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Evaluation of VANETs Routing Protocols for Data-Based Smart Health Monitoring in Intelligent Transportation Systems

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Abstract

Vehicular Ad-hoc Network (VANET) is an essential part of futuristic Intelligent Transportation Systems. VANET can improve the overall traffic control system and reduce road accident deaths by providing remote health monitoring in hazardous conditions to outdoor patients. Nowadays, vehicles have become so intelligent that they can sense patient health data and transmit it to a nearby ambulance or hospital in emergency or road accident situations. Health professionals can provide appropriate treatment without wasting critical time in further testing. Developing an efficient and reliable routing solution is a significant research problem for VANET based health monitoring applications because of time-sensitives. Routing approaches to reduce the transmission delay for critical applications are based on topological, geographical, clustering, and flooding techniques. This article has evaluated and compared widely used topological and geographical routing protocols for data-based VANETs health monitoring applications. A comprehensive analysis is performed on Ad hoc On-Demand Distance Vector (AODV), Destination-Sequenced Distance-Vector (DSDV), Optimized Link State Routing (OLSR), Greedy Perimeter Stateless Routing (GPSR), Greedy Perimeter Stateless Routing-Modified (GPSR-M), and Max duration-Minangle Greedy Perimeter Stateless Routing (MM-GPSR) protocols with different numbers of nodes, CBR connections, communication range and packet size on Network Simulator (NS-3.23) and Simulation of Urban Mobility (SUMO) platforms. Experimental results give useful knowledge in analyzing routing protocols for VANET's data-based smart health monitoring applications.

Keywords- VANET, Intelligent transportation, Remote health monitoring, Connected health.

1. Introduction

Intelligent Transportation System (ITS) is the need of the hour for current road networks as casualties caused by road accidents have increased exponentially (Siddiqua et al., 2019). Millions of people die per year due to chronic diseases like heart failure, cancer, and diabetics also. This disease requires continuous monitoring of vital signs regularly (Girčys et al., 2020). Medical care and assistance can save an injured patient's life in an emergency. Today, people are increasingly concerned about their health and want to monitor it even when traveling (Maskeliūnas et al., 2019). Patient data must be transported quickly to a hospital or health professional to save injured or severe patient's life. If the vehicle can sense patient health information and transmit it to a nearby ambulance or hospital, health professionals can provide appropriate treatment without wasting time in further vital testing (Cheng et al., 2019). Remote health monitoring in hazardous conditions to outdoor patients is possible with WBAN. In WBAN, bio-medical sensors are deployed on or around the human body, and remote health monitoring of physiological parameters like electrocardiogram (ECG), body temperature, and blood pressure is achieved with physical activities (Vanagas et al., 2018).

VANET is an Ad-hoc network that provides wireless communication between running vehicles by utilizing dedicated short-range communication (DSRC). DSRC allows vehicles and roadside infrastructures to communicate at fast speeds and securely. Federal Communications Commission (FCC), USA, has allocated 75 MHz bandwidth in a 5.9 GHz frequency band for DSRC to support ITS applications (Al-Sultan et al., 2014). In VANET, vehicles are equipped with an Application Unit (AU), On-Board Unit (OBU), and access to Global Positioning System (GPS) services. Wireless Access in Vehicular Environment (WAVE) enabled Road Side Unit (RSU) is also installed alongside the roads for better connectivity and Internet facility. The RSUs are connected through a router that provides access to the Internet and cloud computing platforms. OBU is mounted at the top of all vehicles for information exchange between vehicles and RSUs. Vehicles with OBUs have processing ability and data storage capabilities. AU is a unique device that processes the health monitoring, safety, or infotainment applications received from OBU through RSU (Moustafa & Zhang, 2009).

VANET can provide a wide range of safety, comfort, and commercial-related applications to the driver and fellow passengers during traveling. Authors have proposed many VANET applications (Khaliq et al., 2019; Wu et al., 2020). Safety applications use Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication to avoid road accidents and improve road safety. VANET is critical for intelligent transportation systems (ITS) because they differ from other networks in terms of dynamic architecture and high mobility. Therefore, designing a data routing protocol is challenging (Bilal & Khan, 2021). Safety is the highest priority during the journey, and it can be achieved by collecting vehicular sensor information, process and dispatching it to intended users within time. Safety application disseminates warning messages like traffic signal violation, pedestrian crossing, stop sign violation, blind spot and lane change warning, an emergency vehicle approaching, curve speed warning, and low bridge warning. Comfort and commercial-related applications provide cloud-based services like highway toll collection, parking space alerts, traffic congestion announcements, local eateries, retail malls, movie theatre notifications, and offering a hotspot for watching films and playing video games while traveling (Fornaia et al., 2017).

The main contributions of this article are:

- A summary of VANET architecture and Its applications is presented in this paper.

- A WBSN and VANET based health monitoring system and its functionality are presented here.
- Evaluation of the performances of the AODV, DSDV, OLSR, GPSR, MM-GPSR, and GPSR-M protocol for health monitoring purposes in terms of the throughputs, packet drop ratio, end-to-end delay, packet delivery ratio, and mean hop count on NS3.23 Network simulation.

This paper is structured as follows: Section 2 presents a brief overview of the background works. Section 3 presents the WBAN and VANET based communications framework and health monitoring architecture. In section 4, the topology-based and GPSR based routing protocols have been presented. Section 5 and 6 represent the simulation environment, setup, results, and discussions. Finally, section 7 presents the conclusion of the work performed in this paper.

2. Background

Transmitting the PHI to caregivers, wearable sensors must be linked to VANETs. Developing WBAN devices with increased processing power, storage capacity, battery life, and mobility-compliant protection is still a research problem. Biosensor design, biocompatibility and sensor packing, wireless communication capabilities, power-efficient design, and interoperability are key challenges and needs of WBAN (Hanson et al., 2009). Routing, security, privacy, and scalability of sensor nodes further enhance PHI dissemination challenges. The irregular network topology and high mobility of vehicles in VANET significantly affect the PHI dissemination. Privacy and security, congestion and collision avoidance of transmitted PHI, collaboration with other networks, network administration, inadequate and reliable communication, and implementing VANET in the actual ground cause socioeconomic challenges (Mahmood et al., 2021). It is still a research problem to provide optimal routing for health monitoring applications in the VANET. So, numerous improvements to current routing methods for PHI distribution have been proposed (Allal & Boudjit, 2012). The authors (Alazawi et al., 2014) have proposed a VANET and cloud computing-based road disaster management system to improve the transportation evacuation strategies to help save people's lives during road disasters. Another significant application upheld by VANET is mobile medical care services, giving medical care facilities to versatile users even on the fly.

Authors (Noshadi et al., 2008) presented an evaluation of VANET as an alternate data transfer method among health professionals and patients. It also allows reconfiguring wearable Bio-medical devices to select the data demanded by the physicians. A healthcare application that uses an RFID-enabled authentication scheme is proposed in Ahed et al. (2020), which provides medical facilities to traveling patients. It uses RFID technology with Petri nets-based authentication model for the proposed model. A cloud-Based Health Monitoring System is presented in the literature (Adeyemo et al., 2016). The Cloud database is used as the central database to upload and download the patient's health information using a mobile phone or web browser. A health professional may download this uploaded information for monitoring and guidance purpose. RCare is presented as a delay-tolerant, resilient, and long-term medical system to acquire vital parameters from a sick person. RCare provides network connections to rural regions employing regular transport vehicles such as automobiles and buses as relay nodes to reduce healthcare expenses (Barua et al., 2014).

