Im}^{(2)} = \overbrace{\underbrace{\left(\frac{ot_1}{\Omega_1}\right),\cdots,\left(\frac{ot_1}{\Omega_1}\right)}_{o_1},\cdots,\underbrace{\left(\frac{ot_{re}}{\Omega_{re}}\right),\cdots,\left(\frac{ot_{re}}{\Omega_{re}}\right)}_{o_p}}^{\Im} \tag{4.29}$$

$\Omega_{tj} \neq \Omega_q (tj, q = 1,2,3,\cdots,re, tj \neq q)$ represents the average power. The Rayleigh fading channel or the PDF of the sum re of Eq (4.31).

$$hf_{XH}^{Rayleigh}\left(xh\right)=\frac{1}{\prod_{tj=1}^{re}\Omega_{tj}}FG_{re,re}^{re,0}\left[\exp\left(-xh\right)\left|\begin{matrix}1+\frac{1}{\Omega_1},\cdots,1+\frac{1}{\Omega_1}\\ \frac{1}{\Omega_1},\ldots,\frac{1}{\Omega_1}\end{matrix}\right.\right] \tag{4.30}$$

$$hf_{XH}^{Rayleigh}\left(xh\right)=\sum_{tj=1}^{re}\left(\prod_{sg\neq tj}\frac{\frac{1}{\Omega_{sg}}}{\frac{1}{\Omega_{sg}}-\frac{1}{\Omega_{tj}}}\right)\frac{1}{\Omega_{tj}}\exp\left(-\frac{xh}{\Omega_{tj}}\right) \tag{4.31}$$

Finally, the OP for all channels can be explored.

4.3.2.5. Mobility Factor (MOF **):** It represents the capability that a node stability and is computed as "the fraction between an moving average of the node's pause time AV_{pt} and the longest recorded pause duration" MD_{pt} derived in unit time [138] .

$$MOF=\frac{AV_{pt}}{MD_{pt}} \tag{4.32}$$

Finally, this feature aids in the selection of stable relay nodes.

4.4. Conclusion

The cooperative networking in VANETs enhances the performances with spatial diversity. The number of relay nodes and selection of minimal number of relay nodes in VANETs is always a challenge. Traditional methods and their strategies in relay selection proved to be considerably good at the cost of high energy usage, network overhead, imperfect CSI and end-to-end delay. In this chapter, a hybrid heuristic BF-CTSO strategy is projected to analyze the performance of multi-objective energy efficient relay selection with metric like link reliability, Average transmission delay, Energy consumption, Outage Probability and mobility factor. The mathematical expression for the proposed model and algorithm depicted, whereas the optimization of the relays in multi-hop CVNs are projected in Chapter 5.

CHAPTER-5

OPTIMAL RELAY SELECTION WITH SECRECY

CHAPTER-5

OPTIMAL RELAY SELECTION WITH SECRECY

In this chapter, considering the multi-objective functions, present the optimization of relays and multi-hops in CVNs with secrecy capacity, because it is related to its outage probability and throughput. It sets an upper limit on the amount of information that can be securely transmitted. The higher the secrecy capacity of a network, the higher the throughput and lower the outage probability. This is because the increased secrecy capacity allows for greater amounts of secure data transmission, decreasing the chances of data leakage and enabling higher throughput.

The simulation results projected in this chapter represent the assessment of convergence, throughput, outage probability, energy consumption, transmission delay and runtime of the proposed Hybrid heuristic BF-CTSO strategy and compared with traditional strategies like CSO, D-CSO, CSA and TSA. It is observed from the results that, proposed strategy has outperformed the aforementioned traditional algorithms.

5.1. Multi-hop CVN System Concept and Cooperative Technique

In this section multi-hop relay selection strategy in CVN is illustrated for secrecy capacity computation

5.1.1. Cooperative Procedure

In the cooperative phase of the multi-hop CVN, the security of the cooperative phase is explored by presuming that the relay signal transmission power PW_{re}

$$x_{MRDN,re} = \sqrt{PW_{re}}\, hs_{MRDN,re} bx + \beta'_{DN} \tag{5.1}$$

$$x_{MREN,re} = \sqrt{PW_{re}}\, hs_{MREN,re} bx + \beta'_{EN} \tag{5.2}$$

Eq. (5.1) and Eq. (5.2) represents the signals received at DN and EN. The AWGN are denoted as β'_{DN} and β'_{EN} with comparable power β_0. As illustrated in Eq.(5.3), it results in greater privacy capacity during the cooperative stage.

$$\Re_{\ell}^{CP,re} = \left[\log_2 \left(\frac{1+\xi_1 \left| hs_{SNDN,re} \right|^2 + \xi_2 \left| hs_{MR_{re},DN} \right|^2}{1+\xi_1 \left| hs_{SNEN} \right|^2 + \xi_2 \left| hs_{MR_{re},EN} \right|^2} \right) \right]^+ \quad (5.3)$$

$$\xi_2 = \frac{PW_{re}}{\beta_0} \quad (5.4)$$

However, the value ξ_2 is presumed to be zero, and the relay node is unable to forward the source message, resulting in silence throughout this phase. Finally, Eq. (5.5) reveals the total instantaneous privacy capacity from the starting point to the goal.

$$\Re_{\ell}^{re} = \frac{1}{2} \min \left\{ \begin{array}{l} \left[\log_2 \left(\frac{1+\chi_{SCS}^{re}}{1+\chi_{SNEN}^{re}} \right) \right]^+ \\ , \left[\log_2 \left(\frac{1+\chi_{SNDN}+\chi_{MRDN}^{re}}{1+\chi_{SNEN}+\chi_{MREN}^{re}} \right) \right]^+ \end{array} \right\} \quad (5.5)$$

Here $\chi_{MREN}^{re} = \xi_2 \left| hs_{MREN,re} \right|^2$, $\chi_{MRDN}^{re} = \xi_2 \left| hs_{MRDN,re} \right|^2$, $\xi_{SNEN} = \xi_1 \left| hs_{SNEN} \right|^2$, and $\chi_{SCS}^{re} = \xi_1 \left| hs_{SCS,re} \right|^2$.

$\frac{1}{2}$ in the Eq. (5.5) represents secrecy transmission in two time slots. In addition, as specified by Eq.(5.6), a "Generalized version of Optimal Relay Selection" (GORS) strategy is utilized to choose the optimal relay in both cooperative phases.

$$\Re_{\ell}^{GORS} = \frac{1}{2} \max_{re \in \{1,..,RE\}} \left\{ \min \left\{ \Re_{\ell}^{BP,re}, \Re_{\ell}^{CP,re} \right\} \right\} \quad (5.6)$$

This formulation clearly shows that the leaking of undisclosed data in any of the two phases of cooperative impact on the overall system security. As a result, the GORS strategy preserves security through two distinct criteria: (i) the S-to-D connection DN is stronger than links $SN - MR_{re}, (re = 1, \cdots RE)$, and (ii) the S-to-D link is weedier than $SN - MR_{re}, (re = 1, \cdots RE)$ links.

Thus, Eq.(5.7) deduces the security capacity using GORS.

$$\Re_{\ell,1}^{GORS} = \frac{1}{2} \max_{re \in \{1,..,RE\}} \left\{ \min \left\{ \Re_{\ell}^{SNMR,re}, \Re_{\ell}^{CP,re} \right\} \right\} \quad (5.7)$$

Here, $\Re_{\ell}^{SNMR,re} = \left[\log_2 \left(\frac{1+\chi_{SNMR}^{re}}{1+\chi_{SNEN}} \right) \right]^{+}$ and $\chi_{SNMR}^{re} = \xi_1 \left| hs_{SNMR,re} \right|^2$. Eq. (5.7) is similar to the peak *RE* security capacities [125]. Whereas the security capacity can be computed as

$$\Re_{\ell,2}^{GORS} = \frac{1}{2} \max_{re \in \{1,..,RE\}} \left\{ \min \left\{ \Re_{\ell}^{SNDN}, \Re_{\ell}^{CP,re} \right\} \right\} \tag{5.8}$$

In Eq. (5.8), $\Re_{\ell}^{SNDN} = \left[\log_2 \left(\frac{1+\chi_{SNDN}}{1+\chi_{SNEN}} \right) \right]^{+}$ it is peak of *RE* secrecy capabilities and $\Re_{\ell}^{SNDN}$ displays the instant secrecy capability at principal goal through direct transmission.

The aforementioned two criteria are used in the GORS approach, and a factor of 1/2 is applied in Eq. (5.8) to decrease the transmission efficiency value while simultaneously improving the channel estimation in wiretap link with direct link. The direct connection is evaluated in each phase's receiving and sending nodes to determine the optimal relay [142]. When the full CSI the full CSI is available at relay node [142], the source broadcast the secrecy message with a predefined pace δ_{ℓ}. In addition, choices to retrieve the source message through the direct connection are made at the destination, as shown in Eq (5.9).

$$\aleph : \Re_{\ell}^{SNDN} < \delta_{\ell} \tag{5.9}$$

The information is either sent with as secrecy message using AORS scheme from source node or by adapting adaptive relaying to improve the secrecy capacity. The spectral efficiency of the CVN can be boosted and computational complexity can be minimized by employing incremental relaying with full-duplex implementation [143].

$$\Re_{\ell}^{SNDN} < \left[\log_2 \left(\frac{1+\xi_1 \max_{re \in \{1,..,RE\}} \left\{ \left| hs_{SNMR,re} \right|^2 \right\}}{1+\xi_1 \left| hs_{SNEN} \right|^2} \right) \right]^{+} \tag{5.10}$$

$$\eta : \chi_{SNDN} < \max_{re \in \{1,..,RE\}} \chi_{SNMR}^{re} \tag{5.11}$$

This AORS is used to boost the secrecy capacity while computing $\aleph$ the by doing incremental collection with an ideal relay.

5.1.2. System Model

Utilizing physical layer characteristics, cooperative communication has recently developed as a means of enhancing network security. Relay nodes, as opposed to wiretap nodes, are used between the source and principal destination nodes to increase the capacity of the core network. Increase the number of relays to enhance the efficiency of secrecy. In contrast, relay selection is the most well-known way for increasing the efficiency of cooperative systems, regardless of security concerns. The relay selection algorithms considers the active involvement of eavesdropper wiretapping by its operational interference at source and relays to pose significant difficulties. In addition, many relay selection approaches need continual monitoring of all possible channel connections, resulting in an unwelcome increase in system overhead, especially for automotive networks. Consequently, the selection technique and relaying protocol have a substantial impact on the performance of cooperative communication systems. AF and DF are instances of protocols. The effective relay selection method for vehicle networks contributes to a number of real-time applications as presented in chapter 1. Figure 5.1 depicts a multi-hop CVN with multiple number of nodes and dynamic eavesdroppers.

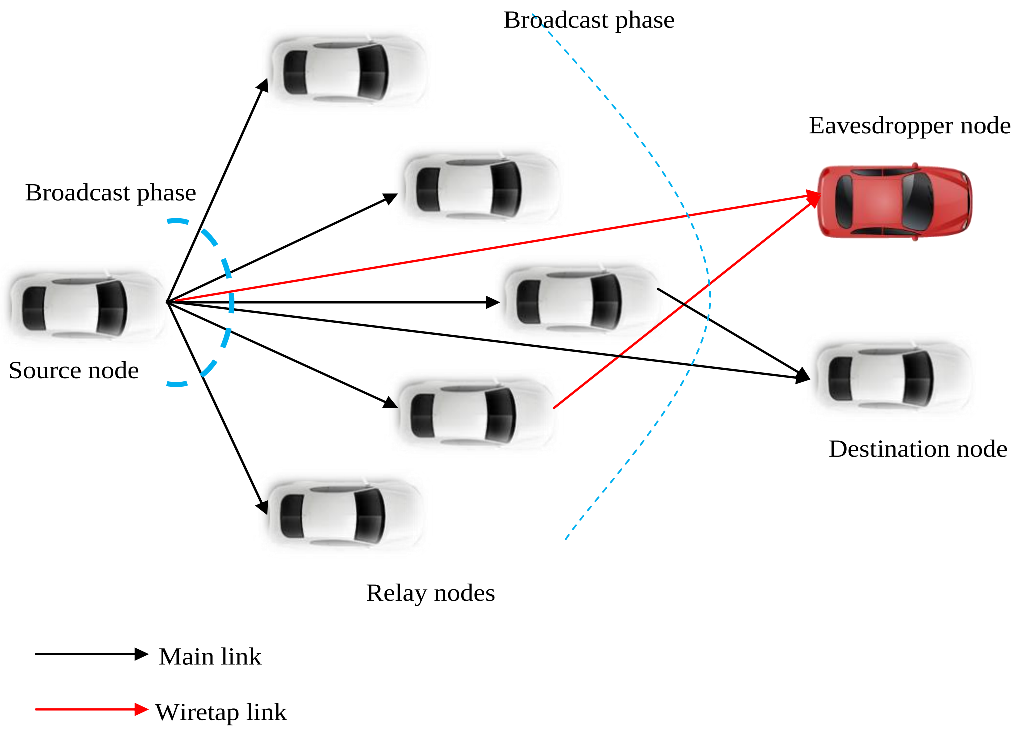


Figure 5.1.Depicts a system concept for a multi-hop CVN with a wiretap channel.

A temporal division multiplexing with unique DF relay multi-hop CVN system is used in this instance. The Source vehicle involved in proposed network are the eavesdropper EN , the destination DN , the $RE-$relays $re = 1,2,3,\cdots,RE$ where $(MR_1, MR_2, \cdots, MR_{RE})$, and the source node, all of which are associated with a single antenna. In addition, because to the practical structure, all accessible nodes function in a half-duplex mode and cannot transmit and receive simultaneously.

With estimating CSI of wiretaps and direct channels, the number of channels involving in information transfer can be known. In this regard, two cases are presented in which CSI is known at transmitter due to feedback in first case and known at receiver in second case. Furthermore, the variance σ^2_{KcTr} and zero mean are used as the channel between each receiver node for $re = 1,2,\cdots,RE$ for $Kc \in (MR_{RE}, EN, DN)$, that is hs_{KcTr}, and transmitter node $Tr \in (SN, MR_{RE})$The message is encoded as a codeword $GS \in GS^{bg}$ from wiretap capacity codebook, example an information of length bg is produced as GS^{bg} . The secret information is communicated by assigning the signal bx with power to the initiating node PW_{SN} .

The permitted nodes obtain the corresponding signals during this phase.

$$x_{DN} = \sqrt{PW_{SN}}\, hs_{SNDN} bx + \beta_{DN} \tag{5.12}$$

$$x_{MR,re} = \sqrt{PW_{SN}}\, hs_{SNMR,re} bx + \beta_{MR} \tag{5.13}$$

In this instance, AWGN at the multiple relays and anticipated destination is symbolized as β_{MR} and β_{DN} . The received signal during the broadcast phase, when the eavesdropper node wiretaps the source, is shown by Eq. (5.14).

$$x_{EN} = \sqrt{PW_{SN}}\, hs_{SNEN} bx + \beta_{EN} \tag{5.14}$$

In this context, AWGN noise EN is defined as β_{EN} density power β_0. The optimal Gaussian code work is used at first relay derived from Selection Combining Scheme (SCS). The security capacities of the two phases in cooperative networking are estimated independently, with the first phase's secrecy capacity being modeled as a Single Input-Multiple Output (SIMO) channel.

The secrecy capacity of SCS selected relay and destination modeled as SIMO channel can be expressed as

$$\Re_{SCS}^{re} = \log_2\left(1+\xi_1\left|hs_{SCS,re}\right|^2\right) \tag{5.15}$$

$$hs_{SCS,re} = \max\left\{\left|hs_{SNDN}\right|^2, \left|hs_{SNMR,re}\right|^2\right\} \tag{5.16}$$

$$\xi_1 = \frac{PW_{SN}}{\beta_0} \tag{5.17}$$

Wiretap channel capacity can be given as

$$\Re_{SNEN} = \log_2\left(1+\xi_1\left|hs_{SNEN}\right|^2\right) \tag{5.18}$$

The difference in the capabilities of link between wiretap and direct link is used to define secrecy capacity, which is used in the cooperative broadcast phase to improve secure transfer of information at the re^{th} relay.

$$\begin{aligned}\Re_{\ell}^{BP,re} &= \left[\Re_{SCS}^{re} - \Re_{SNEN}\right]^+ \\ &= \left[\log_2 \frac{1+\xi_1\left|hs_{SCS,re}\right|^2}{1+\xi_1\left|hs_{SNEN}\right|^2}\right]^+\end{aligned} \tag{5.19}$$

Where, symbolic representation of $[bx]^+$ depicts $\max(0, bx)$.

5.2. Results Evaluation

It presents various evaluations performed to compare the proposed approach to the existing technics and implementation limitations in CVN.

