Chapter 11

The Role of Vehicular Ad Hoc Networks in Intelligent Transport Systems for Healthcare

Rabia Bilal and Bilal Muhammad Khan

11.1 Introduction

11.1.1 Mobile Ad Hoc Networks (MANETs)

The arrival of the globally available computing and the designing of innovative, incredible, capable, handy computing gadgets have permeated wireless mobile communication and networking so that users avail from electronic services at any time, irrespective of their geographical location. There are two kinds of wireless networks: infrastructure-based and infrastructure-less (aka ad hoc networks).

An infrastructure-reliant network has the networking component (i.e., routers and gateways) and the nodes connected within the network range to the nearby base station that comes within its communication range. When a node exceeds the coverage area of that base station, it performs the handoff procedure so that it comes within the scope of the new base station. Cellular communication is a classic example of an infrastructure-based wireless network.

The infrastructure-less network or ad hoc network (AHN) where the Latin expression ad hoc designates literally "to perform something for a particular purpose." AHN is a peer-to-peer (P2P), self-forming, and self-restorative kind of network.

Mobile ad hoc networks (MANETs) can immediately form a mobile node network, combined or segregated into discrete networks while in motion. The

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MANET's nodes depend on the networking requirement and vigorously handle the leaving or joining of network nodes. The main objectives of a MANET include reliability, availability, and scalability. The nodes in the network are self-governing processing devices with low capacity that are capable of moving freely, and due to this factor, the topology of the network changes swiftly, randomly, and periodically. Each network node can host or route (i.e., to transmit the data to other nodes). The achievement of communication is hugely reliant on the cooperation of the other nodes. Nodes are responsible for vigorously finding out the other nodes themselves for the communication in the wireless range. If MANET nodes keep on moving, then this results in a break in connection as well as the restoration capacity frequently. Moreover, the maximum number of nodes in a network has limited resources when it comes to battery power, as well as on computing ability, so the conventional computing routing protocols are not fit for MANET.

The devices, which are part of MANET, include handheld devices like smartphones, laptops, smartwatches, pocket PCs, or any wireless mobile devices. These devices are normally easy to carry and have batteries in them. Figure 11.1 shows an illustration of a heterogeneous mobile ad hoc network and its communication with different devices.

The extracted blood cell features turn out to be the input to a classification stage that categorizes the cells according to hematological models automatically. The classification module should identify the blood cells relying on the extracted features from real images. When it comes to noisy images, this can impair the classification.

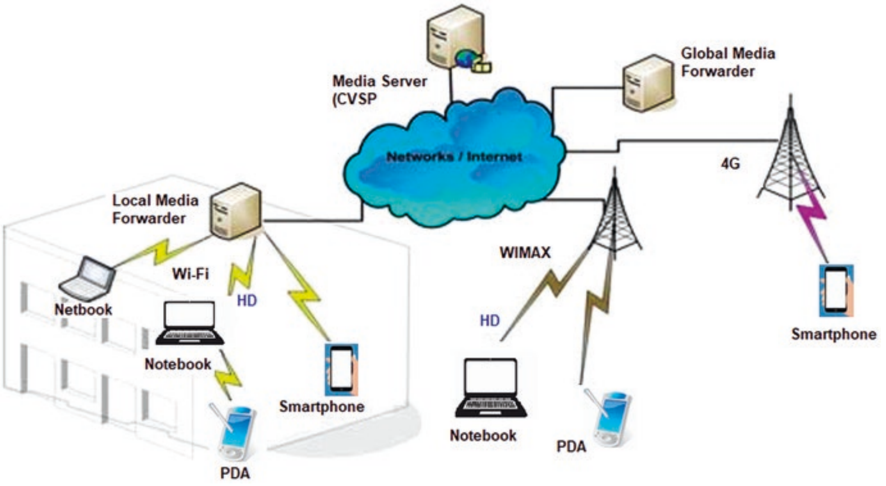

Fig. 11.1 Heterogeneous mobile ad hoc network (MANET)

11.1.2 Vehicular Ad Hoc Networks (VANETs)

Vehicular ad hoc networks (VANETs) have fully fledged out of the necessity to support the increasing amount of wireless products that can now be used in vehicles [1, 2]. Keyless entry devices, tablets, laptops, and smartphones are some of the wireless products. As mobile wireless devices and networks become more and more vital, the demand for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication will augment day by day [2]. VANETs can be used for an extensive range of safety and non-safety applications, e.g., automatic toll payment, traffic management, enhanced navigation, vehicle safety, location-based services, and search for the nearest place for service/entertainment (such as fuel station, restaurant, and motels) [3] as well as information applications employing the Internet. VANET's works are threefold and briefly described as follows:

Vehicle-to-Vehicle (V2V): It involves a Wireless Area Network (WAN) where vehicles converse through messages about the activities they are performing. This information includes many things like their speed, location, direction, braking, and loss of steadiness. DSRC (dedicated short-range communication) technology from V2V communication is a standard set by organizations like FCC and ISO. The frequency used in this communication is 5.9GHz, which is the same as the frequency of Wi-Fi, but calling it a Wi-Fi network is not appropriate. It can be called a Wi-Fi like a network. The range that is covered by the vehicles in this network is up to 300 m. The topology used in this network is mesh; it means that every node, it could be a car or a signal, can send, receive, and capture the signals. V2V network allows the vehicles to communicate with each other without depending on permanent infrastructure support and can be mostly used for safety, security, and dissemination applications (Fig.11.2).

Vehicle-to-Infrastructure (V2I) or On-Board Unit (OBU): It plays a vital role in the coordination of the vehicles. The radio transceivers are known as roadside unit (RSU), so that vehicle and the roadside transceiver communicate with each other for safety, security, and traffic management purpose. These networks collect the information of local signals and the road conditions and then impose some policies on the group of vehicles connected to the network for many useful purposes (Fig.11.3).

Vehicle-to-Vehicle-to-Infrastructure (V2V2I) or Hybrid Architecture: It merges both vehicle-to-vehicle and vehicle-to-infrastructure. In this type of communication, a vehicle can exchange the information with the roadside infrastructure either in a single hop or multi-hop manner, based on the distance, i.e., if it cannot approach the roadside unit directly or vice versa. It enables the vehicles to communicate with each other that are distant or allows a long-distance Internet connection for vehicles.V2V2I is a bit different from the other two types of communication that are discussed above (Fig.11.4).