An emergency routing protocol named VehiHealth (Bhoi & Khilar, 2016) is proposed to quickly forward the patient's health information to a nearby hospital. VehiHealth considers the adjacent intersection to forward the data with minimum delay. It selects the next intersection based on the shortest path, vehicle stability, link breakage, and delay between neighboring intersections. A VANET-based diagnosis and response system, proposed in DasGupta et al. (2021), used VANET technology to set up a virtual communication network throughout a largely rural area with minimal infrastructural cost. They proposed a protocol for vehicles are equipped with OBUs to communicate with each other using the IEEE 802.11p protocol. W-GeoR is proposed in Singh et al. (2021c) for VANET health monitoring applications, emphasizing next-hop node selection for quicker vital sign distribution in urban traffic environments. W-GeoR employed traffic-aware parameters such as traffic movement patterns, distances between vehicles, speed variations, connection expiry time, link quality, and closeness factors for the best neighbor vehicle selection procedure.

A two-level detection system proposed in Kudva et al. (2021) uses a consortium blockchain with an authorized Road Side Unit for vehicular nodes. The developed system enhances VANET performance by blocking internal nodes that attack. The study (Divya et al., 2021) proposed an Ant Colony-based Temporarily Ordered (ACbTO) algorithm to suggest the shortest routes based upon the priority for communication between the vehicles. Traffic Management Unit collected vehicle information and performed data transmission and route suggestions. It enhances the inhabitants' journeying experience. The approach has reduced the travel distance and packet loss and increased the message transmission rate while maintaining low energy consumption. Cryptanalysis of Connected vehicular cloud computing (CVCC) technology is performed in Baruah and Dhal (2021) that integrates VANET and cloud computing for road condition monitoring. AVISPA tool, BAN logic, and an adversary model were used here to evaluate the security of the proposed technology. A genetic algorithm-based ant colony optimization technique (GAACO) was proposed in Singh et al. (2021) to improve the routing algorithm for the Simple traffic Network, Complex traffic Network, and Dehradun realistic VANET traffic scenarios. GAACO integrates genetic algorithm (GA) in the ant colony optimization (ACO) technique. Traffic Dynamism-Balanced Routing Protocol (TDBRP) was proposed in the paper (Kandasamy & Mangai, 2021) for improved safety and regulations for intelligent transportation. TDBRP uses an efficient junction selection algorithm (EJSA) to establish optimal route paths on different traffic dynamics between running vehicles.

3. WBSN and VANET Based Health Monitoring Architecture

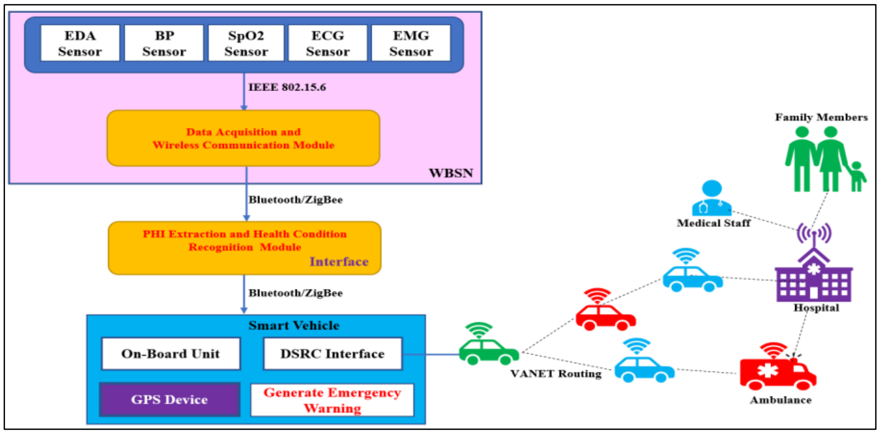

Figure 1. VANET health monitoring architecture.

Health monitoring devices in clinics cannot be worn due to the wires used to communicate with many sensors and their bulkiness. The wired frame limits patient portability and comfort. Hence, it is essential to utilize remote, low force, and miniature sensors to screen the patient's Physical Health Information (PHI). Remote health monitoring can be achieved by integrated Wireless Body Sensor Networks (WBSN) with VANET (Singh et al., 2021a). WBSN plays an essential role in placing sensors inside and near the human body using a gateway to track PHI details. Figure 1 shows the WBSN and VANET based health monitoring architecture. A central control unit system collects the PHI values from all the sensors.

Heterogenous wearable sensors are used to collect the patient's health metrics so patients will no longer need to travel to providers or collect themselves. These sensors may be an electroencephalogram (EEG) sensor, electrocardiogram (ECG) sensor, SpO_2 sensor, BP sensor, and body fever sensor. All collected information is transferred to the OBU through Bluetooth and Zigbee technology. Bluetooth is a low-cost and energy-efficient short-distance wireless communication technology that allows wireless connection between two or more medical devices on a 2.4 GHz frequency band. Zigbee also operates on a 2.4 GHz frequency band but possesses a higher communication range than Bluetooth. Low power consumption, high transmission rate, and large network capacity are all advantages of Zigbee. Analog to digital converter converts the sensed analog parameter to digital form for further processing and transmission. The digitized data passes through data acquisition and health recognition module to store and process the data (Hanson et al., 2009). In an emergency when fetched parameters are abnormal, this module establishes communication with OBU using Bluetooth or Zigbee technology for further transmission. When the OBU intends to transfer its data to a suitable destination, the patient either must be under the coverage of WLAN or must have the capability to use mobile networks. However, neither Wi-Fi nor mobile networks are available in diaster or isolated areas. VANET can act as a medium to transfer PHI data to its final destination in such a scenario. In WBSN and VANET based health monitoring, the patient's PHI data is transferred wirelessly through the central control unit and VANET and transmitted to the hospital or nearby ambulance for real-time diagnosis.

The use of vehicular communications in healthcare monitoring raises several challenges. The information flow process of the health monitoring system using WBSN & VANET is presented in Algorithm 1 (Khaliq et al., 2018). Sensors collect the vital sign of health information at a regular interval. The standard value of health parameters is compared with the sensed value, and in case of abnormality, a warning signal is sent to the vehicle's OBU. These warning messages contain the patient's health data in eXtensible Markup Language (XML) format and the vehicle's IP address and GPS information. Since the WBSN framework needs just a short measure of time to move the PHI to the vehicle's OBU, having wireless radio consistently on is pointless and will deplete the WBSN battery. To minimize battery consumption, sensors are put in sleeping mode unless in an emergency. Data abnormality causes communication between the body control unit (BCU) and the OBU. User Datagram Protocol (UDP) conveys the message from the BCU to the OBU.

The OBU will send an acknowledgment (ACK) message for each delivered message containing the message sequence number to confirm the message delivery. BCU starts a new process and waits for an acknowledgment message. The PHI record will be recognized as delivered when it receives the ACK message. The patient ID, packet destination, and packet number for sensed PHI are all included in the data provided to OBU. The hospital assigns each patient a unique number called a patient ID. A packet destination could be an Internet Protocol (IP) address or an email address to convey a given packet. OBU conveys the stored health information to the adjacent RSU and server room through routing algorithms via V2V communication. The received messages will be ignored if there is no need for data transfer or the vehicle is already connected to an RSU. RSU communicates PHI to the healthcare units. Medical experts make judgments in reply to the vital data they receive, and the PHI is delivered immediately to the nearest medical center or ambulance. The nearest ambulance with life-saving support is transported to the patient's location, thus completing the remote health monitoring system (Aliyu et al., 2018).

