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W-GeoR: Weighted Geographical Routing for VANET's Health Monitoring Applications in Urban Traffic Networks

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ABSTRACT: Natural disasters like earthquakes and tsunami could destroy the existing infrastructure-based communication system. IoT-based health monitoring is not possible in such scenarios. Therefore, there is a need for other resilient health monitoring frameworks to provide consistent health monitoring without depending on existing communication platforms. Wireless Body Sensor Network (WBSN) based health monitoring utilizing Vehicular Ad-hoc Network (VANET) as a communication medium could be a handy solution for transmitting patients' health information to the nearest ambulance or hospital in emergencies or disaster-prone areas. Casualty rates can be reduced significantly by providing emergency treatment to injured patients within a stipulated time. VANET's health monitoring applications are time-critical; therefore, designing a stable and efficient routing algorithm is a significant research challenge. Over the years, the researchers proposed many routing solutions to minimize the delay for critical applications. This paper proposed a Weighted Geographical Routing (W-GeoR) for VANET's health monitoring applications focusing on next-hop node selection for faster vital signs dissemination to facilitate post-disaster health monitoring in urban traffic environments. The proposed protocol utilized traffic-aware information including traffic mobility, inter-vehicle distances, speed differences, communication link expiration time, channel quality, and proximity factors for optimal next-hop node selection procedure. W-GeoR is tested on a post-disaster scenario created with SUMO-0.32 and NS- 3.23 platforms. Simulated results confirm that W-GeoR performs better than the existing state-of-the-art protocols.

INDEX TERMS: VANET, health monitoring, disaster management, geographical routing, GPSR.

I. INTRODUCTION

The devastating consequences caused by cataclysmic events show the weakness of existing communication technologies and demonstrate the requirement for reliable and versatile post-disaster health monitoring and treatment networks. Such a communication framework's primary assignment is to transfer a patient's Physical Health Information (PHI) for locating and providing emergency treatments than other salvage and recuperation work. Finding a critically ill or injured person, sending an ambulance with sophisticated life-saving equipment, and providing emergency treatment are critical challenges in saving patients' lives. Tragically, network availability to perform the location and assortment of valuable data cannot be ensured during or post-disaster. Infrastructure-based network connectivity is unpredictable due to power supply failure and unexpected obliteration of the cellular network's base stations, optical fiber connections, and wireless access points. Many research works have concentrated on designing a health monitoring framework to address the challenging connectivity issue.

An ad-hoc network is formed by a group of nodes that communicate wirelessly without fixed infrastructure. VANETs and WBSN are ad-hoc networks that can operate without the support of any centralized management. WBSN with VANET can provide remote health monitoring in case of the unavailability of traditional communication networks [1]. WBSN has made it conceivable to deploy bio-medical sensors on or around the patient's body and observe vital

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signs like an electrocardiogram, body temperature, blood pressure, SpO_2 level, heartbeat, etc. VANET provides wireless communication capabilities between running vehicles by using dedicated short-range communication (DSRC). DSRC is a wireless technology based on IEEE 802.11p wireless standard and is specially meant for VANET. DSRC provides high-speed and secure communication between the vehicle and roadside infrastructures.

VANET has attracted academia, researcher, and automobile industries to provide different types of advanced traffic applications related to road safety and convenience. VANET's safety applications generate a warning message to alert the drivers about road accidents, traffic jams, road repair work, emergency breaking, ambulance path clearance requests, and the presence of police checking. VANET's comfort and commercial applications provide the services like automatic toll collection, parking availability notifications, traffic jams broadcasting, nearby restaurants, shopping malls, movie theater announcements, providing a hotspot for watching movies and playing video games while traveling [2][3]. Academia and industries are now focusing on providing health monitoring of drivers, passengers, and others to provide medical assistance in emergencies. Focusing on remote health monitoring without traditional communication systems, several research projects are running in industries. Different kinds of sensors like air pressure sensors, rain sensors, cameras, front and back radars, and global positioning systems (GPS) are installed in vehicles. This equipment is connected to an onboard unit (OBU) attached at the top of the vehicle to form a portable computer [4].

OBU enables communication with other OBUs and roadside units (RSU). An RSU refers to a fixed infrastructure installed alongside the road. It provides connectivity among vehicles and other functions like broadcast, channel allocation, data dissemination, hand-off, vehicles localization, routing, multi-hop communication etc. It allows access to application services provided by different vendors and provides a further connection to the central control room. Therefore, RSU may works like a base station in cellular network and helps in all types of vehicular communications. Three types of vehicular communications are possible in VANETs, including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and, vehicle-to-everything (V2E) [5]. Due to the higher mobility of vehicles and unpredictable network topologies, designing a PHI dissemination-focused routing protocol is challenging in the vehicular environment. Frequent connection breakages and massive packet dropping are common issues here. It is caused by outdated beacons received among vehicles because of frequent topology changes in VANETs [6]. Researchers have proposed several routing approaches to deal with these issues in a vehicular environment. As vehicle movement is restricted by road and junction topologies, routing protocols using GPS-based location services and road map knowledge are considered a better choice for making routing decisions in VANETs [7]. Fig. 1 illustrates the VANET health monitoring architecture.

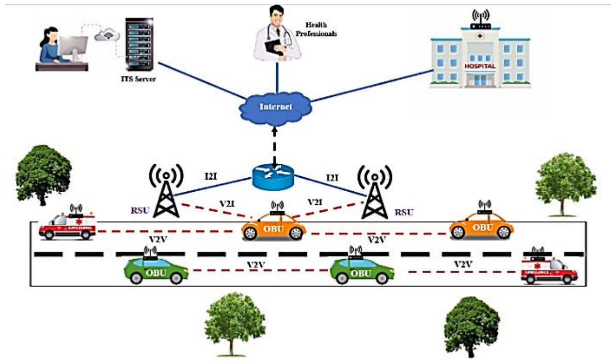

FIGURE 1. VANET Health Monitoring Architecture

II. MOTIVATION

Nowadays, emergency healthcare system demand cannot be underestimated due to many natural and human-made disasters. Over the past decades, transportation and telecommunication networks have seen tremendous progress. Both transportation and telecommunication systems play crucial roles in responding to emergencies and minimizing casualties. Traditional telecommunication system fails or becomes unserviceable when a disaster hits a city. The panic sets in, and inured people could not access the emergency treatments. In such circumstances, WBSN based health monitoring through VANET could be an alternative mechanism for providing emergency healthcare facilities in disaster-prone cities and areas. Due to complicated and frequent changing network topology, and regular network fragmentations, routing in VANETs poses numerous limitations. The efficient routing pathway between mobile nodes for the transmission of information has remained an issue. The Geographical Routing Protocols (GRP) are more acceptable for VANET as the new vehicles are integrated with navigation systems. GRP relies on the knowledge of the geographical location of the source, neighbors, and destination vehicles. Geographical-centric information dissemination approaches always select a neighbor as a next-hop node closer to the destination node from their neighbor list.

Many position-based routings protocols have been proposed based on greedy forwarding in literature [8], but greedy forwarding does not perform well, especially in sparse vehicular traffic networks. There is a possibility of routing loops if the current node does not find any neighbor node closer to its destination. Routing loops frequently occur in a sparse dynamic vehicular environment and can be broken by the right-hand or perimeter forwarding approach [9]. A geographical routing protocol must be aware of frequent link disconnect issues, and it must consider other relevant routing information. In this context, this paper aims to propose a novel Weighted Geographical Routing (W-GeoR) for VANET's health monitoring applications. W-GeoR uses the Analytic Hierarchy Process Method (AHPM)

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to estimate the weight value to select the best next-hop node to forward the packet successfully to the destination.

Further, with the help of multiple routing metrics such as node mobility, link expiration time, channel SNR, and proximity information of neighboring vehicles, we can evaluate the performance of the proposed protocol. These routing metrics help in establishing an enhanced multi-hop routing path with an efficient forwarding policy. The main contribution of this paper can be summarized as follows:

- The detailed framework of post-disaster WBSN based health monitoring using VANET is presented.
- PHI dissemination-centric AHP-based weighted geographical routing algorithm, W-GeoR, is explained in detail. It utilizes greedy forwarding and perimeter forwarding techniques for faster data transmission as required in emergencies.
- The mathematical evaluation of the proposed W-GeoR is presented using the node mobility, link expiration time, channel SNR and proximity information of neighboring vehicles for calculating weight value for the next-hop node selection process.
- Finally, we have simulated the proposed work on routing metrics like the number of lost packets, throughputs, mean delay, packet delivery ratio, and the number of hops by performing simulation using SUMO and NS-3.23 simulators.

The rest of the paper is structured as follows. Section 3 discusses the background and related works of the existing health monitoring routing framework and used protocols. Section 4 describes the working of the proposed W-GeoR protocol. Section 5 discusses the simulation environment, setup, and results of the proposed work. Finally, section 6 presents the conclusion and future work.

III. BACKGROUND AND RELATED WORKS

Intelligent Transportation System (ITS) is the need of the present vehicular networks as excessive utilization of private vehicles has increased the number of casualties that occur due to road accidents. These casualties require consistent checking of fundamental signs on standard premises. In a crisis, emergency treatments can be provided to save a patient's life. Today, individuals are worried about their wellbeing and want to screen their health parameters even during traveling. Patients' vital signs should be shipped rapidly to a clinic or wellbeing expert to save injured or critically ill patient's life. This kind of medical monitoring requires IoT based health monitoring framework, which assists in remote health monitoring using bio-medical sensors. Bio-medical sensors require nearby Wi-Fi access points to transmit sensed data to the dedicated server or intended users, but traditional internet facilities do not work well or may be unavailable in natural disasters. In such scenarios, if the vehicle can sense vital sign data and communicate it to a close-by rescue vehicle or medical clinic, then proper therapy can be given by medical experts without wasting time in further vital testing. An ambulance plays a crucial role in medical science and crisis response programs in an emergency. An ambulance may act as a life-saving vehicle in critical health issues, such as heart failure, injury, respiratory difficulty, etc.

Although it becomes challenging to get timely treatment if it is caught in traffic congestion or long distances to the hospital [10]. In such circumstances, after consulting experienced physicians, the doctor inside an ambulance should provide emergency medication. In order to provide quick treatment and care in emergencies, patient health records must be forwarded easily. Many routing protocols for data dissemination have been proposed to speed up the transmission of PHI data among the relevant authorities [11][12]. Most traditional VANET routing protocols are not more suitable in health monitoring applications due to the high speed of nodes and frequent topology changes. Routing algorithms significantly impact the coverage, interference, and transmission delay of wireless ad-hoc networks. The impact of different routing strategies on the interference generated in a distributed ad-hoc network with power control is investigated in the paper [13].

Developing efficient routing for health monitoring applications in VANET is still a research challenge. Therefore, various enhancements of present routing protocols have been considered for PHI dissemination [14]. Noshadi et al. proposed an evaluation of VANET for collecting patient pre-recorded PHI data and reconfiguring patient's medical wearable body vests to select the data as per physician's requirements [15]. This work discussed the used medical monitoring platform and infrastructure, software components, and architecture assuming that patient is wearing a light-weight body net consisting of the different sensors for measuring PHI parameters. Mica-2 is used as a processing and gateway unit here. Pocket PC and smartphone are used as on-body terminals to collect the sensed data from the sensors broadcasted by processing unit Mica-2 attached to the wearable system. Optimized Link State Routing (OLSR) routing algorithm was used for data forwarding to the hospitals [reference].

