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SYSTEMS-LEVEL QUALITY IMPROVEMENT

VehiHealth: An Emergency Routing Protocol for Vehicular Ad Hoc Network to Support Healthcare System

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Abstract Survival of a patient depends on effective data communication in healthcare system. In this paper, an emergency routing protocol for Vehicular Ad hoc Network (VANET) is proposed to quickly forward the current patient status information from the ambulance to the hospital to provide pre-medical treatment. As the ambulance takes time to reach the hospital, ambulance doctor can provide sudden treatment to the patient in emergency by sending patient status information to the hospital through the vehicles using vehicular communication. Secondly, the experienced doctors respond to the information by quickly sending a treatment information to the ambulance. In this protocol, data is forwarded through that path which has less link breakage problem between the vehicles. This is done by calculating an intersection value I_{value} for the neighboring intersections by using the current traffic information. Then the data is forwarded through that intersection which has minimum I_{value}. Simulation results show VehiHealth performs better than P-GEDIR, GyTAR, A-STAR and GSR routing protocols in terms of average end-to-end delay, number of link breakage, path length, and average response time.

Keywords VehiHealth · Healthcare system · VANET · Routing

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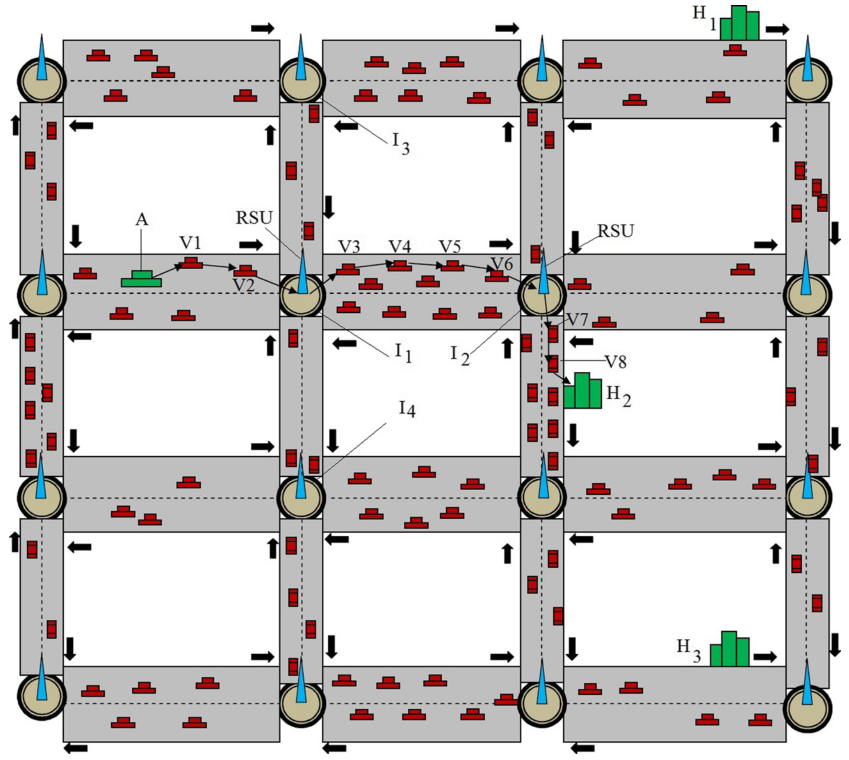
Introduction

VANET is an advanced wireless communication technology in which vehicles communicate to transfer important infomation [1–4]. This is mainly used to reduce the accidents on the roads by sending emergency messages to the vehicles. In VANET system, each vehicle can send, receive, store, and compute the information. VANET provide many types of applications like internet access, media downloading, safety systems, etc. Many car producing companies like BMW, Daimler, Ford, etc. uses the VANET technology to provide Intelligent Transportation Systems (ITS) applications to the users [5–9]. It is mainly implemented in Europe, USA and Japan by using standards like DSRC with 75 MHz spectrum and 5.9 GHz of radio frequency [10, 11]. Figure 1 shows the architecture of VANET in which the vehicles use vehicle to vehicle (V2V), vehicle to Road Side Unit (RSU) and RSU to vehicle communication. RSU is a static unit which acts as a router to connect the vehicles with the server.

VANET provides ITS services to support the healthcare system, where the ambulance acts as a communication node and can send and receive information [3]. In recent years, wireless communication is a need for the medical systems to provide better and faster services to the patients [12–29]. In medical systems, ambulance plays an essential role in saving a life [30–33]. But sometimes, an ambulance may face problems while taking a patient to the hospital like traffic congestion and long distance. In this situation, if a patient suddenly goes through serious health problems like breathing, pain, heart attack, etc. then a sudden treatment is required which is impossible. At this emergency time, the ambulance doctor should provide life saving treatments by consulting the experienced doctors [12–15]. The ambulance doctor sends the patient current status information (images, reports, etc.) to the nearby hospital to get a sudden response.

Fig. 1 Data forwarding from I_1 to I_2



For this method, the data should be quickly forwarded to get a sudden treatment response.

The main problem with VANET is that the vehicles move with random speeds [9]. This creates link breakage problem in VANET, where a vehicle becomes out of range of another vehicle. This creates a problem in forwarding the data to the next vehicle. This increases the delay to forward the data to the hospital. So, VehiHealth is proposed to forward the data quickly to the hospital as soon as possible. This method is a cost free application where the vehicles send the data to the destination without using the web. VehiHealth forward the data through the most connected and stable path, where the vehicles are highly connected to each other and take minimum delay to transfer the data to the destination. The main contribution in this paper is shown as follows:

1. An emergency routing protocol is proposed to send the patient current status information to the nearby hospital as soon as possible to get a sudden treatment response. The data is forwarded through that neighboring intersection, which has minimum I_{value}. I_{value} is calculated by considering the shortest path to the hospital, delay to forward the data from one intersection to another, vehicles stability between the intersections, and number of link breakage. The data is forwarded in a connected path which takes minimum delay.
2. The treatment response information is forwarded from the hospital to the moving ambulance.
3. A link breakage recovery method is proposed to connect the vehicles which suffers from network gap problem.