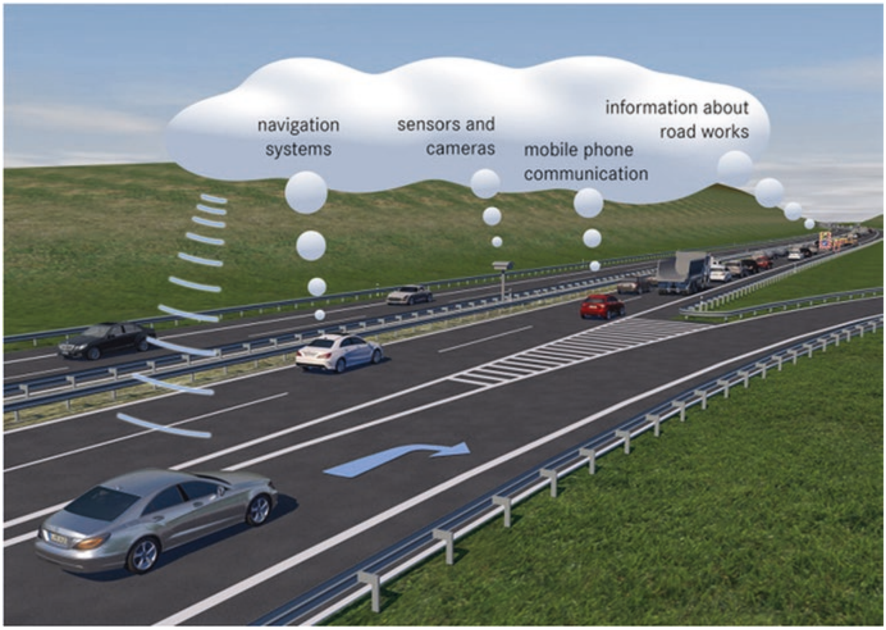

Fig. 11.2 Vehicle-to-vehicle (V2V) communication

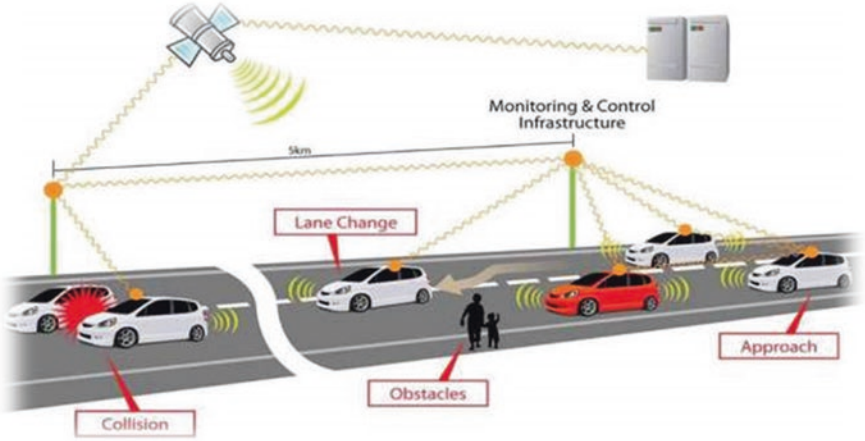

Fig. 11.3 Vehicle-to-infrastructure (V2I) communication

11.1.2.1 Distinguishing Features of VANETs

VANETs have become an important research area for developing countries by increasing their traffic situation day by day. VANETs which belong to the clan of mobile ad hoc networks (MANETs) have distinctive features when compared to

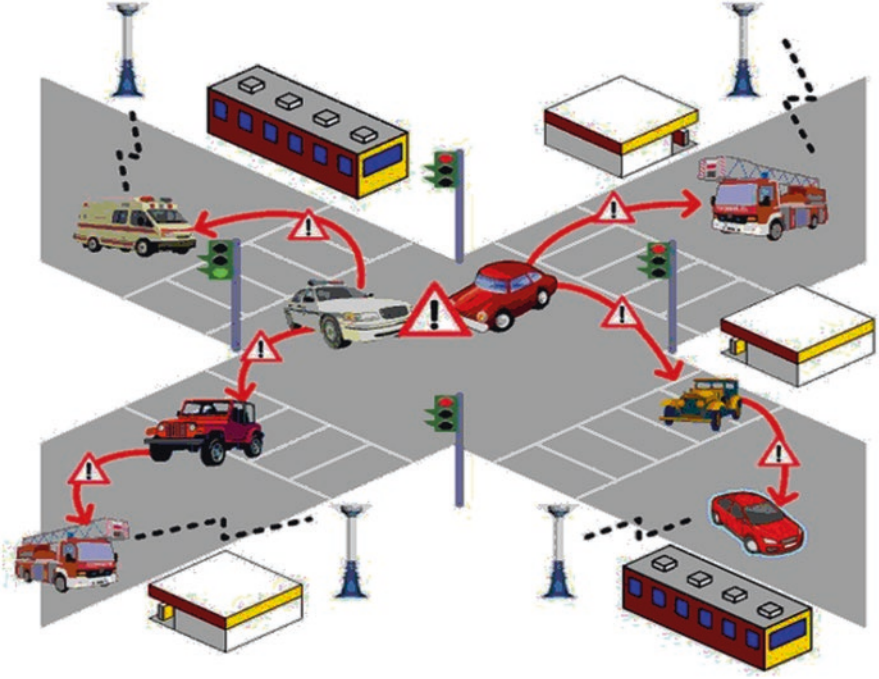

Fig. 11.4 Vehicle-to-vehicle-to-infrastructure (V2V2I) communication

MANETs, and some of them are as follows:

1. *High Computational Capability*: Nodes in the VANETs are vehicles with sufficient sensors and assets for processing, such as a Global Positioning System (GPS), processors, and large memory capacity. These resources are the most significant factor for the increasing capabilities of the nodes, which help in resulting the reliable communication by getting precise information about the vehicle direction, speed, and its current position [4, 5].
2. *Expected Mobility*: The mobility of VANETs is much more predictable than the one from MANETs. The last type of vehicular network node moves randomly, whereas in the VANETs the vehicles (nodes) usually follow the topology defined from the road in which they obey the traffic lights as well as the road signs, which results in the predictability of its movements [6–9].
3. *No Energy Problems*: Energy is not a big issue in VANETs as compared to MANETs because cars continuously provide enough power to OBU by the use of long-life battery [5, 7, 10].
4. *Variable Density in Network*: This factor only depends on the density of the traffic, and it can be low (as in residential traffic), or it can be very high (like during a traffic jam) [9, 10].
5. *Hefty Networks*: The network size in the VANETs varies from small to large such as rural areas, urban areas, highways, or a metropolitan city [9, 10].

