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MOBILITY PATTERN FREE DYNAMIC AND EFFECTIVE LOCATION UPDATE IN MANET

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Abstract

The beaconing approach is the key function in geographic routing to disseminate the location. However, the node mobility is a prominent challenge to the beacon based location broadcasting schemes resulting in high routing overhead. The conventional methods allow some errors on location prediction. As a result, the mobile nodes update their location when the predicted location exceeds the allowable error range. However, the prediction error is more sensible for boundary nodes than adjacent nodes, as the boundary nodes located in the proximity area act as greedy nodes. Consequently, allowing the static prediction-error for all nodes does not efficiently reduce the overhead while maintaining the neighbor list accuracy. To deal with these issues, this work proposes a system called "MObility pattern free Dynamic and Effective Location update" (MODEL) for the maintenance of the trade-off between overhead and precision. Instead of allowing the static prediction-error, the Dynamic Acceptance Error Rate (DAR) in MODEL dynamically calculates the error range to the boundary and adjacent nodes and enhances the neighbor list accuracy with routing overhead. Due to the sensitivity of boundary nodes to the location being accurate, the MODEL efficiently exploits the fuzzy algorithm to allow a minimum error in predicting location rather than in adjacent nodes. This work simulates the proposed MODEL in NS2 simulator and compares the performance of the existing Load Balanced-Dynamic Beaconing Greedy Perimeter Stateless Routing (LB-DB-GPSR).

Keywords:

Location Update, Geographic Routing, Node Stability, Prediction-Error, Fuzzy Algorithm

1. INTRODUCTION

In Mobile Ad-hoc NETworks (MANETs), nodes arbitrarily move at the various speeds and unpredictable direction [1]. The mobility patterns impel the movement of nodes in terms of speed and direction. These mobility patterns reflect the characters of mobile nodes over a period of time [2] [3]. The geographic routing is widely used to forward the data packets to the intended destination using location coordinates [4] [5]. Hence, each node in the network is responsible for disseminating their location to its single-hop neighbors through beacons. However, the dynamic changes of local topology make the scalable beaconing for location dissemination challenging. All nodes in the local topology broadcast their current location as beacon packets in some interval. However, the high mobile nodes require less beaconing interval compared to the slow mobile nodes. The less beaconing interval of high mobile nodes leads to periodic beaconing, and also it creates the possible high overhead. However, the slow mobile nodes do not broadcast the beacon packets frequently. The conventional schemes apply mobility prediction to reduce the routing overhead caused by frequent updating [6]. Moreover, the allowable error range in location prediction makes high mobile nodes update their location when the predicted location exceeds the allowable error range [7]. However, the prediction error is more sensitive to boundary nodes than closer nodes as the boundary nodes are adept at acting like a greedy node. The closer nodes do not respond for updating the location frequently since they are maintained as a neighbor for a long time than boundary nodes. In this, the prediction error cannot be allowed as a static range of all nodes. Thus, the static beaconing approach does not adapt to various mobility patterns, and it supports only a specific mobility pattern. To accelerate the beaconing approach irrespective of mobility patterns, this work proposes the system called MObility pattern free Dynamic and Effective Location update (MODEL) scheme which includes the Dynamic Acceptance Error Rate (DAR) based on a Fuzzy algorithm and assures high neighbor list accuracy with less overhead.

The main contributions are,

- To reduce the overhead in geographical routing, irrespective of various mobility patterns, the proposed system called MODEL maintains the trade-off between beaconing overhead and neighbor list accuracy over a high dynamic network using two components such as beaconing importance and location prediction.
- To efficiently lower the routing overhead, the MODEL estimates the beaconing importance of each mobile node using the node stability and dynamically applies the prediction-error only on that selective node that has high beaconing importance.
- To maintain the neighbor list accuracy with dynamic prediction-error, the fuzzy algorithm considers multiple factors such as node availability for greedy routing and error unacceptance range in terms of distance.
- By estimating the dynamic prediction-error of the nodes, especially in an outer region, which are more sensitive to the location error, the MODEL assists in updating the exact location of greedy nodes with great neighbor list accuracy.
- The performance evaluation of the proposed method is simulated using the extensive NS2 simulator. The simulation result proves the efficient location updation of the proposed method.

The outline of the paper is represented as follows: Section 2 surveys the works related to efficient location update schemes in geographical routing, and it explains the problem statement of the MODEL. Section 3 describes the system model of the MODEL. Section 4 provides a brief detail of the proposed MODEL mechanism. Section 5 defines the simulation setup and evaluates the performance of the MODEL. Section 6 concludes this paper. Section 7 proposes the future enhancement with respect to neighbor list accuracy and throughput.