The paper is organized as follows: "Related works" describes about the standard routing protocols used for vehicular communication. "Proposed routing protocol" describes about the proposed VehiHealth routing protocol and its functionality. "Simulation and results" presents the simulation results of the protocols. "Conclusion" presents the conclusion of the VehiHealth routing protocol.

Related works

To provide faster data transmission, many vehicular routing protocols are proposed [1–3, 34, 35]. These protocols provide ITS services to the passengers and drivers. In this paper, we use the standard routing protocols like P-GEDIR, GyTAR, A-STAR, and GSR routing protocols to forward the data quickly from the ambulance to the hospital and compare their performance with VehiHealth.

Greedy Traffic-Aware Routing (GyTAR) [36] protocol is proposed to forward the data quickly to the destination by selecting the efficient junction among the neighboring junctions. Junction is selected by finding a score for the neighboring junctions and the junction with maximum score is selected as the next junction. It uses a Cell Data Packet (CDP) information to aware other vehicles about the current traffic information. But this increases the congestion in the network and if link breaks then the traffic information is not updated and false score calculation occurs. This increases the delay in the network.

Anchor-based street and traffic aware routing (A-STAR) [37] uses a predefined path which in which the vehicles are mostly connected. This consists of buses and vehicles with a high transmission range. But if it needs to send the data in other paths it may increase the delay due to less density of vehicles. This lacks information about the link breakage ahead.

Geographic source routing (GSR) [38] protocol is proposed to send the data in a shortest path to the destination by sending the data to the vehicles which are nearest to the destination. It increases the delay due to lack of information about the traffic ahead.

Greedy Perimeter Stateless Routing (GPSR) [39] is proposed to send the data through the vehicle which is nearer to the destination, but if a local optimum problem occurs, it goes to perimeter mode. In this mode, it uses planar graphs to recover from this problem. If network gap occurs regularly, then this protocol always stays in perimeter mode and this reduces its performance. This lacks knowledge about the traffic condition and link breakage ahead.

Chen et al. [40] proposed diagonal-intersection-based routing (DIR) protocol to forward the data quickly by choosing the best diagonal intersections. The path is selected by finding a delay and the path with minimum delay to trasfer the data to the diagonal intersection is selected as the next intersection. Auto-adjustability of the system increases the performance of the network.

Chou et al. [41] proposed an Intersection based routing scheme to forward the data through the optimal intersections. To select the optimal intersections, forwarding delay and carrying delay are calculated. The neighboring intersections with minimum forwarding and carrying delay is selected as the next intersection.

Raw et al. [42] proposed a Peripheral node-based GEographic DIstance Routing (P-GEDIR) protocol to send the data quickly to the destination by using the peripheral nodes. The nodes nearer to the boundary takes minimum delay to forward the data to the destination. This lacks knowledge about the traffic conditions and link breakage ahead.

Liu et al. [43] proposed a Stable Direction-Based Routing (SDR) protocol to send the data to the destination through a stable path. A Link expiry time is calculated to execute the communication process between the vehicles. The vehicles in the same direction use RREQ broadcasting scheme to discover the route. This creates a congestion in the network.

El-Masri et al. [44] proposed an emergency system to facilitate healthcare facilities to the patient by searching the nearest ambulance to the patients location. This system also finds the nearest hospital to the patients location and forward the patients health information to the healthcare department to provide pre-medical treatment.

Pavlopoulos et al. [45] developed a device to provide pre-hospital treatment to the patients. This provides telediagnosis and teleconsultations. This connects the patient with the expert doctor to provide quick consultancy and suggestions to save a patients life in an emergency.

In summary, these standard routing protocols are used for vehicular communication to transfer the data quickly from the source to the destination. VehiHealth emergency routing protocol is proposed to transfer the ambulance information quickly to the hospital and vice-versa. This data transfer should be quick to save a patients life. VehiHealth takes minimum delay to forward the data by estimating the traffic condition and link breakage ahead. VehiHealth is compared with other standard routing protocol to identify the performance. It provides a better support to the healthcare system by saving patients life. The notations used in the paper are shown in Table 1.

Proposed routing protocol

System model

In this protocol, the city is considered as a graph G where the roads connecting the intersections are considered as edges and the intersections as vertices. Vehicle uses GPS service to know their own location. Vehicle and RSU beacons at a particular interval of time to aware other vehicles about their position, speed, identity, and direction. A vehicle forwards the data to that vehicle which moves in the same direction. We assume that the ambulance knows the

Table 1 Notation Table

Descriptions	Notations
Ambulance	A
Hospital	H
Vehicle	V
Intersection	I
Source	S
Destination	D
Shortest Path	$P_{shortest}$
Static Vehicle	V_{static}
Range	R
Time	t
Intersection value	I_{value}
Distance	d
Speed	v
Message length	l
Channel rate	r

locations of the hospitals $(H_1, H_2, H_3, ..., H_h)$ in the city areas, where h is the number of hospitals in the city. Hospital uses radio communication to support effective data communication. Ambulance consists of emergency medical instruments like first aid, breathing machine, electrocardiogram machine, multifunctional monitor, etc. RSU is fixed at the intersection to control the data communication by storing the current traffic information received from the vehicles using the beaconing service. RSU and vehicle have enough storage to keep the data.

Functionality of VehiHealth

In emergency medical situation, the ambulance quickly sends the current patient status information to the hospital to get a quick treatment response. The data is forwarded by selecting the best intersections by calculating I_{value} for the intersections. The main objective of VehiHealth routing protocol is to forward the data through that route which is highly connected (vehicle are connected to each other) with less link breakage problems. This reduces the delay to transfer the data to the hospital and receive a response as soon as possible.