To monitor the patient's healthcare constantly and collect the patient's PHI data, VANET and WBSN for the healthcare monitoring system have been investigated [16]. The WBSN collects PHI data, and VANET assists medical professionals in alerting smart vehicles or ambulances and sending an ambulance to the patient's location using efficient routing. A Smart Vehicular Ad hoc Network (SVANET) [17] architecture is proposed, utilizing wireless sensors for event detections and vehicles to disseminate safety and non-safety messages. It uses different sensors which were fitted inside vehicles. SVANET proposes a priority-based data grouping in which different cars can access different categories of data despite being in the same transmission range. SVANET uses weight-based leader selection algorithms to meet user demand for various data types and avoid message duplication in dense traffic conditions. In [18], an advanced WBSN-VANET architecture was implemented. The suggested architecture focuses on avoiding traffic accidents caused by the driver's

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inappropriate conduct. The WBSN was used to detect driver behaviors such as drowsy driving, drugged driving, driving while emotionally disturbed, and distracted driving, all of which can lead to traffic accidents. If driving is affected by the driver's state, warning notifications to the VANET will alert other cars and emergency services. Validation of the proposed work is performed in real driving environments. RCare [19] is introduced as a delay-tolerant, sustainable, and long-term healthcare system to collect confidential PHI from patients. RCare delivers network access to remote areas using traditional transport vehicles like cars and buses as relay nodes to minimize healthcare costs. Vehicles are assumed to store and forward the PHI to the city medical center using opportunistic routing. By offering rewards for cooperative vehicles, RCare increases network efficiency. It also includes identity-based cryptography to guarantee the PHI's protection and privacy during the routing process using short digital signatures and pseudo-identities.

VehiHealth [20] has suggested an emergency routing protocol for health monitoring applications in VANET. *VehiHealth* chose a path that had a minimum link broken problem between vehicles to a nearby hospital. It considers the lowest neighboring intersection value (*Ivalue*) as a forwarding mechanism. It is based on several factors such as the minimum length path from the current node to the hospital, the number of link breakage, waiting time in forwarding packet from one intersection to other and vehicle steadiness between these intersections. *VehiHealth* uses a link breakage recovery method in a sparse density network and selects a highly connected with low delay connection as the next path. However, *VehiHealth* performance may reduce due to the unavailability of vehicles between the junctions.

Bhoi *et al.* [21] proposed a routing protocol to support non-safety applications for urban VANET wherein the players at different parking lots can join a game server and play multi-player games. The objective of the proposed protocol is to transfer the online game data to the desired server within a minimum time.

A fuzzy logic-based Cluster Head Selection Algorithm (CHSA) [22] is developed for cluster head selection. It states that routing parameters related to network conditions, user preferences, and application-specific requirements must be considered for the next-hop node selection procedure. The key routing parameters like speed, acceleration, distance, and path information are taken into account as inputs for optimizing the selection process for cluster heads.

La et al. [23] proposed a framework called relay-assisted diversity systems to improve wireless communication among heterogeneous nodes. It utilized the node positions, radio link characteristics, power allocation, distributed coding, and constellation signaling and diversity methods. Frame error probability (FEP) power allocation method is developed and compared with existing destination-balanced and relay-balanced power allocations.

Enhanced Weight-based Clustering Algorithm (EWCA) is proposed by Tambawal et al. [24] to provide reliable delivery of VANET safety applications. EWCA addresses cluster formation and maintenance. The authors considered only those vehicles with the same road ID, same road segments, and the neighbor's communication to fit the cluster formation for safety message dissemination. A predefined weight value based on its importance was correlated with each car. A vehicle with the highest weight value was elected as the primary cluster head. The secondary cluster head is used as a backup to the primary cluster head to improve the cluster stability. It took over only when the primary cluster head is not found suitable for safety message disseminations.

Bhoi et al. [25] proposed a routing protocol that employs information from the metropolitan road network, such as multi-lane and flyover, to transport data to the target with the shortest possible packet forwarding latency. RSU calculates a path value for each path linked to a junction and chooses the next path for data forwarding. To improve routing performance, the proposed protocol employs Ground Vehicle to Ground Vehicle (GV2GV), Flyover Vehicle to Flyover Vehicle (FV2FV), and Flyover Vehicle to Ground Vehicle/Ground Vehicle to Flyover Vehicle (FV2GV/GV2FV) communication.

Zanella *et al.* [26] developed two opportunistic relay selection mechanisms based on the channel characteristics at the relay side. For each suggested relay selection method, an analytical framework was developed to evaluate the average number of available relays. Under the premise that relay nodes are distributed according to a poisson point process, the performance of the two selection techniques is analyzed in terms of outage probability and average attainable rate. An asymptotical analysis was also offered to calculate the outage probability and average performance limitations in the case of infinite node density.

Geographical routing protocols assume that GPS devices have been installed and do not use routing tables or store routes for the entire network [27]. These protocols select the next-hop neighbor based on the position information of their neighboring nodes and destination nodes. Various studies show that geographical routing protocols are more suited for VANETs health monitoring applications [28][29]. Therefore, we have focused on developing enhanced geographical routing protocols for VANETs health monitoring perspectives.

Greedy Perimeter Stateless Routing (GPSR) [30] is a position-based routing protocol that forwards the packets to the neighboring node geographically nearer to the destination. GPSR assumes that participating nodes are equipped with GPS to calculate the geographical distance of neighboring nodes. GPSR uses greedy forwarding and perimeter forwarding technique to transmit the data to immediate neighbors. GPSR sends the Hello packet periodically to obtain the geographical location of its neighbors. It reduces hop count and transmission delay during packet transmission. It gives better performance even if there are topological changes in the dynamic networks. It suffers from local maxima and has specific shortcomings

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because of too much consideration on distance only. Moreover, it does not count speed difference, the direction of neighbors, and link reliability. Greedy forwarding causes routing hole problems in the network.

In VANET, nodes are highly dynamic, causing frequent topology changes, eventually turning the greedy forwarding incorrect. Therefore, the selected next-hop node by greedy forwarding may have moved out from the communication range before receiving the packet in such a situation. This greedy forwarding failure causes the invocation of perimeter forwarding to building redundant routing paths, leading to increased network load.

Max duration-Minangle GPSR (MM-GPSR) was proposed in the paper [31]. It employs new greedy forwarding techniques that consider the stability of neighbor nodes in a communication area controlled by a λ parameter. Vehicles within this zone will only receive packets, and the node with the highest stability will be chosen as a relay node. When greedy forwarding fails, MM-GPSR uses the concept of a minimum angle to find the next-hop node. The MM-GPSR recovery mode divides the plane into two parts based on the actual node and destination positions, and the minimal angle value is used to determine which neighbor node will be chosen as the next-hop node. Due to the uncertain behavior of the MM-GPSR for greedy forwarding, it utilizes the permitted communication area Q, and the cumulative communication duration T between the nodes, which are dependent on the values of λ and T will cause packets to be routed differently.

The work presented in paper [32] examines the benefits and drawbacks of GPSR and proposes a Greedy Perimeter Stateless Routing protocol based on Weight Gradient (GPSR-WG) that improves link risk degree. Multiple routing criteria, such as direction, distance degree, link risk degree, and normalized speed factor are taken into account by GPSR-WG to improve greedy forwarding for health monitoring applications. GPSR-WG applies a weighted gradient to these criteria when selecting the next-hop node within the communication range to maximize routing performance. Several position-based routing protocols are evaluated for network performance for various applications and scenarios in the literature [33]. However, none of the routing protocols, to our knowledge, highlight the importance and impact of these protocols in health monitoring applications. Therefore, we have presented a significant improvement in the well-known GPSR protocol for health monitoring applications in post-disaster scenarios of urban vehicular environments. Further, we have used the existing routing protocols like GPSR, GPSR-WG, and MM-GPSR protocols for faster information dissemination and compare their performance with the proposed W-GeoR routing protocol.

IV. SYSTEM MODEL AND PROBLEM FORMULATION

A. SYSTEM MODEL

In post- disaster scenarios, VANET could support the healthcare system in which an ambulance can play a crucial role in saving lives. Ambulance acts as a medium to send and receive information from the nearby hospital in disaster-prone areas. The ambulance doctor sends the patient's current vital sign data to a nearby hospital for the desired treatment in an emergency. In Wireless Body Area Network (WBAN) based VANET healthcare system, patients' vital sign data is sensed by different biomedical sensors like EEG sensors, ECG & Heartbeat sensor, SpO_2 sensor, Blood Pressure, and Temperature measuring sensor. All these sensed data is processed and transmitted by Body Control Unit (BCU) to the OBU installed at the top of the vehicle through Bluetooth or Zigbee technology [15]. OBU will transmit the collected PHI to the nearest RSU or control room through VANET routing protocols forming V2V communication. The PHI is transmitted to the healthcare units by the roadside units.

The medical professionals make decisions in response to the received PHI and sent the PHI to the nearest hospital or ambulance with immediate effect. The nearest ambulance is transported with life-saving equipment at the patient's site, and it completes the process of testing and practical on patient health through an intelligent health monitoring system [35]. Fig. 2 represents the entire system model.

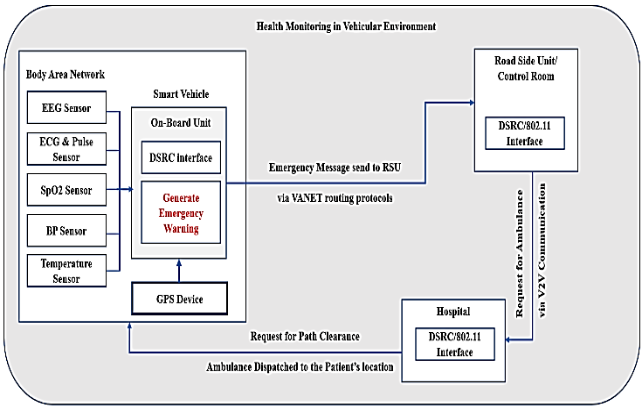

FIGURE 2. **System Model used for W-GeoR Protocol** [34]

Algorithm 1 reparents the workflow for generating emergency signals in case of PHI abnormality sensed by any sensor node. BCU communicates with OBU in emergencies only. Now OBU tries to establish an ad-hoc communication with running vehicles to disseminate the warning messages to the nearby RSUs.