5.2.1. Simulation Setup

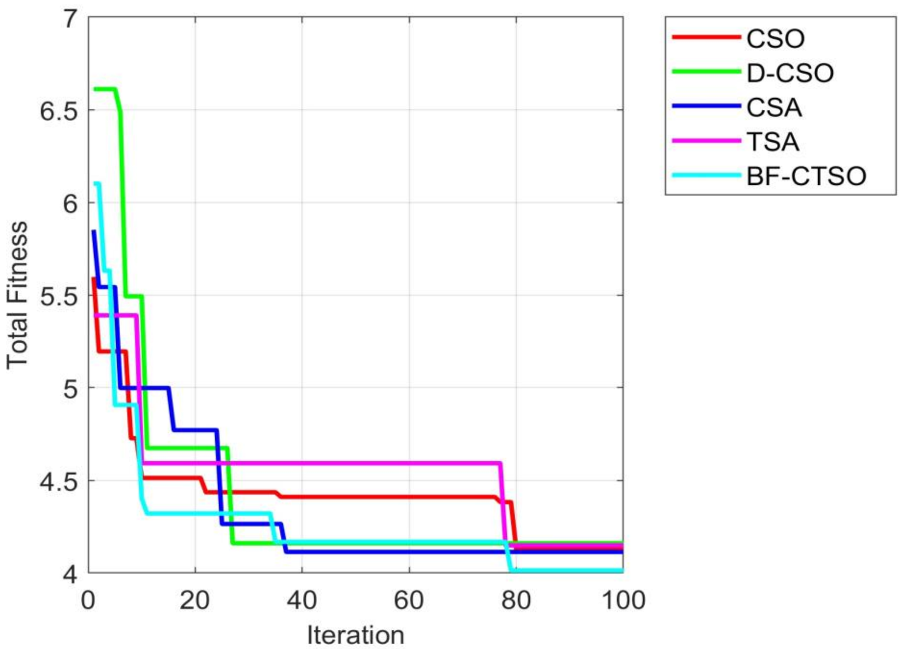
"MATLAB 2020a was used to construct the suggested cooperative vehicle network." In terms of convergence, transmission delay analysis, energy consumption, runtime, and OP analysis, the experimental research was compared to well-known algorithms such as Cat Swarm Optimization (CSO) [125], Dimension-based Cat Swarm Optimization (D-CSO) [141], CSA [142], and TSA [137]. The experiment's parameters are shown in Table 5.1. In this instance, the additional result indicates that 50×50m, 100×100m, and 150×150m are taken into account when evaluating algorithm performance.

Table 5.1: Cooperative VANET simulation parameters.

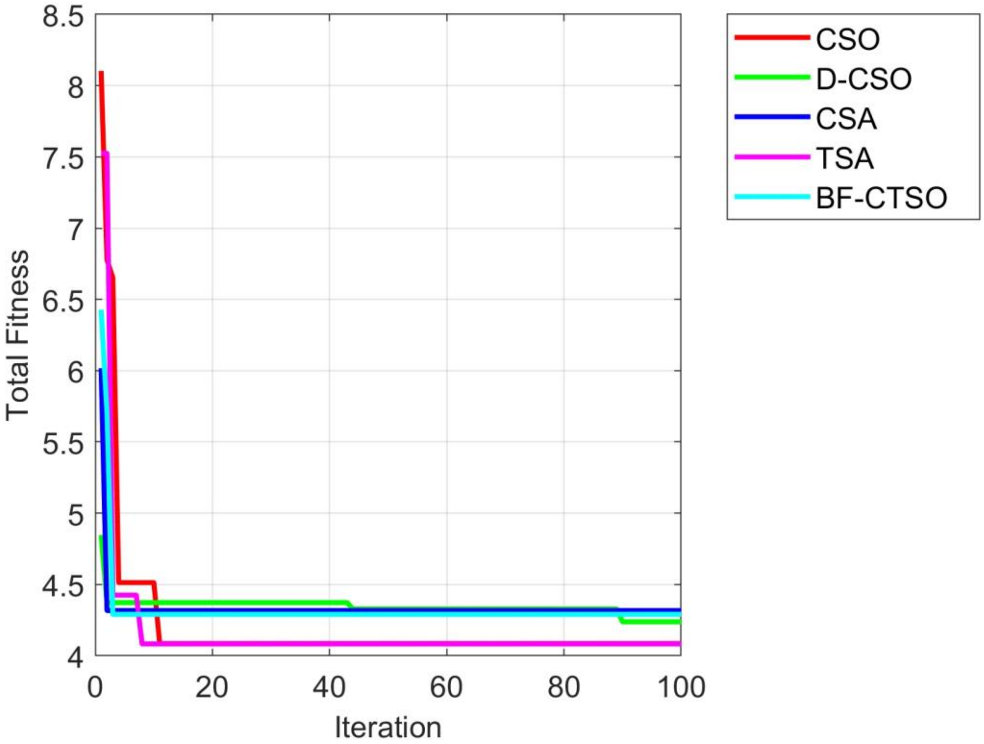
Parameters	Values
Total number of iterations	100
AL	2, 3
KL	5 frames/second
Communication range of antennas	1000 m
Number of population	10
sr	0.5 bits/slot/Hz
χ	105dB
Number of relay nodes	50
Number of nodes	[50, 100, 150]
Number of antennas	01

5.2.2 Evaluation of Convergence

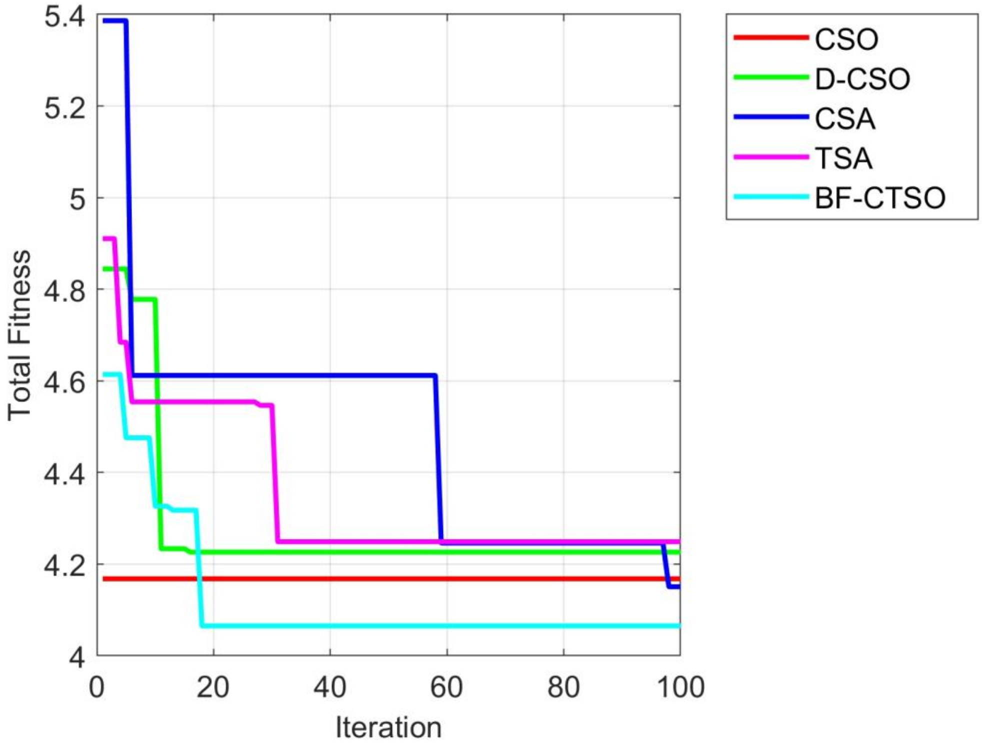
As seen in Figure 5.2, the efficiency of proposed CVN is measured using 3 distinct Cases and empirical methodologies. Figure 5.3 displays how the field size changed as a consequence of study into the convergence of CVN. As presented in the preceding sections, BF-CTSO algorithm reduces the fitness function to increase performance. In 3 instances, a CVN developed with BF-CTSO algorithm for relay selection achieves competitive efficiency in comparison to current empirical approaches



(a) Case One

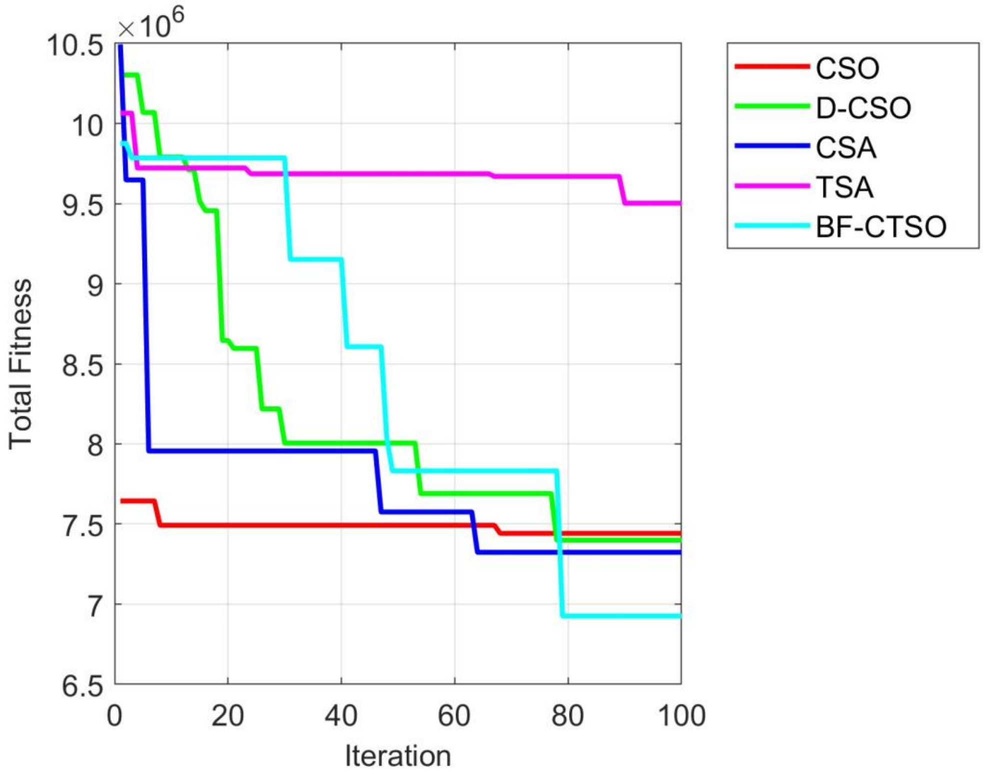


(b) Case Two

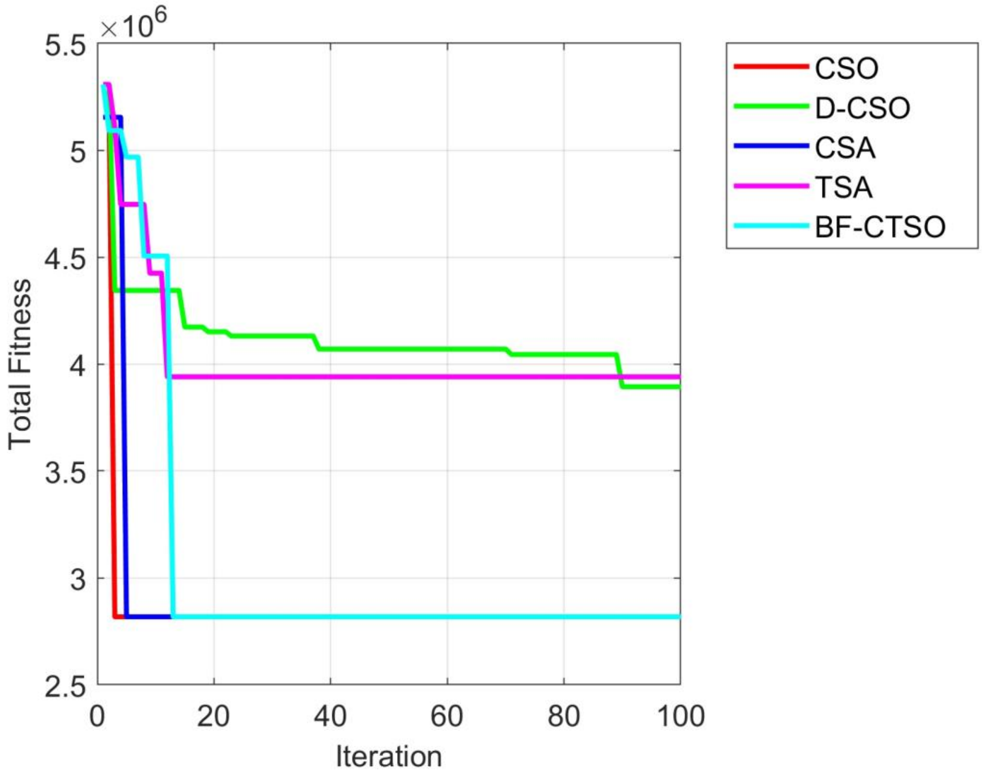


(c) Case Three

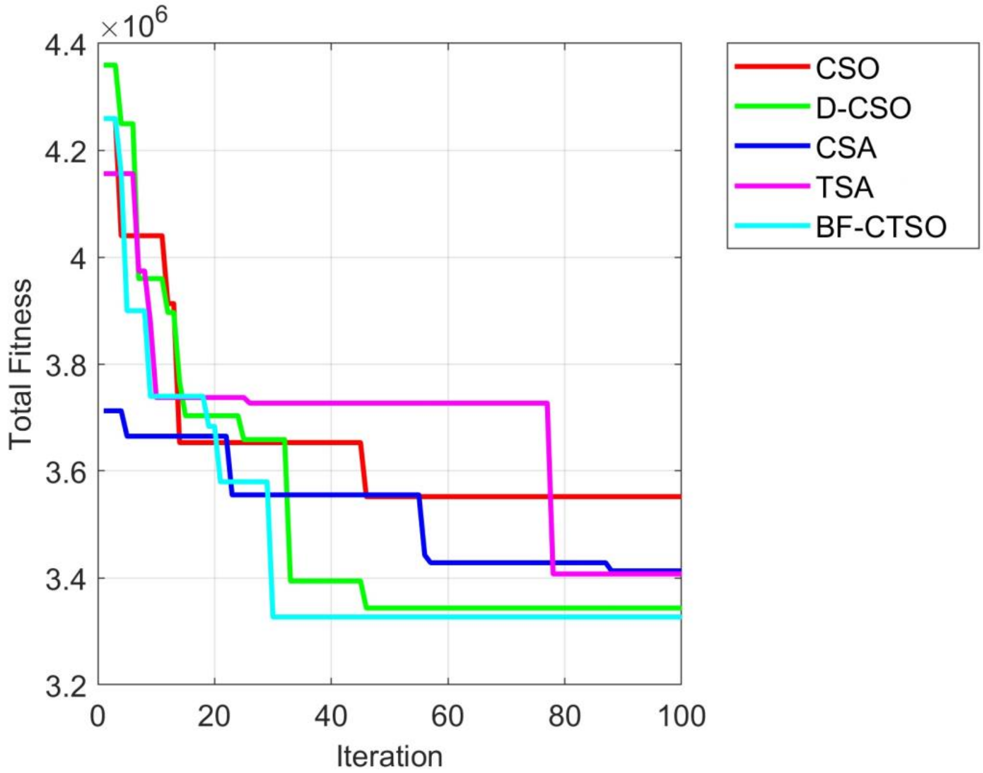
Figure 5.2. Convergence study for proposed approach for (a) Case One, (b) Case Two, and (c) Case Three.