Functionality of the protocol starts with initializing the data forwarding from the ambulance A to the nearest hospital. According to Fig. 1, A first finds the nearest hospitals (H_1, H_2, H_3) in the city by using the Dijkstra algorithm according to its position. Ambulance A finds H_2 as the nearest hospital and the shortest path to the hospital H_2 is represented as $P_{shortest} = A \rightarrow I_1 \rightarrow I_2 \rightarrow H_2$. After getting the $P_{shortest}$, A forward the data to the single nearest intersection I_1. A forward the data to I_1 using multihop communication where a vehicle forward the data to the vehicle $V_{closest}$ in the range which is closest to the destination (I_1). The distance is calculated using Euclidean distance $d_{V_1 V_{closest}} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ where (x_1, y_1) and (x_2, y_2) are the locations of vehicles V_1 and $V_{closest}$. In Fig. 1, the data is forwarded using the multihop communication in the path $A \rightarrow V_1 \rightarrow V_2 \rightarrow I_1$. We assume that when a vehicle with the data come nearer to the intersection it handovers the data to the RSU. Vehicle V_2 when reaches nearer to I_1 handovers the data to the RSU which is the decision maker. RSU further decides where to forward the data using the intersection values of all the neighboring intersections (I_2, I_3, I_4). The algorithm for data transmission is shown in Algorithm 1.

Algorithm 1 Forwarding data from ambulance A to RSU at I_1

```
A calculates the $P_{shortest}$ to the nearest hospitals ($H_1, H_2, H_3$) ▷ Dijkstra algorithm
A selects the hospital $H$ which has minimum $P_{shortest}$
for A to $RSU$ do
    if $RSU$ is in the range $R$ then
        Handover data to the RSU
    else
        Find $V_{closest}$
        Send data to $V_{closest}$
    end if
end for
```

After receiving the data from V_2, RSU needs to calculate the intersection values of the neighboring intersections (I_2, I_3, I_4). To calculate the I_{value}, RSU uses the computation module to compute the values and forward the values to the decision module. The decision module decides by selecting the intersection which has minimum I_{value} and the data is transferred in that direction. The computation module needs many elements to calculate the I_{value} like position coordinates of the vehicles between the intersections, delay to forward the data from one intersection to another, shortest path to the hospital H, average speed of the vehicles between the intersections and number of link breakages. RSU computation and decision module is shown in Fig. 2.

RSU predicts the position coordinate of a vehicle by finding the distance $d_{travelled}$ by a vehicle after the last beacon. RSU stores the information of a vehicle when it passes the intersection by using the beaconing service. If at time $t_{position}$, the position of a vehicle is estimated to be:

$$d_{travelled} = v_{beacon}(t_{position} - t_{beacon}) \quad (1)$$

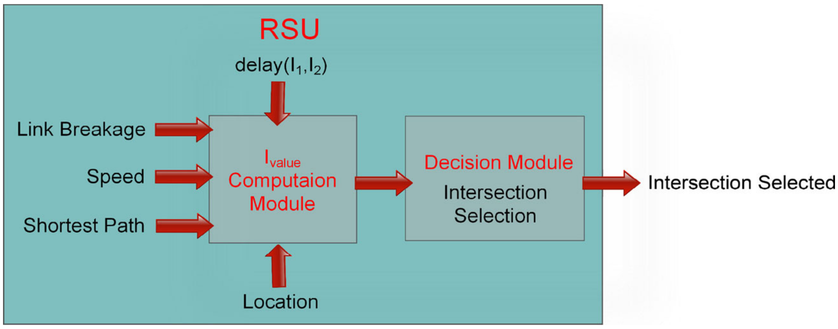


Fig. 2 Computation module and decision module for RSU

where v_{beacon} is the speed of the vehicle in the last beacon message and t_{beacon} is the last time at which RSU receives the beacon message. After getting $d_{travelled}$, coordinate of a vehicle is estimated and position of the vehicle is known to the RSU. RSU finds the locations of all the vehicles between the current intersection and neighboring intersection. But for how many number of vehicles RSU predicts the locations. This is done by calculating a time t_{reach} which signifies the maximum time a vehicle takes to reach an intersection from other intersection. Then t_{reach} is calculated as follows:

$$t_{reach} = \frac{d_{road}}{v_{minimum}}, \tag{2}$$

where d_{road} is the distance between the current intersection and the neighbor intersection and $v_{minimum}$ is the average minimum speed a vehicle moves between the intersections. RSU only predicts the positions for those vehicles which crosses the intersection between $(t_{position} - t_{reach})$ and $t_{position}$. Then the coordinates which lies between the intersections are considered as the valid vehicles. Vehicle position estimation process is shown in Algorithm 2.

Algorithm 2 Estimating vehicle position between the intersections

```
RSU receives the data at intersection $I$
RSU finds the position coordinate by $d_{travelled} = v_{beacon}(t_{position} - t_{beacon})$
RSU finds $t_{reach}$ by: $t_{reach} = \frac{d_{road}}{v_{minimum}}$
if vehicle moves between $(t_{position} - t_{reach})$ and $t_{position}$ then
    position of the vehicle is considered
else
    position is not considered
end if
if $d_{road} > d_{travelled}$ then
    Position is valid
else
    invalid
end if
Valid positions are used to find logical path of transmission $P_{transmission}$
```

After RSU estimates the valid positions of the vehicles, it finds a logical data transmission path $P_{transmission}$. This logical path is used to calculate the I_{value}. The path signifies the connectivity of the vehicles from one intersection to another. According to the positions estimated, $P_{transmission}$ is generated by the range of the vehicles. Vehicle selects $V_{closest}$ to forward the data. So, according to Fig. 1, RSU logically finds V_3 in its range R as $V_{closest}$ to the intersection I_2. Then it finds V_4 as $V_{closest}$ for vehicle V_3. RSU continues the process until another intersection is reached. So, according to Fig. 1, the logical path of transmission $P_{trasmission}=RSU \rightarrow V_3 \rightarrow V_4 \rightarrow V_5 \rightarrow V_6 \rightarrow RSU$.