6. *Immediate Alterations in Network Topology*: Vehicles traveling on the motorways with the high speeds can change the topology of the network instantaneously, and by this, the received information can affect the performance of the driver [8–10].
7. *Assurance of Harmless Driving*: This thing is only possible when the efficiency of the traffic is improved. The communication between the nodes is direct through VANETs, which allows the pack of applications that needs direct communication among the vehicle over the network. Additionally, these applications offer cautioning data to travelers moving along a similar course concerning the criticalness for quick hard breaking or about mishaps. In this manner, the driver needs to make a bigger picture of street topology ahead. Moreover, VANETs can likewise enhance voyager fulfillment and improve movement effectiveness by demonstrating data, for example, shopping malls, service station, climate, restaurants, and hotels [7].
8. *Time Critical*: The data in the VANET network must be delivered to the nodes at a particular time so that it will be easy for the node to make a quick decision and make some action rapidly.

11.2 Vehicular Network Challenges

11.2.1 Mobility

Evidently, in an AHN, each node is mobile, and it keeps on moving from one place to another within the coverage area. Still, mobility is restricted, but when it comes to VANET nodes, they possess high mobility. In this type of network, vehicles connect with other vehicles they never faced before. This connection may not stay as long as the time these vehicles travel their paths, and they may not meet each other again. So, it is a severe problem to secure the mobility challenge [11].

11.2.2 Volatility

The connectivity between the vehicles for communication can be extremely fugacious. This communication might not happen again as the nodes are traveling through their coverage area and build up its link with other nodes. These links/connections will be mislaid due to the high mobility of the vehicles, and they might be move in the opposite direction [11, 12]. Lacking the relatively long-life context will be found in these networks, so the private interaction from the customer's device to the hot spot will need long-life passwords, which seem to be unrealistic for the security of the virtual connection [13].

11.2.3 Verification in Terms of the Privacy

For the prevention of the different attacks on the network, the verification process of the node is vital, and unique or specific identity can be given to the individual vehicle to overcome this problem, but this is not the proper solution for most of the users. These users want to retain their info secure and private [11, 12].

11.2.4 Responsibility in Terms of the Privacy

For legitimate inquiry, responsibility will be an excellent option. This information cannot be repudiated by any user in case of collision and accidents [11]. Furthermore, it is imperative to keep the privacy of the user from others, and they can keep their personal information (ID, account number for toll collection, route, etc.) safe from other drivers as well [13].

11.2.5 Scalability

When it comes to scalability, these networks are vast enough, and their scalability is increasing day by day due to the increment of the vehicles. Moreover, another problem is this network has not any standards that govern by any authority or firm. The DSRC standards for each country vary from one another, and it also varies from vehicle to vehicle [13].

11.2.6 Routing Protocol

To create a new protocol that will able to guarantee the delivery of packets in the small time frame with low packet drops will be considered as a severe issue for VANETs [14–17].

11.2.7 Trifling Operative Diameter

The small diameter results in a weak connection between the nodes during the communication. Hence, it is unfeasible to sustain the topology of the network global for any node [18].

11.2.8 Fading of Signals

Fading occurs due to the obstacles that are placed between the nodes, which are exchanging the information. The barriers can be static, like buildings and other moving vehicles. The effect is that these obstacles fade the signal and try to stop the signals to reach its desired destination [15].

11.2.9 Bandwidth Restrictions

This type of network does not have a centralized coordinator responsible for handling contention as well as bandwidth. Due to the limited range of frequency, the channel congestion probability is high when it comes to the high-density location.

11.2.10 Connectivity

High mobility is the main reason for the frequent disconnections in the network, and the required duration for exchanging the information would be enhanced. It is necessary to increase the transmission power to achieve this goal. Still, it will affect the degradation of throughput.

11.3 Architecture of VANETs

The population of vehicles is also increasing rapidly on roads, which results in the difficulty in driving and making it more dangerous and challenging day by day. Roads are packed with lots of vehicles, the rules that are speed and safety distance are rarely followed, and there is a lack of concentration in travelers while moving on the road. The following are the main objects present in VANET architecture.

11.3.1 On-Board Unit (OBU)

The first thing that comes in VANET architecture is OBU that is usually mounted on-board of a node. This device uses the wireless access in vehicular environment (WAVE) technology for the interchanging of information with other units or with roadside units (RSUs). Any OBU must include a user interface for storing and retrieving messages from memory. It processes all the same things a processor does while being a network sort of interface that creates a link with other OBUs. Last, it is a wireless device for the short communication range that works on 802.11p protocol from the MAC standard for VANETs. A wireless channel is also needed for the connection between the different OBUs/RSUs, and this also works on the IEEE 802.11p standard, which is responsible for the interchanging of messages between OBUs/RSUs. The foremost responsibility of an OBU comprises information security, IP mobility, routing concerning geography, message transfer with reliability, and congestion control in the network [19].

11.3.2 Application Unit (AU)

AUs are gadgets inside the vehicle that utilize the administrations provided by the supplier by abusing OBU capabilities. AU can be any kind of PDA to associate with the Web or a gadget devoted to security applications. A wired or remote association is utilized to associate the AU to the OBU and may be kept in one physical unit with the OBU. The contrast between OBU and the AU is coherent.

11.3.3 Roadside Unit (RSU)

The roadside units (RSU) are the devices that use WAVE protocol, located in places like parking areas, signals, the road segment, or junctions. The RSU is equipped with a dedicated module for the short-range-based communication through radio within the network infrastructure. Different network devices may also be fitted out with RSUs, as shown in figures. The RSU primary operations, which are associated with congestion control communication consortium, are:

1. The enhancement in the range of the network can be achieved through the redistribution of the messages to different OBUs and relaying messages to RSUs so it can be transmitted to different OBUs.
2. It runs for safety purpose applications like accident warning, natural disaster warning, and work zone by using communication of V2I, which serves as a source of information.
3. The Internet connections are provided to OBUs through these units.

11.4 MANETs vs VANETs

The relationship between both types of ad hoc networks is that nodes are self-sustaining and can handle information by themselves without any infra. VANETs have some distinctive features, and it is a subclass of MANETs.

11.4.1 Quickly Variable Topology

In both kinds of network, topology changes swiftly as the nodes are mobilized and cannot stay in a network for long; however, in VANETs the speed of the nodes is comparatively high as compared to MANETs, so the network topology in VANETs is frequent and very fast. In VANETs, topology can be predictable as the vehicles follow the road path, while in MANETs, the nodes can be moved anywhere, and its topology is not that predictable.

11.4.2 Repeated Interruptions

Change in rapid topologies causes frequent interruption in the network. In VANETs, the probability of disconnections is very high as compared to MANETs because the connection between vehicles can disconnect very rapidly due to the high speed of the vehicles. The issue of interruptions becomes more inferior if the density of nodes varies.

