VANET – EBGR RESEARCH

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Abstract
Vehicular Ad-hoc Network a revolutionary step to the intelligent Transportation system plays a vital role in public safety transportation sectors. Vanet requires huge amount of research and new protocols, different routing methods are devised on the daily basis due to its lack of knowledge in the working field. This report revolves around hierarchical pattern of Vanet, its architecture from the system and network point of view, types of routing protocols, mobility models, real-world projects, applications associated with vehicular ad-hoc networks. It deals with the detail description of Edge Node Based Greedy Routing a Vanet routing protocol and two quantified routing models justify its implementation process.

Ad-hoc Networks

An Ad -hoc network is a collection of wireless mobile nodes, which operates temporarily on the infrastructure free environment and follows the working principle of distributed systems with no central administration. Every node in Ad-hoc network is employed as an independent router that aids in conducting multi-hop communication between the nodes, which are located outside the transmission range. Ad-hoc network is enriched with some of the positive technical factors such as more scalability, less complexity and highly dynamic in nature. At the same time ad-hoc networks suffers from some of the constraints such as limited battery back-up, radio range and heterogeneity of devices [1][2][3].

Mobile Ad-hoc networks

A mobile Ad-hoc network (MANET) is a sub class of Ad-hoc networks and an autonomous system consists of integrated mobile nodes operating in the absence of fixed network infrastructure. MANET follows adaptable routing strategy that works on the rapidly changing and unpredictable network environment. MANET is capable of retrieving the whole network topological information at any moment and it has the following characteristics [4]

- Dynamic Topologies
- Bandwidth constrained Links
- Energy constrained operation
- Limited physical security

MANET can be employed in military and other tactical applications such as emergency rescue missions, which demand no cost-effective infrastructure. Some of the commercial applications of MANET includes intelligent and interactive lecture, information sharing during tactical military operations and business informatics sharing during meetings [1][5][6].

Vehicular Ad-hoc Networks

A special interest in Intelligent Transportation System has led to the advent of Vehicular Ad-hoc network, a special and advanced form of Mobile Ad-hoc networks aiming at providing intelligence in public transportation systems, thereby enhancing safety in the transportation sectors [7]. VANET is a self-organizing network based on the wireless short-range communication involving vehicles as wireless nodes, which transmits data among the vehicles and nearby roadside equipment. VANET plays a vital role in safety of the public transportation systems and it is challenging due to its dynamic mobility [11]. Vehicular Ad-hoc networks can be applied based on the three following perspective such as safety related warning systems, improved navigation mechanisms, information and entertainment[13][12]. Federal

Communication Commission (FCC) has allocated 75MHz in 5.9 GHz as a dedicated short range communication for Vanet [15][10].National Highway Traffic Safety Administration(NHTSA) and certain OEM-Original Equipment Manufacturers have joint venture to form Vehicle Safety Communication Consortium(VSCC) to foster VANET's potential growth [13]. The working principle, communication pattern of the vehicular ad-hoc networks can be categorized under the following sections such as

- Characteristics
- Real World Projects
- Applications
- System Architecture
- Network Architecture

- ***Characteristics*** [8][13][14][15]:

1) Unlimited Transmission Power

Power supply is not a constraint for the vehicular network since the vehicle or the node plays as a frequent power source.

2) Highly Dynamic Topology

The network topology is highly dynamic and it will change due to the high mobility of the vehicles.

3) Predicable Mobility

Even though the vehicles are highly dynamic in nature the entire mobility pattern of the wireless nodes or vehicles are confined by the layout of the road.

4) Scalability

VANET is an infrastructure free environment where vehicles can join and leave the network at any moment.

5) Location Specification

Location of the nodes or the vehicles can be monitored with the help of the GPS receiver

6) Hard delay constraints

The network does not require high data rates but at the same time it does not tolerate maximum delay constraints.

7) Frequent Network Fragmentation

It may occur due to the combination of dense and sparse network on the road.

8) Communication Environment

Includes some dense network such as urban areas and some sparse networks such as suburbs, freeways and highways.