After getting the logical $P_{transmission}$, RSU expects the data transmission time $t_{transmission}$ in the path. If a message of length l bits is send from a vehicle V_1 to V_2 then expected delay $t_{transmission}$ is calculated as:

$$t_{transmission(V_1,V_2)} = \frac{l}{rate_{(V_1,V_2)}} + \frac{d_{(V_1,V_2)}}{Prop_{speed}} + t_{rest}, \tag{3}$$

where $rate_{(V_1,V_2)}$ denotes the channel rate, $d_{(V_1,V_2)}$ shows the distance between the vehicles and $Prop_{speed}$ denotes the propagation speed. $\frac{l}{rate_{(V_1,V_2)}}$ signifies the transmission delay, $\frac{d_{(V_1,V_2)}}{Prop_{speed}}$ signifies the propagation delay and t_{rest} signifies the queuing delay and processing delay. In VehiHealth protocol, only transmission delay and propagation delay are considered to calculate $t_{transmission}$. If data is forwarded in the logical path of data transmission $P_{transmission}$, then the expected $t_{transmission}$ to forward the data from intersection I_1 to I_2 is shown as follows:

$$\begin{aligned} t_{transmission(I_1,I_2)} = {} & t_{transmission(RSU,V_3)} \\ & + t_{transmission(V_3,V_4)} \\ & + t_{transmission(V_4,V_5)} \\ & + t_{transmission(V_5,V_6)} \\ & + t_{transmission(V_6,RSU)} \end{aligned} \tag{4}$$

RSU stores the expected $t_{transmission(I_1,I_2)}$ and calculates the number of link breakage in the $P_{transmission}$. As vehicles are connected, there is no link breakage in $P_{transmission}$. Then RSU finds the shortest paths from the current intersection I_1 to the hospital H_2 and from the neighbor intersection I_2 to the hospital H_2. RSU then calculate the average speed of the vehicles between the intersections $(I_1 I_2)$. RSU uses these elements to calculate the I_{value} for the neighbor intersection (I_2) and it is calculated as follows:

$$\begin{aligned} I_{value} = {} & Number\ of\ link\ breakage + t_{transmission(I_1,I_2)} \\ & + \frac{\sum v_n}{Number\ of\ vehicles} + \frac{P_{shortest_{neighbor}}}{P_{shortest_{current}}} \end{aligned} \tag{5}$$

Number of link breakage in the $P_{transmission}$ should be minimum, so that the vehicles are highly connected. Expected data transmission delay $t_{transmission(I_1,I_2)}$ should be minimum to forward the data to the neighbor intersection. $\frac{\sum v_n}{Number\ of\ vehicles}$ signifies the average speed of the vehicles between the intersections. It shows the stability of vehicles between the intersections. If $\frac{\sum v_n}{Number\ of\ vehicles}$ is less, then the vehicles are more stable. $\frac{P_{shortest_{neighbor}}}{Pshortest_{current}}$ denotes the closeness of the neighboring intersection (I_2) to the hospital (H_2) and the value should be minimum. These four parameters should be minimum.

I_{value} is calculated for all the neighboring intersections (I_2, I_3, I_4). Then the computation module forward the

I_{value} of all the neighboring intersections to the decision module. Then the decision module decides and selects the next intersection by selecting the intersection which has minimum I_{value}. Then the data is forwarded in that direction which has minimum I_{value}. The data is forwarded with the position and speed information of all the vehicles between the intersections. This process continues until the data reaches the last intersection I_{last}. Then the data is forwarded to the hospital H_2 by using the multihop communication by selecting the $V_{closest}$ vehicles. Intersection value calculation is shown in Algorithm 3.

Algorithm 3 Intersection value Calculation

```
RSU estimates the positions of the vehicles between the intersections
for $I_{first}$ to $I_{last}$ do   ▷ $I_{first}$ is the first intersection to receive data from $A$
    if $I$ is not equal to $I_{last}$ then
        RSU finds $P_{transmission}$ by the range of the vehicles
        if vehicle is out of range then
            link breakage
        else
            no link breakage
        end if
        RSU finds the number of link breakage in $P_{transmission}$
        RSU calculates the average speed of the vehicles between the inter-sections
        RSU calculates the shortest paths $P_{shortest_{neighbor}}$ and $P_{shortest_{current}}$
        RSU calculates $I_{value} = Number\ of\ link\ breakage + t_{transmission(I_1,I_2)} + \frac{\sum v_n}{Number\ of\ vehicles} + \frac{P_{shortest_{neighbor}}}{P_{shortest_{current}}}$ ▷
        RSU calculates $I_{value}$ for all the neighboring intersections
        Forward data in the direction of $min\ (I_{value})$
    else
        Forward the data by multi hop communication by selecting $V_{closest}$ vehicles
    end if
end for
```

After the patient data reaches the destination (H_2), the experienced doctors from the hospital analyzes the report and quickly sends a treatment message to the moving ambulance A. We assume that, the ambulance uses the same path which it always uses to carry the patients. Then hospital H_2 predicts the current position of the moving ambulance to find the target $Z(x_A, y_A)$ coordinate. Let the total delay $t_{(A,H)}$ to forward and analyze the data from the ambulance to the hospital is calculated as follows:

$$t_{(A,H)} = t_{generate1(A)} + t_{transmission(A,H)} + t_{analyze(H)} + t_{generate2(H)} \tag{6}$$

where $t_{genarate1(A)}$ is the time to generate the patient current data, $t_{transmission(A,H)}$ is the time to transmit the data from the ambulance A to the hospital H, $t_{analyze(H)}$ is the time to analyze the data by the experienced doctors and $t_{generate2(H)}$ is the time to generate the treatment response message. Let the time when $t_{transmission}$ starts is represented as t_{start} and the time when $t_{generate2(H)}$ ends is represented as t_{end}. We assume that ambulance A sends its speed $v_{ambulance}$ and its location to the hospital H. Then the distance moved d_{moved} by the ambulance A is calculated as follows:

$$d_{moved} = (t_{end} - t_{start})v_{ambulance} \tag{7}$$

From Eq. (7), the $Z(x_A, y_A)$ coordinate is estimated and the data is forwarded in the direction of Z. The message contains ambulance identity, coordinate of Z and treatment data. After getting the treatment information, the ambulance doctor saves the life of the patient in an emergency situation. Fig. 3 shows the data forwarding from the hospital to the moving ambulance. Data forwarding process from hospital to ambulance is shown in Algorithm 4.