11.4.3 Energy Constraint

In VANETs, the nodes do not have any energy restrictions as compared to MANET.

11.4.4 Production Cost

When it comes to implementing the cost to produce, the MANET network is much cheaper than the VANET as both networks have different types of nodes and their manufacturing cost of the equipment varies.

11.4.5 Reliability

When it comes to reliability, a VANET is much more reliable than the MANET because, in MANET, the security factor is much lower than the VANET. Further differences on which both networks differ from each other are mentioned in the below table (Table 11.1).

Table 11.1 Difference between MANETs and VANETs

S. No	Parameters	MANETs	VANETs
1	Production	Medium cost	High cost
2	Topology	Static	Highly variable
3	Mobility	Slow	Fast
4	Node density	Low number of nodes	High number of nodes
5	Bandwidth	Low rate	High rate
6	Range	Up to 100 m	Up to 500 m
7	Network active time	Depends on node energy	Depends on the vehicle condition
8	Multi-tier routing	Available	Weakly available
9	Reliability	Medium	High
10	Moving pattern of nodes	Random	Regular
11	Addressing scheme	Attribute-based	Location-based
12	Position acquisition	Using ultrasonic	Using GPS and RADAR

11.5 MAC Protocols for VANETs

For the improvement of transport systems, VANETs deliver safety as well as non-safety services to vehicles, and to attain this objective, vehicles need to communicate where there is no collision, and they can efficiently access the channel for communication. Numerous protocols are proposed for vehicular ad hoc networks, which specify the accessing of the channel by nodes in a different manner. Several problems are faced during the designing of this protocol like high mobility of vehicles, rapid change in the topology of the network, multi-channel separation, neighboring channel interference, and hidden node issues. MAC is categorized into three broad classifications, including contention-based, contention-free, and hybrid MAC protocols (Fig.11.5).

11.5.1 Routing Protocols for VANETs

Routing protocols in VANETs are categorized into five types, which include topology-based, cluster-based, position-based, broadcast, and geo-cast-based routing protocol. These protocols are characterized based on the types where their work and applications are more appropriate.

11.5.1.1 Topology Routing Protocol

This protocol uses information on the links in the network to forward the packets to the nodes. Further, they are divided into reactive and proactive protocols.

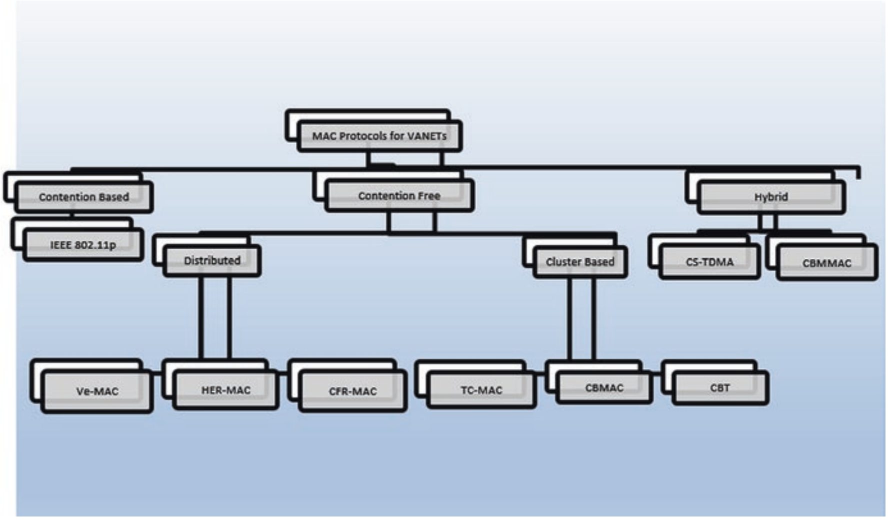

Fig. 11.5 Types of MAC protocols

Reactive Routing

In this type of protocol, the route for the node is only open when it is required for a node to communicate. It only retains the routes that are presently in use during routing, which decreases the burden of the network. This protocol discovers a route by flooding the network nodes and paths with a route discovery packet. This phase ends when the route from source to destination is found. The well-known reactive routing protocols are AODV, DSR, TORA, and PGB [20–23].

Proactive Routing

This routing protocol keeps the information about routing for the next hop in the background regardless of communication needs. As a benefit, this protocol lacks the route discovery phase for the next hop or destination that is saved in the background. Nevertheless, with this advantage comes a drawback of this protocol: for real-time applications, it provides low latency. The routing table is created and maintained in the node. Consequently, the next hop is already defined as the packet when it arrives at the node. Moreover, the protocol keeps the idle paths during communication, thus reducing the available bandwidth of the network. Well-known proactive protocols include DSDV, LSR, OLSR, and B.A.T.M.A.N[24–28].

Cluster-Based Routing Protocol

In this type of routing, a cluster is formed between the groups of nodes. From these nodes, one node becomes the head of the cluster that broadcasts the packets to other cluster heads and the gateway. Scalability can be achieved by using this protocol for large networks, but highly mobile network overhead and delays are experienced. Virtual infra must be formed in this protocol so that it can provide the scalability in the network. Well-known protocols are CBLR, RLSMP, AWCP, CBVANET, and COIN [29–31, 64].

Position-Based Routing

This class of routing algorithms shares geographical positioning properties to select the next hop to transmit the packet without any prior information on the neighborhood map. A neighbor is, by definition, one hop away, close to the destination node. These routing protocols are valuable as there is no requirement to create and maintain the communication path between the source and destination node. This protocol possesses two categories: delay-tolerant and position-based greedy V2V protocols. Examples of such protocols include GPCR, CAR, DIR, MOVE, VADD, and SADV.

Broadcast Routing Protocol

These types of protocols are commonly used in this network for traffic, weather, sharing, road conditions, and emergency between the vehicles and also for conveying broadcasts and commercials among the vehicles. Well-known protocols comprise DV-CAST, V-TRADE, BROADCOM, and UMB.

Geo-cast Routing Protocol

It is multicast routing based on the location. It sends the packets from a source to other nodes that are in the geographical range of the network, also known as the zone of relevance. Vehicles that are not in the range of ZOR are unable to get alerts so that the vehicles can avoid unwanted rapid response. In this routing, an origin zone forwards the flooding of packets. This flooding strategy diminishes congestion and message overhead of the network, which is caused by flooding the packets to the entire network. Unicast routing is performed in the destination zone for the forwarding of the packets. A drawback is the apportioning of the network and the hostile neighbors that can hinder the packet forwarding. Instances of this routing are IVG, Cached Geo-cast, abiding Geo-cast, DRG, ROVER, and DG-CastoR.