2. RELATED WORKS

The mobile nodes assist in efficiently forwarding the packets from source to destination in both the topology and location based routing [8] [9] [10]. The geographic (location based) routing eliminates the need for nodes to share and store the topology information. In geographic routing, the nodes are responsible for broadcasting their current position, and it decreases the costs related to sharing information. Many robust geographical routing protocols have been proposed in the recent years [11] [13]. Each node updates the location as beacon packets to their neighbors. In [14], the hybrid protocol efficiently accommodates the increase in the number of mobile nodes and gracefully adapts to real-life scenarios of limited location information and void regions. Every node changes the beacon broadcast intervals based on node mobility dynamics. For instance, the Adaptive Position Update (APU) method [15] includes the components of mobility prediction and on-demand learning. This feature dynamically updates the position to shorten the beaconing interval.

The stability estimation is taken into account to predict the mobility of nodes based on the self and neighbor stability. The mobility prediction with link stability based multicast routing protocol (Moralism) considers the link stability to predict the movement time of nodes for defining the route path to the destination. The signal strength is exploited to identify whether the direction of the mobile node is away or towards to the estimating node. The mobility prediction system tries to estimate stable links in the communication range of the computing node [16]. The system assists in discovering the neighbors. Each node finds its location by an ever-updated auto regression-based mobility model, and the neighboring nodes identify its position through the same mobility model [17]. Several vector mobility models have been proposed in recent years [18]. Moreover, the prediction is applied for highly mobile nodes. The high mobility creates the Lost Link (LLNK) problem and loop in packet delivery (LOOP) problem. To address these issues, Neighbor Location Prediction (NLP) and Destination Location Prediction (DLP) is introduced. Furthermore, the error is allowed for frequent location changing nodes [19]. The power-saving geographic routing algorithm proposes the Least Expected Distance (LED) that consumes the minimum power. Hence, LED can maximize the probability of selecting a node to ensure minimum power consumption in the presence of location errors [20]. Moreover, the prediction error is allowed for improving multimedia streaming. In [21], it solves the problem of accurately predicting the future location in the infrastructure-less networks. Especially, the boundary nodes have more importance than closer nodes since, they have the possibility of getting selected as a greedy node during data forwarding. The greedy forwarding is a conceptually simple term of geographic routing in which the packets are forwarded to the neighbor nodes located closest to the destination at each hop. In [22] [12], the proposed protocol exploits greedy nodes to forward the data, and that proposes Adaptive Position Update (APU) strategy for eliminating the periodic beaconing. The node broadcasts beacons only when the predicted error in the location is greater than a certain threshold value. Thus, the beaconing importance is restricted, and the resulting is reduced routing overhead.

2.1 PROBLEM STATEMENT

In a MANET, the common beaconing approach for location distribution makes the network more challenging regarding the problem of various mobility pattern scenarios and beaconing overhead. The periodic beaconing is the general approach that is followed for disseminating the beacons which contain location information induces high overhead. The high mobile nodes need short beaconing interval, consequently that creates the great routing overhead. The short beaconing interval is suitable for high mobility nodes. However, it is not reasonable for slow nodes. Hence, it is not feasible to assign a common beaconing interval for all mobile nodes as the nodes engage various mobility patterns. Likewise, the frequent beaconing is reasonable for the nodes those that are closer to the destination. However, it is not efficient for the nodes those that are far away from the destination. To tackle this location inaccuracy, existing systems exploits the location prediction method, but this is not possible for various mobility patterns. It leads to the link failure and makes the inaccurate topology information. Furthermore, allowing the prediction-error for high mobile nodes create the sensible beaconing issue on the boundary nodes more than on other nodes. Therefore, the static error allocation for all mobile nodes does not efficiently support the overhead reduction and neighbor list accuracy. Hence, it is crucial to design the dynamic beaconing approach to adapt perfectly to the various mobility patterns in the high dynamic environment.