(a) Case One



(b) Case Two

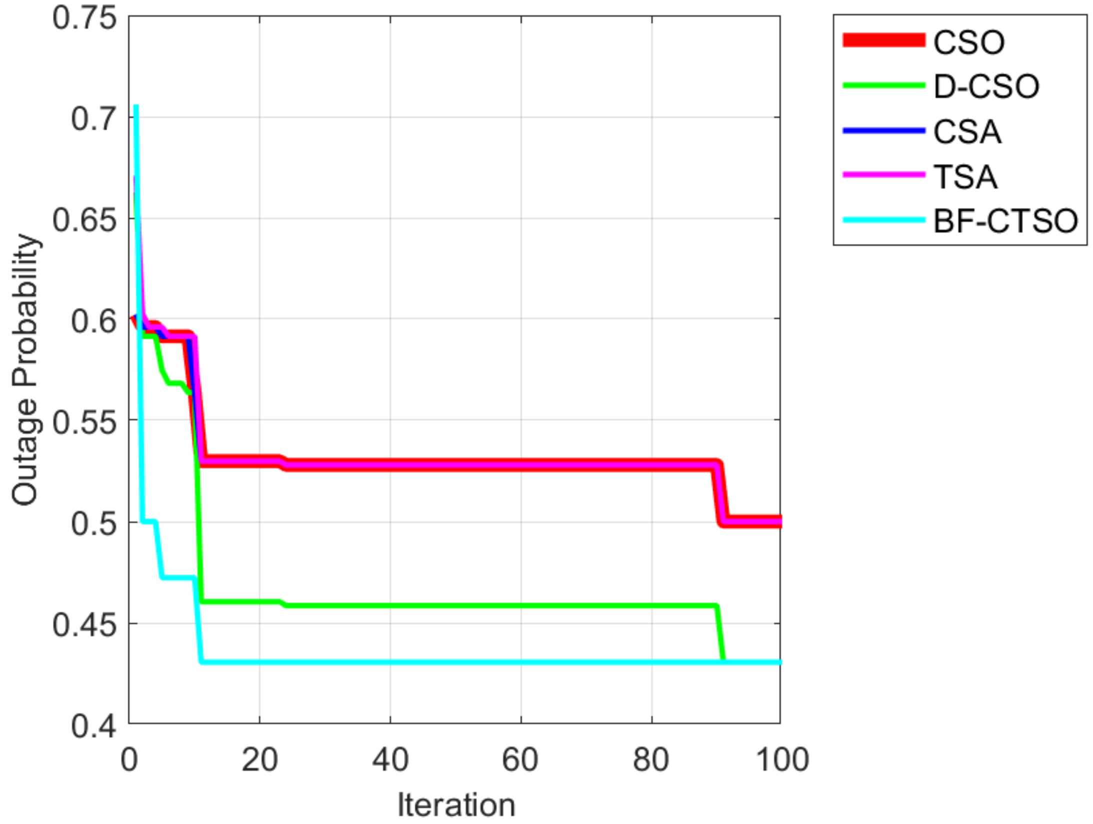


(c) Case Three

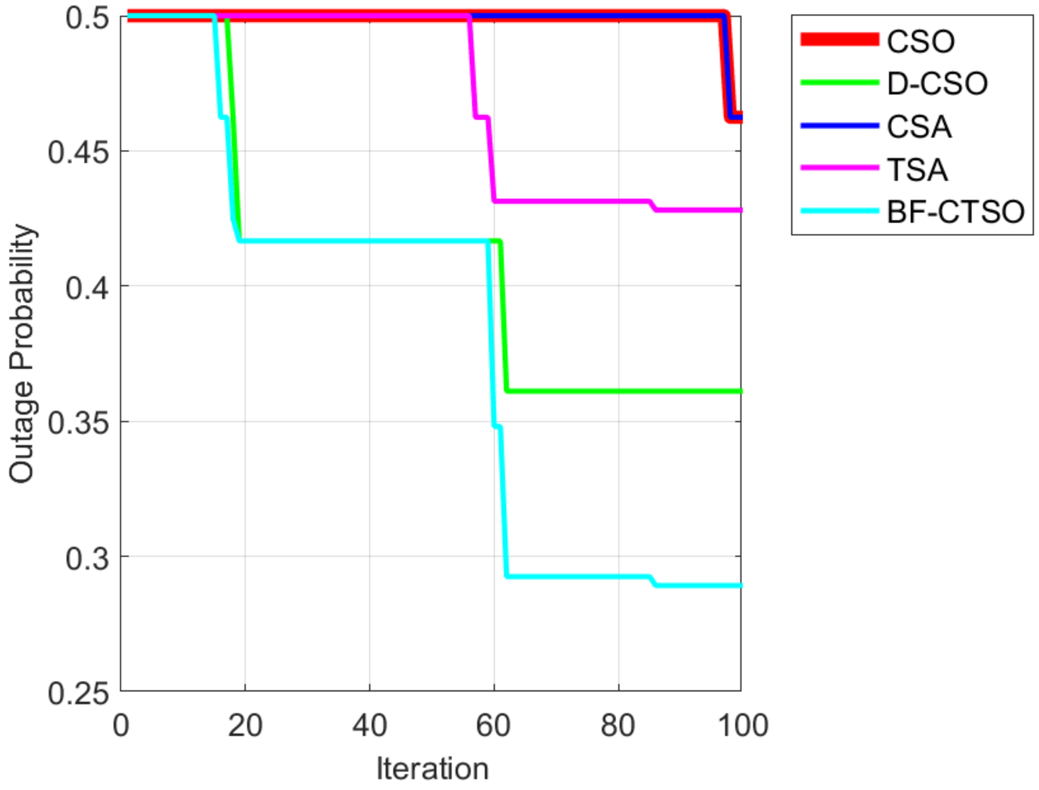
Figure 5.3. Field dimensions variation with convergence study for proposed approach using different techniques for (a) Case One, (b) Case Two, and (c) Case Three.

5.2.3 Analysis of OP

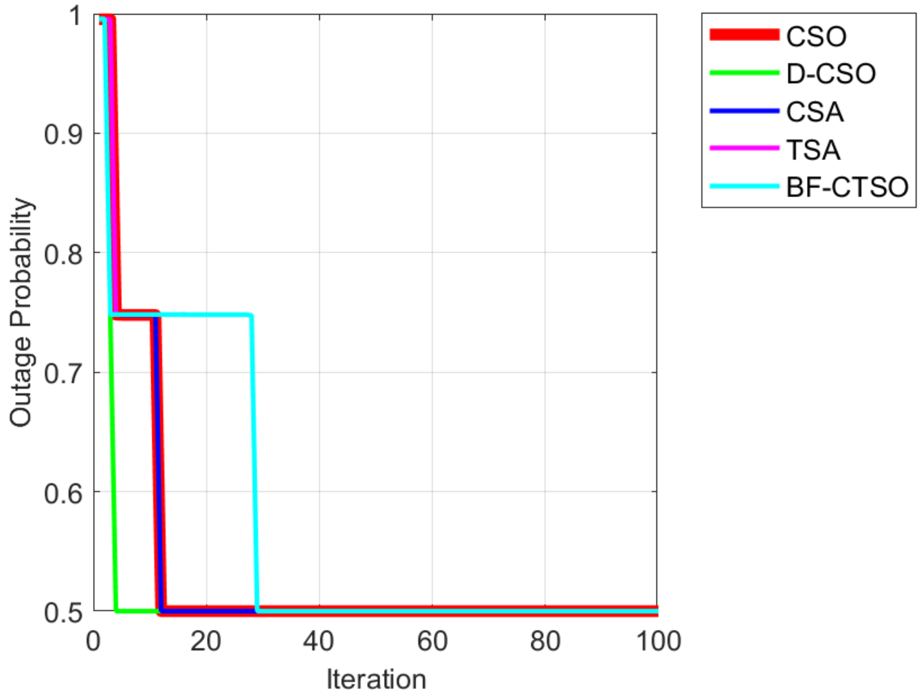
As seen in Figure 5.4, the performance forecast of the projected CVN with OP is tested over 3 Cases using a variety of optimization methodologies. As illustrated in Figure 5.5, the field size varies dependent on the OP investigation of the established CVN. The suggested minimal relay selection using proposed algorithm illustrates the approach's superiority by achieving a lower rate and higher performance.



(a) Case One

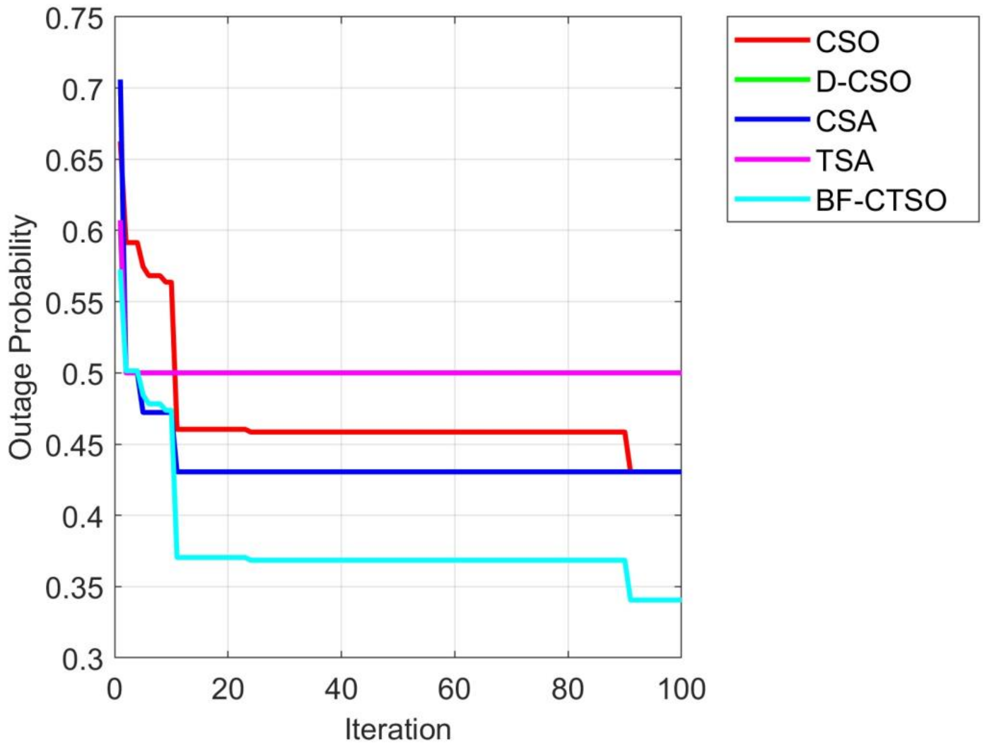


(b) Case Two

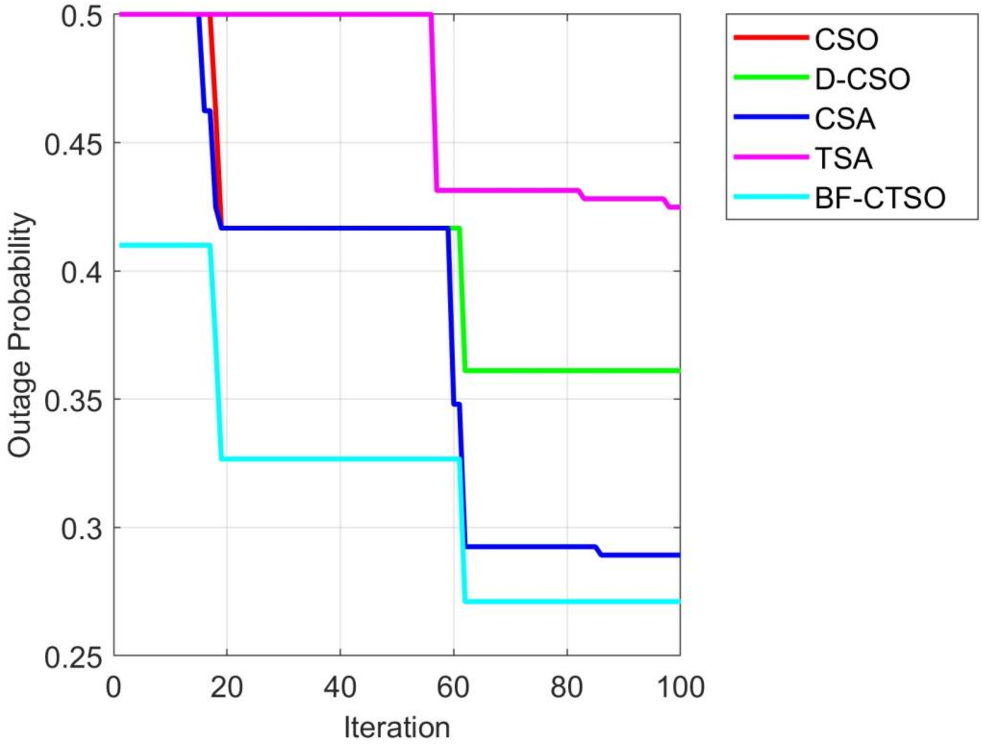


(c) Case Three

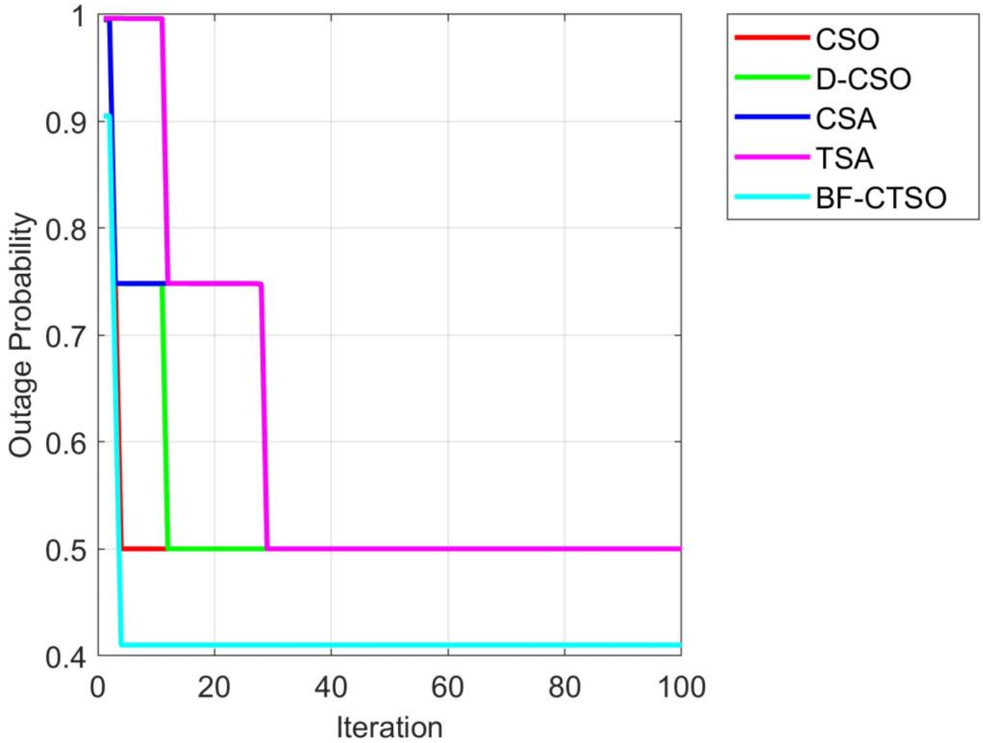
Figure 5.4. OP evaluation for proposed approach for (a) Case One, (b) Case Two, and (c) Case Three.



a) Case One



(b) Case Two

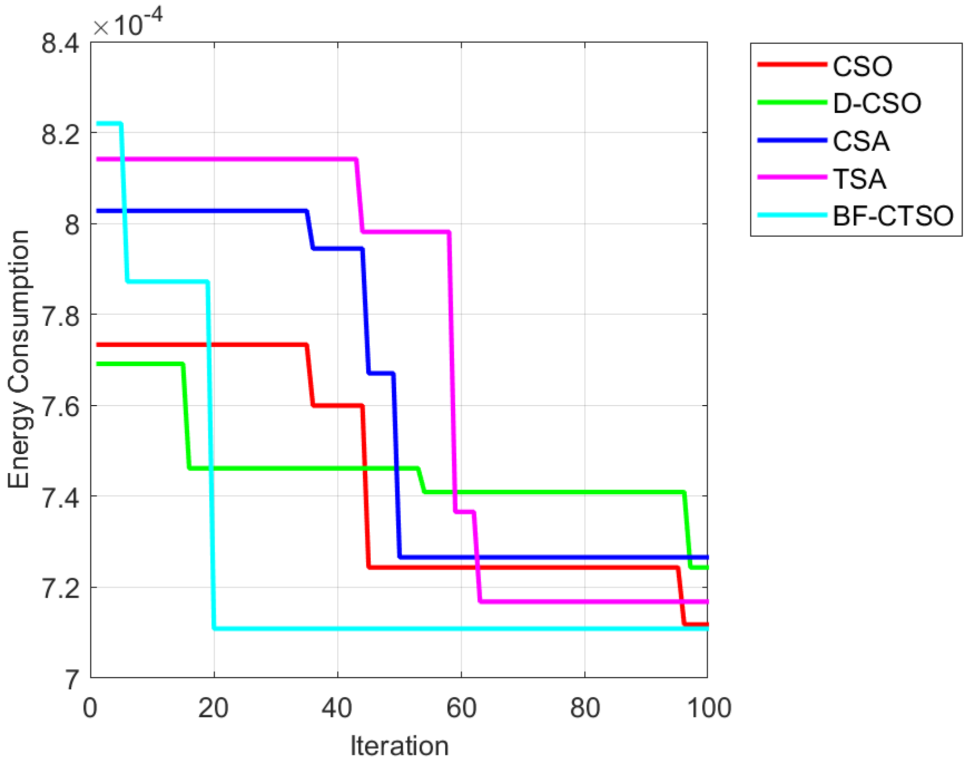


(c) Case Three

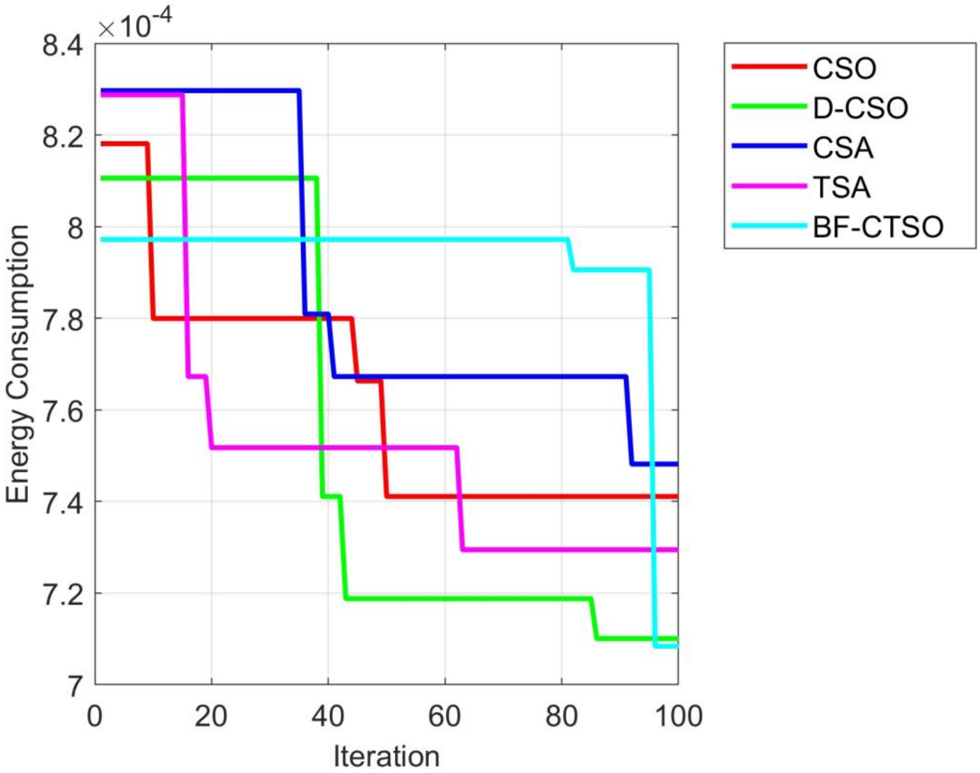
Figure 5.5. Field dimension varied based on OP Analysis for the proposed approach with different methods for (a) Case One, (b) Case Two, and (c) Case Three.