- ***Real World Projects*** [8][13]:
    1) COMCAR
    2) DRIVE
    3) FleetNet
    4) Network Wheels
    5) CarTalk 2000
    6) CarNet
    7) eSafetySupport
    8) PReVENT
    9) COMeSafety

- ***Applications***

    1) Vehicle Collision Warning
    2) Security Distance Warning
    3) Driver Assistance
    4) Dissemination Road Information
    5) Co-operative Cruise Control
    6) Co-operative Driving

- ***System Architecture*** [15][1][9][8]:
  The system architecture of Vehicular Ad-hoc networks can be classified into two types such as
    1) Vehicle-to-Vehicle Communication
    2) Vehicle-to-Infrastructure Communication.

1) *Vehicle-to-Vehicle Communication* [15][1][9][8]:
   In this architecture, vehicles or wireless nodes communicate with other peer nodes with the help of the onboard units - type of communication devices installed in vehicles.

2) *Vehicle-to-Infrastructure Communication* [15][1][9][8]:
   In this architecture, vehicles will tend to communicate with the RSU-Road Side Units a static communication device, which is situated at the side of the road.

- ***Network Architecture*** [13]:

The network architecture of the Vehicular Ad-hoc network can be categorized into three following sectors such as

1) Physical Layer
2) Mac Layer
3) Network Layer

1) Physical Layer

In US Federal Communications Commission (FCC) allocated 75 MHz of spectrum from 5.850 to 5.925 GHz as a dedicated short-range communication. In Europe Car2Car Communication Consortium has allocated 5.885-5.905GHz for transmission strength. In Japan 5.8GHz short-range communication was employed with 60 GHz millimeter wave. IEEE 802.11 is considered as an ideal communication standard for the wireless networks. It can be applied in On-board units and roadside units in Vehicular Ad hoc networks. The basic data rate in IEEE 802.11 standard is 3Mbps and we can expect unto 27Mbps.Basic Technologies involved in VANET are as follows pure ad-hoc networks, Wireless LAN and hybrid Cellular Technology.

a. *Wireless Technologies* [14]:
Vehicular Ad-hoc Network uses the following mobile technologies: Wireless Metropolitan Area Networks, Wireless Local Area Networks, Wireless Personal Area Networks and Dedicated Short Range Communications.

b. *DSRC/WAVE* :
IEEE 802.p protocol is used for generating very short range messages that propagates information from one vehicle to another vehicle.

c. *WMAN*:
Used for interconnecting distant locations. There are two types of WMANs: back haul and last mile. Wireless MAN can communicate in point-to-point or point-to-multi point.

d. *WLAN*:
An IEEE 802.11 transmitter gives a directional communication range of 250 m. Suitable for highway and urban models.

e. *WPAN*:
IEEE 802.15/Bluetooth is used for short-range wireless communications. Average communication range if 10-20 meters.

2) *MAC Layer*
In order to avoid collision and congestion in VANET, MAC layer is required and it can be implemented in the form of two approaches: IEEE 802.11p and an alternate approach is Ad-hoc MAC also known as RR-Aloha.

3) Network Layer
Network Layer plays an important role in showcasing the appropriate routing protocols, which are required for performing multi-hop communication between the source and the destination. All the routing protocols in VANET falls under the following categorization. They are as follows:

a. *Broadcast* - Involves the routing process of delivering the messages from one node to all the neighbor nodes and repeating the process exponentially until it reaches the destination node. This technique is generally employed in finding and updating the whole network topology. This technique is prone to collision and congestion problems.

b. *Unicast* - Unicast routing is used to find an optimum path routing path between the source and the destination and usually maintains the route path between the source and the sink. Follows the carry and foreword strategy.

c. *Geocast*- Used to route the packets between the source and the destination by using appropriate location information from a GPS - Global Positioning System and no maintenance is required for the routing path and it reduces network fragmentation using periodic broadcast. Global Positioning System is helpful in providing certain information factors about the wireless nodes such as Vehicle identification number, Latitude and longitude position, Direction, Speed of the vehicle and timestamp of receiving and sending packets [14].

Classification of VANET Routing Protocol [8]:

Due to the high mobility of the wireless nodes and the dynamic topology of the vehicular ad - hoc network, it is very difficult to implement the desired routing protocol. VANET routing protocols can be broadly classified into following types:

- ***Topology Based Routing*** [8]:

  Topology based routing operates with the help of the link information obtained within the wireless network. Topology based routing can be classified into Proactive and Reactive routing.

