CHAPTER: V

MOBILITY IN GEOGRAPHIC ROUTING SCHEME
5.1 Mobility Scenario

In recent years, the deployment and importance of wireless networks has grown rapidly. Mobility plays a key role in this regard, and has driven the development of many new services, such as VoIP and interactive multimedia. In support of these developments, new mobile and wireless protocols are proposed by researchers to support novel applications and to improve the overall performance of wireless networking amongst mobile nodes. Obviously, developers must evaluate the impact of their protocols on network characteristics and analyze the behaviors of the network under the proposed conditions.

Simulations of wireless networks employ several components critical to the accuracy of the simulations, one of the most important being the choice of mobility model, which creates the movement patterns of mobile nodes that forms the varying topology of the network. A typical mobility model first places the mobile nodes in their initial locations and defines the way that the nodes move within the network. Indeed, the mobility model emulates the real user movement through the inclusion of the critical movement factors such as direction, speed, destination, and the movement histories of the same, or similar, users. [134][135]

The most important characteristic of a mobility model is the degree of realism with respect to the movement of users in real life. More realistic models enable more accurate simulation and evaluation of network parameters. In addition, because there exists no single, comprehensive, mobility model the incorrect selection of an inappropriate model, not mimicking the movement patterns expected in the real life environment under consideration, leads to incorrect observations and results. [133]
5.2 Mobility scenarios in PoEGR:

Node mobility is an inherent part of mobile adhoc networks. The route maintenance phase deals with node movement. We identify following different scenarios:

5.2.1 A node joins the route region:

Two steps needs to be done. First the node needs to find its one-hop neighbors and inform them of its existence. The second step is to update the node information in case it is needed. The first step is done by sending out at most $k + 1$ packets sent from the new node and $k$ packet sent from its one hop neighbors, assuming that the maximum degree of the route region is $k$.

When node $i$ joins the route region two scenarios can happen:

Node $i$ is a candidate node (Entry of $i$ in routing table exist):

A node is a candidate node in this scenario, the node information need to be updated in ad hoc router node, therefore only ad hoc router nodes which are used to forward data packets updates its routing table as required and decides whether to update an entry of candidate node in its routing table or not. So now routing strategy will decide whether node $i$ will work as adhoc router means will select as forwarding node.

Node $i$ is not a candidate node(Entry of $i$ in routing table not exist):

Effectively, this means that $i$ created new path(s) in the route region and hence the node information entry needs to be create in ad hoc router node. An ad hoc router updates its routing table as required and decides whether to create an entry in its routing table. So now routing strategy will decide whether node $i$ will work as adhoc router or not. Other solution is to
ignore route maintenance since the old routes would still deliver the packets.

5.2.1 A node departs the route region:

When node i joins the route region two scenarios can happen:

A regular node departs the route region:
After node i move out of the route region, its neighbors are informed by not receiving the ACK or mobility message from i. Two scenarios can happen: If i was a candidate node, updates for node i in routing table of ad hoc router must be done. If i was not a candidate node, no need to update the routing table.

An adhoc router node departs the route region:
In this case node i take the responsibility of updating the affected routes. If i is a candidate node so it send mobility message to all its 1-hop neighbours and ad hoc router nodes update the information of i.

A fix threshold value for mobility must be set to broadcast the mobility message by the mobile node. Node working as ad hoc router means having an initialize routing table can update the information of mobile nodes accordingly. Although all neighbour are receiving this mobility messages but those who are not working as ad hoc router do not update routing tables for mobile node nor forward the mobility message so control message overhead can be controlled.
5.3 Comparison of Mobility Models

5.3.1 Random Walk Mobility Model

The random walk mobility model is the simplest mobility model, generating completely random movement patterns. It was designed for simulations in which the movement patterns of mobile nodes are completely unpredictable. Since many entities in nature move in extremely unpredictable ways, the Random Walk Mobility Model was developed to mimic this erratic movement. In this mobility model, an MN moves from its current location to a new location by randomly choosing a direction and speed in which to travel. In this model, a mobile node is initially placed in a random location in the simulation area, and then moved in a randomly chosen direction between \([0, 2\pi]\) at a random speed between \([\text{SpeedMin}, \text{SpeedMax}]\). [135]

![Traveling pattern of an MN using the 2-D Random Walk Mobility Model](image)