5.2.4 Assessment of Energy Consumption

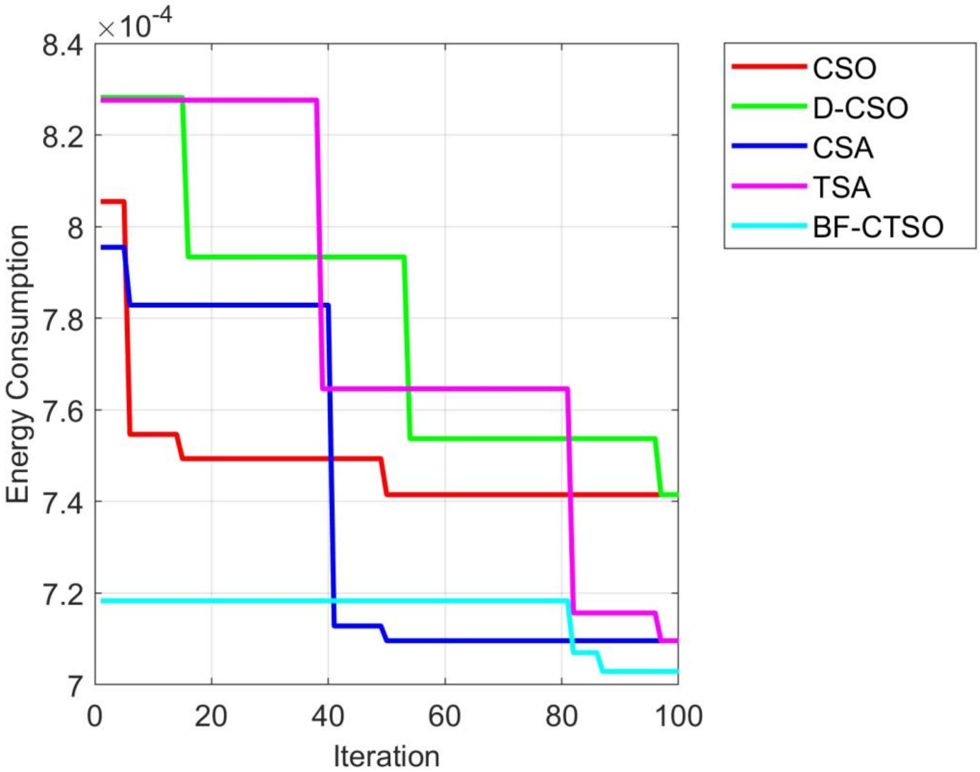
As seen in Figure 5.6, energy used by the proposed CVN is analyzed over three Cases using various empirical techniques. Figure 5.7 displays the evolution of the field size as a consequence of the energy consumption analysis conducted on the developed on CVN. In the 100th iteration of the projected optimum relay selection, the proposed strategy reduces energy consumption. Despite the fact that the proposed strategy costs more energy during the early iterations, the optimal relay selection of the BF-CTSO allows the relay to consume less energy.



(a) Case One

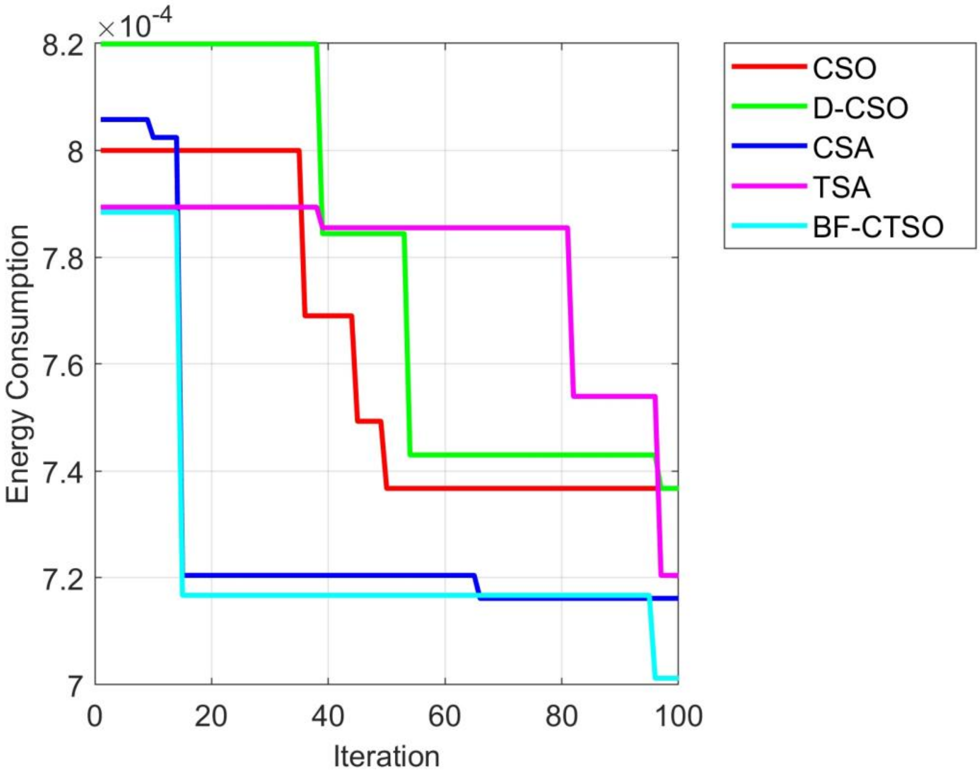


(b) Case Two

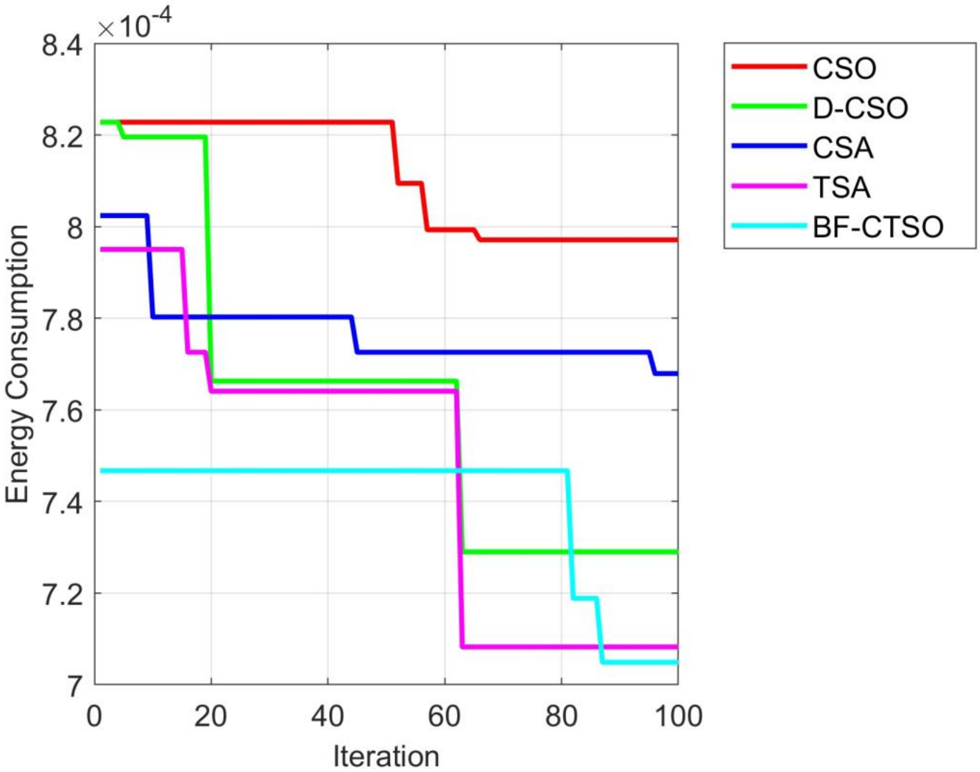


(c) Case Three

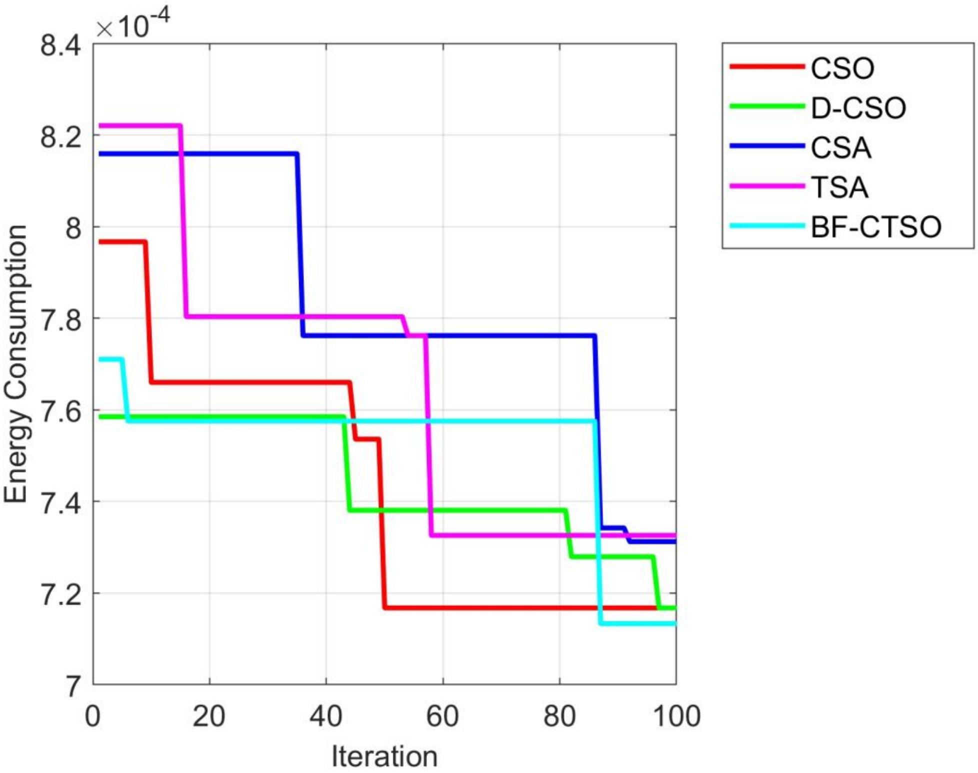
Figure 5.6. Energy consumption analysis for proposed approach with different minimization techniques for (a) Case One, (b) Case Two, and (c) Case Three.



(a) Case One



(b) Case Two

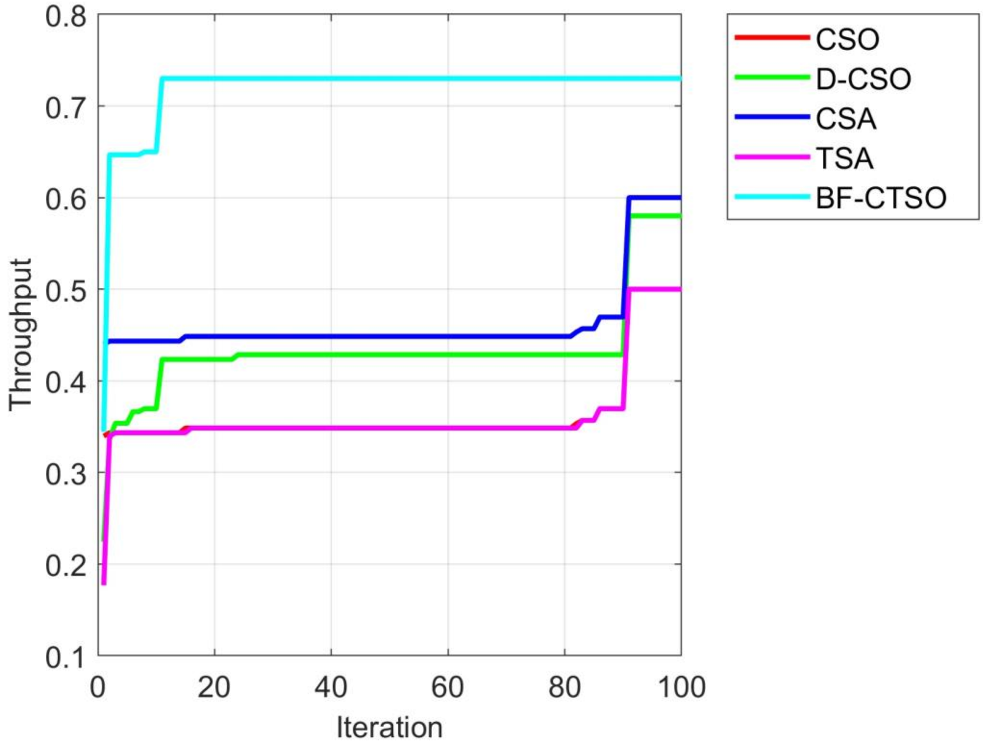


(c) Case Three

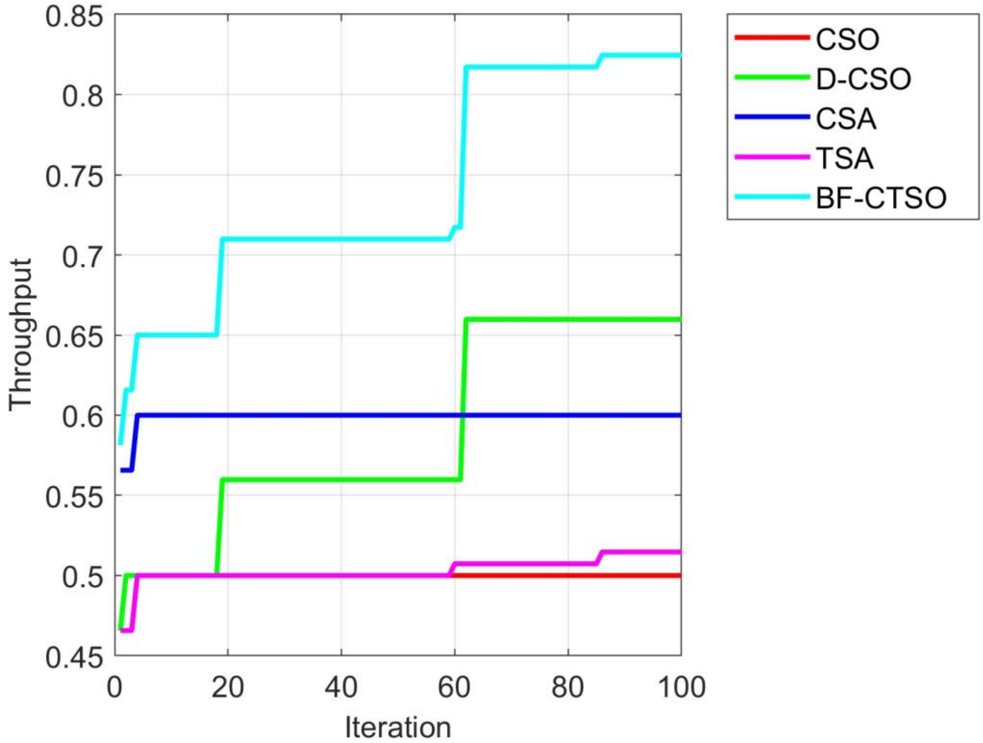
Figure 5.7. Field dimension varies based on energy consumption analysis for the proposed approach with different methods (a) Case One, (b) Case Two, and (c) Case Three.