11.6 Theoretical Analysis of Routing Protocol for VANETs

In this segment, basic AODV will be discussed. Node movements in VANETs make them different from MANETs and corresponding routing protocols [32–34]. Nonetheless, these protocols will give a poor performance on directly applying to the VANETs due to differences in both networks [35]. In VANET networks, topologies changes dynamically and also lack the bandwidth resources, so it is not compulsory to sustain the route of each node. This frequent change of topology affects the effective timing of routing and also reduces the routing rate information. Thus, the protocols that are considered good for VANETs are on-demand routing protocol.

Protocols that come under the umbrella of on-demand follow two processes, i.e., route discovery and maintenance. The route discovery initialization process starts when the source node, which does not have any routing information in its table, needs to form a route to the destination—routing request packets flooded by the source node on the entire network through broadcasting. On the receiving of a route request packet, the destination node sends a route response packet to the source that creates a reverse-path between both nodes. The route maintenance process activates when the definite link of the activated path breaks or on the changing of the node. AODV [36–38], one of the most critical routing protocols in MANETs, also needs an improvement when applied to the VANETs.

11.6.1 Basic AODV

AODV is one of the most popular routing protocols among the ad hoc networks, and it is a reactive protocol. All the routes do not maintain in AODV all the time. When there is a need for the transmission route discovery of the process that starts by decreasing its overhead, the sequence number is used to make sure the freshness of the routes and is also a loop-free topology, which makes this protocol unique. This protocol embraces three phases: route discovery, data transmission, and route maintenance.

11.6.1.1 Data Transmission

After the course revelation stage, the information transmission stage takes put, and the parcels begin to transmit from the source hub to the goal through the same course built up prior. A few of the hubs may pull back themselves from the radio extend as the hubs are energetic and keep on moving, which causes the breakage in connect and transmission stops.

11.6.1.2 Route Maintenance

The course support prepare tries to repair the same interface or to set up a modern course to the goal hub. In this handle, the hub whose interface breaks produces a Course Blunder (RERR) bundle and sends back to the source. On the accepting of this bundle, the source hub looks in its directing table to see up the ancient route to the goal. If there's a course, the source chooses it and once more begins the transmission of information. Else, the source restores the other course to the goal hub and begins its transmission.

11.6.2 Basic AODV Drawback

In route discovery, the RREQ packets are forwarded to nodes adjacent to the source. Due to this process, the entire network is flooded by RREQ packets, which increases the routing overhead of the network as well as upsurges bandwidth consumption. Moreover, more than one route is found by the source node to the destination. The source node chooses a route with the newest sequence number or fewer hops though the route is not long-lasting to complete the transmission specifically in high dynamic VANETs.

11.6.3 Comparison Conclusions

Due to different features of MANETs and VANETs, the MANET protocol cannot be applied directly to the VANETs as it will give poor performance. As compared to other protocols, AODV performs better because of its quick reactiveness capability toward the changing network and establishing the route on demand. In [39], the method proposed by the authors is to add a packet header in the RREQ packet. The results of the simulation illustrate the smaller transmission delay, but there is a trade-off in the packet delivery rate. In [40], the speed and the position are used as information to assess the routes' lifetime and to select the longest lifetime route after evaluating the delivery of packets. Through this method, routes are stable, but in contrast, it increases the control overhead. In [41] the mechanism of route discovery is of two types: quick route discovery mechanism and traditional AODV mechanism. This protocol searches for the route through the first mechanism. If any path is not found, then it uses the second mechanism for the route discovery. On the traditional one, the entire network is flooded by the control packets, which increase the overhead of the network.

11.7 Simulation Results and Protocol Enhancement

This chapter discusses the outcomes of the simulation made for vehicular ad hoc network (VANET) protocol [42] in our designed network model for the performance parameters mentioned in Sect. 11.3.1. This chapter comprises two sections. The first section of the text shows a normal simulation mode of the WAVE [43] protocol in our designed network model. The second part shows the outcomes of enhanced WAVE protocol for VANET using cooperative communication.

11.7.1 802.11P Normal Simulation

Following are the parameters used for the normal simulation mode of 802.11p in our designed network model, as discussed in Sect. 11.3.3:

(a) SNR point range = 10:20
(b) MCS = 4
(c) PSDU length = 10
(d) No. of users = 20
(e) No. of packets = 1000
(f) No. of packet errors = 50

11.7.1.1 SNR (dB) vs PER Graph

This section gives the outcome in Fig. 11.6 as calculated Packet Error Rate (PER) concerning the number of signal-to-noise ratio (SNR) points simulated [44]. In this case, 1000 data packets are first created as discussed in Sect. 11.3.3 and then are passed through the additive white Gaussian noise (AWGN) channel to be simulated on SNR points mentioned. Here, packets are simulated from the SNR range between 10 dB and 20 dB with an interval of 1. Detailed results in the form of exact numeric values of Packet Error Rate (PER), number of packets correctly received at each SNR point, and number of error packets [45] are discussed and given as outcome received on MATLAB command window in Part 11.7.2.

11.7.1.2 Throughput in Percentage per User

This section gives throughput in the percentage of the network in Fig. 11.7. The throughput we are getting against each user/node is being simulated using standard/normal conditions of 802.11p protocol [46] against the packets transmitted at each SNR point. The percent throughput for each user decreases as the number of VANET users or nodes grows because of the increasing number of users sharing packets. This also shrinks the throughput. The exact value of throughput in percentage against each user is mentioned as MATLAB command window output in Sect. 11.7.2.