Algorithm 1 Route Establishment and PHI Transfer

```
Process the PHI values collected from Bio-medical devices;
Communicate to BCU;
if (BCU == Idle) and (Idle_Time >= ThS_Time) then:
 if (PHI > Normal_PHI) then: BCU stars interacting with OBU;
     OBU calls   Route_Discovery (Source IPv4_address, Destination IPv4_ address);
else Bio-medical sensors go to sleeping mode;

Procedure Route_Discovery (Source IPv4_address, Destination IPv4_ address)
    OBU receives PHI message and its update Neighbor_Table;
     if (neighbor IP_address = = Destination IP_address) then:
        Stop broadcasting PHI messages;
    else
         loop while (Neighbor IPv4_address != Destination IPv4_address)
            Calculate Neighbor.Position and Neighbour.Direction
            if (Neighbour.Direction = = Destination.Direction) then:
            Select neighbor IP_address as Next-Hop by using VANET routing algorithm;
            Source IP_address delivers PHI to Neighbor IP_address;
            Neighbor updates its Neighbor_Table;
            Broadcast PHI messages;
          end loop
  end Procedure
End Algorithm 1
```

4. Effective Routing Protocols for Medical Monitoring in VANETs

VANET uses multi-hop techniques for information dissemination from the source vehicle to the target vehicle. Quality of Services requirements of different VANET applications are different; therefore, single routing approaches are not suitable for VANET health monitoring applications (Kumar & Raw, 2017). However, several routing algorithms have been proposed by researchers so far; nevertheless, the optimized routing protocol is still an open research issue in VANET (Kumar et al., 2020). In VANET, routing protocols are classified into topology-based, cluster-based, position-based, broadcast-based, and geo-cast-based routing protocols (Kumar & Dave, 2012; Altayeb & Mahgoub, 2013). This paper analyzes topology-based routing protocols (TBR), GPSR, and their improvements as position-based routing protocols (PBR) (Singh et al., 2021b).

4.1 Ad hoc On-Demand Distance Vector (AODV)

TBR protocols use network topology and communication link information that exists in the network to perform routing. These protocols can be categorized into proactive, reactive, and hybrid routing protocols based on node mobility. AODV (Das et al., 2003) is a reactive approach-based topological routing protocol adapted from DSDV and DSR routing protocols. AODV was specially designed for moveable networking devices in the ad-hoc network. It uses a source-oriented routing approach in which when a source node wants to transmit data to a targeted node without knowing the routing information, it sends Route Request (RREQ) message firstly. Neighboring nodes receive RREQ messages which contain source as well destination node addresses. If the destination address is matched with the neighbor address, then Route Reply (RREP) message is transmitted to the source backwardly. AODV uses a sequence number in searching for route information, which helps avoid routing loops. It broadcasts Route Error (RERR) message when a pre-establish path route is broken or the communication link is down.

4.2 Destination-Sequenced Distance-Vector (DSDV)

DSDV (Perkins & Bhagwat, 1994) protocol is a proactive routing protocol inspired by the Bellman-Ford routing algorithm. This algorithm is modified to prevent a routing loop in the routing table during the pathfinding process. Each node has a routing table causing faster route discovery compared to reactive routing protocols. This routing table maintains the entries of all destination nodes, intermediate nodes required to reach the sink node, and destination sequence number. The sequence number separates stale routes from new ones and evades the routing loop. The routing table in DSDV is updated periodically. All nodes communicate their routing table to neighboring nodes periodically and transmit it again if a significant alteration has occurred from the last one. So, the routing update is event-driven and time-driven (Kumar & Verma, 2019).

4.3 Optimized Link State Routing (OLSR)

OLSR (Jacquet et al., 2001) is a link-state routing algorithm based on proactive routing protocols designed especially for MANETs. OLSR uses multipoint relay (MPR) techniques where MPR are the selected nodes to forward the broadcasted message during the route discovery process. MPR techniques provide two benefits over classical routing: the reduction in control packet size and the minimization of flooding of the control message. OLSR does not create more control traffic in case of link failure. OLSR is appropriate mainly for massive and dense networks because MPRs suit well for optimization purposes in such networks.

4.4 Greedy Perimeter Stateless Routing (GPSR)

PBR protocols use a GPS device for obtaining location information for the source node and destination node (Xiao et al., 2011). These protocols do not keep a routing table, and path selection is based on neighbors and destination node locations. GPSR (Karp & Kung, 2000) is a greedy forwarding policy-based routing protocol that has attracted the attention of academicians and researchers a lot. The GPSR protocol assumes that every mobile node has installed a GPS device at their top to obtain their neighbor nodes and destination position information. GPSR works in two modes: greedy forwarding mode and perimeter forwarding mode. As the source vehicle starts data transmission to the destination vehicle, it enters into a greedy mode that selects the next-hop node closer to the destination node. If the next-hop is unavailable or the local maximum condition is reached, it applies perimeter forwarding mode. The perimeter forwarding approach uses the right-hand rule for next-hop selection.

4.5 Greedy Perimeter Stateless Routing-Modified (GPSR-M)

GPSR-M (Bouras et al., 2015) is a GPSR based PBR protocol developed by C. Bouras in 2015. GPSR-M modifies the greedy forwarding method of traditional GPSR during next-hop selection. It considers the position of neighbor nodes and their direction, speed, and communication link quality for optimal next-hop selection. Hello message of GPSR-M contains velocity vector, which represents the direction and speed of the current node. The position and velocity of each node are obtained from GPS services. A Signal to Noise Ratio (SNR) tag is used for every packet at the physical layer extracted at the routing layer to measure the link quality. Neighbor table of each node stores this information, which is later used in a weight calculation function to select the next forwarding node.

4.6 Max duration-Minangle Greedy Perimeter Stateless Routing (MM-GPSR)

A node chosen by greedy forwarding of GPSR may move out of its communication range in a highly dynamic network. MM-GPSR (Yang et al., 2018) is an enhanced GPSR protocol that utilizes the cumulative communication duration in greedy forwarding. Cumulative communication duration represents the stability of neighbor nodes. The neighboring node with the highest communication time is selected as the next-hop node. When greedy forwarding fails, it does not utilize perimeter forwarding techniques, but the minimum angle between the neighbor node and destination node is used as the criteria for selecting the optimal next-hop node. Table 1 shows the comparative study on different topology-based and position-based routing protocols and their functionalities in VANETs.

Table1. Comparison of TBR and PBR protocols.