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Algorithm 1: Procedure of generating an emergency signal

```
Computes PHI values of all sensors;
Listen to BCU;
if (BCU is idle)
{
if (idle_time>= threshold_Time)
{
if (PHI >Standard_PHI)
{
BCU communicates with OBU using IEEE 802.15;
OBU calls Next-hop_Selection_Process (Source IP_address, Destination_IP address);
}
}
else
Sensors go to sleeping mode;
}
```

The main issue with VANET is that vehicles are highly mobile with random speed and have limited communication range. High-speed mobilities cause frequent link breakage problems in VANET. Therefore, frequent link breakage causes packet drop and further increases the delay in forwarding the data to the medical professionals at the hospital. Moreover, frequent topology changes and link breakage cause routing of data in the network. In case of emergency in disaster-prone areas or in an urban traffic environment, packet forwarding without delay should be timely. Therefore, in such a situation, an effective and efficient routing protocol can play an important role. To overcome these packet delays and routing issues, we have s proposed a W-GeoR protocol aiming to forward the PHI to the nearest hospital quickly and successfully. W-GeoR could be the solution for heath monitoring using VANET where traditional communication either failed or not functioning correctly in disaster-prone areas. W-GeoR disseminates the PHI through the stable path, where vehicles have maximum link expiration time in the neighbor's communication range. It considers only those vehicles as candidates for next-hop nodes moving towards hospitals and having high neighbor's density. The proposed protocol has been analyzed mathematically using performance-centric parameters such as node mobility factor, progress towards the destination, speed differences, link expiration time, sound to noise ratio factor, and proximity factor. Further, these parameters are used to determine the weight value for selecting the best next-hop node for further packet transmission to the intended destination. The proposed protocol is simulated through the well-known simulation tool NS-3.

B. ASSUMPTIONS AND NOTATIONS

To design the proposed model W-GeoR, we consider the urban vehicular traffic environment where traditional communication networks are not functioning caused by natural disasters. For the proposed W-GeoR protocol following assumptions have been made:

- Driver or patient possesses wearable sensors like EEG, ECG, EMG, and body temperature sensors in a wristband or jacket.
- Each vehicle in the network is equipped with digital maps and receive accurate position, velocity, and direction information through GPS.
- Source vehicles are aware of the destination's real-time geographical location.
- Vehicles have bidirectional communication capability within their communication range using DSRC.
- Link breakage between vehicles if the inter-vehicular distance between vehicles becomes larger than the communication range.
- Vehicles in the network area are uniformly distributed and can travel at different speeds.
- Patient health information (PHI) sensed by sensor nodes is handed over to gateway (mobile phone, or PDA), using Bluetooth or ZigBee technologies.
- Gateway hand over this information to the vehicle's OBU for further transmission to intended health services providers or hospitals.
- Vehicles and RSU have adequate storage to carry and forward the data. Vehicle and node are interchangeably used in the whole paper.

The basic notations used in this study are summarized in Table I:

TABLE I
Used notation

Notation	Meaning
S	Source Vehicle
NN_i	Neighbor Vehicle
D	Destination Vehicle
(X_S,Y_S)	Coordinate value of source vehicle S
(X_D,Y_D)	Coordinate value of destination vehicle D
(X_N,Y_N)	Coordinate value of Neighbor vehicle NN
$\vartheta_{S,N}^{D}$	The moving angle between source S and neighbor toward the destination
$Dist_{(S,N)}$	Distances between source vehicle to neighbor vehicle
$(l_{S,N}^{(D)})$	Neighbor's progress towards the destination
$Dshort_{(S,D)}$	Shortest distance between the source and destination vehicles
$Speed_{N_i}$	Speed of neighbor vehicle
$SD_{(S,N_i)}$	Seed differences between Source vehicle and neighbors.
W_{MA}	The relative importance of moving angle
W_P	The relative importance of progress of neighbor vehicle towards the destination
W_{SD}	The relative importance of speed differences between the source node and neighbors
R_v	Vehicle's communication range
$£_{(S,N)}$	Link expiration time between source and neighbor vehicle
NMF_i	Node mobility weight factor

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Notation	Meaning
θ_s	Source velocity angle
SNR	Sound to noise ratio
P_{signal}	Average signal power
P_{noise}	Average noise power
Φ	Proximity factor
$W_{s,i}^{(D)}$	Overall weight gradient
$RREQ$	Rout request
W_{Mob}	The relative importance of node mobility factor
W_{ExpT}	The relative importance of link expiration time
W_{snr}	The relative importance of link SNR value
W_{Prox}	The relative importance of destination proximity information
AHP	Analytical hierarchical process
abs ( )	Absolute value function

V. OVERVIEW OF WEIGHTED GEOGRAPHICAL ROUTING (W-GEOR) PROTOCOL

W-GeoR is a unicast-based geographical routing protocol specially designed for VANET health monitoring applications in urban VANETs environments. The proposed routing protocol is based on the routing metrics such as vehicle mobility information, link expiration time, channel SNR information, and destination proximity information between the source node and the destination node. W-GeoR enhanced the next-hop node selection mechanisms of the widely used geographical routing protocol, GPSR. Each vehicle records the position, velocity, and SNR value information of the immediate neighbor in its neighbor table. This table is updated by information received from periodic beacon packets. After receiving the beacon packets, the source node estimates the distance factor between source and destination vehicles, source and destination vehicle's speed differences, moving angle, link expiration time, channel SNR value, and destination proximity factor. W-GeoR stores this information along with the rest of the neighbor's information. This information is kept in the transmitted beacons' header. Analytical hierarchical process (AHP) is used to estimate the weight for the next-hop node decision-making process, utilizing the above routing metrics. Finally, in W-GeoR, the current node forwards the packet to the neighbor node with maximum weight. If the packet carrier node faces the optimum local problem, i.e., it has the least weight among its neighbor nodes, then the packet is switched to the perimeter mode of routing until a neighbor with more weight is encountered. We have implemented the W-GeoR protocol in the NS-3.23 simulator and have followed the implementation of GPSR as in [36]. Fig. 3 shows an enhanced forwarding algorithm of W-GeoR for the route establishment and PHI transfer phase in health monitoring through VANET. The AHP process used for weight estimation is presented in Fig. 4. The detailed procedure for next-hop node selection for the W-GeoR protocol is explained below.

A. NEXT NEIGHBOR NODE SELECTION PROCEDURE

Due to the highly dynamic nature of VANETs, the selection of the next forwarding vehicle based on a single routing metric like distance or velocity can cause frequent connection breakages. Well-known GPSR utilizes the greedy approach and only considering the distance between neighbors and destination node, leading to frequent recovery modes. Therefore, multiple routing metrics can contribute in a better way to improve overall networking performance by searching for an efficient routing path towards the destination vehicle. W-GeoR can work more efficiently than GPSR. The following sub-section explained the routing metrics used in the W-GeoR protocol for the next-hop node selection procedure.

1) NODE MOBILITY FACTOR (*NMF*)

VANET is different from other networks due to its unique characteristics. The most important characteristic is the high mobility of vehicular nodes, and it must be considered when designing and evaluating any routing protocol. Because for routing, mobility of nodes plays a vital role while making routing decisions. The proposed W-GeoR protocol considers the following metrics to evaluate node mobility factor:

- The moving angle between source and neighbor vehicle towards the destination,
- Progress of the neighbor towards the destination
- Speed differences between source and neighbors

Description of used metrics in the calculation of node mobility factor is given as follow:

- CALCULATION OF NEIGHBOR'S MOVING ANGLE

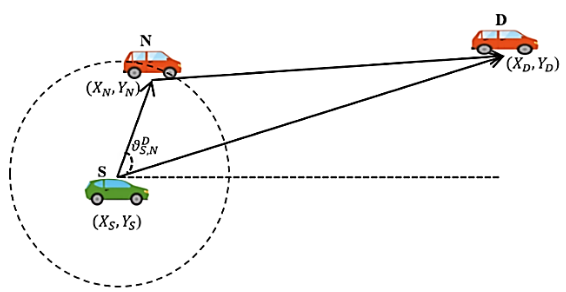

FIGURE 3. **The Direction of Neighboring Vehicle**

In a position-based routing protocol, moving direction of the neighbors towards the destination is very crucial. If the forwarding decision does not consider the moving angle, then the neighbor moving in the opposite direction of the destination may be selected as the next-hop node, leading to recovery mode. The direction of neighbors minimizes the routing loops and reverses transmissions. The W-GeoR protocol considers the moving angle between the source vehicle *S*, the neighbor *N*, and the destination vehicle *D* as the standard for measuring index. Assume, at any time *T*, the coordinate of source vehicle *S*, neighbor vehicle *N*, and destination vehicle *D* are (X_S, Y_S), (X_N, Y_N), and (X_D, Y_D), respectively. Moving angle $\vartheta_{S,N}^D$ between source and neighbor toward the destination can be attained by the following equation [37]:

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$$\vartheta_{S,N}^{D} = arccos \frac{(X_D - X_S)(X_N - X_S) + (Y_D - Y_S)(Y_N - Y_S)}{\sqrt{(X_D - X_S)^2 + (Y_D - Y_S)^2}\sqrt{(X_N - X_S)^2 + (Y_N - Y_S)^2}} \quad (1)$$

If a neighbor is moving towards a destination, then $\vartheta_{S,N}^{D}$ is positive and increases the overall weight value. If the neighbor moves in the opposite direction, then $\vartheta_{S,N}^{D}$ will be negative and reduces the weight value.

- CALCULATION OF PROGRESS DISTANCE TOWARDS THE DESTINATION

W-GeoR protocol assumes that each node knows its own and destination's up-to-date position and direction information by utilizing Hello packet and GPS location services. W-GeoR considers the neighbor's progress towards the destination as a routing parameter in the next-hop node selection decision. The procedure of considering progress towards destination factor ($l_{S,N}^{(D)}$) in finding the next-hop neighbor vehicle is presented in Fig. 4.

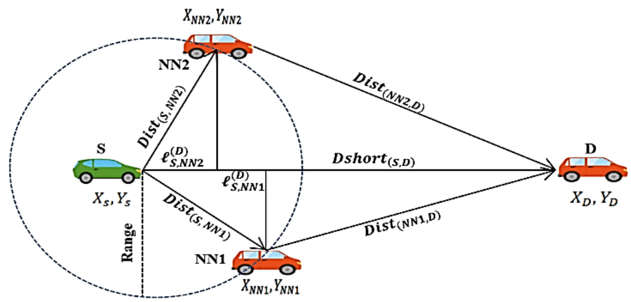

FIGURE 4. **Progress towards destination**

Line segment *SD* joining the source and the destination is drawn to project vehicles *NN1* and *NN2*. The shortest distance between the source and destination vehicles is denoted by $Dshort_{(S,D)}$ whereas $Dist_{(S,NN1)}$ and $Dist_{(NN1,D)}$ denote the distances between source to neighbors *(NN1, NN2)* and between the neighbor to destination, respectively. $l_{S,NN1}^{(D)}$ and $l_{S,NN2}^{(D)}$ are the progress of vehicles *NN1* and *NN2* from the source vehicle toward the destination. It can be evaluated as given below [38]:

$$l_{S,N}^{(D)} = \frac{Dist_{(S,D)}^2 + Dist_{(S,N)}^2 - Dist_{(N,D)}^2}{2 \times Dist_{(S,D)}^2} \quad (2)$$

where,

$$Dist_{(S,D)} = \sqrt{(X_D - X_S)^2 + (Y_D - Y_S)^2} \quad (3)$$

$$Dist_{(S,N)} = \sqrt{(X_N - X_S)^2 + (Y_N - Y_S)^2} \quad (4)$$

$$Dist_{(N,D)} = \sqrt{(X_N - X_D)^2 + (Y_N - Y_D)^2} \quad (5)$$

Hence, the vehicle with the maximum progress towards the destination will be selected as the next forwarding vehicle. Fig. 4 represents that as per the progress factor consideration, vehicle *NN1* would be preferred as a forwarding node rather than *NN2*.