- **Proactive routing protocols**

  Proactive routing protocols are table driven in nature. A routing table will be generated at each node containing information like number of hops, destination address and sequence number for each route entry to the desired destination. A constant update of the routing table is required to keep the nodes in the present loop thereby attaining the overall topological information of the network. Route maintenance is required for the all-possible optimum network path and it is suitable for small networks.

- ***Reactive routing protocols***

  Reactive routing protocols are on-demand in nature. It discovers the route for the source on on-demand basis by employing 1-hop neighbor knowledge method in which each node collects the information of the one-hope neighbor nodes by exchanging “hello” messages. Periodic updating is required and it uses flooding (Global search) for the route discovery process. Not suitable for small networks.

- ***Geographic Routing*** [8]

  In Geographic routing, each nodes position (latitude and longitude) is determined with the help of the position determining services like GPS (Global Positioning Systems). Route discovery and management is not required for this type of routing.

1) *Delay Tolerant Network* [8]
This type of routing uses carry and forward strategy, which involves the opportunistic process of storing the packet and forwarding it based on the metrics of neighbor nodes.

2) *Beacon Based Routing* [8]
This type of network involves nodes transmitting short hello messages periodically, thereby indicating its presence and location in that particular network. The node will be removed from the neighbor table if it does not respond to the beacon signal sent from the appropriate source node.

3) *Overlay Routing* [8]
Overlay network is a virtual network built upon the existing network.

4) *Connection Based Forwarding Routing* [8]
This kind of routing involves broadcast techniques to forward the packets to the direct neighbors in the networks. It saves bandwidth of the network by eliminating the beacon message.

Types of Vanet Routing Protocols [8]

- AODV - Ad-hoc On Demand Distance Vector routing
- DSR- Dynamic Source Routing
- TORA- Temporally Ordered Routing protocol
- VADD - Vehicle Assisted Data Delivery
- GeOpps- Geographical Opportunistic Routing
- GPSR- Greedy Perimeter Stateless Routing
- GPSR+AGF - Greedy Perimeter Stateless with Advanced Greedy Forwarding
- GRANT- Greedy Routing with Abstract Neighbor Table
- GPCR-Greedy Perimeter Co-coordinative Routing
- GyTAR- Greedy Traffic Aware Routing
- GSR - Geographic Source Routing
- A-STAR - Anchor-Based Street and Traffic Aware Routing
- LOUVRE - Landmark Overlays for Urban Vehicular Routing Environments
- TO-GO - Topology-assist Geo-Opportunistic Routing
- EBGR- Edge Node Based Greedy Routing
- PDGR- Predictive Directional Greedy Routing
- MDDV – Mobile Centric Data Dissemination Algorithm for Vehicular Networks.
- VADD- Vehicle Assisted Data Delivery

Routing Protocols	Topology Based Routing		Geographic Routing			
	Proactive	Reactive	DTN	Beacon	Overlay	CBF
Fisheye State Routing	✓					
Global State Routing	✓					
AODV Routing		✓				
Dynamic Source Routing		✓				
Temporally Ordered Routing		✓				
VADD Routing			✓			
GeoApps Routing			✓			
GPSR				✓		
GRANT Routing				✓		
GPSR+AGF Routing				✓		
PBR+DV Routing				✓		
GPCR					✓	
GyTar					✓	
Geographic Source Routing					✓	
A-STAR					✓	
STBR					✓	
LOUVRE					✓	
TO-GO Routing						✓
Geo-DTN Routing			✓	✓		
MDDV Routing		✓	✓	✓		
EBGR		✓	✓	✓		
PDGR		✓	✓	✓		

Mobility Modeling [11][16]

Mobility plays a vital role in determining the protocol preference in VANET. Most of the research activities in VANET is simulation based and only limited understanding can be achieved in mobility models and simulation patterns in VANET. The reason for opting simulation in Vehicular ad-hoc networks is the practical difficulty in conducting large scale of logistic and technological trials. The following aspects are considered for devising a new mobility model for Vehicular Ad-hoc network such as high speed of cars, strict constraint on nodes and movement patterns, continuous occurrence of dense and sparse network areas and finally clustering of users at intersections or in traffic jams.