**Figure 31:** Traveling pattern of an MN using the 2-D Random Walk Mobility Model

Each movement in the Random Walk Mobility Model occurs in either a constant time interval \(t\) or a constant distance travelled \(d\), at the end of
which a new direction and speed are calculated and this process is repeated a predetermined number of times. Figure 31 shows the result of a single node executing the random walk mobility model with a constant travel time. Many derivatives of the Random Walk Mobility Model have been developed including the 1-D, 2-D, 3-D, and d-D walks. In 1921, Polya proved that a random walk on a one or two-dimensional surface returns to the origin with complete certainty, i.e., a probability of 1.0 [137]. This characteristic ensures that the random walk represents a mobility model that tests the movements of entities around their starting points, without worry of the entities wandering away never to return. [135] [133]

Two variations of the random walk mobility model were proposed by Nain et al., [138] to address the problem experienced when mobile nodes reach the boundary of their simulation area namely:

1. Random Walk with wrapping
2. Random Walk with reflection

**Random Walk with wrapping**

In the random walk with wrapping approach [134], when a mobile node reaches an edge, it wraps to the opposite edge and continues its movement with the same direction and speed. This is illustrated in Fig 5.2

![Figure 32: Random Walk with wrapping](image)

*Figure 32:  Random Walk with wrapping*
Random Walk with reflection
In a further approach, random walk with reflection [134], when a mobile node reaches any edge of the simulation area, the node changes its angle of movement and its velocity remains constant. The approach employing reflection clearly generates more accurate movement patterns, simply because real life mobile nodes are more likely to reflect their movement when reaching an obstacle. This is illustrated by Fig 5.3

![Random Walk with reflection](image)

**Figure 33:** Random Walk with reflection

5.3.2 A 2D Random Walk Mobility Model
Mobility of users is a major advantage of wireless over fixed telecommunications systems. The signaling traffic and database processing to support mobility of users are always the key concerns in the design and performance of wireless networks. Mobility models play a key role in studying different mobility management features such as registration, paging, handoff, and database approaches. A mobility model with minimum assumptions and which is simple to analyze will be very useful under such circumstances. In most wireless network performance studies the cell is assumed to be either hexagonal or square in shape, though in real life cell shapes may be highly irregular. [133] [136]
The highlights of the model are its simplicity, minimal assumptions, and adaptability to conduct both location crossing rate and dwell time studies using the same model with slight modifications for both square and hexagonal cells. The model uses a set of aggregate states to trace user movement within one location area and then uses a set of special (asterisk) states when crossing the boundary of the location area. Due to the wrap-around technique, the movement of the mobile is modeled to again enter the original states from the special states, once the mobile starts moving within the new location area. Average number of location area crossing rates or updates made by the user is obtained by solving for the regular Markov chain. [136]

A slightly modified model with absorbing states was used to derive the dwell time. This is the first model of its kind that can be used for studying area-crossing rates and dwell times using a simple model. Overlap location area strategies are commonly used concepts in cellular networks. The fluid flow model and random walk model are the two main types of mobility model that have been applied in location management studies. The fluid flow model can derive the average rate of boundary crossings per unit time out of a given area, but it is difficult to apply the model to the modern per-user based location area strategies or to study overlapped area strategy performance. Most random walk models are designed for dynamic location area strategy or for deriving the dwell time. [134]

The simple 2-D random walk model is based on the properties of the regular and absorbing Markov chain. The regular model is used for computing the location update rates. The same model with absorbing states is used to derive the dwell time in an area. The number of computational states in the model is very less, making it s analysis is
easy. A “states wrap-around” feature has been introduced in the model, which facilitates estimating location update rate using simple equations. The model can be adapted to both square cell and hexagonal cell structures. Because of the simplicity in calculations, the model can be extended to study overlapped location areas strategies, which has hitherto been difficult to handle. These are features, which make the model ideally suited to mobility management studies in cellular networks, though with limitation that the cells will be either square or hexagonal. [136]

Users in cells belonging to a Location Area (LA) have identical movement pattern within and across LAs. Such cells can be assigned to a single state in the Markov chain using the lumped process property. This property has been applied here to achieve reduced computational states in the model. A state which lumps a number of cells with identical movement pattern is called an “aggregate state”.