Algorithm 4 Forwarding data from Hospital to Ambulance

```
Hospital finds the target $Z(x_A, y_A)$
Hospital $H$ initializes the data forwarding in the direction of $Z(x_A, y_A)$
Hospital forward the data to the first intersection $I_{first}$ by using $V_{closest}$ vehicles
for $I_{first}$ to $I_{last}$ do                ▷ $I_{first}$ is $I_2$
    if $I$ is not equal to $I_{last}$ then      ▷ $I_{last}$ is $I_1$
        RSU receives the data
        RSU updates position $Z$ by: $d_{moved(A)} = t_{transmission(H,I_{first})} \times v_{ambulance}$
            ▷ $t_{transmission(H,I_{first})}$ =time to transmit data from $H$ to nearest first intersection
        RSU forward the data to the intersection with $min\ (I_{value})$
    else
        Forward the data using $V_{closest}$ vehicles
    end if
end for
```

Link breakage recovery

Link breakage recovery method is proposed to connect the vehicles which suffers from network gap problem, where a vehicle is out of range of another vehicle and the link between the vehicles break. The victim vehicle V_{victim}, which carries the data, when encounters a gap between itself and the forward vehicles, it adjusts its speed according to the data forwarded by the RSU. As assumed, RSU forwards the data with the locations and speeds of the vehicles in the $P_{transmission}$. V_{victim} adjusts its speed according to the speeds and locations of the vehicles. In this model, we assume that a vehicle moves in a constant speed $v_{average}$.

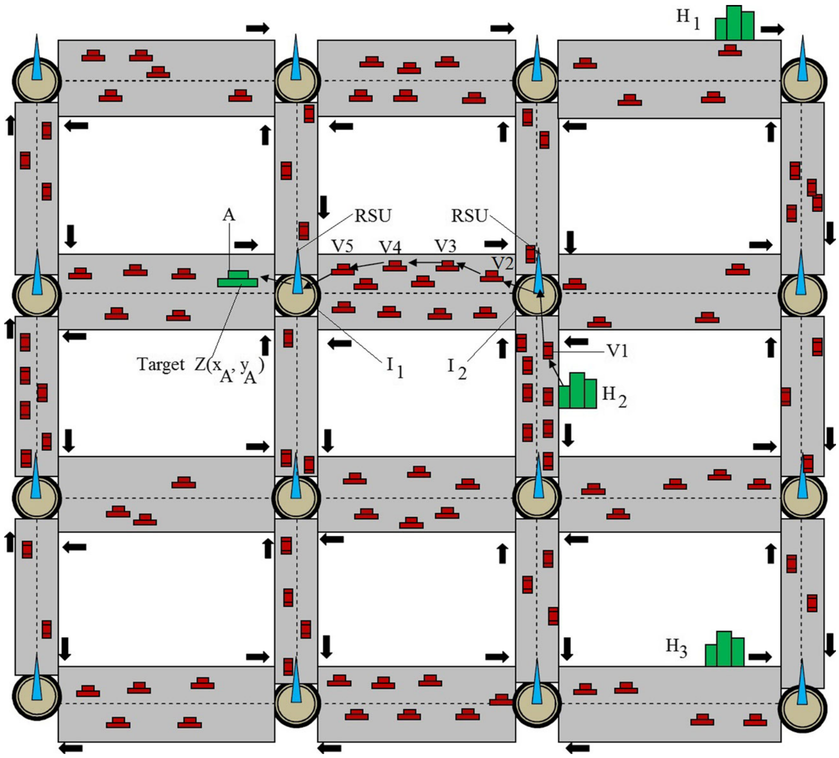


Fig. 3 Data forwarding from H_2 to A

Every vehicle has its own maximum and minimum speeds (v_{max} and v_{min}). So the $v_{average}$ is represented as $v_{max} \geq v_{average} \geq v_{min}$. So vehicle can increase its speed to $v_{increase}$ or decrease to $v_{decrease}$ (in the range of v_{min} to v_{max}). According to Fig. 4, $V_{backward}$ is the vehicle which has a higher speed among the vehicles in the backward positions of V_{victim}. $V_{forward}$ is the vehicle which is out of range, but nearer among the vehicles in the forward positions. Algorithm 5 shows the recovery method from the link breakage problem.

Algorithm 5 Link Breakage Recovery Method

```
1:  if $v_{victim} > v_{forward}$ then    ▷ Speed of victim vehicle is greater than forward vehicle
2:      if $v_{victim} > v_{backward}$ then    ▷ Speed of victim vehicle is greater than backward vehicle
3:          $V_{victim}$ enhances its speed to $v_{increase}$
4:      else if gap is present then
5:          $V_{victim}$ decreases its speed to $V_{decrease}$
6:          Send data to $V_{backward}$ after it overtakes $V_{victim}$
7:      else
8:          $V_{victim}$ carries the data by enhancing its speed
9:      end if
10: else
11:     Continue step-2 to step-9
12: end if
```

The time t_{cover} to cover the communication gap distance d_{gap} at an instant is calculated as $\frac{d_{gap}}{|v_{victim} - v_{forward}|}$. By adjusting the speed of V_{victim}, time t_{cover} can be reduced. This reduces the delay to forward the data from the source (A/H) to the destination (H/A).