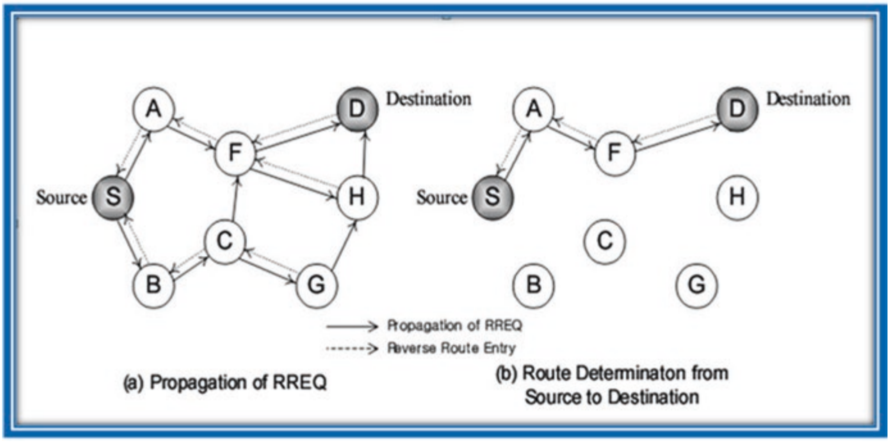

Fig. 11.6 Basic AODV routing protocol mechanism

11.7.1.4 Latency per User

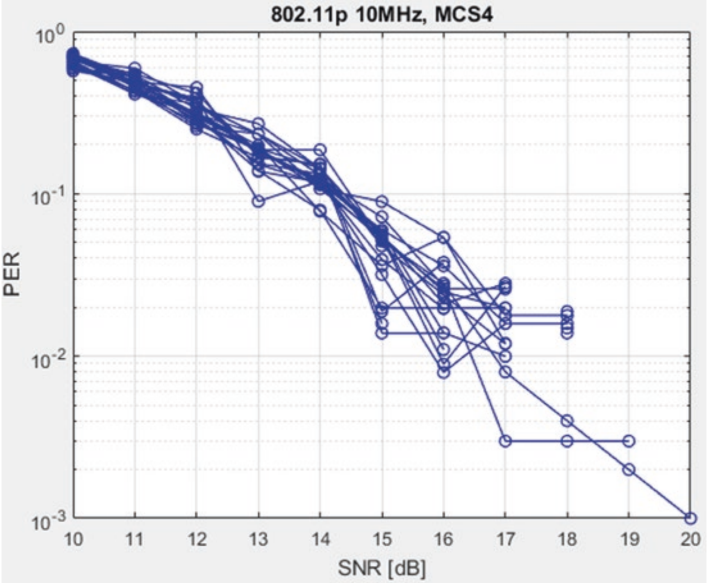

Fig. 11.7 SNR-PER Simulation at 802.11p normal mode

11.7.1.3 Bandwidth Utilization

This section shows the bandwidth utilization of the IEEE 802.11p protocol against the highest percentage of throughput received on the network. As 802.11p uses 10 MHz channel bandwidth in the frequency range of 5.85–5.925 GHz [47–49], the exact utilization of its 10-MHz band appears in Fig. 11.8.

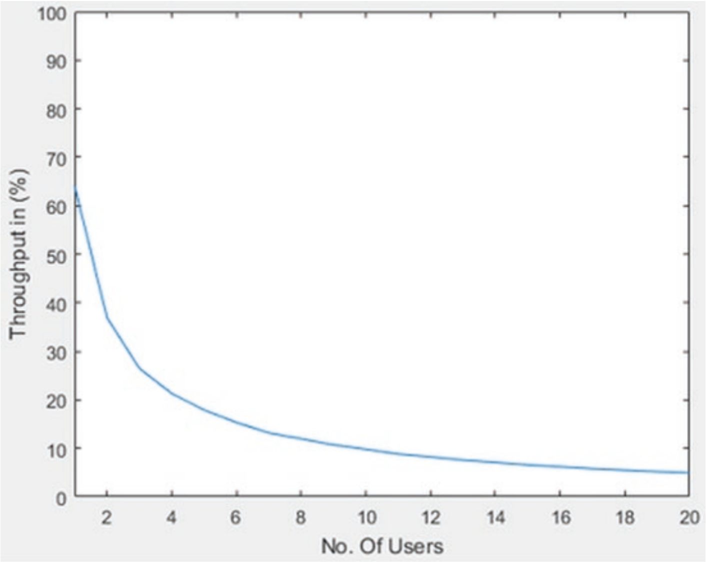

Fig. 11.8 Throughput in % per user for 802.11p normal mode

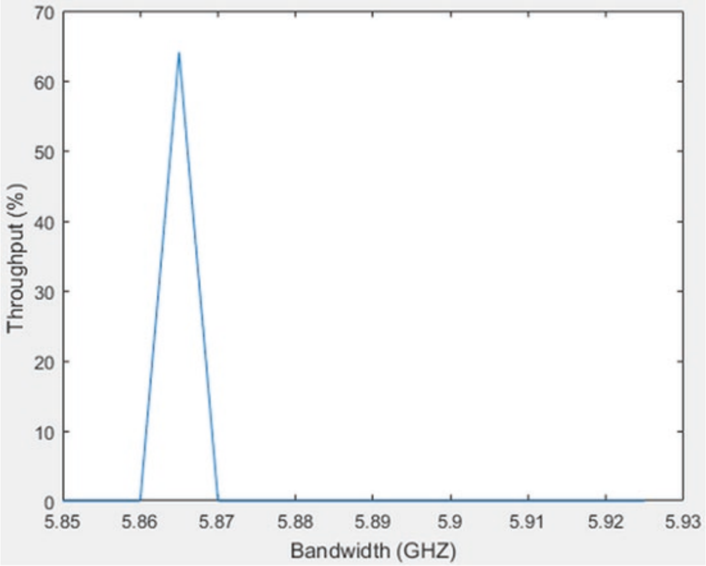

Fig. 11.9 Bandwidth utilization at the IEEE 802.11p normal mode

Network latency per user against the throughput received [50] on the network can be seen in Fig. 11.9. As the number of users on the network increases, the latency per user also grows, indicating that as the network gets busier with the number of vehicular nodes rises, it will take more time to share data packets between then as throughput across each user decreases.

11.7.2 Data Results on the Command Window for the IEEE 802.11p Normal Simulation

This section explains the output waveforms of the first four sections. These values are obtained as the MATLAB command window outcome of normal simulation mode of 802.11p protocol. As discussed in the methodology of the subsection of 11.3.3, the values of how packets are transferred at each SNR point against each user can be seen below. As 1000 packets are transmitted with 50 error packets at an SNR range from 10 to 20, below-mentioned values give a complete simulation range of each user at every SNR point.

First, 72 packets were transferred with SNR = 10 dB, which gives a PER of 0.708 with 51 packets [51] received with error considering the below-mentioned outcome of USER 1. The PER is calculated by dividing the number of error packets by the number of packets correctly received [53]. It is to make clear that 72 packets are not transmitted due to the presence of 51 error packets. Hence:

$$Npcr = Ntp - Nep,$$

where:

Npcr = number of packets [52] correctly received
Ntp = number of total packets received at an SNR point
Nep = number of error packets received at that SNR point

Therefore, here for the first value of USER 1 at SNR = 10 dB, the number of actually corrected packets received becomes 72–51 = 21.