3. SYSTEM MODEL

The network area of MANET is represented as $G(V,E)$ in which V represents a set of mobile nodes and E represents the direct communication links between two mobile nodes V. Transmission range of each node is represented as R which is partitioned into (inner, middle, outer) $R/3$, $2R/3$, and R respectively. The nodes V are moving in various mobility speeds. The beaconing importance of nodes V is varied according to their stability. If the node $n.V$ have high beaconing importance, some error E_r is allowed to update the current location (L_c) in a high beaconing interval resulting in less overhead. When $L_c > E_r$, node 'n' broadcast its new L_c. When 'n' moves to the outer region, 'n' is responsible for broadcast L_c with minimum E_r. The proposed model estimates the number of neighbor nodes whose involve 'n' as their boundary node and considers the common neighbors $\{C_i \backslash n\}$ (i=1,2,3,...,N) in R to both own node and neighbor node as well as error unacceptance distance (R-L_{cd}). L_{cd} represents the distance between the own node and 'n'. Apply fuzzy rule on both $\{C_i \backslash n\}$ and (R-Lcd) to dynamically allow E_r. By this, the overhead and neighbor list accuracy are maintained efficiently over the highly dynamic environment.

4. OVERVIEW OF PROPOSED MODEL

Due to the mobility of nodes in the MANET, the inaccurate neighbor list makes unreliable wireless communication. Frequent beaconing is the widely used technique to maintain the accurate neighbor list. However, it escalates the routing overhead and collision. Therefore, the proposed system called MObility pattern free Dynamic and Effective Location update (MODEL) is accountable to dynamically tune beaconing interval and maintain better trade-off between neighbor list accuracy and overhead. Instead of periodic beaconing, the MODEL initially measures the beaconing importance which reflects the location change of a node. However, the value of beaconing importance is high even if a node has slight changes in its location, resulting in higher overhead. Furthermore, it reveals the comparable result to periodic beaconing. To deal with this issue, MODEL exploits another key component named as location prediction which allows some acceptable error range of mobile nodes. However, the prediction error range is more sensitive to boundary nodes than inner regional nodes, and that node is responsible for broadcasting the beacons even in minimum error. This is because the boundary nodes are mostly involved as a greedy node during data forwarding. In this, the statically allowable error range disrupts the neighbor list accuracy. To tackle this, the Dynamic Acceptance Error Rate (DAR) takes into account based on a Fuzzy algorithm. Thus, the dynamic allocation of error range reduces the overhead as well as maintaining the neighbor list accuracy.

4.1 NODE STABILITY BASED BEACONING IMPORTANCE

The mobility is a complicating factor that significantly affects the effectiveness and performance of the network. The nodes frequently update their current location to their neighbors through beacons. Each node in the mobile network has different stability ranges regarding their movement. If the movement of nodes oscillates within a fraction of transmission range, these nodes are stable. The highly stable nodes reduce the beaconing frequency resulting in less control overhead. In contrast, if the mobility is high, low frequency of beaconing is not adequate to keep track of the changes of neighbors, besides it creates the inaccurate neighbor list. Therefore, assigning the same beaconing frequency for all nodes is not fair, since the importance for beaconing is varied for nodes according to their mobility. Hence, the proposed MODEL quantifies the beaconing importance of nodes in a short interval so that, the frequent location changes of fast moving nodes can be updated even in a fraction of movement as well as the slow mobile nodes also can be updated. This short interval leads to obtaining a better location updation.

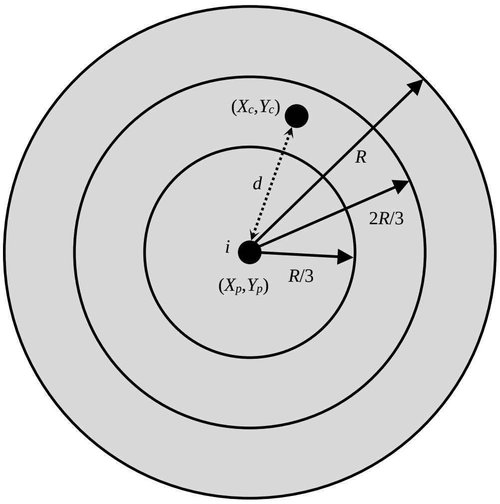

Fig.1. Representation of Self-Stability Prediction

4.1.1 *Self-Stability:*

The stability of the node keeps varying on the current position. When a node is trying to move away from its current position, the distance of the movement and transmission range decide the node stability. Each node predicts its self-stability at every time interval regarding the distance between the previous and current position as well as its transmission range as shown in Fig.1. In case, the distance between the previous and current position is zero; a node has a high self-stability. If the distance between the previous and current position is closer to or greater than the transmission range; a node has a poor self-stability.