Simulation and results

VehiHealth is evaluated by comparing with P-GEDIR, GyTAR, A-STAR and GSR routing protocols. Performance evaluation is done by considering four parameters discussed as follows:

1. Average End-to-End Delay: This is the average delay to send a data packet from the ambulance to hospital.
2. Number of Link Breakage: This represents the total number of link breakage in the path, when data is forwarded from the ambulance to the hospital.
3. Path Length: This represents the total number of vehicles used in the path to forward the data from the ambulance to the hospital.
4. Average Response Time: This represents the average time to send a response packet from the hospital to the moving ambulance.

In this simulation, the simulation area is considered as a square grid, where 36 intersections are considered and the distance between the intersections is set to 3000 m. The

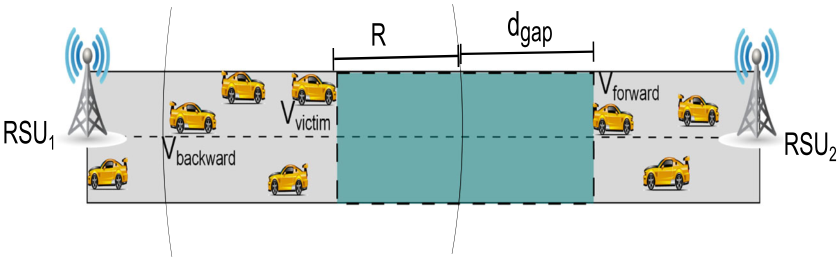


Fig. 4 Recovery from link breakage problem

numbers of vehicles between the intersections are varied from 20 to 100 to identify the performance of the protocol. The speed of the vehicles is assumed to be constant between the intersections. The speed limit of the vehicles is varied between 50 to 90 Km/H. Vehicle range is set to 250 m and RSU range is set to 500 m. The packet size is set to 512 bytes and channel rate is set to 2 Mbps. The simulations are performed in MATLAB version R2013a (8.1.0.604). The experiments are carried in two scenarios, where in the first scenario, the speed of the vehicles is varied from 50-70 Km/H and in the second scenario, the vehicles speed limit is varied from 50-90 Km/H. Simulation environment is set according to Table 2 and shown as follows:

According to Figs. 5 and 6, VehiHealth performs better than GyTAR, A-STAR, P-GEDIR and GSR routing protocols. VehiHealth takes minimum delay to forward the data to the hospital. In Fig. 5, when the number of vehicles between the intersections increases, delay reduces due to high chance of connectivity between the vehicles. According to Fig. 5, VehiHealth takes an average of 3.74 s, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 4.74, 9.16, 12.18 and 13.42 s respectively. In Fig. 6, when speed increases, there is a high chance of link breakage which leads to carry and forward mechanisms. This increases the delay to forward the data to the hospital, where Fig. 5 takes minimum delay. According to Fig. 6, VehiHealth takes an average of 5.32 s, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 5.92, 11.84, 14.86 and 16.5 s respectively.

According to Figs. 7 and 8, VehiHealth performs better than GyTAR, A-STAR, P-GEDIR and GSR routing protocols. VehiHealth encounters minimum number of link breakage problem. In Fig. 7, when the number of vehicles between the intersections increases, number of link breakage reduces due to high chance of getting a vehicle in the range. According to Fig. 7, VehiHealth takes an average of 0.6 number of link breakage, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 1, 2, 2.8 and 3.2 numbers of link breakage respectively. In Fig. 8, when speed of the vehicles increases, there is a high chance of link breakage problem. This increases the number of link breakage, where Fig. 7 takes less breakage. According to Fig. 8, VehiHealth takes an average of 1.2 numbers of link breakage, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 2.2, 4.4, 5 and 5.6 numbers of link breakage respectively.

According to Figs. 9 and 10, VehiHealth performs better than GyTAR, A-STAR, P-GEDIR and GSR routing protocols. VehiHealth uses less number of vehicles to forward

Table 2 Simulation setup

Parameter	Parameter value
Number of intersections	36
Distance between the intersections	3000 m
Number of vehicles between the intersections	20-100
Vehicle speed	50-90 Km/H
Vehicle range	250 m
RSU Range	500 m
Packet size	512 bytes
Rate	2 Mbps