- SPEED DIFFERENCES CALCULATION

In the case of safety and health monitoring applications, it is crucial to send information in a time-bound manner. Speedy vehicles can transmit this information in a faster manner than slower vehicles. If (X_S, Y_S) and (X_{N_i}, Y_{N_i}) are the coordinate of the velocity vector of source *S* neighbor node N_i, then speed differences ($SD_{(S,N_i)}$) between them can be calculated by the following formula:

$$Speed_S = \sqrt{X_s^2 + Y_s^2} \quad (6)$$

$$Speed_{N_i} = \sqrt{X_{N_i}^2 + Y_{N_i}^2} \quad (7)$$

$$SD_{(S,N_i)} = abs(Speed_{N_i} - Speed_S) \quad (8)$$

Vehicles having high-speed differences are chosen firstly than slower vehicles and improves the weight value. Thus, the impact of node mobility factor on the next-hop node selection decision for the W-GeoR routing protocol can be calculated by the following equation:

$$NMF_i = \vartheta_{S,N}^{D} \times W_{MA} + l_{(S,NN)_i}^{(D)} \times W_P + SD_{(S,N_i)} \times W_{SD} \quad (9)$$

Here, W_{MA} indicate the relative importance of moving angle between source and neighbor vehicle towards the destination, W_P indicates the relative importance of progress of neighbor vehicle towards destination and W_{SD} indicates the relative importance of speed differences between the source node and neighbors.

2) Link Expiration Time (LET) Calculation

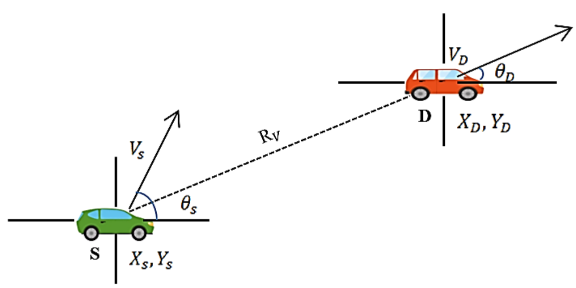

FIGURE 5. **Calculation of Link Expiration Time**

In VANET, networks characterized by high mobility of vehicles, it is strongly recommended to consider the durability of the links when creating routing paths. A long duration of the link between the nodes makes the routing paths more efficient and functional for a long time [39]. Routing paths based on more durable links increase data transmission performance and reduce network maintenance costs. The LET ($£_{(S,N)}$) defines the duration for which a vehicle remains in the communication range of the sender. Thus, while selecting the next-hop node, a vehicle predicts the communication link expiration time with its neighbors based on the communication lifetime factor. Fig. 5 represents the concept of link expiration time.

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If we consider two vehicles *S* and *D*, with coordinates (X_S,Y_S) and (X_D,Y_D) are within each other's communication range denoted by R_v and having velocity angles θ_s and θ_D respectively, then the predicted LET between them can be computed as follows [40]:

$$£_{(S,N)} = arccos\frac{-(AB+CD)+\sqrt{(A^2+C^2)R_v^2-(AD-BC)^2}}{A^2+\ C^2} \quad (10)$$

Where,

$$A = V_s\ cos\ cos\ \theta_s\ -\ V_D\ cos\ cos\ \theta_D \quad (11)$$

$$B = X_s\ -\ X_D \quad (12)$$

$$C = V_s\ sin\ sin\ \theta_s\ -\ V_D\ sin\ sin\ \theta_D \quad (13)$$

$$D = Y_s\ -\ Y_D \quad (14)$$

Paths with a high LET value are considered the most appropriate because of link stability.

3) SIGNAL TO NOISE RATIO (SNR) FACTOR

For link quality assessment, every packet is tagged with an SNR value at the physical layer. This SNR packet tag is extracted at the routing layer during the Hello messages receipt. The position, velocity, and SNR information are stored in every node's neighbor table and then included in the next-hop node's weight calculation. The SNR is defined as the ratio of the power of a meaningful signal to the power of background noise [41].

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (15)$$

Here, P_{signal} is average signal power and P_{noise} is average noise power. Both signal and noise power must be measured at the equivalent points in a system and within the same bandwidth. A link that has a higher *SNR* value is preferred than the lower one. Higher *SNR* will increase the overall weight value used for the selection of next-hop node and routing decision.

4) PROXIMITY FACTOR CALCULATION

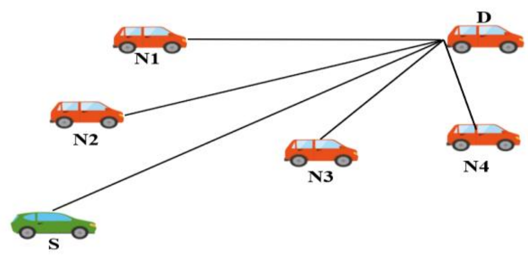

FIGURE 6. **Destination Proximity**

In order to reduce the transmission delay and routing hops of data packets, this paper introduces a new measurement factor: proximity. The proximity characterizes the distance between each vehicle and the destination vehicle in the ad hoc network. It can be seen from Fig. 6, *S* is the source vehicle, *D* is the destination vehicle, N_1, N_2, N_3 and N_4 are the numbers of other vehicles in the network.

The formula for calculating the proximity (φ) is given as follows:

$$\varphi = \frac{(Dist_{(S,D)} - Dist_{(N_i,D)})}{R_v} \quad (16)$$

Where, $Dist_{(S,D)}$ is the distance from the source vehicle to the destination vehicle, $Dist_{(N_i,D)}$ is the distance from any vehicle to the destination vehicle, and R_v is the vehicle's communication radius. As per equation 16, if the $Dist_{(N_i,D)}$ is smaller and $Dist_{(S,D)}$ is larger, then the destination vehicle will be closer, and the value of the proximity φ will be larger. Similarly, the vehicle's weight value will be high as calculated in the following sub-section.

5) WEIGHT VALUE CALCULATION

In the proposed protocol, source node *S* calculates the weight of neighbor node *i* towards destination *D* considering the important routing metrics as explained above, such as node mobility, link expiration time, link SNR value, and destination proximity information in the process of optimal next-hop node selection. The main motive of the W-GeoR protocol is to improve the routing performance as it is required to send PHI data promptly in case of emergency for health monitoring-related applications using VANETs. Weight value ($W_{s,i}^{(D)}$) is a weight function of used routing metrics which can be calculated by using the following equation:

$$W_{s,i}^{(D)} = NMF_i \times W_{Mob} +\ £_{(S,N_i)} \times W_{ExpT} + SNR_i \times W_{snr} + \varphi_i \times W_{Prox} \quad (17)$$

Where, W_{Mob} indicates the relative importance of node mobility factor, W_{ExpT} indicates the relative importance of link expiration time, W_{snr} is the relative importance of link SNR value and W_{Prox} indicates the relative importance of destination proximity information. In selecting the next forwarding vehicle, W-GeoR will select the vehicle that contains the maximum value in it as the next-hop node or next-hop forwarding vehicle. To measure the relative importance of the routing metrics mentioned above in the next-hop node selection decision of W-GeoR, we have chosen widely used Analytical Hierarchical Process (AHP) [42] techniques discussed in the following section.

B. EVALUATION OF RELATIVE IMPORTANCE OF THE ROUTING METRICS

W-GeoR protocol uses node mobility factor, link expiration time, link *SNR* value, and destination proximity information as discussed in the above sections. The relative importance of these metrics in the next-hop node selection procedure is calculated using the AHP, a mathematical tool developed by Thomas L. Saaty in the 1970s to solve complex decision-making problems in math and psychology. It divides the problem into a hierarchy of sub-problems and computes its criteria and alternative options. W-GeoR utilizes the *AHP*

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techniques to calculate all the neighbors' weight values and selects a vehicle as a forwarding vehicle with the maximum weight. The next-hop node selection problem is decomposed into a hierarchy of sub-problems to select an efficient forwarding node at the top of the hierarchy, as shown in Fig. 7.

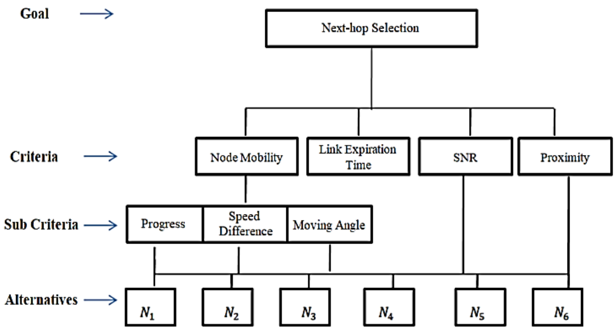

FIGURE 7. **W-GeoR's AHP technique hierarchical view**

The lower level of the hierarchy consists of decision metrics such as node mobility, link expiration time, link SNR, and destination proximity contributing to achieving the desired goal. The next level divides criteria into more detailed sub-criteria. The bottom level includes the neighbor nodes (N_1, N_2,...N_k) as decision alternatives to evaluate the source vehicle's communication range. Further, W-GeoR uses AHP that generates a weight for each evaluation criterion according to the decision maker's pair-wise comparison matrix. The higher the weight, the more important the criterion. In order to this, two comparison matrixes are created, one for criteria and one for sub-criteria, as shown in Table II and Table III. We have used GNU octave software [43] for calculating the relative ranking of the criteria and checking data consistency for the following pair-wise comparison matrix:

Table II
Pair-wise comparison matrix 1 for the criteria

	Node Mobility	LET	SNR	Proximity	Relative ranking of the criterion
Node Mobility	1	3	3	5	**0.49158**
LET	0.33	1	3	5	**0.29115**
SNR	0.33	0.33	1	3	**0.15024**
Proximity	0.20	0.20	0.33	1	**0.06703**

Table III
Pair-wise comparison matrix 2 for the sub-criteria

	Moving Angle	Speed Differences	Progress	Relative ranking of the sub-criterion
Moving Angle	1	3	5	**0.634**
Speed Differences	0.33	1	3	**0.260**
Progress	0.20	0.33	1	**0.106**

The consistency checking of aforesaid comparison matrices is also performed using the same tool to check whether it is consistent. In the proposed protocol comparison matrix *1* shows Consistency Ratio = 0.070805 < 0.1 and comparison matrix 2 shows Consistency Ratio = 0.028644 < 0.1 which depicts that both matrices are consistent.

C. W-GEOR PROTOCOL'S WORKING FLOWCHART AND ALGORITHMS

W-GeoR uses greedy forwarding with AHP and perimeter forwarding techniques for the next-hop node selection procedure. Fig. 8 demonstrates the working of the proposed W-GeoR protocol, where W-GeoR starts evaluating neighbor nodes to select a suitable next-hop neighbor with maximum weight value to reach the intended destination. Further, it uses an iterative process to calculate each entry's weight values from its neighbor table and select the appropriate neighbor with maximum weight. Suppose no such neighbor is found from the current forwarding vehicle list, then switched to recovery mode where it uses the perimeter forwarding technique of GPSR protocol, which uses the right-hand rule to select the next-hop node. During the greedy forwarding process, W-GeoR considers node mobility, link expiration time, link SNR, and destination proximity for next-hop node selection and routing decisions.