The node 'i' moves from previous position (X_p, Y_p) to current position (X_c, Y_c) at the given time 't'. The 'd' represents the distance between previous and current position and R represents the transmission range of node 'i'. The R is divided into R/3, 2R/3, for stability estimation. The stability of node 'i' keeps varying concerning (X_p,Y_p) and d. Thus, the mobility distance of node 'i' (d_i^t) can be measured at time 't' by using Eq.(1).

$$d_i^t = \sqrt{\left(X_c - X_p\right)^2 + \left(Y_c - Y_p\right)^2} \tag{1}$$

$$SS_i^t = \begin{cases} 1 - \dfrac{d_i^t}{2R/3} & \text{if } \left(d_i^t < 2R/3\right) \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

According to the distance moved at every period, the self-stability metric (SS_i^t) can be determined as in Eq.(2). Allowing a node to move in the range of $d_i^t < 2R/3$ may not create a negative impact on greedy routing. However, the node stability becomes zero when it moves to the distance more than that of 2R/3, as it leads to packet loss due to location error.

4.1.2 *Neighbor Stability:*

The nodes can exchange their location through beacons when it has low self-stability. The node stability depends on the self-stability, and on the neighbor stability. The proposed MODEL estimates the neighbor stability level to lower the beaconing importance. Each node maintains a neighbor list, which carries the previous mobility history of neighbors, and the node takes the decision about its stability using Eq.(3). For all neighboring nodes, a node 'i' calculates the neighbor stability (NS_i^t) at the time 't' using previous three history values and among them, a neighbor who has the minimum NS_i^t is taken into stability factor (Sf_i^t) calculation of a node. Because such a neighbor has the high possibility to affect the stability factor.

$$NS_i^t = \min\left[\frac{1}{3}\left[\sum_{n=1}^{3} SS_i^{(t-n)}\right]\right] \tag{3}$$

where $SS_i^{(t-n)}$ represents the self-stability of a neighbor node. To make the use of stability in beaconing importance measurement, the MODEL takes into account the local topology changes due to its own and neighbor mobility.

$$Sf_i^t = \alpha \times SS_i^t + \left(1-\alpha\right) \times NS_i^t \tag{4}$$

In Eq.(4), α is a weighting factor (0 to 1) which entails the relative importance to both the self and neighbor stability. The beaconing importance is equal to the inverse of Sf_i^t. The nodes those have a low stability need high beaconing importance, as well as the nodes those have high stability, require low beaconing importance. According to the beaconing importance, the MODEL decides to apply the prediction algorithm on neighboring nodes. The neighbors that frequently change their mobility forces a node to predict its location. In contrary, the nodes those move slowly, do not require to predict the location. The location prediction model allows a small error in predicting location. However, small and same prediction-error for all nodes is not adequate, since providing large error acceptance in location prediction to the nodes located in the inner region further, reduces the beaconing overhead while maintaining the reliability of routing performance.

If the predicted error is greater than the acceptance error range, it triggers the node to broadcast the new location as beacons. However, the boundary nodes have more importance than inner region nodes as the boundary nodes have high possibility to act like a greedy forwarding node. Hence, the boundary nodes are responsible for updating their current location even in very low error when compared with closer nodes. To attain this aim, Dynamic Acceptance Error Rate (DAR) is being referred to dynamically change the acceptance error range depending on the location and mobility of the nodes.

4.2 FUZZY BASED DYNAMIC ERROR CALCULATION

The transmission range of each mobile node is partitioned into three regions, namely inner, middle, and outer for allowing the prediction-error dynamically. The proposed DAR dynamically allows the error to inner, middle, and outer region nodes depending on their stability. The boundary (outer region) nodes are very sensitive to prediction-error due to their capability of selecting as a greedy node during data forwarding. However, the minimum error is constantly maintained to the inner region nodes resulting in higher overhead. The MODEL dynamically allows different prediction-error to the nodes in inner and boundary region on the availability of common boundary neighbors and error acceptance distance.