Classification [11][16]

Mobility models can be classified according to certain factors such as behavior of the driver, movement of the vehicles and also the evaluating factors differs from model to model. Mobility models can be classified into following types

- Macroscopic Models
- Mesoscopic Models

- Microscopic Models
- Stochastic Models
- Traffic Stream Models
- Car-following Models
- Flows-interaction Models

- ***Macroscopic Models*** [11][16]
  Macroscopic Models resembles fluid dynamics theory where the traffic flow is considered as a continuous flow and the density or the mean velocity of the vehicles or nodes are calculated in this model.

- ***Mesoscopic Models*** [11][16]
  Individual mobile nodes are modeled at the aggregate level and the working pattern of the model resembles gas kinetic and queuing theory concepts. Velocity and density relationships are helpful in determining the motion of the vehicles or the nodes in this working model. This model is suitable for capturing the dynamics of large vehicular network covering the vast region and countries.

- ***Microscopic Models*** [11][16]
  Each node movement and pattern is described in detailed manner and their dynamics is treated independently. It has the ability to reproduce fine-grained real world situations such as lane chaining, intersections, front to rear car interaction and flows merging at ramps. Due to their high computational cost and complexity, it is applied in small environment like single highways and urban areas.

- ***Stochastic Models*** [11]
  Stochastic models are very trivial in nature, which involves nodes with randomly chosen speed.

- ***Traffic Stream Models*** [11]
  Traffic stream models are high level in nature and it determines each node's speed by applying hydrodynamics theory to determine the relationship between the nodes interns of velocity and density of the vehicles. It falls under macroscopic models.

- ***Car-following Models*** [11]
  Car-following models are based on the behavior of the driver and it determines the position, speed and acceleration of the nodes or vehicles. It falls under microscopic models.

- ***Flows-Interaction Model*** [11]
  Flows Interaction model is based on mutual dynamics of the vehicles and it follows the working principle of the above mentioned mobility models.

Types [11]

There different types of existing mobility models and they are as follows

- Freeway Mobility Models
- Manhattan Mobility Models
- City Section Mobility Models

- ***Freeway Mobility Model*** [16]

  Freeway mobility model is map generated based model. It includes many freeways and no urban routes thus leads to no intersection scenario. It is not a realistic model and nodes in this model are placed randomly. The minimum security distance is followed and change of lanes is not allowed here.

- ***Manhattan Mobility Model*** [16]

  Manhattan mobility model is map generated based model, where vehicles or nodes are randomly placed and the calculation is based on the historical data generated from the previous encounters. The routing decision is based on the probability range and the security distance is also maintained at this model.

- ***City-Section Mobility Model*** [16]

  City section mobility model is the combination of random way point and Manhattan mobility model. It uses shortest path strategy and follows a pause time limit at the destination. Speeds of the nodes are constrained by security distance along with the maximum speed limit of the road.

Routing Strategies [6][15][17][19][20][21][22][23][24][25]:

Routing algorithms plays a vital role in decision making to forward the data packets between the source and the sink and the relative performance of the routing protocol can be rated based on how well an optimum path is determined in time of routing. Routing algorithms are dominant to two factors such as the rate of change of topology and the number of routers in the routing domain [19]. There are different types of routing algorithms, which are as follows

- Greedy Forwarding
- Opportunistic Forwarding
- Perimeter or Face-2 mode
- Geographical Forwarding
- Restricted Greedy Forwarding
- Trajectory based Forwarding
- Predictive Mobility Forwarding

- ***Greedy Forwarding*** [9][15][19]:

  Greedy Forwarding is the process of locally opting a optimal neighbor node as a next hop by applying 1-hop neighbor node information. The main goal of this process is to find the ideal node, which has minimum distance from the destination node as a suitable next hop.

- ***Opportunistic Forwarding*** [23]:
  Opportunistic Forwarding is also known as carry and forward approach, where a neighbor node stores the data packet when it witness a local maximum scenario in the network and transmits the packet when it acknowledges a new node within that particular transmission range.