Protocol	**Year**	**Metrics used**	**Forwarding strategy**	**Location service available**	**Recovery strategy**	**Simulation tool**
AODV (Das et al., 2003)	2003	Fast and short path	Multi-hop Forwarding	No	Carry and forward	NS-2
DSDV (Perkins & Bhagwat, 1994)	1994	Position, number of nodes, short path	Multi-hop Forwarding	No	Multi-Hop Forwarding	NS-2
OLSR (Clausen & Jacquet, 2003)	2003	Status of the link	Multi-hop Forwarding	No	Multi-Hop Forwarding	NS-2
GPSR (Xiao et al., 2011)	2000	Position	Greedy Forwarding	GPS	Perimeter Forwarding	NS-2
GPSR-M (Bouras et al., 2015)	2015	Distance, speed, direction, and link quality	Greedy Forwarding	GPS	Perimeter Forwarding	JOSM, SUMO, Bonmotion, NS-3
MM-GPSR (Yang et al., 2018)	2018	Maximum cumulative communication duration and minimum angle	Greedy Forwarding	GPS	Minimum angle Forwarding	NS-2, VanetMobiSim

5. Simulation Environment and Setup

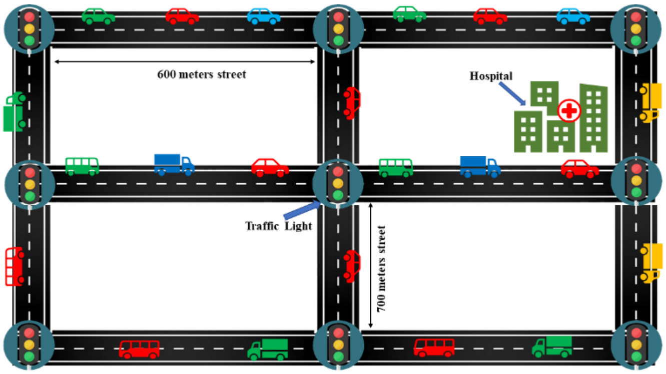

Figure 2. Simulation scenario of a road network.

Road networks are simulated as depicted in Figure 2 to analyze the performance of state-of-art routing protocol on NS-3.23. A road network of 1200 m × 1400 m area with nine intersections and 12 two-way streets is created by using NETEDIT, a SUMO utility (Krajzewicz et al., 2012). randomTrips.py utility generates random trips of vehicles with restricted street mobility on the roadways. The traceExporter.py tool converts SUMO trace data into NS-3.23 compliant vehicle mobility files. Vehicles were traveling at a top speed of 15 m/s. Different situations are created by varying the node density and source-destination pairs. Traffic density is varied from 30 to 110 cars vehicle types. CBR traffic flows with a packet size of 512, 1024, 1500, and 2048 Bytes, a channel data rate of 3 Mbps, and 1 second hello packet interval was used in the experiments. The fading characteristics of the wireless channel were calculated based on the two-ray ground radio propagation model. Vehicles are equipped with a 1.5 meter high above ground unidirectional antenna with a communication range between 200 to 300 meters. Random source-destination in 5, 10, 15, and 20 pairs were used for each simulation. Simulation execution time was set at 500 seconds for each scenario. Each simulation was repeated 30 times, and the 95% confidence intervals were computed. Figure 3 represents the detailed simulation methodology used to create VANET road networks and obtain results.

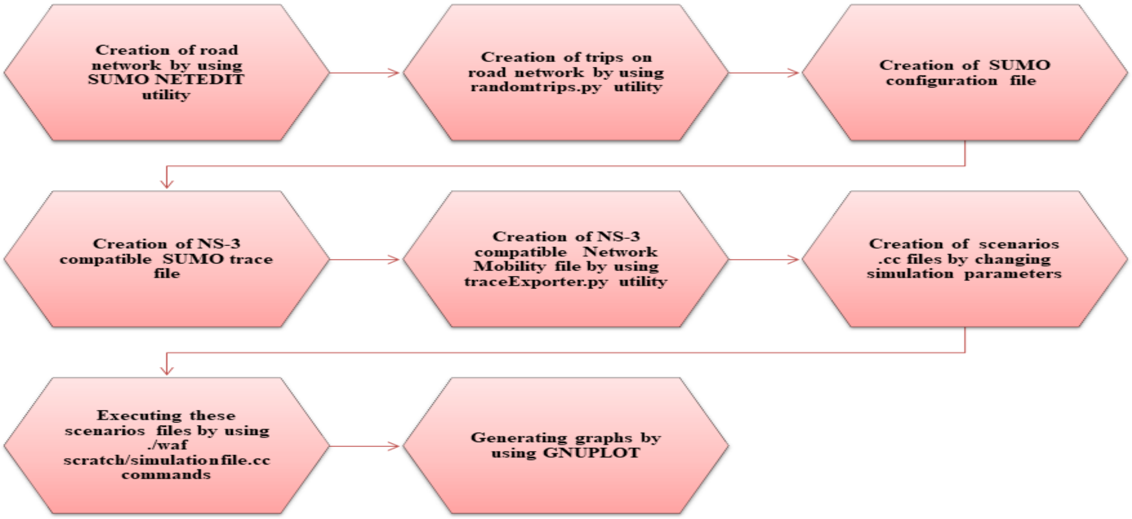

Figure 3. Simulation methodology used in a simulated experiment.

Table 2 summarizes the network parameters for topology-based and position-based routing protocols used in our experiments.

Table 2. Simulation setup.

Parameters	Values
Road Traffic simulator	SUMO −0.32.0
Network simulator	NS-3.23
Simulation area	1200 m × 1400 m
Data rate of channel	3 Mbps
Radio propagation model	Two-ray Ground Loss Model

Propagation delay model	Constant Speed Propagation Delay Model
MAC layer	IEEE 802.11p
Traffic type	Constant Bit Rate
Hello packet interval	1 second
Data packet interval	0.2 second
Antenna type	Omni-directional
Routing protocols	AODV, DSDV, OLSR, GPSR, GPSR-M, MM-GPSR
λ value of MM-GPSR	0.3
Vehicles density	30, 50, 70, 90, 110
Number of connections	5, 10, 15, 20
Communication rRange	200–300 meters
Maximum speed	15 m/s
CBR packet size	512–2048 Bytes
Trip type	Random Trips
Simulation time	500 sec

6. Results and Discussions

In this section, performance analysis of topology-based and position-based routing protocols for VANET is achieved by executing AODV, DSDV, OLSR, GPSR, GPSR-M, and MM-GPSR protocols in NS-3.23 by creating road network simulation as mentioned in section 5. This section introduces the performance metrics used to compare topology-based and position-based protocols and discusses obtained results.

6.1 Packet Delivery Ratio (PDR)

PDR is defined by the "ratio of packets received at the destination vehicles to packets transmitted by all the source vehicles". Figure 4 represents the variance in the packet delivery ratio on different numbers of nodes, connections, range, and packet sizes. Figure 4(a) shows that the AODV achieves the maximum packet delivery of packets followed by protocols MM-GPSR, GPSR-M, GPSR, OLSR, and DSDV. AODV provides the highest up to 97% PDR, whereas DSDV provides the lowest up to 13% PDR with the highest node density. This is because DSDV sends a periodic control message to the routers, which consume more bandwidth that causes a decrement of packet delivery ratio. As per Figure 4(b) results, the AODV has a peak PDR of 98% on five source and destination vehicles connections. As CBR connection increases, the PDR of mentioned protocols starts decreasing. It is caused by the higher traffic presence in the network when the CBR connections pair increased. In Figure 4(c), PDR is plotted against the variation in the vehicle's communication range, and it shows that the PDR of mentioned protocols starts increasing steadily on 200 to 300 meters communication range. However, AODV has the highest PDR in every network scenario which is followed by MM-GPSR, GPSR-M, GPSR, OLSR, and DSDV. Figure 4(d) shows the performance of the state-of-art protocol in terms of PDR against packet size variations. As we enlarge the packet size, the PDR of mentioned protocols seems constant in different CBR packet sizes. AODV provides the highest PDR, followed by MM-GPSR, GPSR-M, GPSR, OLSR, and DSDV. AODV provides 98%, whereas MM-GPSR 65%, GPSR-M 63%, and GPSR 57%. OLSR provides 28% PDR followed by DSDV with 16% PDR only in most scenarios.