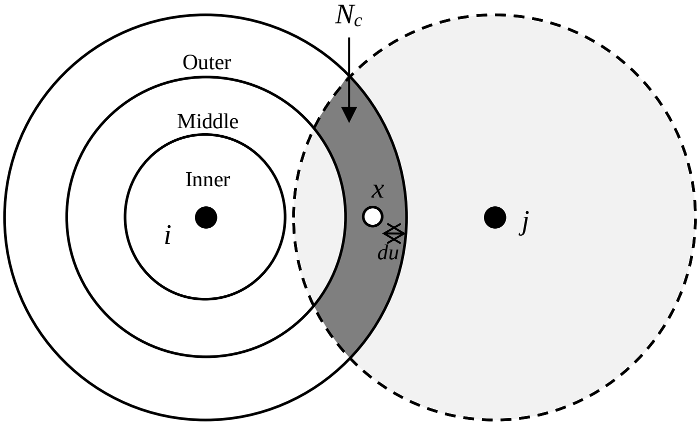

Fig.2. Representation of DAR

In Fig.2, the node '*x*' is arbitrarily moving in the outer region of the node '*i*' besides, the node '*x*' is also involved as a boundary node of node '*j*'. The DAR permits the dynamic error range to every node with the fuzzy algorithm. The fuzzy algorithm calculates the dynamic error based on the number of neighbors in the outer region of '*i*' (N_c) which is common to both '*i*' and '*j*' (represented as dark area in Fig.2) as well as the error unacceptance distance from the transmission range of '*i*' (*du*). The value of N_c exposes the availability of common greedy nodes in both '*i*' and '*j*'. If N_c is maximum, both '*i*' and '*j*' have more probability to select the greedy forwarding node. The du represents the remaining distance to move out of the transmission range. The Table.1 reveals the dynamic error calculation based on fuzzy rules.

Table.1. Fuzzy Rules for Dynamic Error Estimation

Number of Common Boundary Neighbors (N_c)	**Error Unacceptance Range (*du*)**	**Allowed Error**
Low	Low	Minimum
	Medium	Medium
	High	Maximum
Medium	Low	Minimum
	Medium	Medium
	High	Maximum
High	Low	Medium
	Medium	Medium
	High	Maximum

The error unacceptance range plays a main role in the error prediction since, when the boundary node crosses the unacceptance range of node '*i*', both the nodes are unable to communicate directly. Thus, the error unacceptance range is low for the boundary nodes resulting in minimum prediction error. The dynamic error calculation efficiently retains the neighbor list accuracy with low routing overhead. The Fig.3 shows the dynamic location update algorithm.

Aim: To update the neighbor list with less overhead and high accuracy
Input: Beaconing importance
Output: Dynamic calculation of prediction-error acceptance range
Each node do{
  Estimates the self-stability based on the distance between previous (L_p) and current location (L_c);
  Estimates the neighbor's stability using the recent mobility history in its neighbor list;
  Estimate the beaconing importance (B_i) based on the stability values;
  if (B_i == "LOW")
  {
   Update L_n to its neighbors via beacons in a normal beaconing interval;
  }
  else (B_i == "HIGH") {
   Allows dynamic error in location prediction;
   if (node == "boundary node (*x*)") {
    Calculates the number of nodes which involves same '*x*' as their boundary node;
    Estimate the remaining number of common neighbors in the outer region (N_c) except '*x*';
    Calculate the error unacceptance distance (*du*) from the transmission range;
    end
  end

Fig.3. Algorithm for Dynamic location update

4.3 ADAPTABILITY FOR VARIOUS MOBILITY PATTERNS

The proposed MODEL based beaconing strategy exploits two metrics namely beaconing importance and prediction-error for dynamically and accurately updating the location with less overhead. The MODEL supports various mobility patterns like Reference Point Group (RPG), Random Way Point (RWP), Random Walk (RW), Random Direction (RD), Gauss-Markov (GM), and Boundless Simulation Area (BSA).

The mobility patterns such as RWP, RD, and RPG arbitrarily chooses the pause time between node mobility. In RPG mobility pattern, a group of mobile nodes is moving in the same direction with equal speed. In this, the MODEL efficiently supports to lower the overhead even when there are continuous topology changes as a consideration of node stability. Due to the consideration of neighbor movement in a node stability measurement, a group of nodes movement which has a low impact on the local topology is predicted accurately and updated for a long interval. The RW and RD are the variants of the RWP pattern in which RW mobility pattern has zero pause time and unpredictable node mobility as well as it selects the random speed and direction to move. The RD allows the nodes to move to the border of the area, before changing the direction and speed. By the capability of updating the location with some reasonable prediction-error, the MODEL maintains the overhead low and accuracy in the neighbor list high. The GM and BSA mobility patterns utilize the tuning parameter to change the direction when they reach the border of the simulated area. In these patterns, even though the movement of the node is unpredictable, the proposed MODEL exploits the DAR technique to allow the prediction-error to the boundary nodes dynamically. The DAR reduces the overhead and improves the accuracy using dynamic error estimation.