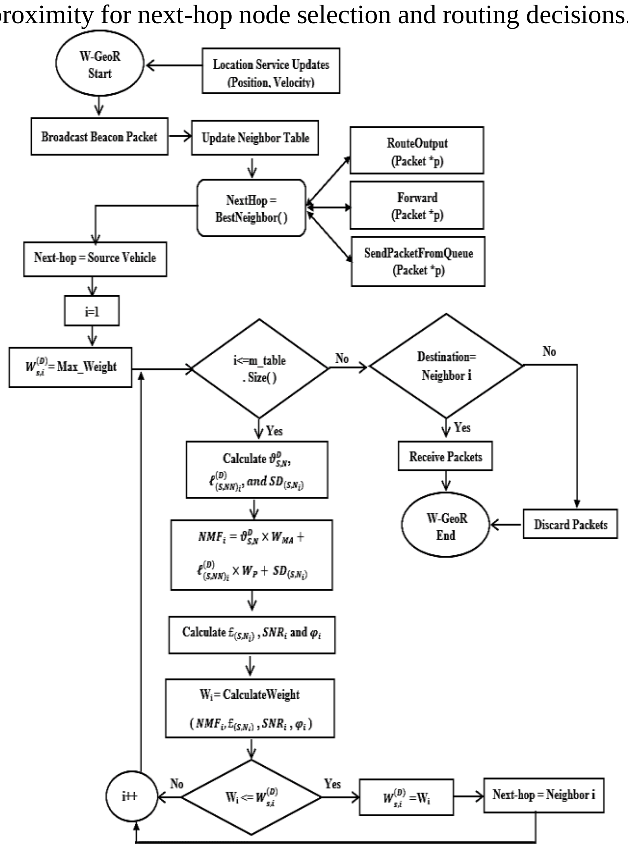

FIGURE 8. **Flow Diagram of W-GeoR Routing Protocol**

Algorithm 2 represents the pseudocode of the next-hop node selection and packet forwarding procedure of the proposed protocol. W-GeoR is utilizing GPS services that provide location coordinates and velocity information of vehicles. Before forwarding a packet, the source node initiates the W-GeoR protocol, which broadcast beacon packets to vehicles within the communication range and updates its neighbor

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table accordingly. This procedure further calls to the *CalculateWeight* procedure for measuring the relative weights of all the neighboring vehicles.

Algorithm 2: Next-hop Node Selection and Packet Forwarding Procedure

Input: Position and Velocity information of Sender and Destination
Output: The Next-hop IP
Notation:
- S: Source Vehicle
- D: Destination
- CFV: Current Forwarding Vehicle
- R_c: Communication Range
- Set_{CFV}: Set of neighbor vehicles within the Communication range (R_c) of the current forwarding vehicle.
- WF_{max}: Maximum Weight Factor
- NV: Neighbor Vehicle
- NHV: Next-hop Vehicle

Begin Algorithm 2
1. The source vehicle S generates data to send;
2. Let CFV = S;
3. CFV broadcast "Hello packet" to its neighbor vehicles
4. CFV node updates the NV Table
5. **if** (D ε Set_{CFV})
6. **{**
7. Direct link is available
8. CFV transmit the PHI data packet to vehicle D;
9. }
10. **else**
11. **{**
12. **for** i=1 to sizeof (Set_{CFV})
13. **{**
14. **calculate** WF*i* of all NV using *CalculateWeight*( );
15. **if** (WFi > WF_{max})
16. {
17. WF_{max} = WF_i ;
18. Set NHV = NV_i ;
19. **}**
20. **}**
21. **}**
22. Set CFV= NHV;
23. Repeat step 4 to 23 until the PHI packet reached the D;

End Algorithm 2

Algorithm 3 represents the pseudocode of calculating the weight value procedure of the W-GeoR protocol. The next-hop node selection function repeats through the neighbor table of the current node, and it calls the *CalculateWeight* procedure for each neighbor to return the optimal next-hop node. The *CalculateWeight* procedure is invoked for each neighbor vehicle and returns the neighboring node's weight based on the inputted routing information. Weight factors ($W_{Progress}$, W_{Speed}, W_{Angle}, $W_{Mobility}$, W_{LET}, W_{SNR}, and W_{Prox}) are initialized after evaluating AHP Consistency Ratio (0.070805) by using GNU octave software for the *CalculateWeight* procedure.

Algorithm 3: *CalculateWeight* Procedure

Input: Position, Velocity, Channel SNR information of Source, Current and Destination vehicle
Output: Weight Gradient
Notation:
- W_G: Weight Gradient value
- $W_{Progress}$: Relative importance of progress
- W_{Speed}: Relative importance of Speed Difference
- W_{Angle}: Relative importance of Moving angle.
- $W_{Mobility}$: Overall weight factor of vehicle mobility
- W_{LET}: Relative importance of Link Expiration Time
- W_{SNR}: Relative importance of Channel SNR
- W_{Prox}: Relative importance of proximity.

Initialization:
- W_G=0, $W_{Progres}$ = 0.106, W_{Speed} = 0.260, W_{Angle}= 0.634, $W_{Mobility}$ = 0.49158, W_{LET} = 0.2945, W_{SNR} = 0.067032, $W_{Proximity}$ = 0.15024;

Begin Algorithm 3
1. Calculate moving angle ($\vartheta_{S,N}^{D}$) by using equation (1);
2. Calculate progress towards destination factor ($l_{S,N}^{(D)}$) by using equation (2);
3. Calculate speed differences ($SD_{(S,N_i)}$) by using equation (8);
4. $NMF_i = \vartheta_{S,N}^{D} \times W_{Angle} + l_{(S,NN)_i}^{(D)} \times W_{Progress} + SD_{(S,N_i)} \times W_{Speed}$;
5. Calculate Link Expiration Time ($£_{(S,N)}$)by using equation (10);
6. Calculate *SNR* value by using equation (15);
7. Calculating the proximity (φ) by using equation (16);
8. W_G= $NMF_i \times W_{Mobility} + £_{(S,N_i)} \times W_{LET} + SNR_i \times W_{SNR} + \varphi_i \times W_{Prox}$
9. Return W_G;

End Algorithm 3

VI. SIMULATION SETUP, RESULTS ANALYSIS, AND PERFORMANCE EVALUATIONS

In this section, we present the scenario implementation using simulation setup parameters, result analysis and then evaluated the performance of the proposed protocol with the help of results obtained through NS-3.23.

A. SCENARIO IMPLEMENTATION

To evaluate the performance of the proposed W-GeoR protocol, a grid road network is created to perform post-

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disaster health monitoring in urban vehicular environments, as shown in Fig. 9.

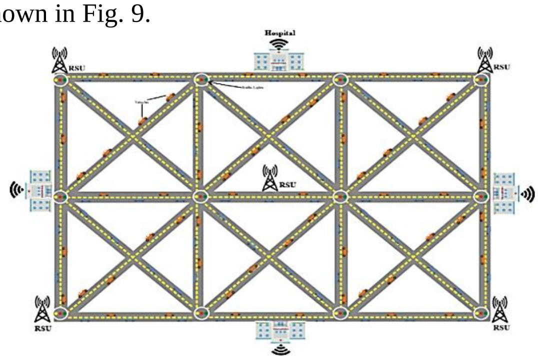

FIGURE 9. Simulation scenario of a road network

A grid road network of 1500 m × 1200 m is created by the netedit utility of the SUMO simulator [44] with detailed route information like road directions, speed limit, junctions, traffic light, etc. SUMO is an open-source realistic microscopic traffic simulator that models the vehicles' microscopic mobility and driver's behavior. We used the Random Waypoint Mobility (RWM) model, which enables vehicles to starts from a random location with random speed and direction in a simulated environment. Vehicle movements are based on random trips generated by the randomTrips.py utility [45]. The traceExporter.py [46] utility is used to obtain an NS-3.23 compatible vehicle mobility file corresponding to SUMO-generated trace files.

The vehicle's movement trace file obtained from the traffic simulator is imported to network simulator NS-3.23 [47] for simulating the proposed W-GeoR protocol. The proposed W-GeoR protocol is designed for urban post-disaster circumstances, including a dense road traffic network with obstacles on the roads. These environmental circumstances are taken into count for designing the novel W-GeoR protocol for health monitoring. The major mobility model parameters and network parameters are summarized in Table IV.

We have considered the two-ray ground propagation loss model to simulate the fading features of the wireless channel used by the physical layer of VANET's nodes. The radio transmission range for vehicles is varied between 200m to 300m. We varied the vehicular density from 20 to 200 within a rectangular area of 1.5 km by 1 km to evaluate the effectiveness of W-GeoR in an urban vehicular environment where many nodes with high mobility are interconnected. A constant bit rate (CBR) data source with the beaconing interval of 1 second and packet interval of 0.2 seconds is used in the simulation. The CBR packet size was varied from 512 to 2048 bytes with a 2 Mbps data rate. IEEE 802.11p was used for the Medium Access Control (MAC) layer with 3 Mbps channel bandwidth. Each vehicle was equipped with a unidirectional antenna with a 1.5-meter height above the ground, and we assume the presences of obstacles on the road wherever no line-of-sight (LOS) was experienced. CBR source and destination are chosen randomly with the variation of pair from 5 to 20. We assume that a GPS receiver is attached to each vehicle, and vehicles exchanged their position, speed, and direction through a precise location service.

Table IV
Major simulation setup parameters

Parameters	Values
Network Simulator	NS-allinone-3.23
Traffic Simulator	SUMO -0.32.0
Channel Data Rate	3 Mbps
Radio Propagation Model	Two-ray Ground
MAC Type	IEEE 802.11p
Antenna Model	Omni-directional Antenna
MM-GPSR λ Factor	0.3
Traffic Type	UDP/CBR
Hello Interval	1 second
Packet Interval	0.2 second
Number of Vehicles	20 – 200
Transmission Range	200, 250, 300 meters
Packet Size	512, 2048, 1500, 2048 Bytes
CBR Connections	5, 10, 15, 20
Vehicle Speed	10-80 Km/hrs.
Simulation Area	1500 m × 1000 m
Simulation Time	200 sec
Routing Protocol	GPSR, W-GeoR, GPSR-WG, MM-GPSR

B. SIMULATION RESULTS

In this section, the simulation results of the proposed protocol W-GeoR are discussed in terms of the number of lost packets, packet delivery ratio, mean hop count, mean delay, and throughputs. The following figures illustrate the comparison of the results of W-GeoR with widely used position-based routing protocol GPSR, MM-GPSR, and GPSR-WG. Performances of the state of art protocols have been evaluated by varying node density, communication range, packet size, and the number of source-destination pairs. All the results shown in this paper represent an average of 30 simulation runs and a 95% confidence interval. Results graph plotting is performed by Gnuplot [48], which is an open-source and command-line utility that can generate 2D and 3D plots.