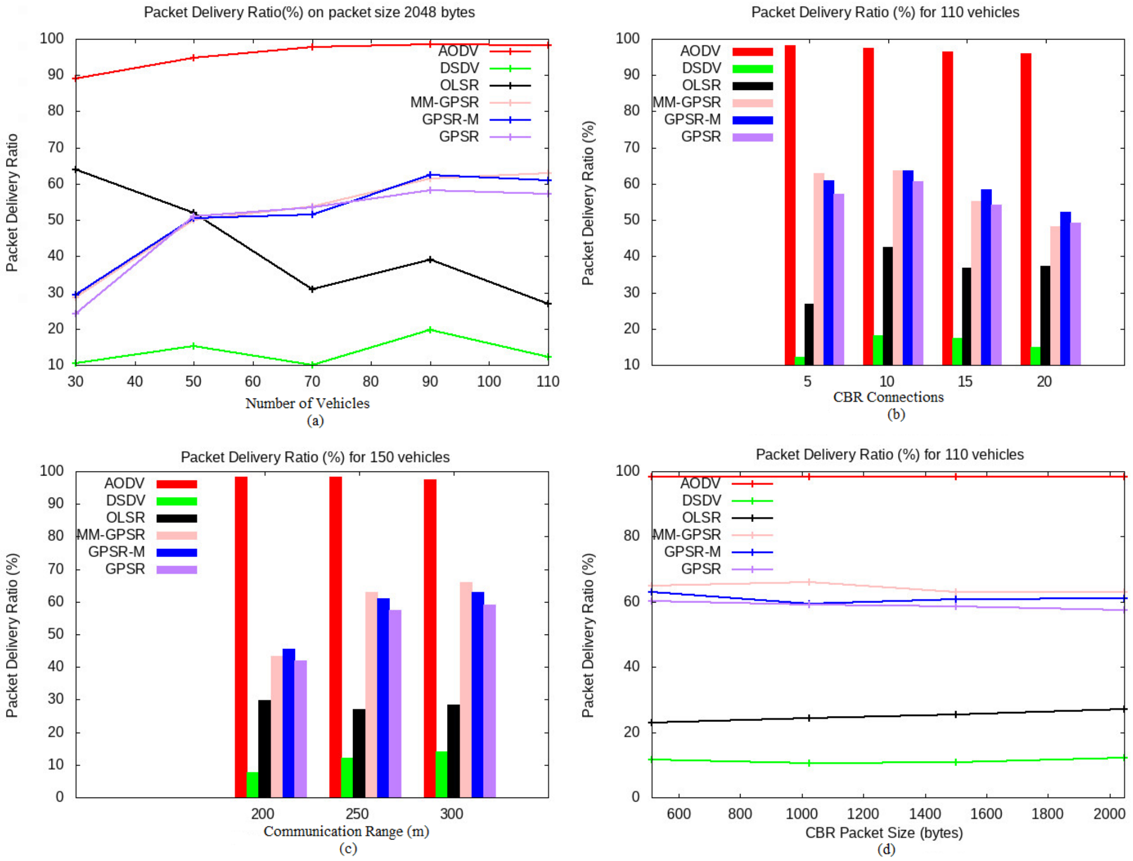

Figure 4. PDR results on various network parameters.

6.2 Packet Drop Ratio (PLR)

It is defined as the "ratio of the sum of all lost packets to the sum of all sent packets by the source node". Figure 5 depicts the PLR investigation on different network scenarios for the studied protocols. It is observed from Figure 5(a) that the AODV protocol shows minimum PLR than others. When node destiny is 30, it is 10%; as density increase up to 110, it is near to 2% only. DSDV shows a height drop ratio near 90% in most scenarios. OLSR shows a 35% loss ratio on 30 node densities, and it reaches up to 72% as density reaches up to 110. Packet loss ratio of GPSR, MM-GPSR, and GPSR-M vary between 45% to 75%. It is higher on low node density, and as node density is increased, it is decreased to 45%. GPSR based protocols choose the next forwarding node closer to the border of the current forwarding node's radio range, causing the next-hop node to move out of its range, further leading to frequent connection breakage and packet loss. Figure 5(b) indicates that the AODV protocol has the lowest drop ratio of about 4%, and DSDV has the highest packet drop ratio near 88% on five pair CBR connections. Improving the traffic load by increasing the CBR connection from 5 to 20, PLR of all protocols also increases. It is caused by the higher traffic presence in the network when the pair of CBR connections increase. Figure 5(c) draws the PLR on various transmission ranges. It is visible from the figure that AODV still has the lowest drop ratio in all scenarios, with a minimum value in the range of 200 meters. As the transmission range increases, PLR of studied protocols starts decreasing except OLSR. DSDV shows the highest PLR, followed by OLSR, GPSR, GPSR-M, MM-GPSR, and AODV. Figure 5(d) depicts the graph of PLR vs. the CBR packet size. As packet size increases, the packet loss ratio of GPSR, MM-GPSR, and GPSR-M vary between 35% to 45%. GPSR has 43%, followed by GPSR-M with 40%, and MM-GPSR with a 35% PLR. Increased packet size does not change the PLR of AODV and DSDV. DSDV shows the highest loss ratio of 88%, whereas AODV shows 2%. The drop ratio of OLSR declined from 76% to 70%.