### 5.3.3 Model for square cells

Fig. 34A shows an LA configuration for n*n square cells where n = 5. The bold lines indicate the boundary of the LA. Cells in the adjacent LAs are shown outside the thick boundary lines. There are 25 cells in the LA and they have been numbered, identifying each cell with its row and column position. It is assumed that the mobile user can make movement in 4 directions only with an equal probability of ¼ in each direction as shown in Fig. 34B. In Fig 34A arrows show the possible user movement across cells within one LA and across LAs. In some of the cells, with reference to the LA, the mobile user will have identical movement patterns to other cells within the same LA and to cells in adjacent LAs. For e.g. from cells numbered 11, 15, 55 and 51 the mobile user movement pattern and transition probabilities will be identical but rotated
by 90 degrees. The rotation of the movement pattern will not affect the studies to be conducted using Markov chains. Hence these four cells can be grouped into one aggregate state in the Markov chain model. This property of lumping the states was carried out to reduce the total number of computational states in the mathematical analysis. An algorithm to perform state aggregation is given below (Figs 35A and 35B are provided for the purpose of explaining the aggregation process) [136]

5.3.4 Algorithm

1. Number the cells belonging to an LA as “rc” where r is the row number and c is the column number as shown in Fig 34A. The numbering scheme has been applied to the cells in the adjacent LAs also i.e. cells just outside the bold lines.

2. As shown as in Fig. 35A assign the cells to different loops. In this case there are 3 loops. Let l = number of loops. Then l=1 is the outer loop, l=2 is the next loop and l=3 is the innermost loop. Cell 33 belongs to loop 3. Cells numbered 22, 23, 24, 34, 44, 43, 42, 32 belong to loop 2. The rest of the cells in the LA belong to loop 1.

```
Start with n =5, l=1
Until ( n =l)
Repeat { x= l; y = n;
            Until( x > y)
            x = {Src ∪ Scr}
            Repeat {
                set S x = {Src ∪ Scr}
                Where r = l for c = x, y and r = n for c = x, y x = x +1; y = y-1;
            }
            n = n-1, l= l+1;
        }
```
$S_{1x}$ is the aggregate state obtained as a set of the cells Src and Scr where, Src is the cell numbered “rc” and Scr is the cell numbered “cr”.

After the aggregation process the following state aggregation is obtained:

\[
\begin{align*}
S_{11} &= \{S_{11}, S_{15}, S_{51}, S_{55}\}, \\
S_1 &= \{S_{21}, S_{25}, S_{41}, S_{45}, S_{52}, S_{52}, S_{14}, S_{54}\}, \\
S_1 &= \{S_{31}, S_{35}, S_{13}, S_{53}\}, \\
S_{12} &= \{S_{22}, S_{24}, S_{42}, S_{44}\}, \\
S_{22} &= \{S_{32}, S_{34}, S_{23}, S_{43}\}, \\
S_{13} &= \{S_{33}\}
\end{align*}
\]

For ease-of-use, the aggregate states were assigned numbers as shown below.

$S_{11} \rightarrow 1, S_1 \rightarrow 2, S_1 \rightarrow 3, S_{12} \rightarrow 4, S_{22} \rightarrow 5, S_{13} \rightarrow 6$.

We now have 6 aggregate states. The LA is redrawn in Fig. 35B with the cells numbered with their newly assigned aggregate state numbers. In Fig. 35B aggregate states 1, 2 and 3 are in the boundary of the LA and are called the “boundary” states. We further define “asterisk boundary” states (or “star states”) i.e. 1*, 2* and 3*, which are the boundary states in the adjacent LAs. Let LA0 be the LA under consideration then in Fig 35B, LA1, LA2, LA3 and LA4 are the adjacent LAs. From LA0 a user can move only into any one of these adjacent LAs. [136]

Using the direction and movement probabilities given in Fig. 34B, the state transition diagram for the regular Markov chain based on the aggregate states can be derived as shown in Fig 36. In this approach the entire movement of the mobile user across different cells and across LAs is modeled. The “asterisk boundary” states and the wrap around mechanisms; achieve this freedom of movement feature. Movement into an “asterisk” boundary state indicates a location area crossing and can be used to study the location area crossing rates or location updates.
As long as the user moves within cells in a location area, he is in one of the main aggregate states i.e. 1, 2, 3, 4, 5 or 6. His movement is accordingly traced by the transitions shown. Transition probabilities are marked beside the transition. The dotted transitions to the asterisk states indicate the mobile user’s transition to a boundary state in an adjacent location area and the probabilities of such transitions are given besides these dotted transitions. These transitions accordingly model the mobile user’s movement probability from the main location area cells to the adjacent location area cells. While in an asterisk states the user can move across to other asterisk states. For e.g. (in Fig 35B) the user move from 1* in LA3 to 1* in LA7 or from 2* in the adjacent LA3 back to 2 in LA0 (2 in LA0 now would be 2* from the mobile user perspective as it is in an adjacent LA). [136]