Means 21 packets are correctly received, and rest 51 are error packets [54], which are still present. Similarly, at SNR = 16 dB for USER 1, we can see that number of packets transferred has reached its maximum limit as 1001. But the number of error packets has started decreasing now to 28. This shows that still complete 1000 packets are not transferred properly through an SNR range, and correctly received packets at SNR = 16 dB using the same formula mentioned just above is 1001–28 = 973 successfully received packets, and 27 packets are still left. From here on, the number of error packets that were maximum started decreasing to correctly transmit the total number of corrected packets [55] and at SNR = 20 dB. The number of error packet is reduced to 1, only mentioning that all 1000 packets are correctly transmitted now.

This is the reason for selecting the SNR range from 10 dB to 20 dB, because IEEE 802.11p packetsok at non-HT configuration objects start transmitting packets from SNR = 10 dB and almost complete its transmission at SNR = 20 dB.

The same mechanism goes for USER 2 and onward. The only change is that as the number of users increases, the total number of transmitted packets mutually shared between the users available on the network and its impact on the SNR of the simulated points grow.

11.7.3 802.11P Simulation with Cooperative Communication

The same parameters, as used in Sect. 11.4.1, are used here. But for enhancement of 802.11p in our designed network model, user cooperation is used adding relaying [56] concept reducing path length and delays as discussed in the previous section:

(a) SNR point range = 10:20
(b) MCS = 4
(c) PSDU length = 10
(d) No. of users = 20
(e) No. of packets = 1000
(f) No. of packet errors = 50

11.7.3.1 SNR-PER Graph

The response of user cooperation can be seen in Fig. 11.10 in the form of the SNR-PER graph as enhanced the IEEE 802.11p protocol is now simulated hereafter implementation of cooperative communication. We observe more packets received at each SNR point with the implementation of the technique from Sect. 11.7.2. A MATLAB command window interface displays the exact numeric values. The authors would like to explain that the same number of packets is simulated, even after incorporation of cooperative communication, with the same number of error packets, and the same simulated SNR points for a comparative analysis between the actual normal mode present simulation results of the IEEE 802.11p protocol and the enhancement made via user cooperation.

11.7.3.2 Throughput in Percentage per User

Figure 11.11 alludes to the network throughput [57] in percentage per user. The highest network throughput in normal simulation on a shared network was 64%, but this throughput considerably increases to more than 90% when the node/users cooperate with the relay nodes incorporated. The detailed numeric value results appear in Sect. 11.7.2.

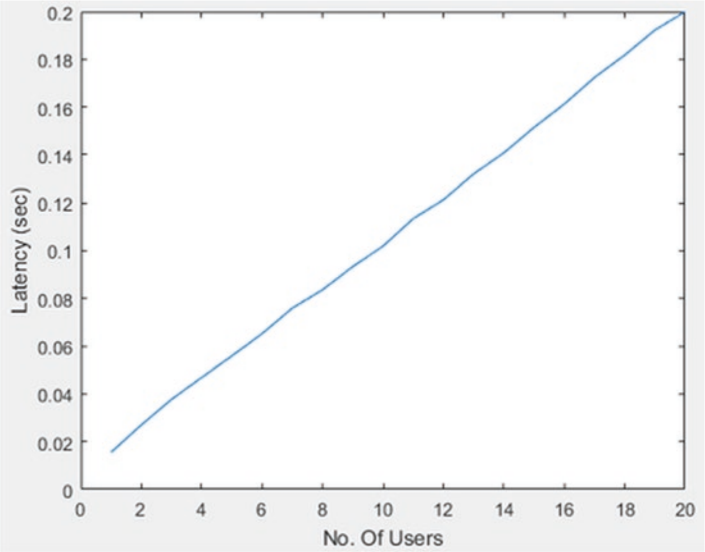

Fig. 11.10 Latency per user for 802.11p normal mode

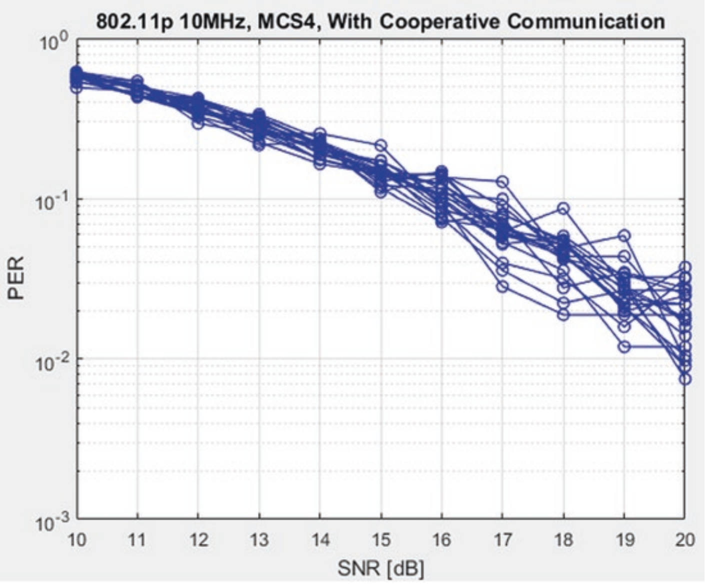

Fig. 11.11 SNR-PER simulation at the IEEE 802.11p with cooperative communication

11.7.3.3 Bandwidth Utilization

The enhancement in bandwidth utilization [58] due to better throughput received in that same 10 MHz channel of the IEEE 802.11p [59] appears in Fig. 11.12 with the incorporation of user cooperation. The channel in this scenario is also using that same range of 10 MHz between 5.86 GHz and 5.87 GHz for enhancement is in the form of better throughput against network usage.

11.7.3.4 Latency per User

The user cooperation clearly shows a fair decrease in network latency per user, as in Fig. 11.13 compared to Sect. 4.1.4. Likewise, the latency grows with an increase in the number of users on a network and a decrease in throughput [60], respectively. However, the users need not take a long time enough as earlier with the incorporation of cooperative communication and can be more quick and reliable with the help of relay nodes having better throughput on the enhanced protocol (Fig. 11.14).