5.2.5 Estimation of Throughput

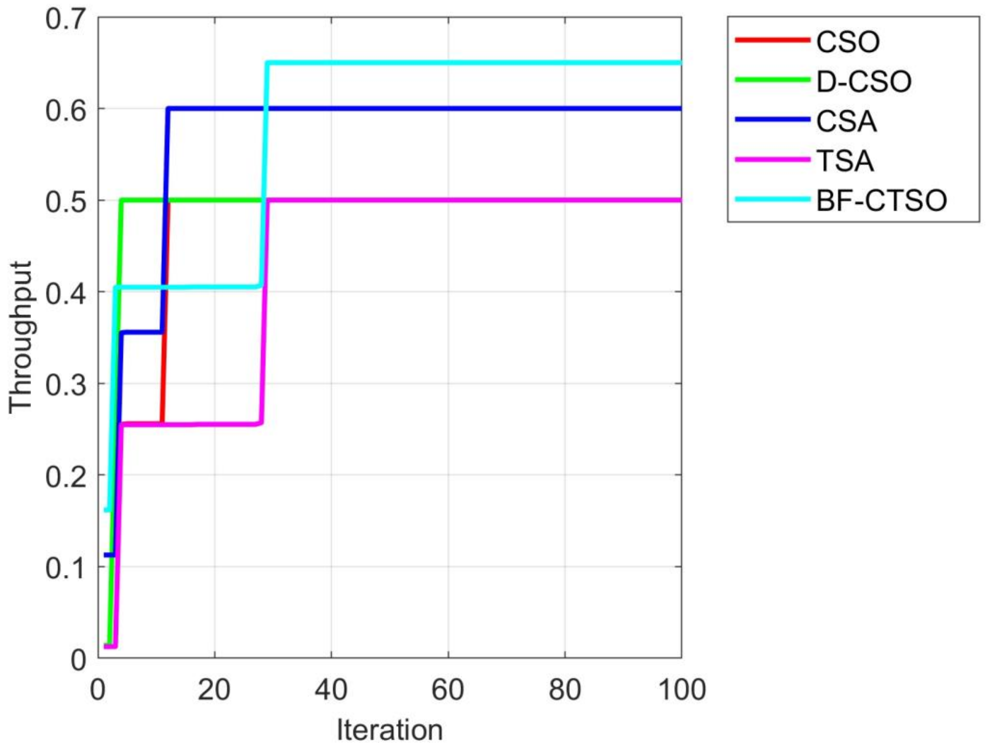
Figure 5.8 depicts an estimate of the complete performance of proposed approach in CVN using three separate minimization strategies. Figure 5.9 displays how the field size changed as a consequence of the throughput analysis of the built CVN. The BF-CTSO method offers increased efficiency in terms of throughput range. In Case one, the BF-CTSO performs 44%, 24%, 20%, and 44% better than the CSO, D-CSO, CSA, and TSA approaches, respectively.



(a) Case One

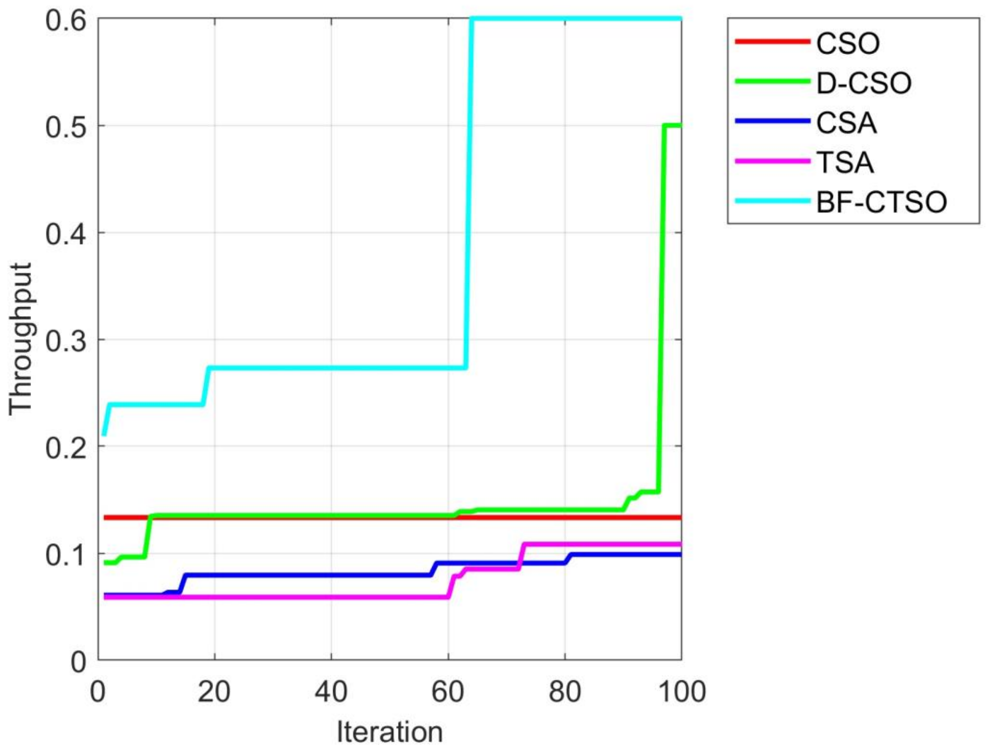


(b) Case Two

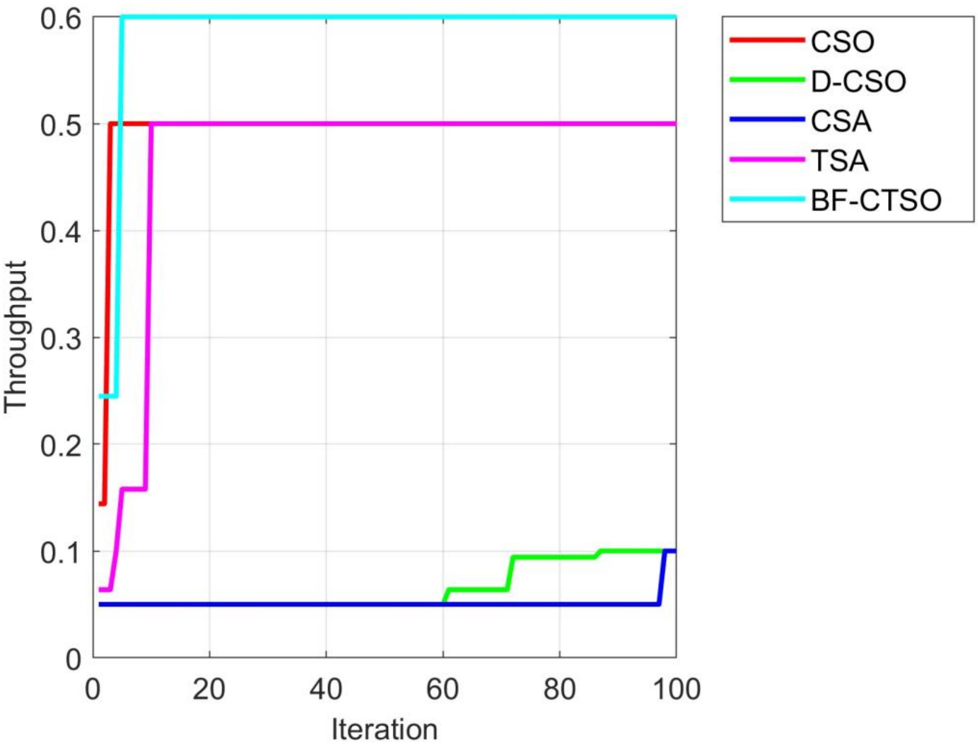


(c) Case Three

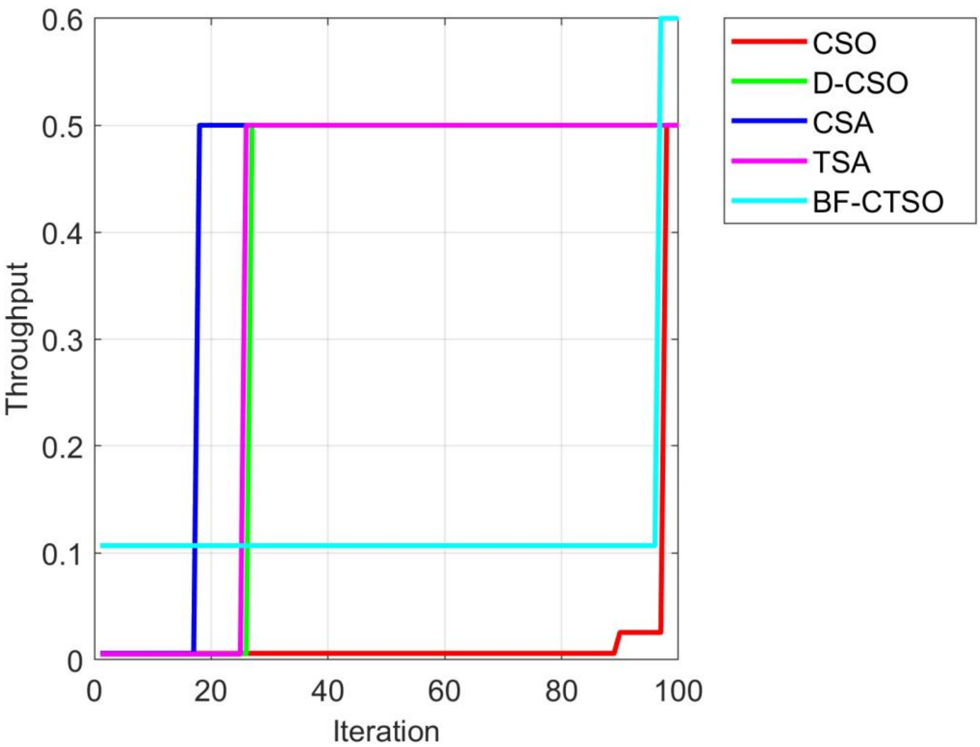
Figure 5.8. Throughput analysis for proposed using several minimization techniques for (a) Case One, (b) Case Two, and (c) Case Three.



(a) Case One



(b) Case Two

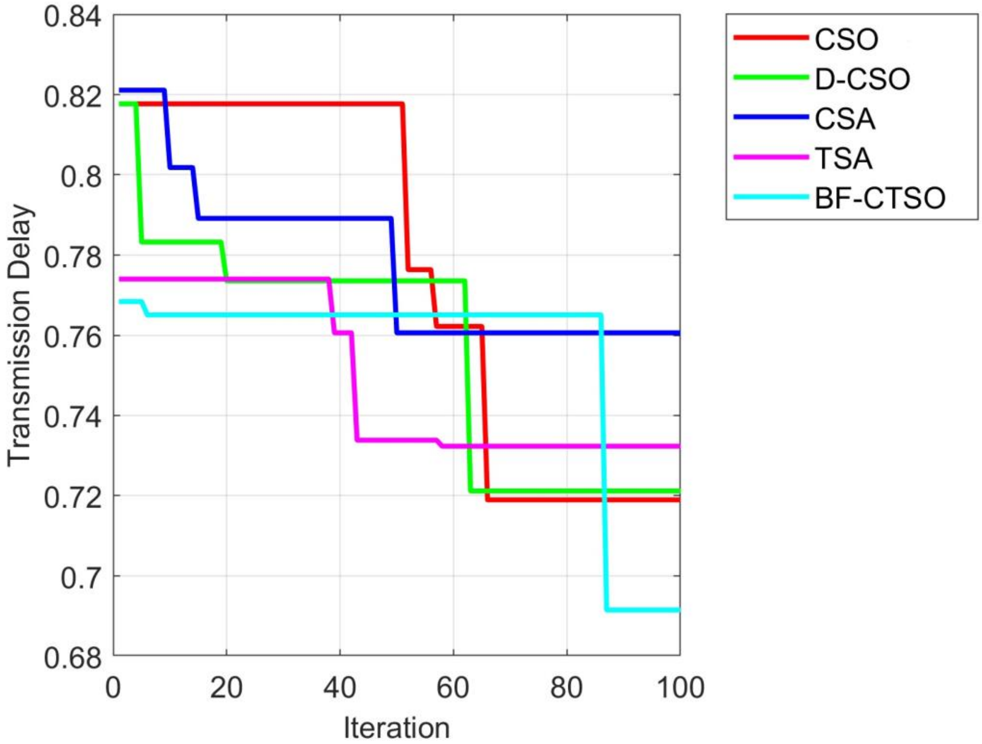


(c) Case Three

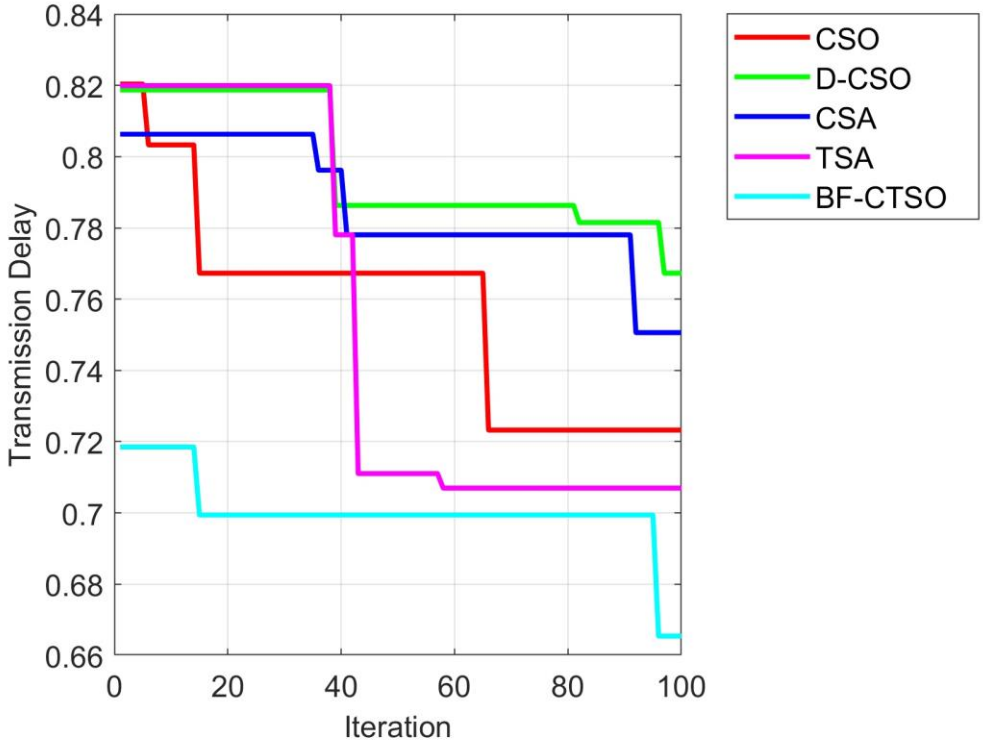
Figure 5.9**.** Field dimension varies based on throughput for the designed approach with different methods for (a) Case One, (b) Case Two, and (c) Case Three.

5.2.6 Assessment of Transmission Delay

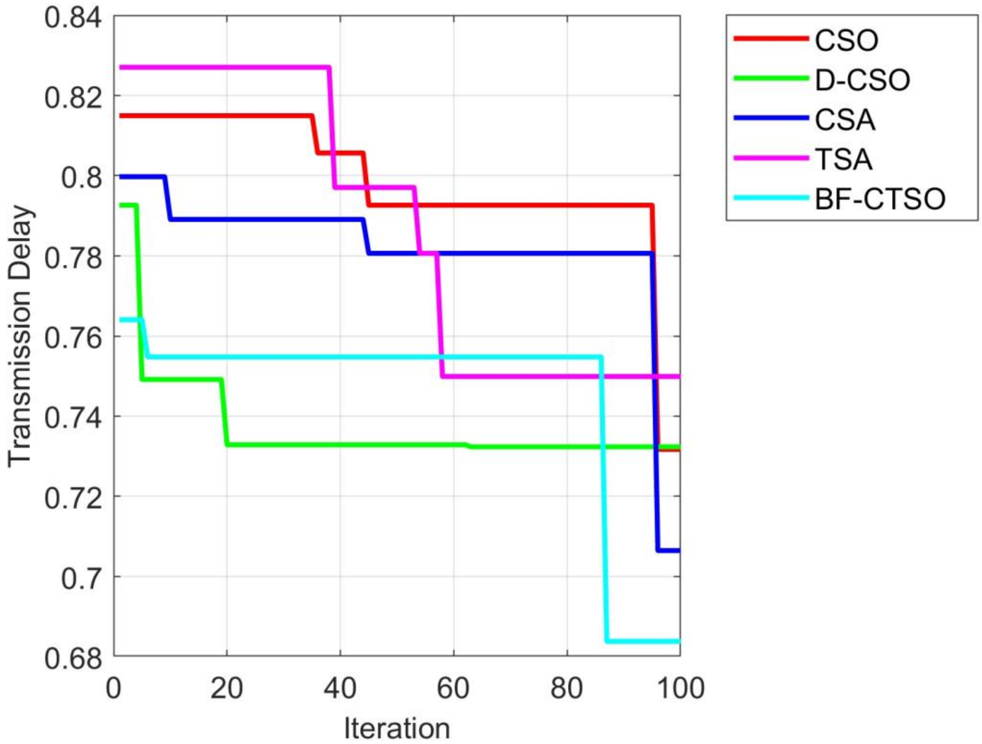
As seen in Figure 5.10, the efficiency of proposed approach is evaluated with transmission delay using different minimization strategies over 3 Cases. Figure 5.11 depicts, the arena size modified with transmission delay investigation of CVN. The BF-CTSO technique reduces transmission delay of the proposed CVN by selecting suitable relays. In all three cases, the designed technique gets lower delay at the initial iterations itself while estimating with others. This kind is suitable for vehicular networks since it offers the highest performance and lowest transmission latency.