In Fig. 36, this movement is modeled by the dotted transitions to itself in the asterisk states. Again, looking at the user movement from state 1* in LA3 (Fig 35B), the user has a probability of ¼ to move into state 1* in LA7, and probability of a ¼ to move into state 1 in LA0 (which is now state 1* in the adjacent LA from the user perspective) - hence a transition probability of ½ to itself in state 1* is shown in the Fig. 36. [136]

When the user starts moving in the new LA, for e.g. when he moves from state 1* in LA3 to 2* in LA3 or from 2* to 1* in LA3 the model wraps back to the normal states - indicating that the user has now started moving in cells belonging to the new LA. This is shown by the dotted transitions from the asterisk states to the normal states in Fig 36. This novel wrap-around feature has subsequently led to the possibility of studying the location area crossings using simple equations. This model can be applied at various levels of the network hierarchy. It can used to
study the LA crossing and dwell time within one VLR (Visitor Location Area) and the traffic due to VLR crossing at the next higher level in the hierarchy. [136]

**Figure 34:** Location Area (LA)

**Figure 35:** Location Area (LA) with boundary state
5.3.5 Advantages of RW Mobility Model

1. The simplest model to implement.
2. Generates unpredictable movements, enabling a long-running simulation to consider all locations and node interactions. [134]

5.3.6 Disadvantages of RW Mobility Model

1. Unrealistic movement patterns
2. Sharp and sudden turns.
3. Wrapping not observed in real applications. [134]

5.3.7 Random Waypoint Mobility Model

The random waypoint mobility model introduces specific pause times between movement’s i.e changes in direction and speed. The random waypoint model is the most popular mobility model employed in contemporary research, and can be considered a foundation for building other mobility models. [133] [134]
An MN begins by staying in one location for a certain period of time (i.e., a pause time). Once this time expires, the MN chooses a random destination as well as a speed that is uniformly distributed between [0, MAXSPEED]. It then travels towards the newly chosen destination at the selected speed. Upon arrival, the MN takes another break before starting the process again. [133]

We note that the movement pattern of an MN using the Random Waypoint Mobility Model is similar to the Random Walk Mobility Model if pause time is zero and [0, MAXSPEED] = [speedmin, speedmax]. This is a simple mobility model and is hence adopted by many authors in their simulation studies. [133] [135]

Fig 37 shows the travelling pattern of an MN using the Random Waypoint Mobility Model.

![Traveling pattern of an MN using the 2-D Random WayPoint Mobility Model](image)

**Figure 37:** Traveling pattern of an MN using the 2-D Random WayPoint Mobility Model
5.3.8 Advantages of RWP Mobility Model

1. The most common use mobility model, because of its simplicity.
2. A building block for developing a variety of mobility models.

[134]

5.3.9 Disadvantages of RWP Mobility Model

1. Lack of regular movement modeling.
2. Exhibits speed decay.
3. Exhibits density wave.
4. Memory-less movement behaviors (a common problem for all random waypoint variations). [134]

5.3.10 Random Direction Mobility Model

The Random Direction Mobility Model (Royer et al., Submitted) was created in order to overcome a defect discovered in the Random Waypoint Mobility Model. MNs using the Random Waypoint Mobility Model often choose new destinations, and the probability of choosing a new destination that is located in the center of the simulation area, or requires travel through the middle of the simulation area, is high. The MNs moving with the Random Waypoint Mobility Model appear to converge, disperse, converge again, etc. In order to alleviate this type of behavior and promote a semi-constant number of neighbors, the Random Direction Mobility Model was developed. [133] [135]

In this model, MNs choose a random direction in which to travel instead of a random destination. After choosing a random direction, an MN travels to the border of the simulation area in that direction. As soon as the boundary is reached the MN stops for a certain period of time, chooses another angular direction (between 0 and 180 degrees) and
continues the process. Figure 38 shows an example path of an MN, which begins at the center of the simulation area using the Random Direction Mobility Model. [133] [134]

![Figure 38: Travelling pattern of an MN using the Random Direction Mobility Model](image)