- ***Perimeter or Face-2 Forwarding*** [18][21]:
  Perimeter or face-2 forwarding acts as a recovery algorithm for the greedy forwarding and it operates based on the right hand rule. If the neighbor node encounters a local maximum condition inside the network then it switches over to perimeter mode and traverses the along the edge of the other nodes in the form of planar graphs by implementing right hand rule.

- ***Geographical Forwarding*** [23][25]:
  Geographic forwarding involves in transmitting the packets to the desired destination by accumulating all the potential factors like speed, position, velocity of the respective nodes with the help of the reactive location service known as GPS-Global Positioning System.

- ***Restricted Greedy Forwarding*** [23]:
  Restricted Greedy Forwarding plays a vital role in transmitting the packets at the junction areas in a city environment where all the buildings and the blocks acts as an obstacle for the data transmission.

- ***Trajectory Based Forwarding*** [18][23][24]:
  Trajectory based forwarding is based on the process of forwarding the packets to the idle neighbor nodes which are in the same direction of the desired destination node. This type of routing works hand in hand with the geographical forwarding.

- ***Predictive Mobility Forwarding*** [24]:
  Predictive Mobility Forwarding involves the process of forwarding the data packets by performing some prediction method for the multi hop communication using some of the probabilistic theory models.

EBGR - Edge Node Based Greedy Routing [7][15][24]:

Edge node based greedy routing algorithm follows a greedy position based routing approach, where it implements two techniques known as greedy routing and geographic routing. EBGR is a reactive protocol, where a source node attains the geographical information of its immediate or one-hop neighbors in a greedy fashion by using certain reactive location service known as Beacon signals. This type of routing detects the address of the destination nodes with the help of reactive location service known as GPS - Global Positioning System. The goal of the EBGR algorithm is to find the optimum node at each transmission range by performing greedy forwarding techniques. Edge node is defined as the optimum node and it plays a crucial role in transferring the message from source to destination. There are certain metric calculations involved in determining the edge node in a network. These metrics are considered as evaluation parameters which are affected by certain potential factors like speed, location, direction, velocity etc.

The overall configuration required for the Edge Node Based Greedy Routing algorithm is categorized into following sub sections

- System Architecture
- Network Architecture
- Mobility Modeling
- Routing Approach

- ***System Architecture***

The scenario used for Edge node based greedy routing is based on V2V communication, where a node communicates with other peer nodes with the help of the OBU- Onboard Units, which are installed in every mobile node.

- ***Network Architecture***

The network architecture is categorized into following layers

1) Physical Layer
2) MAC Layer
3) Network Layer

1)Physical Layer

Wireless Local Area Network (WLAN) is used for EBGR, where it employs EEE 802.11 a transmitter gives a directional communication range of 250 m. Highly suitable for highway and urban models.

2)*MAC Layer* [25]

IEEE 802.11 DCF- Distributive Co-coordinative Function protocol is used in the MAC layer where it uses both carrier sensing and virtual carrier sensing for transmitting packets between the peer nodes. Two types of control messages are RTS-(Request To Send) and CTS - (Clear To Send) ,are transmitted between the source and destination before communicating the necessary packets.

3)*Network Layer*[15]

Greedy routing and position based routing techniques are implemented in this layer.

- ***Mobility Modeling*** [11]

Relative Mobility model is used for Edge Node Based Greedy Routing algorithm. Location services like GPS can be employed in this model. All the nodes with different speed are randomly distributed by using concept known as Linear Node density. Deterministic and instantaneous transmission mechanism can be implemented within the transmission range of 250 meters in this model. Front hop and back hop communication is also possible in this model.

Features	Relative Mobility Model
Real Maps	
No of Lanes	✓
Bidirectional Vehicle Movement	✓
Intersections	✓
Lane Changing	✓
Traffic Control	
Overtaking	✓
Security Distance	✓
Pause Time	✓

- ***Routing Approach*** [15][24]

Edge Node Based Greedy Routing algorithm uses certain evaluation parameters to calculate the optimum node in a particular transmission range and these metrics are categorized into following functional units.