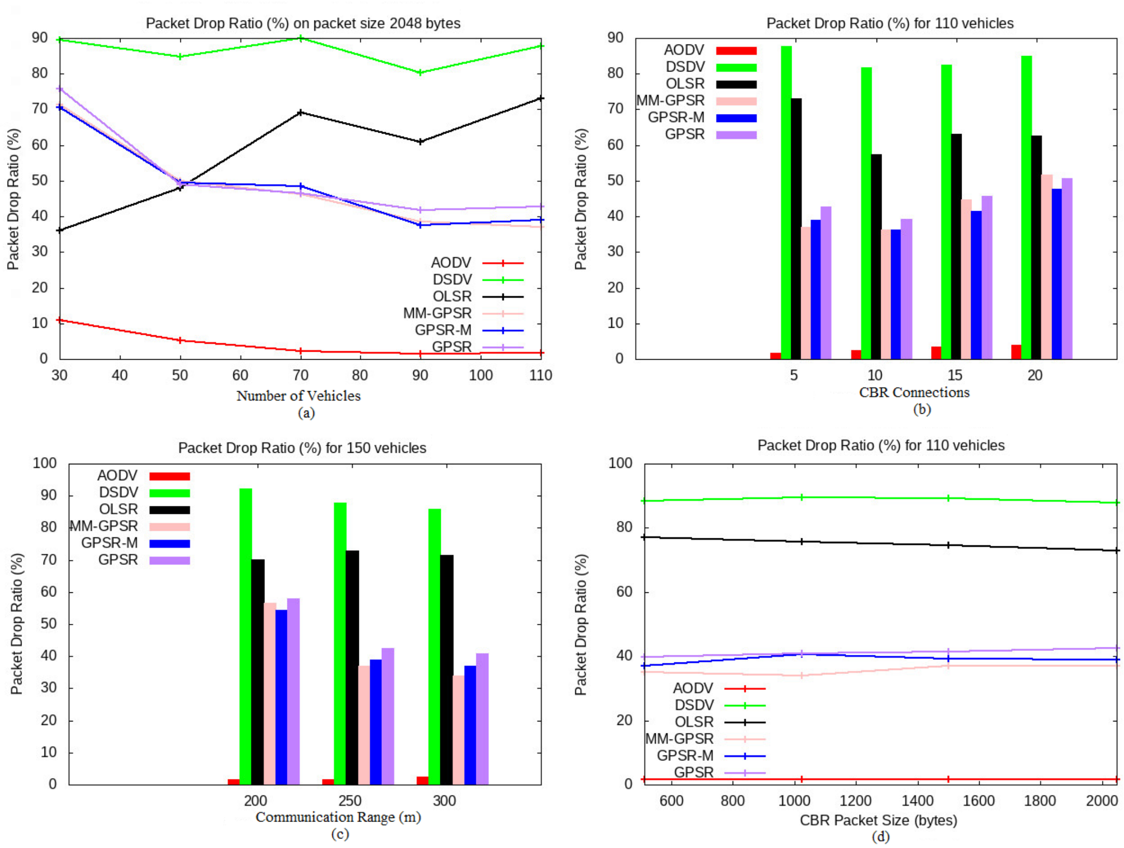

Figure 5. PLR results on various network parameters.

6.3 Mean Hop Count (MHC)

Hop count refers to the number of traversed intermediate routers to reach the destination. MHC is calculated after averaging the hop counts value for all the received messages. Figure 6 represents the impact on MHC value with the different network scenarios for the state-of-arts protocols. It is observed from Figure 6(a) that the MM-GPSR protocol shows maximum MHC between 5 to 6 in all node density scenarios. AODV performs better than all protocols, with 1 MHC in all node densities. OLSR follows it with 2 MHC, DSDV with 3 MHC, and GPSR, GPSR-M with 4 MHC in all scenarios. The next-hop node is selected closer to the edge of the current node's coverage area by GPSR, GPSR-M, and MM-GPSR, increasing the likelihood of the next-hop node falling out of radio range, resulting in a hop change and an increase in hop count. Figure 6(b) shows that by increasing the traffic load by increasing the CBR connection from 5 to 20, the MHC of all protocols is decreased. MM-GPSR performs worst with 4 to 6 MHC, and AODV consumes minimum MHC in all scenarios. Figure 6(c) plots the MHC on various transmission ranges. It depicts that increment in communication range does not much affect the MHC value of all protocols. DSDV, GPSR-M, and GPSR have MCV values 4 in the 200 to 300-meter communication range. It means an increment in communication range does not reduce the MHC value of these protocols. Figure 6(d) represents the graph of MHC vs. packet size. As packet size increases, MHC does not change too much of all protocols and shows study performance throughout all the scenarios, but MM-GPSR's MHC increases from 6 to 7.

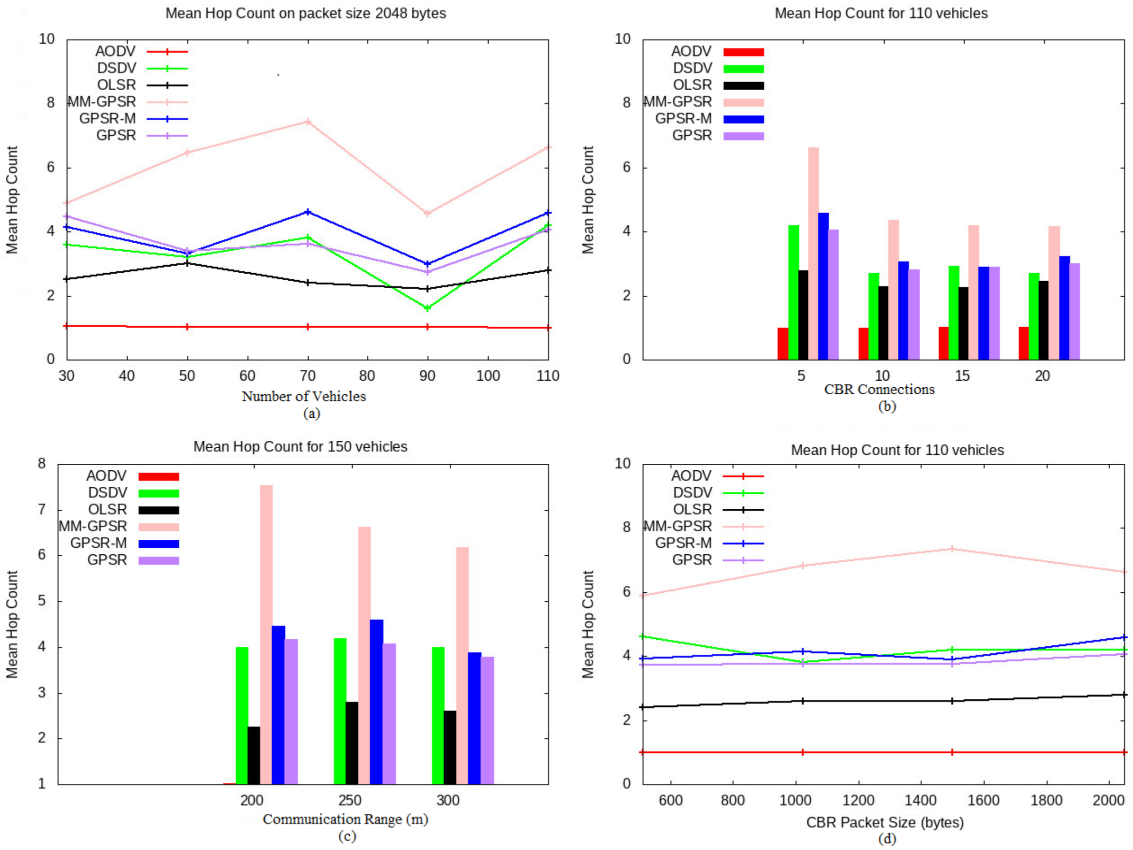

Figure 6. MHC results on various network parameters.

6.4 Average End to End Delay (AEED)

AEED is defined as the "total waiting time in packet transmission by the application agent at the source vehicle until the packet arrives at the destination vehicle". AEED is measured in milliseconds (ms). Figure 7 shows the variance in AEED on different network conditions. It is indicated by Figure 7(a) that on low node density, state-of-art protocols have a high AEED. When vehicle density is low, the neighbor vehicles of every source vehicle are less, and connection with the neighboring vehicle is fragile and unreliable. Perimeter forwarding begins more frequently when a data packet is sent, resulting in increased route redundancy and end-to-end latency. The more connected vehicles, the more stable the neighbor connection is, decreasing the end-to-end delay. MM-GPSR has the highest delay, and OLSR consumes minimum delay in all scenarios. AEED of AODV protocol is increased with increment in vehicle density. Figure 7(b) represents the graph of AEED vs. CBR connections. OLSR protocol shows the lowermost AEED on five pairs of CBR connections. As CBR connections pairs increase by more than 10, OLSR outperforms all the protocols again. MM-GPSR performs the worst and uses more delay as network traffic load increases. OLSR is followed by GPSR-M, GPSR, DSDV, and MM-GPSR with high AEED in all scenarios.