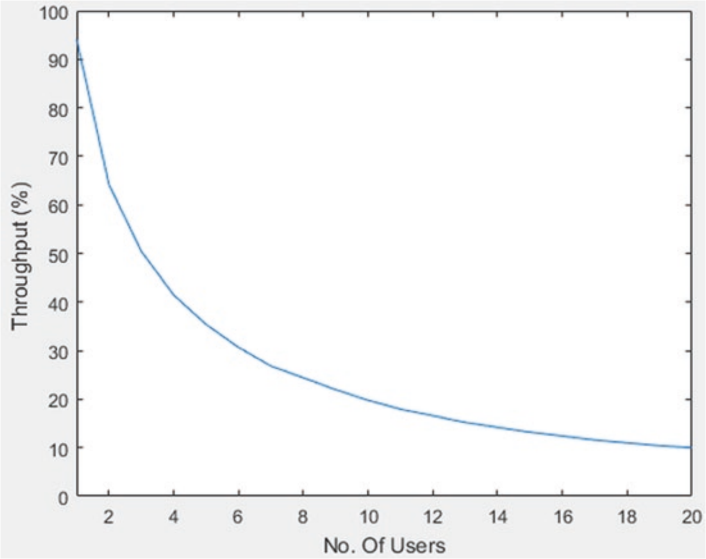

Fig. 11.12 Throughput in % per user for the IEEE 802.11p with cooperative communication

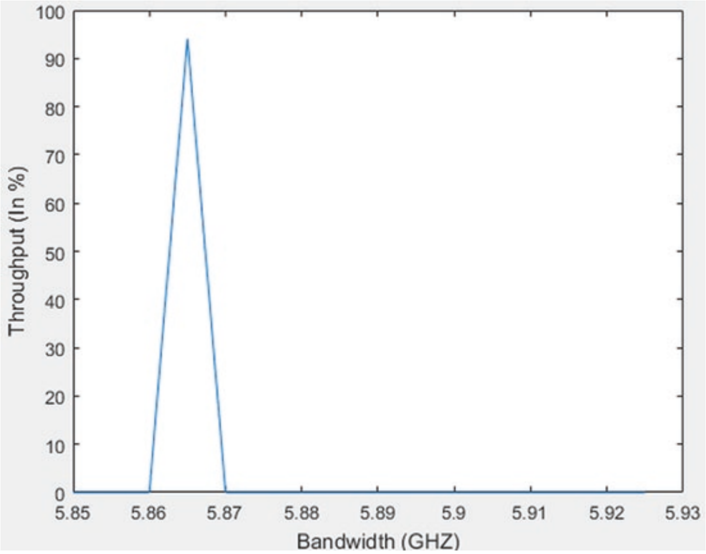

Fig. 11.13 Bandwidth utilization for the IEEE 802.11p with cooperative communication

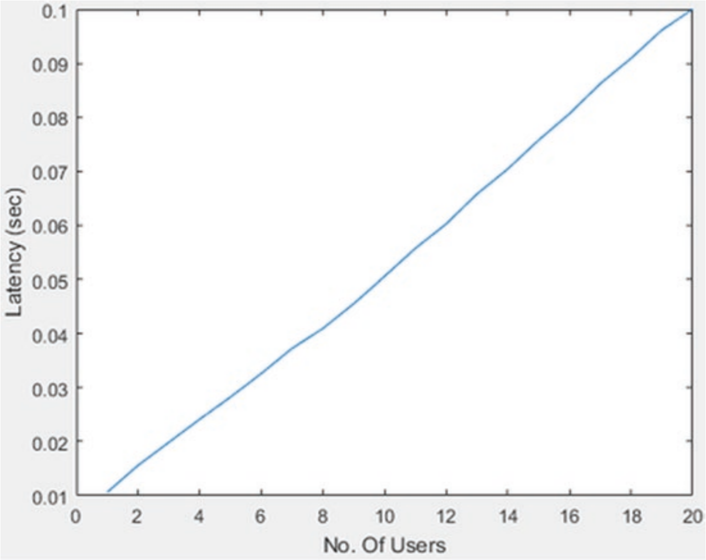

Fig. 11.14 Latency per user for the IEEE 802.11p with cooperative communication

11.7.3.5 Data Results on Command Window with the User Cooperation

After the implementation of cooperative communication for enhancement in the IEEE 802.11p standard protocol, the results in this subsection present exact numeric values obtained via the MATLAB command window interface, and they show a fair improvement [61] in the form of more packets transmitted at each SNR point. This can be checked and verified by observing any number of packets received at any SNR point for any USER below and comparing it with the ones received from Sect. 4.1.5 in normal simulation model using the IEEE 802.11p standard protocol.

11.8 Conclusion

The appropriate supervision of personal health-related data is paramount to healthcare. The foremost challenge for all stakeholders is to handle health records that will be available to all parts and the healthcare providers involved. In recent times, the utilization of wireless sensors and actuators in the medical arena has been augmenting tremendously due to the need to observe/follow patients and hazardous environments in real-time. An important topic is the deployment of healthcare-oriented vehicular ad hoc networks that converse with wireless sensor networks.

The implementation of the intelligent transportation system (ITS) [62] is a priority in all over the world due to the increased number of vehicles on roads, especially in a country like Pakistan, where the population is increasing day by day with limited resources to survive. Continuous jam-packed roads are prevalent nowadays, leading to an increase in travel time of vehicles from minutes to hours. Deadly accidents on highways due to smog or non-indication are no more any new thing that may suddenly have happened. This gives rise to the introduction of vehicular ad hoc networks (VANETs) in such type of traffic environment.

This research focuses on the protocol used for VANET, i.e., WAVE [63], which uses the IEEE WLAN protocol standard of 802.11p. A type of cooperative communication with modified functions is used on the designed network flow of 802.11p protocol to enhance its performance parameters and quality of service (QoS) [74] of a VANET [65]. This research contribution toward society may help in making intelligent transportation system (ITS) [66] even better, safer, and faster as mobile communication between vehicular nodes of a vehicular ad hoc network becomes more reliable [50].

In the future, more attention should be given to multimodality imaging that takes place on each vehicle [67–69]. When an environment and its constituents are mapped, several sources of information must be fused. Furthermore, augmented reality and the option to improve the resolution of regions of interest via, for instance, super-resolution will pose an overhead to the moving network nodes [70, 71]. Besides the issues mentioned in this manuscript, for fleets with a high number of vehicles subject to an intense working regimen, one needs to guarantee reliability, fast processing, and clever node assignment in case they need to make up for node failure and concurrent high-performance computing tasks [72, 73]. It should be stressed that healthcare and disaster mitigation call for a heavy computational load. Such substantial computational demand may call for lighter implementations using metaheuristics [73, 74].

Unmanned aerial vehicles (UAVs) can also serve as ambulance drones to reach the disaster-stricken regions speedier than any conventional rescue vehicles. Such strategy spares time and actions toward handling the unique wellbeing parameters and scenario changes. Flying ad hoc networks (FANETs) resemble MANETs and VANETs, despite their characteristics. UAVs when structured are FANETs, which are mission-based. Their mobility models are habitually determined by the mission purpose and the nature of the undertaking to be accomplished. Thus, FANET routing protocols should consider the types of applications and services involved and the associated mobility models. Nonetheless, routing protocols for FANETs are not an easy task because of the highly dynamic topologies and the flying restrictions they face [75–77].

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