Functional Units [15][24]:

- Neighbor Node Selection
- Distance Calculation
- Direction of Motion Identification
- Reckoning Link Stability
- Potential Score Calculation
- Edge Node Identification

- ***Neighbor Node Selection*** [15]

Neighbor node selection is the process of collecting information about all the neighbor nodes in that particular transmission range. The neighbor node uses beacon signals to notify its presence to the source node by sending messages periodically for μ seconds in the form of a label known as neighbor set. A node is said to be dropped out of the network if it does not respond to the source node after α*μ seconds where α is the number of times a node is allowed to miss the beacon signal.

- ***Distance Calculation*** [15][12]

Distance calculation is used to find the closeness of the next hop. That is, it is the shortest distance between the neighbor nodes which are inside the transmission range of the source node to the desired destination node.

$$DC = \left(1 - \frac{Di}{Dc}\right)$$

1) Di – Shortest distance from neighbor node to the destination node.
2) Dc – Shortest distance from packet forwarding to the destination node.
3) Di - Closeness of next hop

- ***Direction of Motion Identification*** [15][12]

Direction of Motion Identification is used to determine whether the neighbor node is in the direction of the destination node.

$$DMI = \cos(\vec{Vi}, \vec{Li,d})$$

1) $\vec{Vi}$ – Vector for Velocity of neighbor node.
2) $\vec{Li,d}$ – Vector for the location of neighbor node to the location of destination node.
3) $\cos(\vec{Vi}, \vec{Li,d})$ - Cosine value of angle made by these vectors.

- ***Reckoning Link Stability*** [15][26]

Link stability is used to calculate the stability between the source node and the forwarder node in each transmission range. The term σ is the routing route validity time of the network and it is proved in the case study that σ=α*μ that is, the counter used to determine whether the neighbor node is in the network or not. The counter α can also be considered as a potential factor which determines whether the node is in the communication range or not.

$$D^2 = ((X_{io} + Vx_i\Delta t) - (X_{Jo} + Vx_J\Delta t) + (Y_{io} + Vy_i\Delta t) - (Y_{Jo} + Vy_J\Delta t))^2$$

$$D^2 = A\Delta t^2 + B\Delta t + C$$

$$A = (Vx_i - Vx_J)^2 + (Vy_i - Vy_J)^2$$

$$B = 2[(X_{io} - X_{Jo})(Vx_i - Vx_J) + (Y_{io} - Y_{Jo})(Vy_i - Vy_J)]$$

$$C = (X_{io} - X_{Jo})^2 + (Y_{io} - Y_{Jo})^2$$

$$\Delta t = A\Delta t^2 + B\Delta t + C - R^2$$

$$L,S[i,j] = \frac{\Delta t}{\sigma}$$

Here LS[i,j] = 1 when Lifetime[i,j] >= σ

1) X_o - Initial position of the node in terms of X-axis.
2) Y_o - Initial position of the node in terms of Y-axis.
3)
4) Vx – Speed of the node along x-axis, $Vx = \frac{X2 - X1}{T2 - T1}$
5) Vy – Speed of the node along y-axis, $Vy = \frac{Y2 - Y1}{T2 - T1}$
6) Σ – Route Validity Time = α*μ seconds.

- ***Potential Score Calculation*** [15][12]

Potential Score is used to identify an optimum node in the network by considering the following aspects like closeness of the next hop to destination, direction of motion and link stability between the nodes. An Edge node is determined based on the potential score.

$$PS_i = \rho * \left(1-\frac{Di}{Dc} \right) + \omega * \cos(\vec{Vi}, \overrightarrow{Li,d}) + \lambda * LS[i,j]$$

$$\rho + \omega + \lambda = 1,\ \lambda>\rho,\ \lambda>\omega,\ \rho>\omega$$

(ρ,ω,λ) – Potential Factors used for trade -off between the evaluation parameters.

- ***Edge Node Selection*** [15]

An Edge node is considered as an optimum node in that particular transmission range by evaluating certain functional units such as distance calculation, direction of motion and reckoning link stability. A node with higher potential score is nominated as an edge node.