1) NUMBER OF PATH BREAKS

Frequent path breaks indicate the less stability of routing protocols for data forwarding. High-speed vehicles and frequent topology changes cause more significant numbers of path breaks in VANET [49]. Fig. 10(a-b) illustrates the comparative path breaks of W-GeoR, GPSR, MM-GPSR, and GPSR-WG routing protocols with node density and vehicle speed. To measure the impact of vehicular density on path breaks, we randomly vary the vehicle density from 20 to 200 vehicles with five source-destination pairs. The vehicle generates packets of 2048 bytes at the interval of 0.2 seconds with 250 meters communication range.

As shown in Fig.10(a), the number of path breaks reduces as the vehicle's density increase in the network area because the high node density increases the probability of finding the optimal next-hop vehicle towards the destination. W-GeoR takes into account link expiration time for the next-hop node selection process. A higher link expiration time indicates the stable path between two moving vehicles. As shown in the figure, W-GeoR shows the minimum number of paths break in the range of 08 to 45 followed by MM-GPSR with 12 to

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52, GPSR-WG with 13 to 57 GPSR with 17 to 60. The comparative path breaks of the state-of-the-art protocols are shown in Fig. 10(b) on 110 vehicles with increased vehicle velocity from 10 to 80 km/h. It can be observed that the number of paths that break in each protocol increases as the vehicle speed increases. As the vehicle speed increases, the neighbor vehicles remain in contact only for a short time interval because of their limited communication range. In the proposed W-GeoR, due to the vehicle's movement direction, progress towards the destination, channel SNR, and connection time, the path breaks are low compared to the remaining protocols.

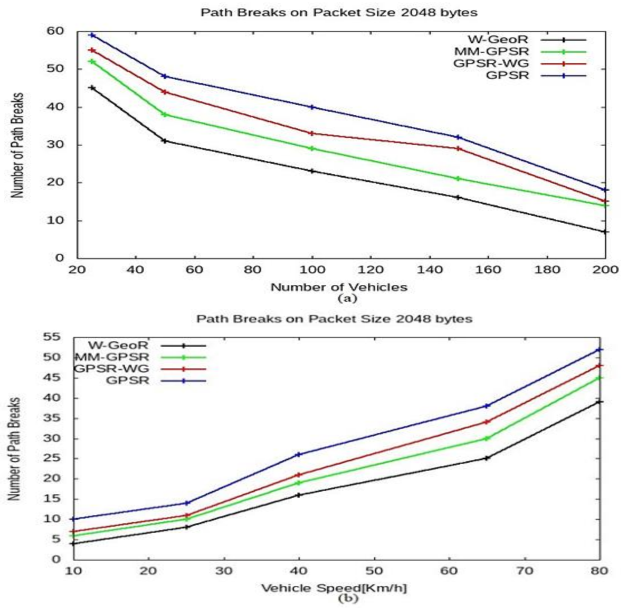

FIGURE 10. Path breaks vs. number of vehicles (a) and vehicle speed (b)

2) LOST PACKETS

Lost packets are defined by the total number of packets lost during simulation time. It can be measured by the difference between the total number of packets sent by all the sources and the total number of packets are received at the destination side within simulated time. Protocol having a minimum number of lost packets is assumed to be a good and stable protocol. Lost packets are measured in decimals and can be calculated by the following equation:

$$Lost\ Packets\ =\ \sum Pkt_{Sj} - \sum Pkt_{Rj} \tag{18}$$

Here, $\sum Pkt_{Rj}$ is the total number of packets received by sinks and $\sum Pkt_{Sj}$ is the total number of packets sent by all sources. As shown in Fig. 11(a), the number of packets lost increased when the number of vehicles increased. Results indicate that W-GeoR is better and provides lower packet loss than the state-of-the-art protocols in all node density scenarios. The GPSR and MM-GPSR are based on a distance-based greedy forwarding mechanism that is not appropriate for VANETs health monitoring applications. This was why W-GeoR provides low packet loss than GPSR-WG, followed by GPSR and MM-GPSR. Next, we investigate the impact of variation of CBR connections on state-of-the-art protocols' performance. We set the communication range at 250 meters, CBR packet size 2048 bytes for 150 vehicles. We vary the CBR connection from 5 to 20 pairs of randomly chosen source and destination nodes. Fig. 11(b) indicates W-GeoR has the minimum lost packets than GPSR-WG and GPSR's enhancements protocol on all CBR connection scenarios. An increment in source and destination pairs causes more packet loss caused by high traffic load when the pair of source and destination nodes increased. GPSR-WG performs better than MM-GPSR and GPSR because of having a better route discovery process.

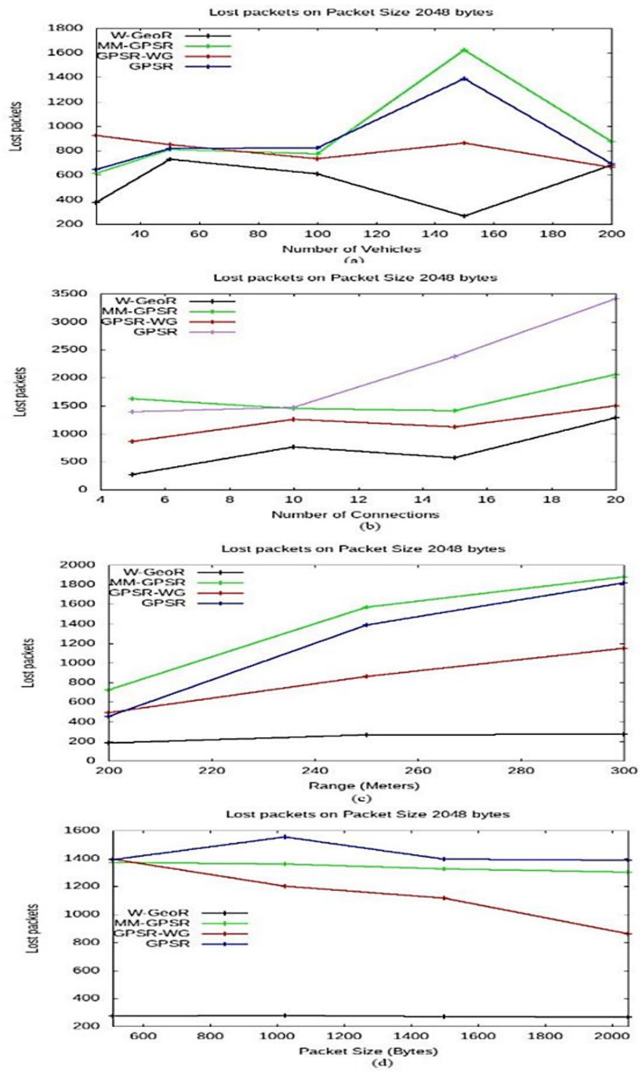

FIGURE 11. Packet lost vs. the number of vehicles (a), CBR connections (b), Range (c), and packet size (d)

Next, we investigate the impact of variation of communication range on state-of-the-art protocols' performance. We vary the communication range from 200 to 300 meters for 150 vehicles with five pairs of source and destination nodes and 2048 bytes packet size. Fig. 11(c) shows that in all communication ranges scenarios, W-GeoR protocol has the lowest number of packets lost than state-of-the-art protocols because the increment in the range is causing more vehicles inside radio coverage, i.e., more

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options for optimal next-hop node selection. W-GeoR selects the neighbor with maximum progress with more link expiration time, causing low packet loss than the remaining protocols. MM-GPSR shows higher packet loss followed by GPSR and GPSR-WG with increment in communication range. Finally, we investigate the impact of packet size on the packet lost in VANETs. We vary the packet size from 512 bytes to 2048 bytes and keep the transmission range of all 150 vehicles on 250 meters with randomly chosen five pairs of sources- destinations. Packet loss is plotted against packet size in Fig. 11(d). As packet size increases, packet loss is also decreasing of all protocols. W-GeoR performs steadily and illustrates the lowest packet lost against others in all scenarios, whereas GPSR performs worst with the highest packet lost, followed by MM-GPSR and GPSR-WG with an increment of packet size.

3) Packet Delivery Ratio (PDR)

PDR is defined by the ratio of successfully received packets at the CBR destinations to packets transmitted by all the CBR sources [50]. PDR is measured in percentage and can be calculated by the following equation:

$$PDR = \left(\frac{\sum Pkt_{Ri}}{\sum Pkt_{Sj}}\right) \times 100 \qquad (19)$$

Where, $\sum Pkt_{Ri}$ is the total number of packets received by the destination nodes and $\sum Pkt_{Sj}$ is the total number of packets sent by all the source nodes. Fig. 12 (a-d) depicts the PDR variation on different network scenarios by changing node density, communication range, CBR connections, and packet sizes. Previous simulation settings are used to measure the performance in terms of the PDR of the state-of-the-art protocols. As shown in Fig. 12(a), the W-GeoR protocol provides the highest PDR, followed by GPSR-WG, MM-GPSR, and GPSR. It is also illustrated that as the node density increases, the successful packet delivery ratio also increases. As the network becomes more connected, the chances of getting into void problems are less; hence the PDR increases consistently with an increased node density. W-GeoR having the highest PDR in the range of 25 to 62%, whereas GPSR-WG provides between 21% to 58%, MM-GPSR provides between 12% to 56%, and GPSR provides the minimum PDR between 8% to 53% in different vehicle density scenarios. W-GeoR considers the channel status in order to avoid the highly congested node for the next-hop node selection.

Further, we analyze the impact of variation of CBR connections on PDR. Fig. 12(b) indicates that the proposed protocol has the highest PDR on 20 CBR connections. As CBR connections increase, the PDR of all state-of-the-art protocols also increased. It is because the network had a higher traffic load when the pair of source and destination nodes increased. In Fig. 12(c), we plot the PDR by varying the transmission range. It is observed that increment of the range also increases the PDR of W-GeoR, and it outperforms others, whereas, for remaining protocols, PDR shows inconsistency. At the 200-meter range, W-GeoR provides the highest PDR of 12.5%, followed by GPSR 11.75%, MM-GPSR-M 10%, and GPSR-WG 9%. At the 250-meter range, W-GeoR provides the highest PDR of 19%, followed by GPSR-WG 14.35%, MM-GPSR 13.75%, and GPSR 9%. Similarly, at the 300-meter range, W-GeoR provides the highest PDR of 22.75%, followed by GPSR-WG 18.45%, MM-GPSR 12.50%, and GPSR only 8.5%. Finally, we investigate the impact of packet size on the 4-routing protocol's PDR in VANETs. PDR is plotted against packet size in Fig.12(d). As packet size increases, the PDR of all protocols varies in different CBR packet sizes. W-GeoR provides the highest PDR in the range of 19% to 28%, followed by GPSR-WG 18% to 23%, MM-GPSR 14% to 17%, and GPSR-M 6% to 10%.