(a) Case One

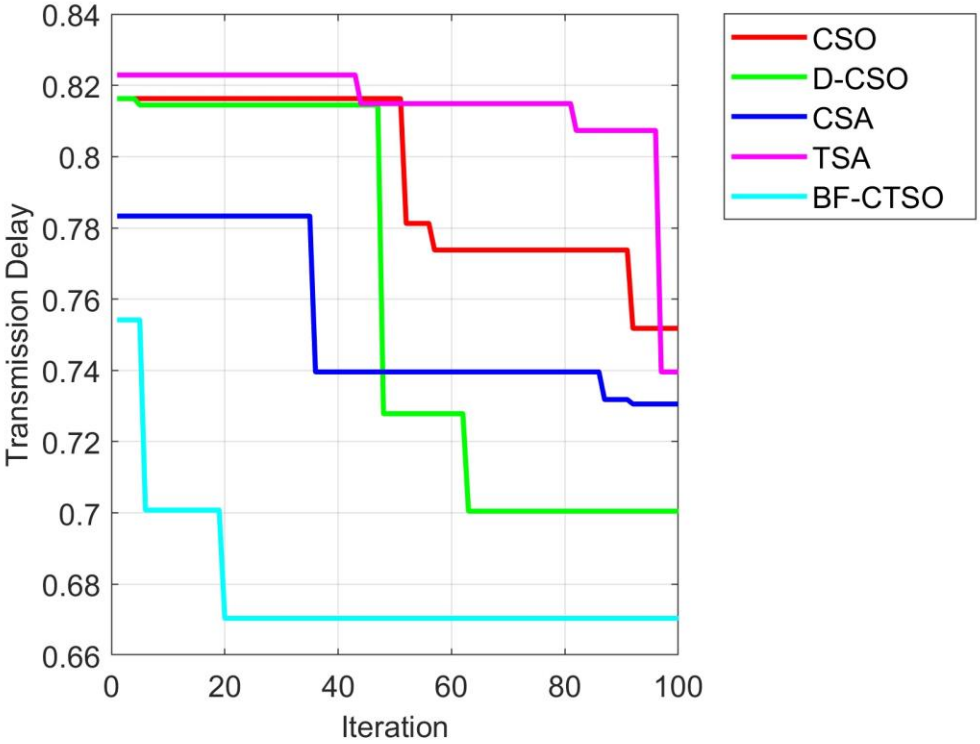


(b) Case Two

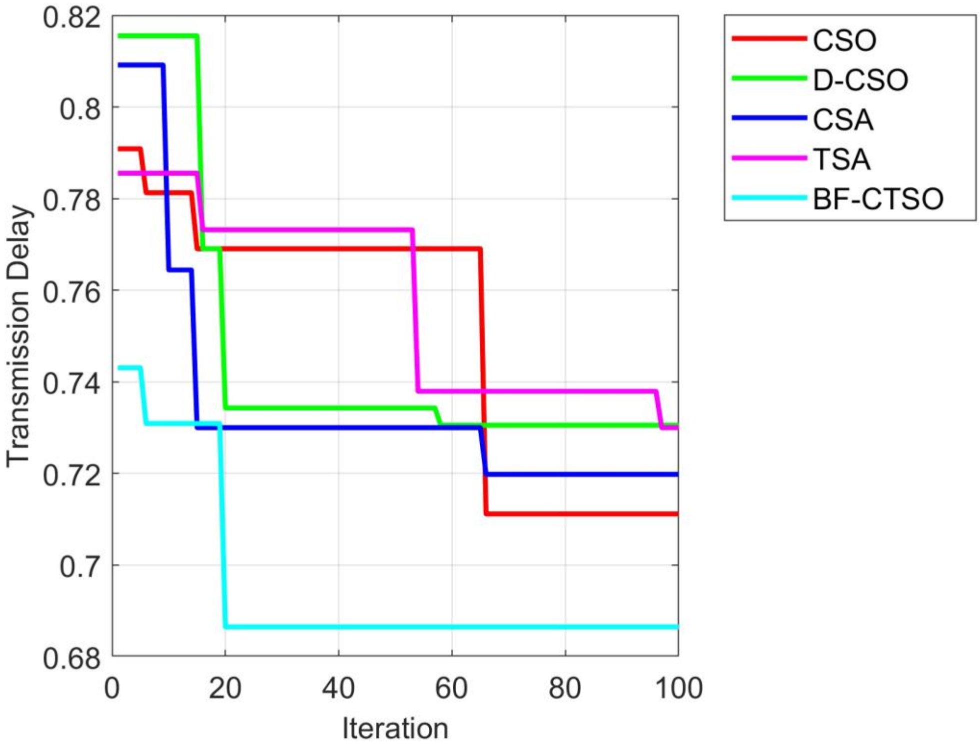


(c) Case Three

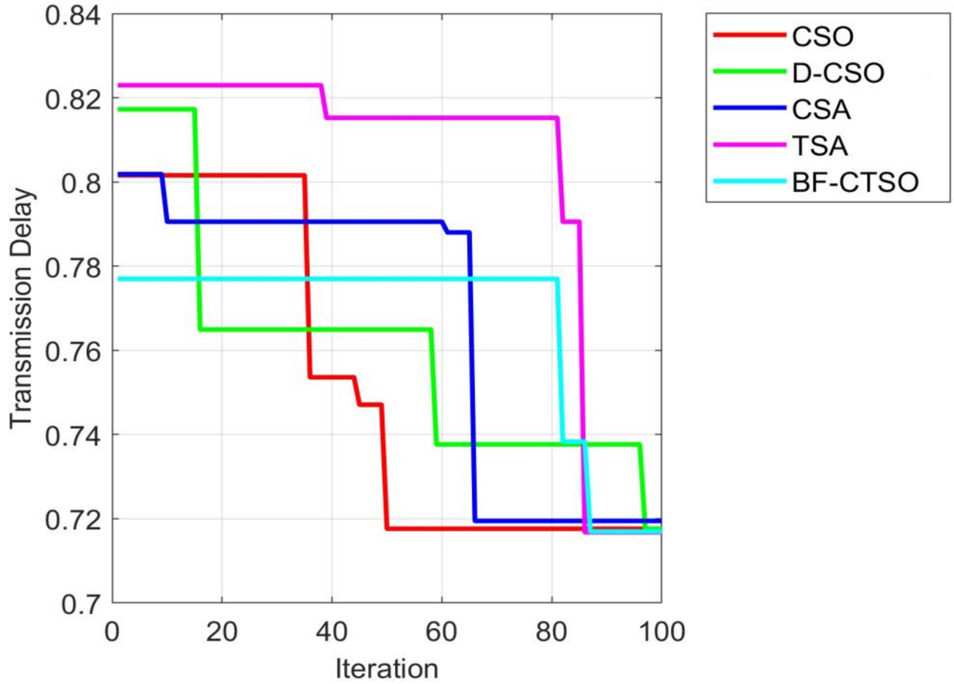
Figure 5.10. Transmission delay analysis, using different methods for (a) Case One, (b) Case Two, and (c) Case Three.



(a) Case One



(b) Case Two



(c) Case Three

Figure 5.11. For the developed proposal, using different methods for (a) Case One, (b) Case Two, and (c) Case Three, the arena measurements modified based on transmission delay.

5.2.7 Runtime Investigation

The run time investigation of suggested optimum relay selection in CVN is shown in Table 5.2 and Table 5.3 how field size has evolved. Table 5.4 also displays the computational difficulty of proposed approach developed. In Table 5.4, the term Max_{iter} is denoted as the maximum number of iterations and the variable N_{pop} is represented as the number of populations. The term $chlen$ is indicated as chromosome length. In scenario 3, the designed BF-CTSO algorithm achieves 21.6%, 23%, 15%, and 2% accordingly enhanced than CSO, D-CSO, CSA, and TSA techniques.

Table 5.2. For three situations, run time of proposed optimal relay selection in a CVN was analysed using various empirical methods.

Time	CSO [125]	D-CSO [141]	CSA [142]	TSA [137]	BF-CTSO
Case 1					
Time (sec)	0.88	0.75	0.58	0.54	0.50
Case 2					
Time (sec)	0.53	0.54	0.49	0.42	0.41
Case 3					
Time (sec)	0.24	0.31	0.21	0.20	0.08

Table 5.3. In three cases, arena size modified with reference to run time of the stated optimum selection of relay in CVN using different empirical approaches.

Time	CSO [125]	D-CSO [141]	CSA [142]	TSA [137]	BF-CTSO
Case 1					
Time (sec)	28.07	22.628	41.34	24.901	22.453
Case 2					
Time (sec)	27.136	26.869	29.802	25.576	24.38
Case 3					
Time (sec)	25.838	25.294	25.427	25.862	25.394

Table 5.4**.** Evaluation difficulty of the designed proposed apporach

Proposed algorithm	Evaluation difficulty
BF-CTSO	$O[(Max_{iter} * (N_{pop} + N_{pop} * chlen))]$

5.3. Conclusion

The purpose of this chapter was to create an energy-efficient optimum relay selection model in multi-hop cooperative VANETs using a hybrid heuristic technique. To compute the minimal number of relays vehicles between Source" and Destination" for the cooperative VANETs, BF-CTSO hybrid optimization model was proposed. A multi-objective function addressing the system's link dependability, energy consumption, OP, mobility factor, and transmission latency was designed in order to provide an energy-efficient optimal relay selection. In case three, 100^{th} iteration of the proposed BF-CTSO technique decreased transmission latency by 9%, 9.3%, 4.2%, and 9%, when compared to the CSO, D-CSO, CSA, and TSA methods, respectively.

CHAPTER-6

CONCLUSION AND FUTURE WORK

CHAPTER-6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

There has been a huge amount of research on cooperative communication and the benefits that can be imparted in the system are considerably worthful. In 5G, Vehicular ad-hoc networks have dragged attention of many researchers, to provide user value added services like safety messages, traffic congestion, destination routing and huge data transfer applications. However, there remain still many challenges ahead for them, especially concerning the implementation aspects of these networks. In particular, there are several practical limitations concerning the physical layer of VANETs. The most significant feature of VANET is reliable links and efficient routing but due real-time scenarios and its dynamic topology of makes it almost impossible to eliminate link breakage. Therefore, the GA approach is applied and integrated with existing standard algorithm from the most reputed swarm intelligence-based techniques. The agenda of this research work is to improve the energy efficiency, security capacity and throughput by implementing empirical hybrid optimization strategies to reduce the number of relays and multi-hops between the source and destination.

A D-CSO algorithm and BF-CTSO Swarm intelligence algorithms are proposed and implemented in multi-hop cooperative VANETs to resolve multi-objective functional metrics like reliability, energy efficiency, outage probability ad throughput by selecting optimal number of relays. D-CSO algorithm performance is analyzed by comparing with existing heuristic algorithms like PSO, JA, GWO, and CSO, respectively for multiple iterations in three senarios. It is obeserved from the simulations results that proposed D-CSO had outperformed comapred to other algortithms. To improve the energy efficiency and reduce transmission latency in addition to the aforementioned multi-objective, a novel Hybrid algorithm in conjunction with Best Fitness-derived Crow Tunicate Swarm Optimization (BF-CTSO) algorithm was proposed. The performance is analyzed for three scenarios and compared with the conventional algorithm like the CSO, D-CSO, CSA, and TSA. In iteration, proposed BF-CTSO technique outstripped by decreased transmission latency by 9%, 9.3%, 4.2%, and 9%, respectively with aforementioned strategies.

The present research emphases on the VANETs with stationary vehicles, it might be improved in the future by including dynamic behaviour in VANETs. It can accommodate for dynamic aspects such as fluctuating mobility, interferences, random channel quality, and hence removing the problem of stationary VANETs.

6.2 Future Work

This thesis presents evidence that cooperative transmission in VANETs can improve energy efficiency with careful consideration of relay selection and route determination. Despite of greater achievements, there are still many challenges to cope with in VANET field, which expand several new research directions to extend some proposals or consider further complementary developments.

Future research can also be carried out on highway scenarios, as vehicles move at very high speeds and may not be distributed uniformly. More focus to investigate the opportunity of developing even more optimized algorithms that may be used to develop a shared framework by reducing the computation complexity and adaptable to the dynamic changes. It is quite difficult to create a vehicle mobility model that accurately reflects and creates completely realistic metropolitan surroundings. Thus, it would be intriguing to create some sophisticated mobility models and implement them in the core aspects of routing. Real-time mobility assistance, knowledge of one's surroundings, and effective geo-distributed RSU are frequently required for VANET applications in urban scenarios. Using big data technologies to VANETs has significant implications for improving traffic management procedures including planning, engineering, and operations by providing relevant insight from a vast quantity of operational data.

In high-mobility VANETs, resource balancing and divesting computation are vital elements that define optimal system value. High-mobility vehicular communication may enhance these related components by employing heuristic techniques. By interacting with the environment about the present status of edge user link computation, cooperative reliability, and divesting, empirical algorithms boost the real-time sensitivity of vehicular environmental data.

Bibliography

[1]. Y.-L. Tseng, "*LTE-advanced enhancement for vehicular communication*," IEEE Wireless Commun., vol. 22, no. 6, pp. 4–7, 2015.

[2]. B. Ko, H. Lee, and S. H. Son, "*GPS-Less localization system in vehicular networks using dedicated short range communication*," Proc. 22nd Int. Conf. Embedded Real-Time Comput. Syst. Appl. (RTCSA), pp. 106., 2016.

[3]. AFM Shahen. Shah and N. Mustari, "*Modeling and performance analysis of the IEEE 802.11p enhanced distributed channel access function for vehicular network*," 2016 Future Technologies Conference (FTC), pp. 173–178. IEEE, 2016.

[4]. IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Identifier Allocations, IEEE Standard 1609.12-2016 (Revision IEEE Std 1609.12-2012), pp. 1–21, 2016.

[5]. G. Araniti, C. Campolo, M. Condoluci, A. Iera, and A. Molinaro, "*LTE for vehicular networking: A survey*," IEEE Commun. Mag., vol. 51, no. 5, pp. 148–157, 2013.

[6]. H. A. Omar, N. Lu, and W. Zhuang, "*Wireless access technologies for vehicular network safety applications*," IEEE Netw., vol. 30, no. 4, pp. 22–26, 2016.

[7]. De Felice, M., Cuomo, F., Baiocchi, A., Turcanu, I., Zennaro, S, "*Traffic monitoring and incident detection using cellular and early stage VANET technology deployment*", Proc. ACM 1st Int. Workshop Internet Vehicles Vehicles Internet; 2016.

[8]. E. Erkip, A. Sendonaris, A. Stefanov, and B. Aazhang, "*Cooperative communication in wireless systems*," DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, vol. 66. Providence, RI, USA:pp. 303–320., 2004.

[9]. H. Gharavi and B. Hu, "*Cooperative diversity routing and transmission for wireless sensor networks*," IET Wireless Sensor Syst., vol. 3, no. 4, pp. 277–288, 2013.

[10]. X. Ge, H. Cheng, G. Mao, Y. Yang, and S. Tu, "*Vehicular communications for 5G cooperative small-cell networks*," IEEE Trans. Veh. Technol., vol. 65, no. 10, pp. 7882–7894, 2016.

[11]. T. S. Abraham and K. Narayanan, "*Cooperative communication for vehicular networks*," Proc. IEEE Int. Conf. Adv. Commun. Control Comput. Technol. (ICACCCT), pp. 1163–1167, 2014.

[12]. A. M. Vegni, "*Smart Vehicles, Technologies and Main Applications in Vehicular Ad-hoc Networks*," M. Biagi, Ed. Rijeka: IntechOpen, Ch. 1., 2013.

[13]. C. He, K. Zhang, and S. Wei, "*Analysis of the Channel Capacity with Shadowing Fading in VANET*," 14th International Wireless Communications and Mobile Computing Conference, IWCMC 2018, 2018, pp. 577–581, 2018.

[14]. N. Haouari, S. Moussaoui, S. M. Senouci, A. Boualouache, and M. A. Messous, "*An efficient management of the control channel bandwidth in VANETs,*" in IEEE International Conference on Communications, 2017.

[15]. L. Qiao, Y. Shi, and S. Chen, "*An empirical study on the temporal structural characteristics of VANETs on a Taxi GPS Dataset*," IEEE Access, Vol. 5, pp. 722–731, 2017.

[16]. F. Qu, Z. Wu, F. Wang, and W. Cho, "*A Security and Privacy Review of VANETs*," IEEE Transactions on Intelligent Transportation Systems, Vol. 16, No. 6. Institute of Electrical and Electronics Engineers Inc., pp. 2985–2996, 2015.

[17]. R. Hussain and S. Zeadally, "*Autonomous Cars: Research Results, Issues, and Future Challenges*," IEEE Communications Surveys and Tutorials, Vol. 21, No. 2. Institute of Electrical and Electronics Engineers Inc., pp. 1275–1313, 2019.

[18]. Q. Yang and L. Shen, "A Multi-Hop Broadcast scheme for propagation of emergency messages in VANET," IEEE 12th International Conference on Communication Technology, 2010, pp. 1072–1075, 2010.

[19]. P. Singh, "*Comparative study between unicast and Multicast Routing Protocols in different data rates using vanet*," Proceedings of the 2014 International Conference on Issues and Challenges in Intelligent Computing Techniques, ICICT, pp. 278–284, 2014.

[20]. G. D. Singh, R. Tomar, H. G. Sastry, and M. Prateek, "*A review on VANET routing protocols and wireless standards*," Smart Innovation, Systems and Technologies, Vol. 78, pp. 329–340, 2018.

[21]. T. Taleb, E. Sakhaee, A. Jamalipour, K. Hashimoto, N. Kato, and Y. Nemoto, "*A Stable Routing Protocol to Support ITS Services in VANET Networks*," IEEE Transactions on Vehicular Technology, Vol. 56, No. 6, pp. 3337–3347, 2007.

[22]. M. Chaqfeh and A. Lakas, "*A novel approach for scalable multi-hop data dissemination in vehicular Ad-hoc networks*," Ad-hoc Networks, Vol. 37, pp. 228–239, 2016.