A slight modification to the Random Direction Mobility Model is the Modified Random Direction Mobility Model. In this modified version, MNs continue to choose random directions but they are no longer forced to travel to the simulation boundary before stopping to change direction. Instead, an MN chooses a random direction and selects a destination anywhere along that direction of travel. [133]

### 5.3.11 Advantages of RD Mobility Model

1. A variation of the random waypoint without drawback of density wave.
2. Uniform distribution of chosen routes [134]
5.3.12 Disadvantages of RD Mobility Model

1. Unrealistic movement pattern
2. Average distances between mobile nodes are much higher than other models, leading to incorrect results for routing protocols evaluation [134]

5.3.13 Limitations of the Random Waypoint Model and other Random models

The Random Waypoint model and its variants are designed to mimic the movement of mobile nodes in a simplified way. Because of its simplicity of implementation and analysis, they are widely accepted. However, they may not adequately capture certain mobility characteristics of some realistic scenarios, including temporal dependency, spatial dependency and geographic restriction [135].

- Temporal Dependency of Velocity: In Random Waypoint and other random models, the velocity of mobile node is a memory less random process, i.e., the velocity at current period is independent of the previous period. Thus, some extreme mobility behavior, such as sudden stop, sudden acceleration and sharp turn, may frequently occur in the trace generated by the Random Waypoint model. However, in many real life scenarios, the speed of vehicles and pedestrians will accelerate incrementally. In addition, the direction change is also smooth. [135]

- Spatial Dependency of Velocity: In Random Waypoint and other random models, the mobile node is considered as an entity that moves independently of other nodes. This kind of mobility model is classified as entity mobility model. However, in some scenarios...
including battlefield communication and museum touring, the movement pattern of a mobile node may be influenced by certain specific 'leader' node in its neighborhood. Hence, the mobility of various nodes is indeed correlated. [135]

- Geographic Restrictions of Movement: In Random Waypoint and other random models, the mobile nodes can move freely within simulation field without any restrictions. However, in many realistic cases, especially for the applications used in urban areas, the movement of a mobile node may be bounded by obstacles, buildings, streets or freeways. [135]

Due to these shortcomings, other realistic mobility models were developed to examine the network characteristics of a scenario employing mobile nodes. Gauss-Markov Mobility model and Smooth-Random Mobility model are examples of mobility models with temporal dependency. Reference Point Group Mobility model (RPGM), Column Mobility model, Pursue Mobility model etc are examples of mobility models with spatial dependency. Pathway mobility model and Obstacle Mobility model are examples of mobility models with geographic restriction.
5.4 PoEGR Modified Packet structure for mobile nodes:

<table>
<thead>
<tr>
<th>Source Address</th>
<th>Source Location</th>
<th>Target Address</th>
<th>Target Location</th>
<th>RDF Optional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDF Header</td>
<td>NDR Header</td>
<td>Payload</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type (T)</td>
<td>Type Specific Information</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There are now three types of NDR packets: FLD, BLD and MLD. FLD and BLD and MLD specify FLD/BLD/MLD control packets, respectively. The type-specific information of FLD (Type = FLD) and BLD (Type = BLD) packets are almost the same except BLD packets additionally include the forwarding node id and relay cancellation flag (RCF) as shown in Fig. 39. Note that a FLD packet can carry the data payload when it is available. MLD (Type=MLD) packet are broadcast at a movement of mobile node greater than threshold value. MLD control packet update the routing table of node working as ad
hoc router. Ad hoc router updates its routing table according to mobile nodes update.

5.5 Modified PoEGR (PoEGR-M) for mobile nodes:

As consider in mobility for ad hoc network, either the mobile node will join the network or may leave the route region. If node joins the route region the node may either candidate node or non-candidate node similar can be consider for mobile node leave the route region, the node leave the network may be candidate node or non-candidate node. Along with this ad hoc router node can also leave the route region. If mobile nodes are there in network there location may vary after each time interval T.

Taking care of all above possibilities appropriate solution must be in taken for our algorithm. Note that no update will be done by the nodes which are not working as ad hoc router. Triggering update must be done for specific mobility varying value.

Ad hoc router node look updateSeqAngle field in routing table when a candidate node joins the route region, if current angle is less than in routing table, then update for redundant node is made. Similar for non-candidate node if angle of node discovery is greater than the current angle new entry for non-candidate node will be done.