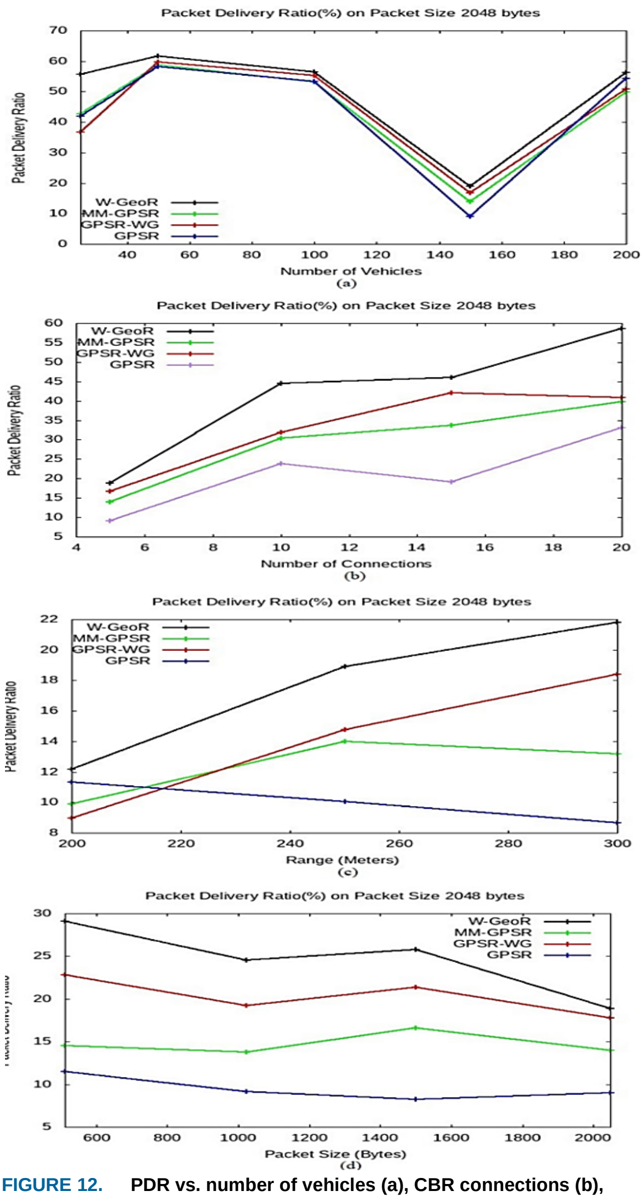

FIGURE 12. PDR vs. number of vehicles (a), CBR connections (b), communication range (c), and packet size (d)

4) Mean Hop Count (MHC)

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Hop count refers to the number of hops the packets need to reach their destination. It is the number of intermediate nodes through which a given piece of data must pass between the source node and destination node. If we take the mean of the hop counts value for all received messages, then we could estimate the mean hop count as per the following equation [37]:

$$MHC = \frac{1}{n}\left(\sum_{i=1}^{n}\frac{1}{R_i}\left(\sum_{j=1}^{R_i}\sum_{K=1}^{P_{ij}} H_{ijk}\right)\right) \tag{20}$$

Where, H_{ijk} represents that source node *i* sent a packet *j* that is traveled to hop *k* to reach the destination. Fig. 13(a-d) shows the impact on mean hop count with the different number of nodes, transmission range, CBR connections, and CBR packet size for the proposed W-GeoR and other routing protocols. A routing protocol is assumed to be a better protocol if it required a minimum hop count. It is observed from Fig. 13 (a), an average number of hops traversed by the successfully delivered packet is reduced as the node density increases. In a sparsely connected network with about 20–50 vehicles, the number of hops traversed in W-GeoR is between 2.7 to 3.2, whereas the remaining protocol has a better mean hop count between 1 and 2.75. GPSR-WG consumes the highest MHC between 3.5 to 4.2 initially on lower node density. When node density increases gradually above 100 vehicles per km^2, W-GeoR required minimum MHC followed by GPSR, GPSR-WG, and MM-GPSR. MM-GPSR required the highest MHC with an increment of node density. This is because it does not consider the next-hop node selection procedure for moving angle. Fig. 13(b) represents the relation between MHC and the number of connection variations of state-of-the-art protocols. It is observed that W-GeoR required MHC between 1.35 to 2.20, which is minimum to all remaining protocols. When the CBR pair is set at 5, MM-GPSR has MHC 7.5, GPSR 3.5, and GPSR-WG 4.2, respectively. As the traffic increase, MHC is decreased considerably for all protocols. As shown in Fig. 13(b), the proposed protocol gives minimum MHC values in all CBR connection scenarios, whereas GPSR-WG takes MHC between 1.35 to 2.35, GPSR 1.85 to 2.5, and MM-GPSR 1.5 to 2.80 MHC for successfully delivering data packets to the destinations. The W-GeoR reduces the packet drop considerably by avoiding the nodes with lower channel SNR values.

Moreover, we investigate the impact of variation of communication range on mean hop count by plotting the MHC with range variation, as illustrated in Fig. 13(c). It is visible from the figure that increment in transmission range reduces all protocols' MHC value because of the greedy approach. W-GeoR selects the node with maximum progress towards the destination, causing minimum hop requirements to reach the destination. MM-GPSR performs poorly with a maximum MHC value of 17.80, followed by GPSR-M with 4.2 MHC, GPSR with MHC 3.8, and proposed W-GeoR with a minimum MHC of 2.10 at a 200-meters communication range. When the range is set at 250 meters, MM-GPSR performs better than MHC values achieved on the 200-meters range with 11.00 MHC followed by GPSR-WG with 4.15 MHC, GPSR 3.75 MHC, and W-GeoR with a minimum MHC of 2.20 only. At 300 meters communication range, W-GeoR shows 1.75 MHC values preceded by GPSR-WG with 2.75 MHC, MM-GPSR with 2.85 MHC, GPSR with 5.20 MHC values. We finally investigate the impact of CBR packet size on the MHC value of the state-of-the-art protocols in VANETs by plotting MHC against the CBR packet size, as illustrated in Fig. 13(d). As packet size increases, the MHC of all protocols decreases gradually, and W-GeoR shows the best performance compared to others in packet size scenarios. Further, W-GeoR's MHC values vary between 2.2 to 2.70, whereas GPSR's MHC values vary between 3.5 and 6.25, GPSR-WG takes MHC between 2.90 and 4.20, and MM-GPSR performs poorly with MHC between 3.90 to 8.30. Overall, the proposed W-GeoR protocol gives better performance than others.

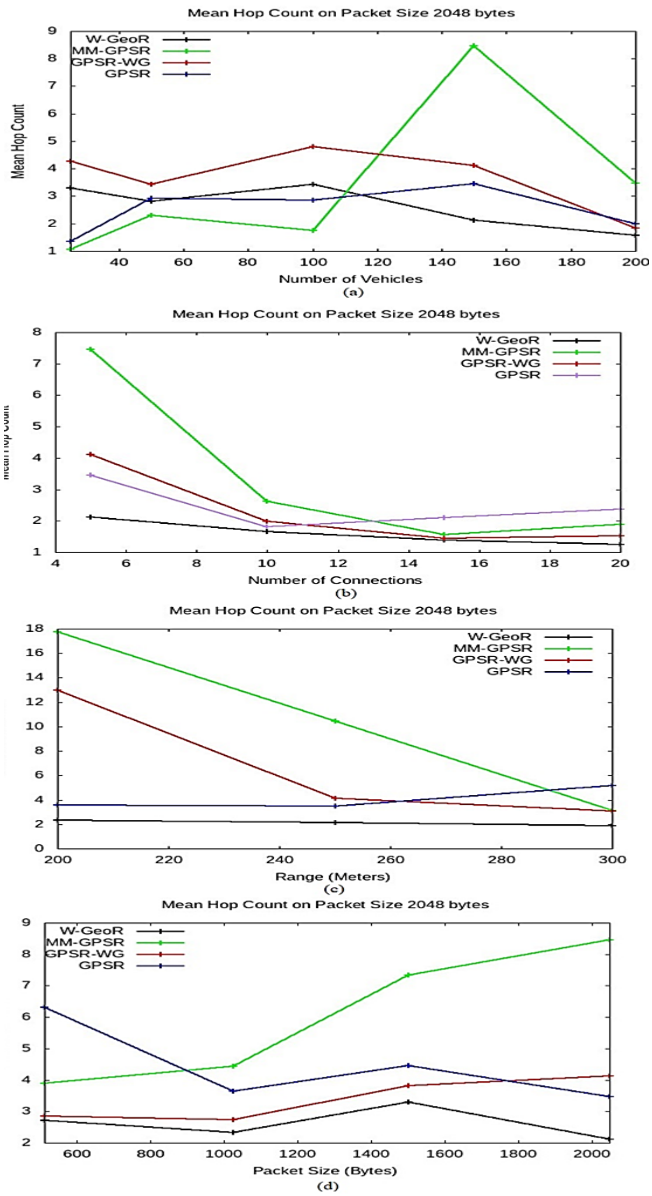

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FIGURE 13. Mean Hop Count vs. number of vehicles (a), CBR connections (b), Range (c), and packet size (d)

5) MEAN DELAY (MD)

The next performance metric analyzed with simulation results is the Mean Delay (MD), as shown in Fig. 14(a-d). This metrics provides the mean delay time encountered by a packet to reach its intended destination. Delay can be caused by buffering during the route searching process, waiting time in queuing, MAC layer retransmission delay, propagation delay, and transfer time [51]–[56]. Lower MD represents a better routing protocol considered for VANET health monitoring applications. It is measured in milliseconds (ms) and can be calculated by the following equation:

$$MD = \frac{1}{\sum_{i=1}^{n} R_i}\left(\left(\sum_{i=1}^{n}\sum_{j=1}^{R_i} RT_{ij} - ST_{ij}\right)\right) \qquad (21)$$

Here, RT_{ij} indicates the time at which the j^{th} packet received at the destination, which was sent by source i and ST_{ij} indicate the time at which the j^{th} packet is transmitted from the i^{th} source.

Fig. 14(a) shows that all protocols have a high end-to-end delay when node density is low and gradually decreases on high node density. It is observed from the figure that W-GeoR requires less propagation time for high node density, followed by GPSR-WG, GPSR, and MM-GPSR. When the node density is low, neighbors in the communication range are few; therefore, the neighbor relationship is unsteady and untrustworthy. During packet transmission, greedy forwarding frequently fails, causes the calling of the perimeter forwarding more frequently, consequences more path redundancy and high propagation delay. When the number of vehicles increases, the steadiness of the neighbor connection between the vehicles increased, and the correspondence interface is more consistent and powerful, so the average end-to-end delay is decreased. Fig. 14(b) indicates the impact of variation of CBR connections on MD. When source-destination pairs are set at 5, W-GeoR shows a minimum MD of 115ms, followed by GPSR-WG with 190ms, GPSR with 310ms, and MM-GPSR with 760ms. As the number of connections increases, the MD of the state-of-the-art protocol is also decreased. When CBR connections are between 10-15, W-GeoR shows minimum delay in the range of 90ms to 120ms, followed by GPSR-WG with 110ms to 125ms, MM-GPSR with 180ms to 250ms, and GPSR with 180ms to 320ms. When CBR connections are set at 20, W-GeoR still shows a minimum MD of 180ms, followed by GPSR-WG with 265ms, MM-GPSR with 470ms, and GPSR with 540ms.

Further, we investigate the impact of variation of communication range on MD for the state-of-the-art protocols, as shown in Fig. 14(c). It is observed that the proposed W-GeoR protocol requires less propagation time in different communication range. When the communication range is set at 200 meters, W-GeoR requires a minimum delay, followed by GPSR, GPSR-WG, and MM-GPSR.