[23]. A. A. Almohammedi, N. K. Noordin, A. Sali, F. Hashim, W. A. Jabbar, and S. Saeed, "*Modeling and analysis of IEEE 1609.4 MAC in the presence of error-prone channels*," International Journal of Electrical and Computer Engineering (IJECE), Vol. 9, No. 5, pp. 3531–3541, 2019.

[24]. K. Na Nakorn and K. Rojviboonchai, "*Non-GPS data dissemination for VANET*," International Journal of Distributed Sensor Networks, Vol. 2014, No. 1, p. 906084, 2014.

[25]. A. Srivastava, A. Prakash, and R. Tripathi, "*Location based routing protocols in VANET: Issues and existing solutions*," Vehicular Communications, Vol. 23. Elsevier Inc., p. 100231, 2020.

[26]. P. Deshmukh, "*Improving Energy and Efficiency in cluster based VANETs through AODV Protocol*," International Journal of Computer Science and Information Technologies. Vol. 5, No. 3, pp. 4788–4792, 2014.

[27]. B. Gui, L. Dai, and L. Cimini, "*Routing strategies in multi-hop cooperative networks*," Wireless Communications, IEEE Transactions on, vol. 8, no. 2, pp. 843–855, Feb 2009.

[28]. F. Khan, F. Yilmaz, and M.-S. Alouini, "*Generalized routing protocols for multihop relay networks*," in Wireless Communications and Mobile Computing Conference (IWCMC), pp. 754–759, 2011.

[29]. Nosratinia, Aria, Todd E. Hunter, and Ahmadreza Hedayat. "*Cooperative communication in wireless networks",* IEEE communications Magazine 42.10: 74-80, 2004.

[30]. Rege. Y and Abdullah. "*M,A survey on relay selection techniques in cooperative communication*", Journals for International Shodh in Engineering and Technology,1(7), pp. 1-7, 2016.

[31]. Su, W., Sadek, A. K., & Ray Liu, K. J., "*Cooperative communication protocols in wireless networks: Performance analysis and optimum power allocation*", Wireless Personal Communications, 44(2), 181–217, 2008.

[32]. Laneman, J. Nicholas, David NC Tse, and Gregory W. Wornell. "*Cooperative diversity in wireless networks: Efficient protocols and outage behavior*." IEEE Transactions on Information theory 50.12: 3062-3080, 2004.

[33]. Fitzek, F. H., & Katz, M. D., "*Cooperation in wireless networks: principles and applications*", pp. 421-461, New York: Springer, 2006.

[34]. Hong, Y.-W. P., Huang, W.-J., & Kuo, C.-C. J. "Cooperative Communications with Multiple Sources" Cooperative communications and networking, 2010.

[35]. Zhang, D., Chen, Z., Zhou, H., Chen, L., & Shen, X. S., "*Energy-balanced cooperative transmission based on relay selection and power control in energy harvesting wireless sensor network*", Computer Networks, 104, 189-197, 2016.

[36]. Ibrahim, A. S., Sadek, A. K., Su, W., & Liu, K. J. R., "*Cooperative communications with relay-selection: When to cooperate and whom to cooperate with?*", IEEE Transactions on Wireless Communications, 7(7), 2814-2827, 2008.

[37]. Kim, H. S., Seo, W., Kim, H., Bae, S., You, C., & Hong, D, "*Performance analysis of wireless dual-hop systems with multirelay and multiuser*" 2007 IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications (pp. 1- 5). IEEE, 2007.

[38]. Bonder. V and Kanade. S., "*Review on techniques for total throughput maximization of two-way relay networks using at cooperative protocol*", International Journal of Modern Engineering Research, 4(12), pp. 76-80., 2014

[39]. Bletsas, Aggelos, et al. "*A simple cooperative diversity method based on network path selection*," IEEE Journal on selected areas in communications 24.3 ,659-672, 2006.

[40]. S. Hayat, X. Liu, Y. Li, and Y. Zhou, "*Comparative analysis of VANET's routing protocol classes: An overview of existing routing protocol classes and futuristic*

challenges," 2nd International Conference on Electronics Technology, ICET 2019, pp. 1–, 2019.

[41]. B. Paul, A. Roy, and S. K. Paul, "*Comparison of DSR, AODV, and DSDV routing protocols with varying pause time & Node density over TCP & CBR connections in VANET*," 2014 6th International Conference on Computational Intelligence and Communication Networks, CICN, pp. 374–379, 2014.

[42]. A. K. Basil, M. Ismail, M. A. Altahrawi, H. Mahdi, and N. Ramli, "*Performance of AODV and OLSR routing protocols in VANET under various traffic scenarios,"* 2017 IEEE 13th Malaysia International Conference on Communications, MICC, pp. 107–112, 2018.

[43]. N. Javaid, A. Bibi, S. H. Bouk, A. Javaid, and I. Sasase, "*Modeling enhancements in DSR, FSR, OLSR under mobility and scalability constraints in VANETs*," IEEE International Conference on Communications, pp. 6504–6508, 2012.

[44]. P. Kaleeswari, N. M. J. a, and P. G. Student, "*SURVEY ARTICLE A Survey on Routing Protocols in VANET*," Vol. 2, No. 3, pp. 383–388, 2013.

[45]. T. K. Araghi, M. Zamani, and A. B. T. Abdul Mnaf, "*Performance analysis in reactive routing protocols in wireless mobile Ad-hoc networks using DSR, AODV and AOMDV*," International Conference on Informatics and Creative Multimedia, ICICM , pp. 81–84, 2013.

[46]. Priyanshu and A. K. Maurya, "*Impact of node density on the performance of GSR & TORA routing protocols*," 5th IEEE International Conference on Computer and Communication Technology, ICCCT, pp. 251–255, 2015.

[48]. B Pete and P. Jaini, "*Continuous connectivity aware routing in VANET using hybrid protocol*," 2nd International Conference on Electronics and Communication Systems, ICECS, pp. 223–226, 2015.

[49]. D. Lin, J. Kang, A. Squicciarini, Y. Wu, S. Gurung, and O. Tonguz, "*MoZo: A Moving Zone Based Routing Protocol Using Pure V2V Communication in VANETs*," IEEE Transactions on Mobile Computing, Vol. 16, No. 5, pp. 1357–1370, 2017.

[50]. J. Bhatia, R. Dave, H. Bhayani, S. Tanwar, and A. Nayyar, "*SDN-based real-time urban traffic analysis in VANET environment*," Computer Communications, Vol. 149, pp. 162–175, 2020.

[51]. J. Alonso-Zárate, C. Crespo, C. Skianis, L. Alonso, and C. Verikoukis, "*Distributed Point Coordination Function for IEEE 802.11 wireless Ad-hoc networks*," Ad-hoc Networks, Vol. 10, No. 3, pp. 536–551, 2012.

[52]. P. D. Dorge, G. H. Raisoni, and M. B. Chakole, "*Implementation of MIMO and AMC Techniques in WiMAX Network based VANET System Implementation of MIMO and AMC Techniques in WiMAX Network based VANET System*", International Journal of Information Technology and Computer Science, Vol. 2, pp. 60–68, 2016.

[53]. M. Rajesh Kumar and S. K. Routray, "*Ant Colony based Dynamic source routing for VANET*," 2nd International Conference on Applied and Theoretical Computing and Communication Technology, iCATccT, pp. 279–282, 2017.

[54]. A. Elbery, H. Rakha, M. Y. Elnainay, F. Filali, and W. Drira, "*Ecorouting: An Ant Colony based Approach*", International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS 2016), pages 31-38 ISBN: 978-989-758-185-4, 2016.

[55]. M. Jafer, M. A. Khan, S. Ur Rehman, and T. A. Zia, "*Optimizing Broadcasting Scheme for VANETs Using Genetic Algorithm*," International Conference on Local Computer Networks, LCN, pp. 222–229, 2016.

[56]. B. Ranjan Senapati and P. Mohan Khilar, "*Optimization of performance parameter for vehicular ad-hoc network (VANET) using swarm intelligence*," Computational Intelligence, Vol. SCI 871, Springer, pp. 83–107, 2020.

[57]. G. H. Alsuhli, A. Khattab, and Y. A. Fahmy, "*Double-head clustering for resilient VANETs*," Wireless Communications and Mobile Computing, Vol. 2019, 2019.

[58]. B. Dappuri, M. Amru, and A. M. Venkatanaga, "*A stable routing algorithm based on link prediction method for clustered VANET*," Intelligent Systems Reference Library, Vol. 172, Springer, pp. 85– 95, 2019.

[59]. H. Bello-Salau, A. M. Aibinu, Z. Wang, A. J. Onumanyi, E. N. Onwuka, and J. J. Dukiya, “*An optimized routing algorithm for vehicle ad-hoc networks*,” Engineering Science and Technology, an International Journal, Vol. 22, No. 3, pp. 754–766, 2019.

[60]. S. Harifi, J. Mohammadzadeh, M. Khalilian, and S. Ebrahimnejad, “*Giza Pyramids Construction: an ancient-inspired metaheuristic algorithm for optimization*,” Evolutionary Intelligence, pp. 1–19, 2020.

[61]. C. Wang, Q. Fan, X. Chen, and W. Xu, “*Prediction based Greedy Perimeter Stateless Routing Protocol for Vehicular Self-organizing Network*,” IOP Conference Series: Materials Science and Engineering, 2018, Vol. 322, No. 5, 2019.

[62]. Usha Mohanakrishnan & B. Ramakrishnan "*MCTRP: An Energy Efficient Tree Routing Protocol for Vehicular Ad-hoc Network Using Genetic Whale Optimization Algorithm*," Wireless Personal Communications, vol. 110, pp. 185–206, 2020.

[63]. Wang, S.-S.; Lin, Y.-S. “*PassCAR: A passive clustering aided routing protocol for vehicular Ad-hoc networks*”, Comput. Commun., 36, 170–179, 2013.

[64]. Kuhn, F.; Wattenhofer, R.; Zhang, Y.; Zollinger, “*A. Geometric ad-hoc routing: Of theory and practice*”, Proceedings of the Twenty-Second Annual ACM Symposium on Principles of Distributed Computing, Boston, MA, USA, 13–16, 2003.

[65]. Yu, H.; Yoo, J.; Ahn, S, “*A VANET routing based on the real-time road vehicle density in the city environment*”, Fifth International Conference on Ubiquitous and Future Networks (ICUFN), Da Nang, Vietnam, pp. 333–337, 2013.

[66]. Taleb, T.; Ochi, M.; Jamalipour, A.; Kato, N.; Nemoto, Y, “*An efficient vehicle-heading based routing protocol for VANET networks*”, IEEE Wirel. Commun. Netw. Conf. 2006, 4, 2199–2204, 2006.

[67]. Eiza, M.H.; Ni, Q., “*A Reliability-Based Routing Scheme for Vehicular Ad-hoc Networks (VANETs) on Highways*”, IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications, Liverpool, UK,; pp. 1578–1585, 25–27, 2012.

[68]. Al-Rabayah, M.; Malaney, R., “*A New Scalable Hybrid Routing Protocol for VANETs*” , IEEE Trans. Veh. Technol., 61, 2625–2635, 2012.

[69]. Liu, C.; Shu, Y.; Yang, O.; Xia, Z.; Xia, R. , "*SDR: A Stable Direction-Based Routing for Vehicular Ad-hoc Networks*", Journal on Wirel. Pers. Commun. , 73, 1289–1308, 2013.

[70]. Chen, Y., Yu, G., Qiu, P., & Zhang, Z., "*Power-aware cooperative relay selection strategies in wireless Ad-hoc networks*", IEEE personal, indoor and mobile radio communications symposium (PIMRC). Helsinki, Finland, 2006.

[71]. Tajer, A., & Nosratinia, A., "*Opportunistic cooperation via relay selection with minimal information exchange*" IEEE international symposium on information theory (ISIT). Nice, France, 2007.

[72]. Bletsas, A., Shin, H., & Win, M. Z., "*Cooperative communications with outage-optimal opportunistic relaying*", IEEE Transactions on Wireless Communications, 6(9), 3450- 3460, 2007.

[73]. Wang, C.-L., & Syue, S.-J., "*An efficient relay selection protocol for cooperative wireless sensor networks*", IEEE wireless communications and networking conference (WCNC) (pp. 1–5). Dresden, Germany, 2009.

[74]. Ying, B., and Nayak, A., "*A Power-Efficient and Social-Aware Relay Selection Method for Multi-Hop D2D Communications*", IEEE Communications Letters, 22(7), 1450-1453, 2018.

[75]. Tian, D., Zhou, J., Sheng, Z., Chen, M., Ni, Q., and Leung, "*V.C.M. 2017. Self-Organized Relay Selection for Cooperative Transmission in Vehicular Ad-Hoc Networks*", IEEE Transactions on Vehicular Technology, 66(10), 9534-9549.

[76]. T. W. Chim, S. M. Yiu, L. C. K. Hui, and V. O.k. Li, "*VSPN: VANET based secure and privacy-preserving navigation*," IEEE Transactions on Computers, Vol. 63, No. 2, pp. 510–524, 2014.

[77]. Siddig, A.A., Ibrahim, A.S., and Ismail, M.H., "*An Optimal Power Allocation and Relay Selection Full-Duplex Store-Carry-Forward Scheme for Intermittently Connected Vehicular Networks*", IEEE Access, 8, 163903-163916, 2020.

[78]. Poursajadi, S., and Madani, M.H., "*Adaptive optimal relay selection in cooperative vehicular communications under security constraints*", Vehicular Communications, 31, 2021.

[79]. Dan, C., Hong, J.I., Xi, L.I., Yi, L.I., "*QoS-guaranteed multi-relay selection and power allocation optimization in cooperative systems*", The Journal of China Universities of Posts and Telecommunications, 17(6), 25-31, 2010.

[80]. K. G. Lim, K. W. Teh, M. K. Tan, H. Lago, S. S. Yang and K. T. Kin Teo, "*Enhanced Multi-Hop Mechanism in Vehicular Communication System using Swarm Algorithm*," IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET), pp. 1-6, 2021.

[81]. Yang, H. C., & Alouini, M. S., "*MRC and GSC diversity combining with an output threshold*", IEEE Transactions on Vehicular Technology, 54(3), 1081–1090, 2005.

[82]. W. Pam Siriwongpairat, T. Himsoon W. Su, K. J. Ray Liu, "*Optimum ThresholdSelection Relaying for Decode-and-Forward Cooperation Protocol*," in Proc. IEEE Wireless Networking and Communication Conference, WCNC, 2006.

[83]. Wang, T., Wang, R., & Giannakis, G. B., "*Smart regenerative relays for link-adaptive cooperative communications*", IEEE Conference on Information Sciences and Systems, CISS 2006 - Proceedings, 1038–1043, 2006.

[84]. Herhold, P., Zimmermann, E., & Fettweis, G., "*A simple cooperative extension to wireless relaying*", International Zurich Seminar on Communications, 2004 (pp. 36-39). IEEE, 2004.

[85]. Adinoyi, A., & Yanikomeroglu, H., "*Cooperative relaying in multi-antenna fixed relay networks*", IEEE Transactions on Wireless Communications, 6(2), 533-544, 2007.

[86]. Onat, F. A., Adinoyi, A., Fan, Y., Yanikomeroglu, H., & Thompson, J. S., "*Optimum threshold for SNR-based selective digital relaying schemes in cooperative wireless networks*", IEEE Wireless Communications and Networking Conference (pp. 969-974). IEEE, 2007.

[87]. Ponnaluri, S. P., & Wilson, S. G., "*On diversity of cooperative relaying protocols*", International Conference on Communications and Networking in China (pp. 123-127). IEEE, 2007.

[88]. Hwang, Kyu-Sung, and Young-Chai Ko. "*An efficient relay selection algorithm for cooperative networks*" IEEE 66th Vehicular Technology Conference. IEEE, 2007.

[89]. Onat, F. A., Adinoyi, A., Fan, Y., Yanikomeroglu, H., Thompson, J. S., & Marsland, I. D., "*Threshold selection for SNR-based selective digital relaying in cooperative wireless networks*", IEEE Transactions on Wireless Communications, 7(11), 4226-4237, 2008.

[90]. Lioumpas, A., Karagiannidis, G., & Tsiftsis, T, "*Adaptive generalized selection combining (A-GSC) receivers*", IEEE Transactions on Wireless Communications, 7(12), 5214–5219, 2008.

[91]. Liu, K. H., "*Double threshold digital relaying for cooperative wireless networks*", IEEE 71st Vehicular Technology Conference (pp. 1-5). IEEE, 2010.

[92]. Amarasuriya, G., Ardakani, M., & Tellambura, C., "*Output-threshold multiple-relayselection scheme for cooperative wireless networks*", IEEE Transactions on Vehicular Technology, 59(6), 3091-3097, 2010.

[93]. Hao, N., Taiyi, Z., & Li, S., "*Performance analysis of a threshold-based relay selection algorithm in wireless networks*", Journal on Communications and Network, 2010.

[94]. Park, S. C., Kim, D. I., & Nam, S. S., "*Adaptive Threshold Based Relay Selection for Minimum Feedback and Channel Usage*", 10(11), 3620–3625, 2011.

[95]. Gharanjik, A., & Mohamed-Pour, K., "*Switch-and-stay partial relay selection over Rayleigh fading channels*", IET communications, 5(9), 1199-1203, 2011.