When candidate node departure the route region and due to mobility threshold value it broadcast control message updates is mentioned in routing table of ad hoc router and if non-candidate node departure the route region no updates are made in ad hoc router.

Although ad hoc router node depart the route region and it is candidate node so it send mobility message to all its 1-hop ad hoc router nodes to update the information. Probability of ad hoc router broadcast the
mobility message depends on mobility threshold value. As mobility
threshold values is small ad router nodes routing table will hold more live
values.

```
TriggeringUpdates(Forwarding node A, packet)
{
  If (packet = Mobility Message)
  {
    if (SearchNode(A_neigh, RT_A) != Match and _
     RouteDiscoveryAngle of A > C₀)
    {
      Insert A_neigh into RT_A as a new entry E_new;
      RT_A[E_new].Sr += 1;
      RT_A[E_new].NodeID = A_neigh.NodeID;
      RT_A[E_new].NLV = CalculateNLV(A_neigh, A);
      RT_A[E_new].hops = 1;
      RT_A[E_new].ForwardingFlag = B;
      RT_A[E_new].UpdateSeqAngle = Θ
      RT_A[E_new].LinkStatus = B
    }
    Else {
      Update A_neigh into RT_A as a entry E_old;
      RT_A[E_old].NodePos = A_neigh.NodePos;
      RT_A[E_old].NLV = CalculateNLV(A_neigh, A);
    }
  }
  ElseIf (packet != ACK)
  {
    RTA.LinkStatus[NFN] = C;
    ForwardPacket(packet, A);
  }
}
```
5.6 Simulation Environment

We simulated our protocol using NS-2 and the wireless extension to NS-2 which was developed at Carnegie Mellon Ns-2 is a discrete network simulator developed at UC Berkeley.

In the following we describe NS-2 network model in some detail.

- **Radio Propagation Model:** The physical model we used is called TwoRayGround. The TwoRayGround model is the most realistic model to use for ad hoc wireless network simulations. The advantage of the TwoRayGround model is that it extends the ideal circle model to a statistical model where the nodes near the edge of the circle can only probabilistically communicate.

- **Energy Model:** NS-2 has an implementation of a simple energy model in which every time a packet is transmit, the total energy of the node decreases by the value, The same formula applies for decreasing the energy when a packet is received.

  \[ \text{Energy Reduced} = \text{Packet Transmit} \times \text{Transmit Time} \]

5.7 Comparison Metrics

In order to compare the performance, we choose the following metrics:

- **Packet delivery ratio:** This is defined as the ratio of the number of packets received by the destination, to the number of packets originated by the source.

- **Delay:** The average time taken between when a packet was initially sent by the source, and the time it was successfully received at the destination.

- **Path Length:** Path length is defined as the number of hops a packet takes to reach its destination.
- **Number of Retransmissions**: The total number of valid retransmissions required to go from a source to destination. Valid retransmissions are defined as retransmissions due to not receiving an acknowledgement (ACK) for a transmitted data packet.

## 5.8 Simulation Setup:
We have compared simulation results with the following Geographic Routing Protocols:

- **DREAM**: A Distance Routing Effect Algorithm for Mobility
- **MFR**: Most forward progress within radius
- **LAR**: Location-Aided Routing
- **LGF**: Location-based geocasting and forwarding
- **ARP**: Angular Routing Protocol
- **PoEGR**: Probabilistic Energy aware Geographic Routing

The initial energy of the nodes is set to 1000 J, and transmit and receive powers are equal and set to 0.281 J. The idle power is set to 0.035 J. We simulate 5, 10, and 20 Constant Bit Rate (CBR) traffic flows. The source and destination of these flows are chosen at random. Each CBR flow has a rate of 4 packets per second, a packet size of 512, and max packet size of 1024. The simulation time is set to 500 seconds. The discovery time is set to 40 seconds. The other statistic regarding simulation setup is below as shown in the table:
Simulation Parameter | Value
---|---
Radio Propagation Model | TwoRayGround
Number of Nodes | 50-100
Square Area | 1000 x 1000 m
Antenna type | Omni Directional
Transmission Range | 200m
Interference Range | 500m
CBR Flow | 4 Packet/sec
Packet size | 512 bytes
Max Packet size | 1024 bytes
Simulation time: | 500 sec
Initial Energy of Nodes | 1000 Jules
Mobility Model | Random Way Point
Min Node Velocity | 0 m/s
Max Node Velocity | 5 m/s