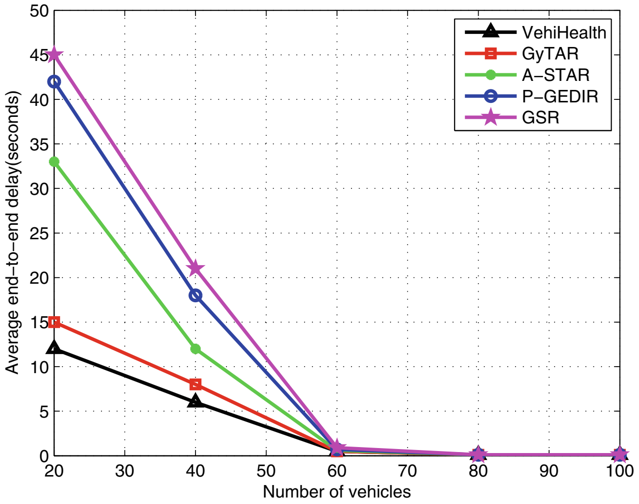


Fig. 5 Average end-to-end delay with speed 50-70 Km/H

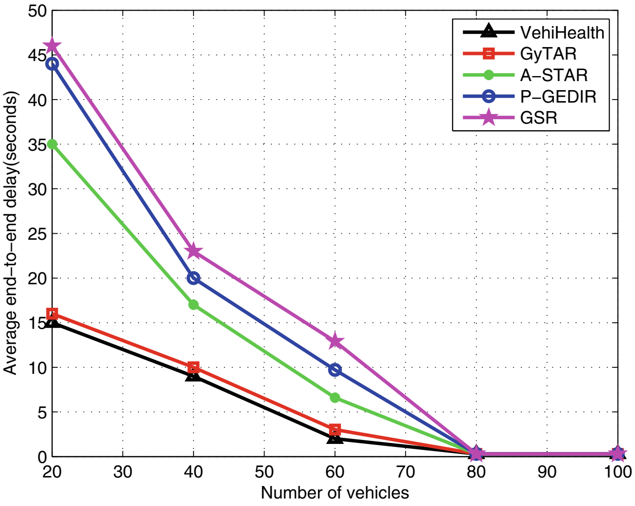


Fig. 6 Average end-to-end delay with speed 50-90 Km/H

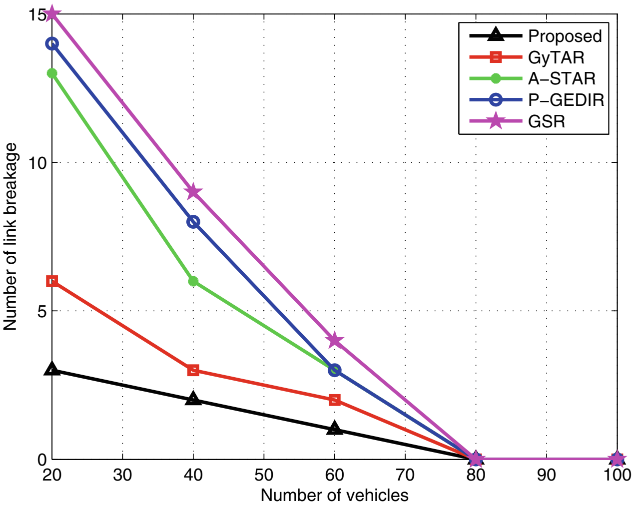


Fig. 8 Number of link breakage with speed 50-90 Km/H

the data in the path. In Fig. 9, when the number of vehicles between the intersections increases, link breakage reduces and chance of getting a vehicle in the range increases to select $V_{closest}$. Carry and forward mechanisms uses many vehicles between the intersections which increases the path length. According to Fig. 10, VehiHealth takes an average path length of 62.2, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 64.4, 67, 69.4 and 71.2 respectively. In Fig. 10, when speed of the vehicles increases, there is a high chance of link breakage problem. This increases the path length, where Fig. 9 takes short path. According to Fig. 10, VehiHealth takes an average path length of 64.2, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 65.8, 69, 70.8 and 73 respectively.

According to Figs. 11 and 12, VehiHealth performs better than GyTAR, A-STAR, P-GEDIR and GSR routing protocols. VehiHealth takes minimum average response time to forward the data to the ambulance. According to Fig. 11, VehiHealth takes an average of 2.14 s, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 2.42, 7.56, 10.58 and 11.42 s respectively. In Fig. 12, when speed increases, there is a high chance of link breakage problem. This increases the delay to forward the data to the ambulance, where Fig. 11 takes minimum delay. According