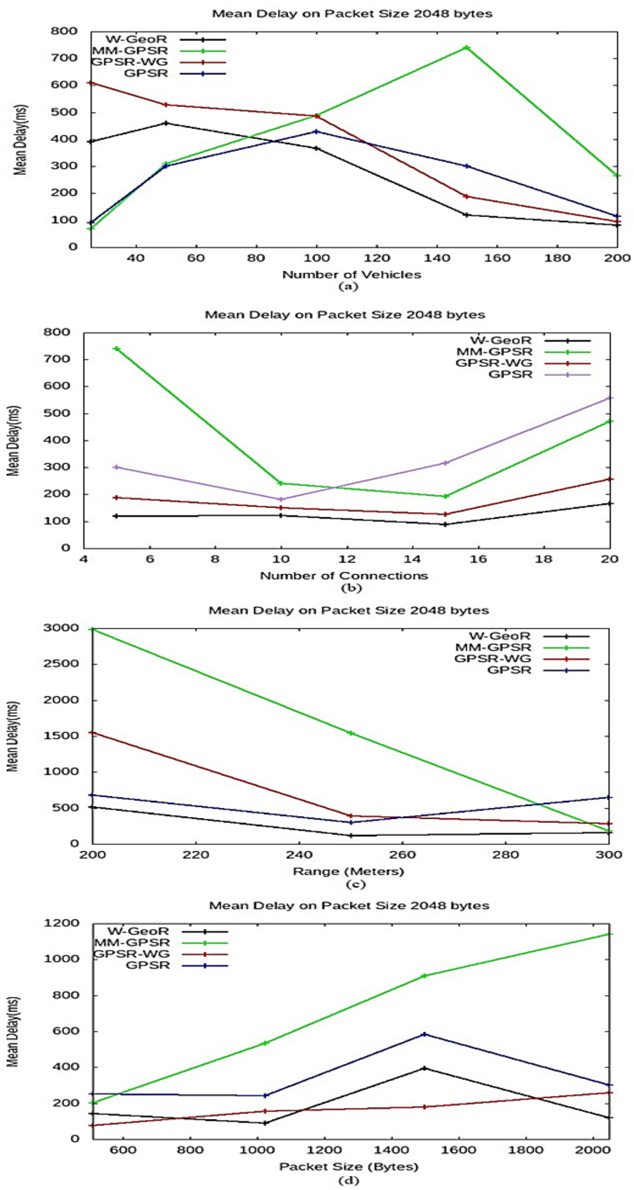

FIGURE 14. Mean Delay (ms) vs. number of vehicles (a), CBR connections (b), Range (c), and packet size (d)

When the range is increased, the MD is decreased because increment in communication range provides more vehicle for selection for optimal next-hop node, and greedy forwarding does not fail frequently. When the communication range is set at 250 meters, W-GeoR requires a minimum delay, followed by GPSR, GPSR-WG, and MM-GPSR, when the range is at 300-meter, MM-GPSR, and W-GeoR showing similar MD followed by GPSR-WG and GPSR. We finally investigate the impact of CBR packet size on the MD for the state-of-the-art protocols, as shown in Fig. 14(d). When the CBR packet size exceeds the limit, it gets fragmented into smaller size packets. If the link is failed during packet transmission, it causes more delay in fragmented packet transmission, as Fig. 14(d) shows that increment in packet size increases the MD of all protocols. W-GeoR shows the minimum delay between 120ms to 400ms, followed by

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GPSR-WG with 70ms to 238ms, GPSR with 240ms to 580ms, MM-GPSR performs worst with 200ms to 1140ms MD on CBR packet size between 512 bytes to 2048 bytes simulation scenarios.

6) THROUGHPUT

It is defined by the ratio of effectively delivered messages over a communication channel. It is measured in Kbps. The following equation can be used to calculate throughput:

$$Throughput = \left(\frac{\sum Pkt_{Ri}}{Sim_{Time}}\right) \times Pkt_{Size} \tag{22}$$

Here, $\sum Pkt_{Ri}$ indicate the total number of received packets at the destination, Pkt_{Size} indicates the size of the CBR data packet and Sim_{Time} indicates the simulation run time. As shown in Fig. 15(a), throughput decreased when the number of vehicles increased. It is observed that W-GeoR performs better and provides higher throughput than other routing protocols in all node density scenarios except on vehicle density 20. When node density is less than 20, GPSR provides higher throughputs, followed by W-GeoR, GPSR-WG, and MM-GPSR. As the number of nodes increases, W-GeoR outperforms all the protocols in terms of throughput, followed by GPSR-WG, GPSR, and MM-GPSR. Fig. 15(b) indicates that throughputs of all protocols are increased with an increased number of source and destination pairs until connections have not reached 20. More source node generates more data packets causing more bandwidth utilization, so throughput decrements are observed here. W-GeoR provides the highest throughput on 10, 15, and 20 CBR connection scenarios followed by GPSR-WG because it chooses a more connected and stable path having more link expiration time, whereas remaining protocols are based on distance-based greedy forwarding, which is not more suitable for VANETs applications. When CBR connection is between 5-10, GPSR provides maximum throughputs followed by W-GeoR, GPSR-WG, and MM-GPSR, whereas when CBR connection is between 15-20, then W-GeoR provides maximum throughputs followed by GPSR-WG, MM-GPSR, and GPSR.

Fig. 15(c) shows that on a 200 meters communication range scenario, W-GeoR performs 1780 Kbps throughputs followed by GPSR-WG with 1481 Kbps, GPSR with 1435 Kbps, and MM-GPSR at the bottom with 98 Kbps throughputs only. As the communication range is increased in simulation, throughputs are decreased. It is due to more traffic cause more bandwidth consumption consequently low throughputs. When the communication range is set at 250 meters, W-GeoR's throughput is reduced to 1400 Kbps, followed by GPSR-WG with 1180 Kbps, GPSR with 1090 Kbps, and MM-GPSR with 650 Kbps throughputs. MM-GPSR behaves oppositely to remaining protocols, and its throughputs are increasing with increment in communication range.

Further, when a range is set at 300 meters, W-GeoR's throughput is reduced to 1243 Kbps, followed by MM-GPSR with 1082Kbps, GPSR-WG with 754 Kbps, and GPSR with 632 Kbps throughputs. Finally, we investigate the impact of packet size on throughput, as depicted in Fig. 15(d). As packet size increases, throughput is also increased of all protocols. W-GeoR protocol shows adequate performance with GPSR-WG and MM-GPSR, and GPSR shows minimum throughput in 512 to 1024 bytes CBR packet size scenarios. As packet size increases from 1024 bytes to 2048 bytes, GPSR outperforms all protocols followed by W-GeoR, GPSR-WG, and MM-GPSR.

Finally, we can see from all the simulation results of all the performance metrics and for all the parameters, the proposed W-GeoR protocol outperforms the state-of-the-art protocols.

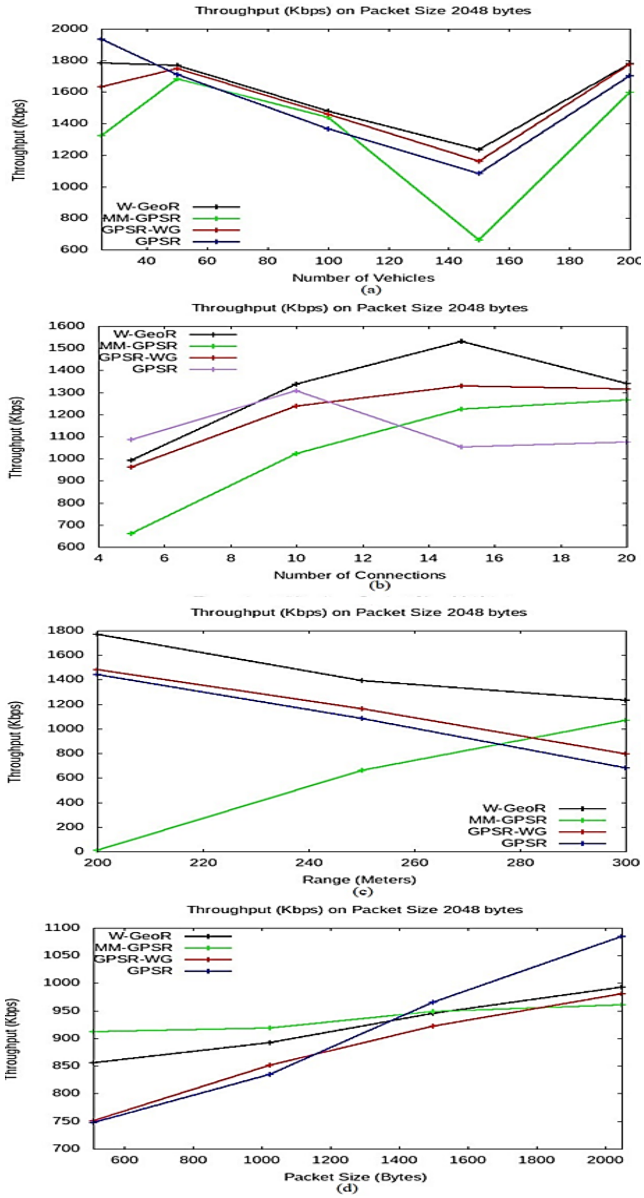

FIGURE 15. Mean Delay (ms) vs. number of vehicles (a), CBR connections (b), Range (c), and packet size (d)

VII. CONCLUSION

In natural disasters, traditional communication systems become impractical, and health monitoring and caregiving become arduous. We should opt for ad-hoc communication technologies as a choice for health monitoring perspectives

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in disaster circumstances. High speed and random topologies pose constraints in designing suitable routing protocols for VANET health monitoring applications. This paper has proposed a novel geographical routing protocol that we call Weighted Geographical Routing (W-GeoR) for health monitoring applications using VANET and WBSN. The proposed W-GeoR protocol provides an optimal path using the best next-hop forwarding node. W-GeoR is a more suitable routing protocol for VANET health monitoring applications in emergencies or disaster situations in urban vehicular traffic environments. W-GeoR provides a novelty by making a unique routing decision considering crucial routing metrics such as node mobility, link expiration time, channel SNR and destination proximity information to select the next-hop vehicle in the ad-hoc route discovery process. W-GeoR protocol consists of two phases, the ad-hoc route discovery and packet transmission phase and the recovery phase. We have explained the proposed protocol in detail and evaluated its performance mathematically using very effective routing metrics. W-GeoR protocol is based on weight value as calculated in this paper. The neighbor node with maximum weight value will be selected as the next-hop node to transmit the packet to the destination successfully. We have implemented W-GeoR for the post-disaster circumstances under an urban vehicular traffic environment and simulated it using network simulator NS-3.23 with traffic simulator SUMO-0.32.0. Simulation is done to perform a case study for health monitoring perspectives. Further, the proposed work W-GeoR protocol has been compared with existing state-of-the-art protocols. The simulated results have shown that W-GeoR performs better than GPSR-WG, GPSR, and MM-GPSR regarding the number of path breaks, lost packets, throughput, packet delivery ratio, mean delay, and mean hop count.

The impact of signal-to-noise errors and speed differences on the link expiration time and considering more routing constraints such as route reliability, border node connectivity, urban mobility model, and hop delay in our developed routing protocol will be our future extensions.

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