Table 5: Simulation setup parameters

5.9 Simulation Results
The results we present here have been averaged.

5.91 Results based on Successful Transmission:
Here link value is based on successful transmission Successful transmission.

\[ \text{NLV(Dist)} = \text{LV(Aneigh)} \times \text{ST(Aneigh)} \]  

[Equation 3.3]
**Figure 40:** Delay (seconds) with 5-20 CBR source/destination pairs (Link Value based on successful transmission)
Figure 41: Throughput (%) with 5-20 CBR source/destination pairs (Link Value based on Successful Transmission)
Figure 42: Number of Retransmissions (Link Value based on Successful Transmission)

Figure 43: Path Length (Link Value based on Successful Transmission)

Evaluating the above mentioned results for the link value based on successful transmission means those nodes are selected which had more successfully transmit the packets; shows that as number of nodes in geographic region increases, delay in packet delivery becomes more
constant in PoEGR, it shows that as network change in node density not affects the major change in results i.e. PoEGR is more scalable protocol. Higher values of throughput (%) results show higher delivery ratio inform the better efficiency of PoEGR.

Less Number of retransmission show decrease in packet drop out ratio notify less overhead.

Better path length for different density of nodes in specified geographic region predicts efficiency of routing.

5.92 Result based on Packet Error Charge:
Here link value is based on Packet error charge.

\[ NLV(error) = \frac{LV(Aneigh)}{(1 - \alpha) \times PE_{C_N} + \alpha \times F} \]  
\[ \text{[Equation 3.5]} \]

We use \( \alpha = 0.1 \), and the default PEC value is set to 0. Note that \( F = 1 \) even when an ACK frame failure occurs in IEEE 802.11 networks.
CHAPTER V: Mobility in Geographic Routing

**Figure 44:** Delay (seconds) with 5-20 CBR source/destination pairs (Link Value based on Packet Error Charge)
Figure 45: Throughput (%) with 5-20 CBR source/destination pairs (Link Value based on Packet Error Charge)
Evaluating the above mention results for the link value based on packet error charge means those nodes are selected which had less amount of errors in transmission; delay in packet delivery increases as node increase in network for 5 CBR and become more constant for 10 and 20 CBR for PoEGR. Error free nodes give better throughput and less number of retransmission in PoEGR notify less overhead.
Path length increases as density of nodes in specified geographic region increases.

5.93 Result based on Link Interruption

Here link value is based on Link interruption.

\[ \text{NLV(Interruption)} = \frac{\text{LV(Aneigh)}}{\text{LinkCost(Interruption)}} \]

[Equation 3.6]

We use LinkCost(Interruption) = Time required by medium to transmit
Figure 48: Delay (seconds) with 5-20 CBR source/destination pairs (Link Value based on Link Interruption)
Figure 49: Throughput (%) with 5-20 CBR source/destination pairs (Link Value based on Link Interruption)
Figure 50: Number of Retransmissions (Link Value based on Link Interruption)

Figure 51: Path Length (Link Value based on Link Interruption)

Evaluating the above mention results for the link value based on link interruption means link required time to transmit the packets; shows that those link which require less time to transmit are selected due to after a specific node density in network delay value become more constant in PoEGR shows more scalability of protocol.
Efficient link reduce the number of retransmission show decrease in packet drop out ratio notify less overhead and better path length for different density of nodes in specified geographic region.

5.94 Result based on Power Utilization

Here link value is based on Power utilization

\[ NLV(\text{power}) = \frac{LV(\text{Aneigh})}{\text{LinkCost(power)}} \]  

[Equation 3.7]

We use LinkCost(power) = Energy used to transmit
Figure 52: Delay (seconds) with 5-20 CBR source/destination pairs (Link Value based on Power Utilization)
**Figure 53:** Throughput (%) with 5-20 CBR source/destination pairs (Link Value based on Power Utilization)
Figure 54: Number of Retransmission (Link Value based on Power Utilization)

Figure 55: Path Length (Link Value based on Power Utilization)

Evaluating the above mention results for the link value based on power utilization means those nodes are selected which had higher battery power to transmit the packets; shows better result for delay and throughput by energy efficient nodes at 10 and 20 CBR, as network node density change not affects and shows the scalability of PoEGR protocol. Number of retransmission and path length are also reduced by routing by energy efficient nodes in PoEGR protocol notify less overhead.