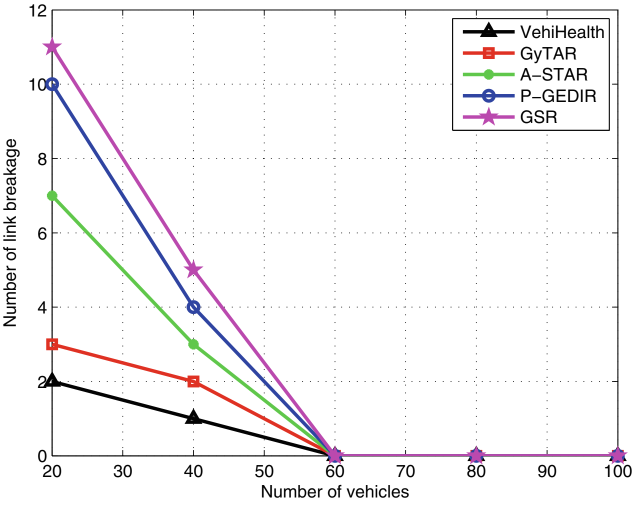


Fig. 7 Number of link breakage with speed 50-70 Km/H

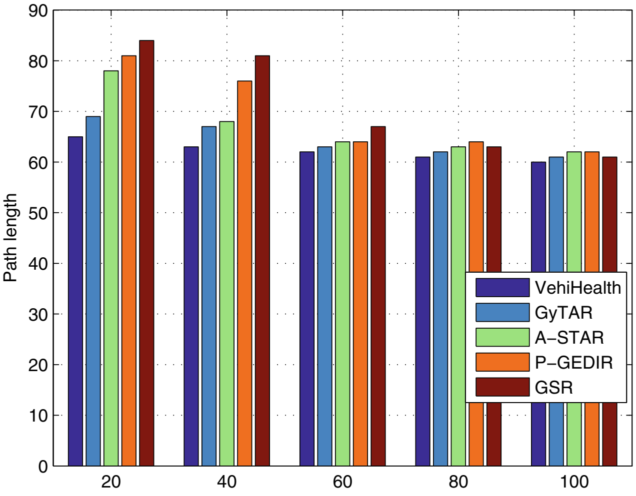


Fig. 9 Path length with speed 50-70 Km/H

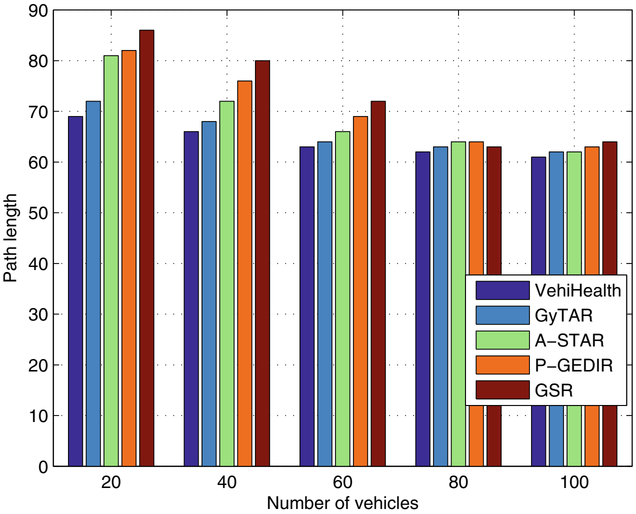


Fig. 10 Path length with speed 50-90 Km/H

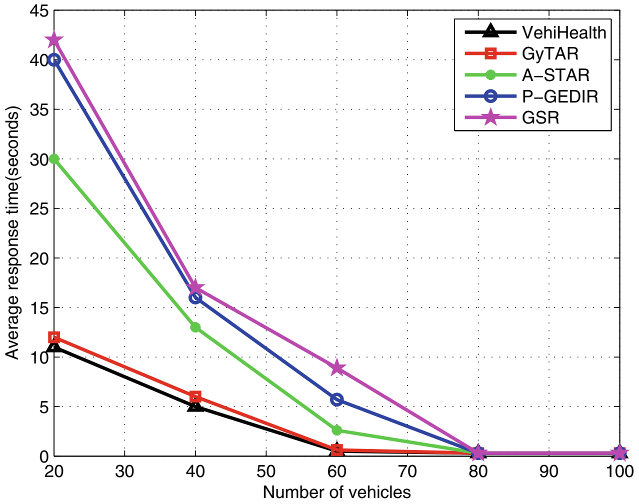


Fig. 12 Average response time with speed 50-90 Km/H

to Fig. 12, VehiHealth takes an average of 3.42 s, where GyTAR, A-STAR, P-GEDIR and GSR takes an average of 3.84, 9.24, 12.38 and 13.7 s respectively.

Table 3 shows the traffic information of a city, which presents the average density of the vehicles moving in the same direction between the junctions at different timings (day and night). This information is used to compute the end-to-end delay at the given timings.

From Table 3, it is observed that at the morning time 6:00 AM to 8:00 AM and at the night time (10:00 PM onwards) the density is low. When there is less density (10, 20, and 40), vehicles encounter communication gaps and this increases the end-to-end delay because of carry and forward mechanism. From Fig. 13, it is observed that communication is possible between 6:00 AM to 8:00 AM and when the density is 20 at 7:00 AM, the average delay is less than 10 s. When the density is moderate and high after 9:00 AM, the average delay between 9:00 AM to 20:00 PM is less than 20 ms. At night time after 22:00 PM to 00:00 AM, the communication is possible and the average delay is less than 20 s. The average end-to-end delay after 00:00 AM is too high and it is difficult for the routing protocol to forward the data to the destination due to less density of vehicles. Therefore, according to the traffic information shown in Table 2, the routing protocol performs well in this scenario from 6:00 AM (morning) to 00:00 AM (midnight).

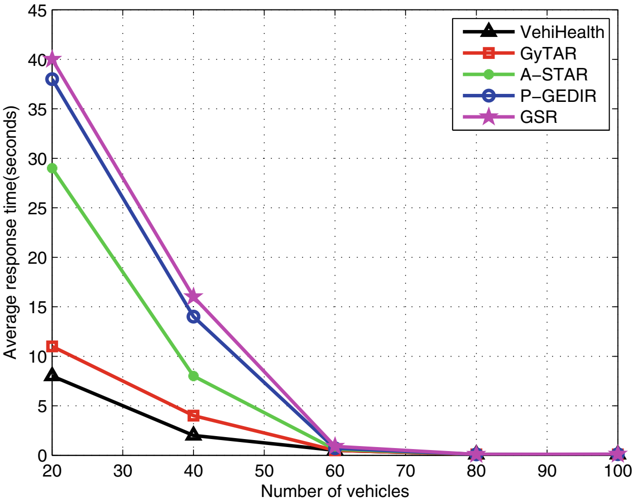


Fig. 11 Average response time with speed 50-70 Km/H

Table 3 Density of vehicles at different timings

Time	Density	Density characteristics
6:00 AM	10	Low
7:00 AM	20	Low
8:00 AM	40	Low
9:00 AM	50	Moderate
10:00 AM	70	High
11:00 AM	80	High
12:00 PM	60	Moderate
14:00 PM	50	Moderate
16:00 PM	60	Moderate
18:00 PM	70	High
20:00 PM	60	Moderate
22:00 PM	40	Low
23:00 PM	20	Low
00:00 AM	10	Low

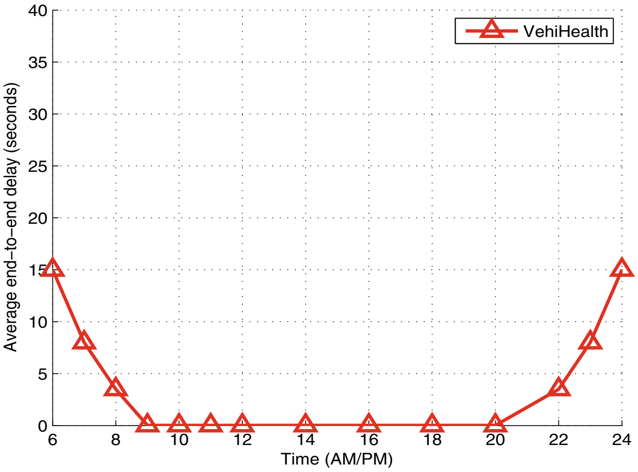


Fig. 13 Average end-to-end delay in seconds at different timings when the speed vehicles are set between 50-90 Km/H

Conclusion

VehiHealth promises a better routing protocol to support healthcare system by providing pre-medical treatment to the patients in emergency situation. It is a cost effective routing solution where the data is send to the destination free of cost by using ad hoc communication. To forward the data, intersections are selected by finding I_{value} of the neighboring intersections. The minimum I_{value} intersection is selected as the next intersection through which the data is forwarded. This method reduces the end-to-end delay by predicting the connectivity of the road. So, the path which is highly connected and takes minimum delay is selected as the next path. This method supports the medical system by attaining faster data exchanges between the ambulance and hospital. From the simulation results, it is observed that VehiHealth performs well from morning hour 6:00 AM (morning) to 00:00 AM (midnight). However, after midnight to 6:00 AM its performance reduces and the end-to-end delay is high due to few or no vehicles between the junctions. In future, we will focus on the data communication between the ambulance and hospital at midnight and early morning time using wireless communication technology.

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