EBGR Implementation in C++ Language

Neighbor Node Selection

```
float range(int x1, int y1, int x2, int y2)
{
    float rr;
    rr=sqrt(pow((x2-x1),2) + pow((y2-y1),2));
    return rr;
}
```

Distance Calculation

```
float edge_node::distance_calculation( float x, float y, float z,
float w, float a, float b)
{

    di= sqrt(pow((a-z),2)+pow((b-w),2));
    df= sqrt(pow((a-x),2)+pow((b-y),2));
    dc=1-(di/df);
    cout<<endl;
    return dc;
}
```

Direction of Motion Identification

```
float edge_node::direction_motion(float j, float m, float n)
{


    num = (m* j) + (n * 0);
    dem = (sqrt(pow(m,2)+pow(n,2))) * (sqrt(pow(j,2)+pow(0,2)));
    dm = num/dem;
    cout<<"=============================================="<<endl;
    return dm;
}
```

Reckoning Link Stability

```
float edge_node::link_stability(float s, float e,float v, float j,
float o, float q)
{

    a=pow((o-q),2);
    c=pow((s-v),2)+pow((e-j),2) - r;
    b=2*(s-v)*(o-q);
    t1=((-b)+sqrt(abs(pow(b,2)- (4*a*c))))/(2*a);
    t2=((-b)-sqrt(abs(pow(b,2)- (4*a*c))))/(2*a);
    r1=t1/beacon;
    r2=t2/beacon;

cout<<"============================================================"<<
endl;
    if (r1>r2)
    {
        return r1;
    }
    else
    {
        return r2;
    }

}
```

Potential Score Calculation

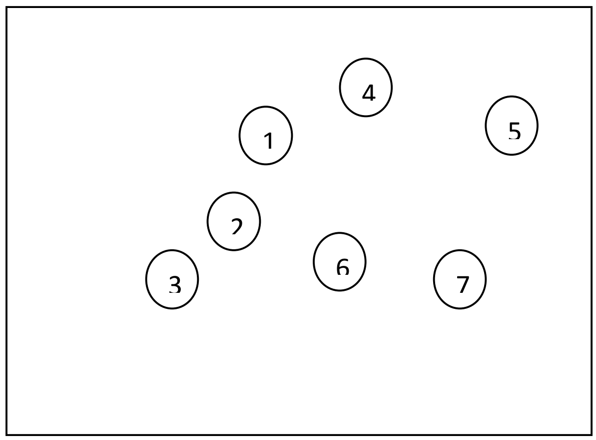
```
float edge_node::potential_score(float l, float d , float s)
{

    result= (rho*l)+(omega*d)+(lamda*s);

cout<<"========================================================"<<endl
```

```
;
    return result;
}
```

Quantified Models

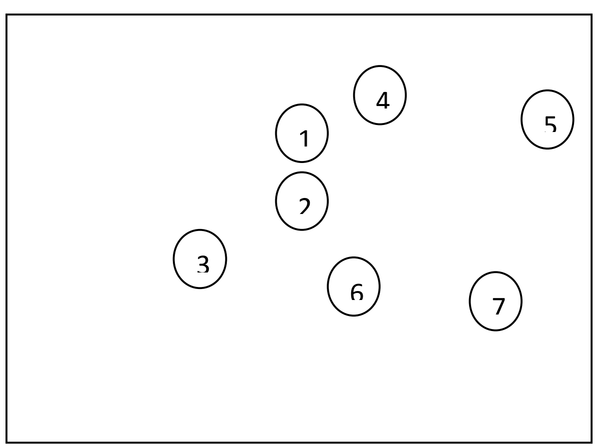
The quantified results for the two highway models are calculated using EBGR code. They are as follows

Model 1



Source – N3
Destination – N5
Transmission Route – N3 – N2—N1 –N4 –N5

Model 2



Source – N2
Destination – N5
Transmission Route: N2—N1—N4—N5

Conclusion

All the factors related for the Vehicular ad-hoc routing like routing protocols, mobility models and respective system and network architecture were discussed in detail manner. A Vanet routing protocol known as Edge node based greedy routing is implemented in C++ language and it is justified by testing two quantified routing models. The future work for this project includes the process of implementing EBGR in Ns-2 simulation software to achieve the maximum technical knowledge of this protocol in different routing scenarios.

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