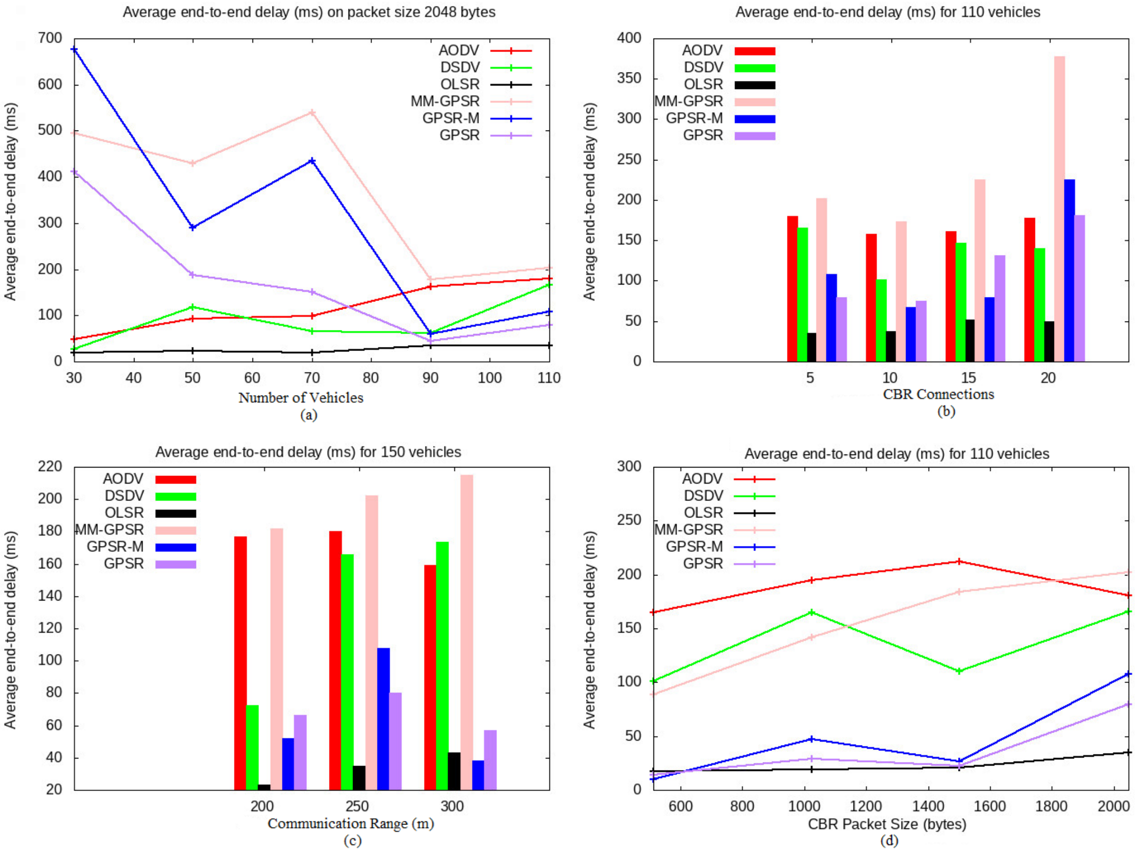

Figure 7. AEED results on various network parameters.

It is observed from Figure 7(c) that when the communication range is 200, OLSR performs better than all, and MM-GPSR performs worst in terms of delay. MM-GPSR is followed by AODV, DSDV, GPSR, and GPSR-M with minimum delay. As the range value increases from 200 to 250 and 300 meters, the AEED of MM-GPSR also increases, and GPSR-M seems the best protocol on the 300-meter range. When the size of a CBR packet reaches the limit, it is subdivided into smaller packets. When a fragment is transmitted, a connection failure impacts the transmission of the divided packet. As a result, the delivery of the original packet is also hampered. AEED has plotted against packet size in Figure 7(d). The AEED of all protocols rises as packet size increases. In all circumstances, OLSR protocols have the lowest AEED compared to others, followed by MM-GPSR, GPSR, DSDV, and AODV with a long delay. AEED starts increasing as the packet size surpasses the threshold value for fragmentation in mentioned protocols, but the delay performance of OLSR is not much affected by varying packet size.

6.5 Jitter

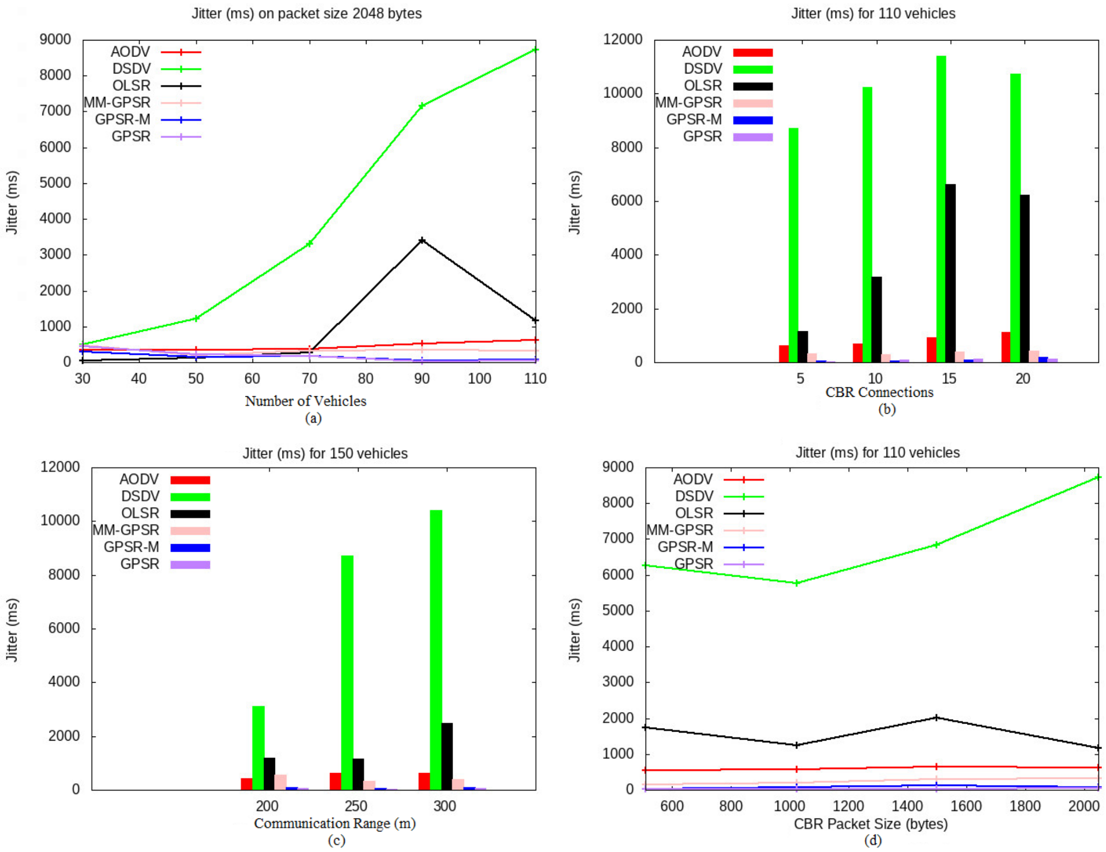

Figure 8. Jitter results on various network parameters.