[96]. Hwang, K. S., & Ju, M., "*Adaptive relay selection based on incremental relaying with output threshold*", International Conference on ICT Convergence (ICTC) (pp. 39-43). IEEE, 2012.

[97]. Herath, P., Gunawardana, U., & Liyanapathirana, R., "*Distributed switch-and examine combining with threshold-based relaying*", Australian Communications Theory Workshop (AusCTW) (pp. 13-18). IEEE, 2012.

[98]. Yang, H. C., & Alouini, M. S., "*Performance analysis of multibranch switched diversity systems*", IEEE Transactions on Communications, 51(5), 782-794, 2003.

[99]. Hwang, K. S., & Ko, Y. C., "*Switch-and-examine node selection for efficient relaying systems*", International conference on Wireless communications and mobile computing (pp. 469-474), 2007.

[100]. Salhab, A. M., & Zummo, S. A., "*A low-complexity relay selection scheme based on switch-and-examine diversity combining for AF relay systems*", IET Communications, 7(9), 848-859, 2013.

[101]. Ahmed, Q. Z., Abuzaid, A., & Alouini, M. S., "*Threshold-based detection for amplify-and-forward cooperative communication systems with channel estimation error*" IEEE 80th Vehicular Technology Conference (VTC2014-Fall) (pp. 1-5). IEEE, 2014.

[102]. Xie, N., Liu, Z., Wang, R., Wang, H., & Lin, X., "*Generalized selection combining with double threshold and performance analysis*" Wireless Communications and Mobile Computing, 14(1), 56-63, 2014.

[103]. Aydın, E., & Illian, H., "*SNR-based relay selection scheme for cooperative relay networks*", International Wireless Communications and Mobile Computing Conference (IWCMC) (pp. 448-453). IEEE, 2015.

[104]. Bai, Z., Jia, J., Wang, C. X., & Yuan, D., "*Performance analysis of SNR-based incremental hybrid decode-amplify-forward cooperative relaying protocol*", IEEE Transactions on Communications, 63(6), 2094-2106, 2015.

[105]. Duy, T. T., & Kong, H., "*Performance analysis of hybrid decode-amplify-forward incremental relaying cooperative diversity protocol using SNR-based relay selection*", Journal of Communications and Networks, 14(6), 703-709, 2012.

[106]. Nagarajan, V., & Balasaraswathi, M., "*Threshold-based selection combining for relay networks*", Computers and Electrical Engineering, 60, 129-139, 2017.

[107]. Dayanidhy, M., & Kumar, V. J. S., "*Performance investigation of multi-relay cooperative diversity networks*", Computers and Electrical Engineering, 60, 151–160, 2017.

[108]. Nam, S. S., Choi, S., Hwang, D., & Ko, Y. C., "*SER Analysis of Adaptive ThresholdBased Relay Selection With Limited Feedback for Type II Relay*", IEEE Access, 7, 2148- 2160, 2018.

[109]. Kara, F., & Kaya, H., "*Threshold-based selective cooperative-NOMA*", IEEE Communications Letters, 23(7), 1263-1266, 2019.

[110]. Kara, F., & Kaya, H., "*Threshold-based Selective Cooperative NOMA: Capacity/Outage Analysis and A Joint Power Allocation-Threshold Selection Optimization*", IEEE Communications Letters, 24(9), 1929-1933, 2020.

[111]. Surya Narayan Mahapatra, Binod Kumar Singh & Vinay Kumar "*A secure multi-hop relay node selection scheme based data transmission in wireless ad-hoc network via block chain*," Multimedia Tools and Applications, 2022.

[112]. Yin Wu, Wenbo Liu & Kaiyu Li "*Power allocation and relay selection for energy efficient cooperation in wireless sensor networks with energy harvesting*," EURASIP Journal on Wireless Communications and Networking, vol. 2017, No. 26, 2017.

[113]. X. Xu, J. Bao, H. Cao, Y. Yao and S. Hu, "*Energy-Efficiency-Based Optimal Relay Selection Scheme With a BER Constraint in Cooperative Cognitive Radio Networks*," IEEE Transactions on Vehicular Technology, vol. 65, no. 1, pp. 191-203, 2016.

[114]. Y. Li, C. Liao, Y. Wang and C. Wang, "*Energy-Efficient Optimal Relay Selection in Cooperative Cellular Networks Based on Double Auction*," IEEE Transactions on Wireless Communications, vol. 14, no. 8, pp. 4093-4104, 2015.

[115]. Maryam Hayati, Hashem Kalbkhani, Mahrokh G. Shayesteh, "*Energy-efficient relay selection and power allocation for multi-source multicast network-coded D2D communications*," AEU - International Journal of Electronics and Communications, Vol. 128, 2021.

[116]. YANG Wei, LI Li-hua, SUN Wan-lu, WANG Ying, "*Energy-efficient relay selection and optimal relay location in cooperative cellular networks with asymmetric traffic*," The Journal of China Universities of Posts and Telecommunications, Vol. 17, Issue. 6, pp. 80-88, 2010.

[117]. Daxin Tian, Kunxian Zheng, Jianshan Zhou, Xuting Duan, Yunpeng Wang, Zhengguo Sheng, Qiang Ni, "*A Microbial Inspired Routing Protocol for VANETs*," IEEE Internet of Things Journal, Volume:5, Issue:4, pp. 2293-2303, 2018.

[118]. Daxin Tian, Jianshan Zhou, Zhengguo Sheng, "*An Adaptive Fusion Strategy for Distributed Information Estimation Over Cooperative Multi-Agent Networks,*" IEEE Transactions on Information Theory, Volume 63, Issue 5, pp. 3076-3091, 2017.

[119]. Benish Sharfeen Khan, Sobia Jangsher, Hassaan Khaliq Qureshi, Syed Hassan Ahmed, "*Predicted mobility based profitable relay selection in cooperative cellular network with mobile relays*," Physical Communication, Vol. 37, 2019.

[120]. Akin, A.I., Ilhan, H., & Özdemir, Ö., "*Relay selection for DF-based cooperative vehicular systems*", EURASIP Journal on Wireless Communications and Networking, 2015.

[121]. Saghezchi, F.B., Radwana, A., Rodriguez, J., "*Energy-aware relay selection in cooperative wireless networks: An assignment game approach*", Ad-hoc Networks, 56, 96-108, 2017.

[122]. Hui, Y., Su, Z., Luan, T.H., and Li, C. Reservation Service, "*Trusted Relay Selection for Edge Computing Services in Vehicular Networks*", IEEE Journal on Selected Areas in Communications, 38(12), 2734-2746, 2020.

[123]. Achour, I., Alfayez, F., & Busson, A., "*A robust and efficient adaptive data dissemination protocol based on smart relay selection in vehicular networks*", Wireless Networks, 27, 4497–4511, 2021.

[124]. Krikidis, I., Thompson, J.S., Laughlin, S.M., "*Relay selection for secure cooperative networks with jamming"*, IEEE Transactions on Wireless Communications, 8, (10), 5003-5011, 2008.

[125]. Bouzidi, A., Riffi, M.E., and Barkatou, M., "*Cat swarm optimization for solving the open shop scheduling problem*, Journal of Industrial Engineering International, 15, 367–378, 2019.

[126]. Jagadeeshwar Tabjula, S. Kalyani, Prabhu Rajagopal, Balaji Srinivasan "*Statistics-based baseline-free approach for rapid inspection of delamination in composite structures using ultrasonic guided waves*," Structural Health Monitoring, 2021.

[127]. Babu Illuri & Deepa Jose "*Design and Implementation of Hybrid Integration of Cognitive Learning and Chaotic Countermeasures for Side Channel Attacks*," Journal of Ambient Intelligence and Humanized Computing, volume 12, pages 5427–5441, 2021.

[128]. Rao, R.V. Jaya, "*A simple and new optimization algorithm for solving constrained and unconstrained optimization problems*", International Journal of Industrial Engineering Computations, 7(1), 19 – 34, 2016.

[129]. Ai, T.J., and Kachitvichyanukul, V. "*A particle swarm optimization for the vehicle routing problem with simultaneous pickup and delivery*", Computers & Operations Research, 36(5), 1693-1702, 2009.

[130]. Mirjalili, S., Mirjalili, S.M., and Lewis, A. Grey Wolf Optimizer, "*Advances in Engineering Software"*, 69, 46–61, 2014.

[131]. B. V. Nguyen and K. Kim, "*Secrecy Outage Probability of Optimal Relay Selection for Secure AnF Cooperative Networks*," IEEE Communications Letters, vol. 19, no. 12, pp. 2086-2089, 2015.

[132]. M. M. Salim, D. Wang, Y. Liu, H. Abd El Atty Elsayed and M. Abd Elaziz, "*Optimal Resource and Power Allocation With Relay Selection for RF/RE Energy Harvesting Relay-Aided D2D Communication*," IEEE Access, vol. 7, pp. 89670-89686, 2019.

[133]. J. Luo, S. Zhao, Z. Yang, G. Huang and D. Tang, "*Data-Driven-Based Relay Selection and Cooperative Beamforming for Non-Regenerative Multi-Antenna Relay Networks*," IEEE Access, vol. 9, pp. 167154-167161, 2021.

[134]. P. Das and N. B. Mehta, "*Direct Link-Aware Optimal Relay Selection and a Low Feedback Variant for Underlay CR*," IEEE Transactions on Communications, vol. 63, no. 6, pp. 2044-2055, 2015.

[135]. A. Dimas, D. S. Kalogerias and A. P. Petropulu, "*Cooperative Beamforming With Predictive Relay Selection for Urban mmWave Communications*," IEEE Access, vol. 7, pp. 157057-157071, 2019.

[136]. A. H. Bastami and S. Habibi, "*Cognitive MIMO Two-Way Relay Network: Joint Optimal Relay Selection and Spectrum Allocation*," IEEE Transactions on Vehicular Technology, vol. 67, no. 7, pp. 5937-5952, 2018.

[137]. SatnamKaur, Lalit K.Awasthi, A.L.Sangal, and GauravDhiman, "*Tunicate Swarm Algorithm: A new bio-inspired based meta-heuristic paradigm for global optimization*", Engineering Applications of Artificial Intelligence, Volume 90, 2020.

[138]. Tauseef Jamal, Paulo Mendes, André Zúquete, "*Wireless Cooperative Relaying Based on Opportunistic Relay Selection*," International Journal on Advances in Networks and Services, 2012.

[139]. Jose, Deepa; Kumar, P Nirmal; Shirley, J Abanah; Ghayathrrie, S. "*Implementation of Genetic Algorithm framework for Fault-Tolerant System on Chip*," International Information Institute (Tokyo). Information; Koganei, Volume 17, Issue 8, pp: 3921-3945, 2014.

[140]. Abdullah Al Hayajneh, Md Zakirul Alam Bhuiyan and Ian McAndrew, "*A Novel Security Protocol for Wireless Sensor Networks with Cooperative Communication*," Computers, Volume 9, Issue 1, 2020.

[141]. Uppula Kiran, Krishan Kumar, "*Throughput and Outage Probability-aware Intelligent Swarm-based Multi-hop Selection in Vehicular Network*" Cybernetics and Systems, 2022.

[142]. Alireza, Askarzadeh, "*A novel metaheuristic method for solving constrained engineering optimization problems: Crow search algorithm*", Computers & Structures, vol.169, pp.1-12, 2016.

Appendix 1

List of Abbreviations

Acronyms	Meaning
ATRS	Adaptive-Threshold-based Relay-Selection Scheme
AWGN	Additive White Gaussian Noise
AOMDV	Ad-hoc On Demand Multipath Distance Vector Routing
AODV	Ad-hoc On-Demand Distance Vector
AP-AF	All Participate Amplify and Forward
AF	Amplify-and-Forward
ARQ	Automatic Repeat Request
BW	Band Width
BF-CTSO	Best Fitness-derived Crow Tunicate Swarm Optimization
BEP	Bit Error Probability
BER	Bit Error Rate
BAS	Buffer and Switch
CSO	Cat Swarm Optimization
CSI	Channel State Information
CH	Cluster Head
CF	Compress-and-Forward
CC	Cooperative Communication
CVN	Cooperative Vehicular Networking
C-NOMA	Cooperative-Non-Orthogonal Multiple Access
CDC	Count of Dimension Change
CSA	Crow Search Algorithm

CDF	Cumulative Distribution Function
DF	Decode-and-Forward
DSRC	Dedicated Short-Range Communications
D	Destination Node
DSDV	Destination Sequence Distance Vector
D2D	Device to Device
D-CSO	Dimension-based Cat Swarm Optimization
DTMC	Discrete Time Markov Chain
DSEC-T	Distributed Switch-and-Examine Combining based on Threshold
DSR	Dynamic Source Routing Protocol
EAORS	Energy Awareness Optimal Relay Selection
EH-WSN	Energy Harvesting-Wireless Sensor Networks
FSR	Fisheye State Routing Protocol
FER	Frame Error Rate
GSC	Generalised-Selection-Combining
GORS	Generalized Optimal Relay Selection
AT-GSC	Generalized Selection Combining with an Absolute Threshold
GA	Genetic Algorithm
GWOA	Genetic Whale Optimization Algorithm
GPC	Giza Pyramids Construction
GPS	Global Positioning System
GPSR-R	Greedy Parameter Stateless Routing
GWO	Grey Wolf Optimizer
HOLSR	Hierarchical Optimized Link State Routing

IGAROT	Improved Genetic Algorithm-based Routing Optimization Technique
IR	Incremental Relaying
ISDF	Incremental Selective DF
IoT	Internet of Things
JA	Jaya Algorithm
JUDRS	Joint Uplink and Downlink Relay Selection
LAR	Link-Adaptive-Relaying
LTE	Long-Term Evolution
MRC	Maximum Ratio Combining
MAC	Message Authentication Code
MS	Minimum Selection
MANETs	Mobile Ad-hoc Networks
MOF	Mobility Factor
MCTRP	Modified Cognitive Tree Routing Protocol
MIMO	Multiple Input Multiple Output
MPR	Multi-Point Relays
NC	Network Coding
NOMA	Non-Orthogonal Multiple Access
NTS	Normalized Threshold Selection
OR	Opportunistic relaying
OLSR	Optimized Link State Routing Protocol
OP	Outage Probability
OT-MRS	Output Threshold Multiple Relay Selection
OT-MRC	Output-Threshold MRC

PSO	Particle Swarm Optimization
PARS	Power-Aware Relay Selection
PMPRSA	Predicted Mobility Based Profitable Relay Selection Algorithm
PDF	Probability Density Function
QoS	Quality of Service
QASO-BDT	Quantum Atom Search Optimization combined with Blockchain assisted Data Transfer
R-DSDV	Randomized Destination Sequence Distance Vector
R	Relay Node
RTS/CTS	Request to Sender/Clear to Sender
RSU	Road Side Units
SMP	Seeking-Memory-Pool
SRD	Seeking-Range-selected Dimensions
SC	Selection Combining
S-AF	Selection-based Amplify-and-Forward
SPC	Self-Position-Consideration
SNR	Signal to Noise Ratio
SIMO	Single Input-Multiple Output
S	Source Node
SCF	Store-Carry-and-Forward
SENS	Switch-and-Examine-Node-Selection
SS-PRS	Switch-and-Stay Partial-Relay Selection
SEP	Symbol Error Probability
TORA	Temporally Ordered Routing Algorithm
TSA	Tunicate Swarm Algorithm

UE	User Equipment
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
VANETs	Vehicular Ad-hoc Networks
ZRP	Zone Routing Protocol

List of Publications

1. Kiran U, Kumar K, Ajay Roy, Shamimul Qamar, Abdul Azeem, "An intelligent dimension-based cat swarm optimization for efficient cooperative multi-hop relay selection in vehicular network", *Neural Comput & Applic* (2023). https://doi.org/10.1007/s00521-023-08541-w , **(SCI, Impact Factor: 5.102).**

2. Kiran U, Kumar K., *"An Hybrid Heuristic optimal relay selection strategy for energy efficient multi hop cooperative cellular communication"*, Ad-hoc Networks, Publisher: Elsevier, DOI: 10.1016/j.Ad-hoc.2022.103058, Volume 140, March 2023, 103058, ISSN: 1570-8705, **(SCI, Impact Factor: 4.816).**

3. Uppula Kiran & Krishan Kumar , *"Throughput and Outage Probability-aware Intelligent Swarm-based Multi-hop Selection in Vehicular Network",* Cybernetics & Systems: An International Journal, DOI: 10.1080/01969722.2022.2103232, Aug-2022(SCI), Vol. 53, Print ISSN: 0196-9722, online ISSN: 1087-6553, **(SCI, Impact Factor: 1.879)**.

4. U. Kiran and K. Kumar, *"Energy-Efficient Cooperative Communications System,"* 2022 Second International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT), 2022, pp. 1-7, DOI: 10.1109/ICAECT54875.2022.9807900. Electronic ISBN: 978-1-6654-1120-2, Print on Demand(PoD) ISBN:978-1-6654-1121-9.

5. U. Kiran and K. Kumar, "*An Optimized Relay Selection to Improve Reliability and Reduce Energy Consumption in Cooperative Network*", 2nd International Conference on Advances in Signal Processing, VLSI, Communications and Embedded Systems (ICSVCE 2022), August-2022(Proceedings under Process).