Jitter is defined as the time gap between when a packet is expected to arrive at the sink and when it arrives. Milliseconds(ms) is the measurement unit of Jitter. Figure 8 shows the variance in Jitter on different network conditions. Figure 8(a) is plotted with node density and Jitter (ms). It shows that DSDV has the highest Jitter in all cases, but OLSR performance is degraded only when node size is greater than 70. GPSR-M gives the best performance, followed by GPSR, MM-GPSR, and AODV. It is also being observed that as we increase node density, Jitter is also increased for all protocols. Figure 8(b) investigates the impact of CBR connections on Jitter. It shows that when connections are 5, all protocols show low Jitter except DSDV, but an increment in the number of CBR connections also causes increments in Jitter value. GPSR-M gives the best performance in most cases, followed by GPSR, MM-GPSR, AODV, OLSR, and DSDV protocol. It is visible from Figure 8(c) that on 200 meters range, the Jitter is low, and as we increase the transmission range, the Jitter value of all state-of-the-art protocols improves steadily except the DSDV protocol. GPSR provides the lowest Jitter, followed by GPSR-M, MM-GPSR, AODV, OLSR, and DSDV protocol. DSDV performs worst in all scenarios. Figure 8(d) depicts the graph of Jitter vs. packet size. It shows that as the packet size gets larger, the Jitter of DSDV increases. The Jitter of GPSR, GPSR-M, and MM-GPSR is not affected too much, but OLSR varies between 1200 ms to 2000 ms.

6.6 Throughput

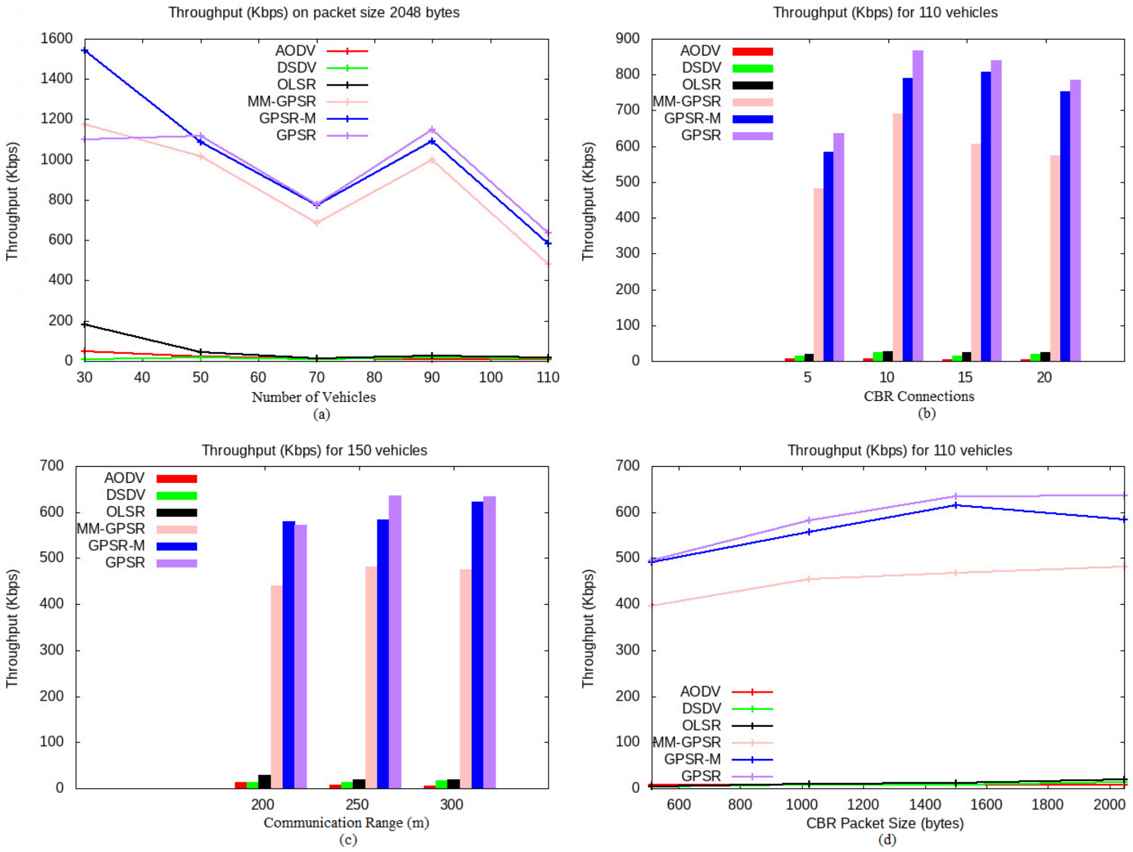

Figure 9. Throughput results on various network parameters.

Throughput is stated as the "number of packets that reach the sink out of the total packets transmitted by sources nodes". Kbps is the measurement unit of it. Figure 9 investigates the impact of vehicle density, connections, range, and packet size on throughput for the state-of-arts protocols. It is observed from Figure 9(a) that throughput starts decreasing when the density of the vehicles increases. PBR protocols before better and provide higher throughput than TBR protocols in various vehicles density scenarios, consistent with the results of other studies (Singh et al., 2021a). On 20–40 vehicles density, GPSR-M achieves higher throughputs, followed by MM-GPSR, GPSR, OLSR, AODV, and DSDV. As the vehicle's density increases, GPSR outperforms all protocols. Figure 9(b) indicates that GPSR and its enhancements have the highest throughput on all CBR connection scenarios. When the number of CBR connections reached 10, all protocols' throughputs improved as well. But when the number of connections is increased up to 15, throughputs start decreasing. GPSR provides the highest throughputs, followed by GPSR-M, MM-GPSR, OLSR, DSDV, and AODV. Figure 9(c) depicts that geographical protocols perform better than topological protocols in scenarios of all communication ranges. Throughputs of GPSR and its enhancements increase as range increases. GPSR-M has the highest throughput at 200 meters, but GPSR outperforms all other protocols when ranges increase. Figure 9(d) depicts the graph of throughput vs. packet size. The throughput of all protocols improves as packet size grows. GPSR provides the highest throughput and optimal performance in 2048 Bytes packet size scenarios.

7. Conclusion

High-speed and unpredictable topologies challenge the design of appropriate routing algorithms for VANET based medical monitoring. This paper shows how routing protocols can be used and resolve communication-related issues in emergencies using VANET. This paper briefly explained the WBAN and VANET based health monitoring framework and research challenges in health monitoring applications. Routing approaches have been explained to support health monitoring in different applications like disaster-prone areas or smart cities. Authors have described the role of routing protocols and compared the performances of topology-based routing protocols like AODV, DSDV, OLSR, and position-based routing protocols like GPSR, MM-GPSR, and GPSR-M for health monitoring application perspectives. Authors have used Ubuntu 18.04 LTS operating system, NS3.23 Network Simulator, SUMO-0.32.0 Traffic Simulator for performance analysis. Our experimental results show that position-based routing protocols perform better than topological protocols in terms of throughput. AODV outperforms all protocols in PDR and PLR matrices. GPSR and its enhancements required more hop count than OLSR. DSDV and AODV. Topology-based protocols show low AEED than GPSR based protocols but suffer from Jitter in high node density networks. Future works include developing improved position-based routing algorithms using Analytical Hierarchical Process (AHP) and fuzzy logic methods for faster PHI disseminations for specific applications in disaster-prone areas, Warfield, and smart cities.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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