5. PERFORMANCE EVALUATION

The extensive NS-2 simulation is applied to simulate the performance of the proposed MODEL and also compare the results with existing LB-DB-GPSR [23]. The simulation takes in 50-90 mobile nodes over an area of 800m×800m. The transmission range of a mobile node is 250m, and the communication is established among the neighbors who are within 250m distance. The overall simulation time is 50 seconds. To overcome the beaconing overhead in conventional schemes, the proposed MODEL is implemented as two main components such as beaconing importance and the prediction-error. The first component is implemented by enabling each node to quantify the self and neighbor stability values, allowing some error range to those nodes that have high beaconing importance. Thus, the routing overhead is significantly reduced. The second component of MODEL is executed by dynamically, allowing the error range of highly sensitive mobile nodes. Using a fuzzy algorithm, the proposed MODEL estimates the dynamic error range together considering the availability of common boundary nodes and error unacceptance distance. The proposed MODEL proves its better performance in terms of the overhead, neighbor list accuracy, and throughput when compared to LB-DB-GPSR with varying speed and varying the number of nodes.

5.1 SIMULATION RESULTS: OVERHEAD

The performance of the proposed MODEL is profoundly illustrated in terms of overhead, with respect to Varying Speed of Nodes and Varying Number of Nodes. The overhead denotes the number of control packets involved in data transmission.

5.1.1 Varying Speed of Nodes:

The overhead between the proposed MODEL and existing LB-DB-GPSR with varying speed of nodes from 5 to 25m/sec is shown in Fig.4. The proposed MODEL aims at reducing the beacon overhead in the network. In 5m/sec speed, the nodes update their current location in the high beaconing interval. The MODEL achieves an overhead of 47.6% less than the existing method due to its capability of the efficient prediction-error mechanism. After that, the routing overhead escalates as the speed increases. This is because the unpredictable speed frequently changes the location of nodes and that creates the possibility to frequent beaconing resulting in high overhead at 10m/sec. Beyond 10m/sec speed, both the methods tend to lower the overhead. As the high speed of nodes frequently changes their location, it leads to the lack of updation in the neighbor list and thus resulting in reduced overhead. In addition, the proposed MODEL concentrates on the high sensitive mobile nodes, specifically in the outer region for lowering the overhead and entrusting it to the approaches in the existing methods. The dynamic prediction-error approach of the proposed MODEL limits the rate of generating beacon packets. Finally, the MODEL accomplishes an overhead which is 46.4% lesser than the existing method even in 25m/sec speed.

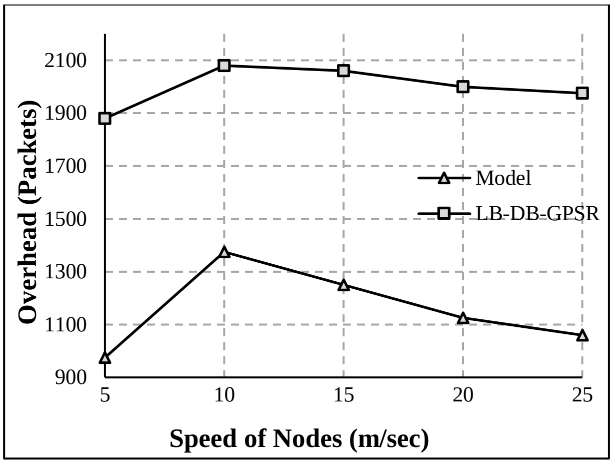

Fig.4. Speed of Nodes vs. Overhead

5.1.2 Varying Number of Nodes:

The overhead between the proposed MODEL and existing LB-DB-GPSR with varying number of nodes from 50 to 90 is shown in Fig.5. The overhead gets elevated in both the methods on the increment of nodes. However, in 50 nodes, the proposed MODEL exposes 38.5% low overhead than LB-DB-GPSR method since, the possibility to present the high mobile nodes along with 50 nodes is low. Moreover, the MODEL allows some error on predicted location for high mobile nodes. By that reason, the MODEL initially shows reduced overhead when compared with the existing method. Later, the overhead of both the methods has linearly escalated on the increment of nodes. Because the escalation in the number of nodes produces the high possibility of presenting the high mobile nodes. The frequent location changes of higher mobile nodes lead to an escalation of the beacons, and it produces high overhead in both the methods. Eventually, the MODEL displays quite comparable overhead in 90 nodes. Even though, the MODEL attains comparably less overhead by 10.5% than existing LB-DB-GPSR in 90 nodes.

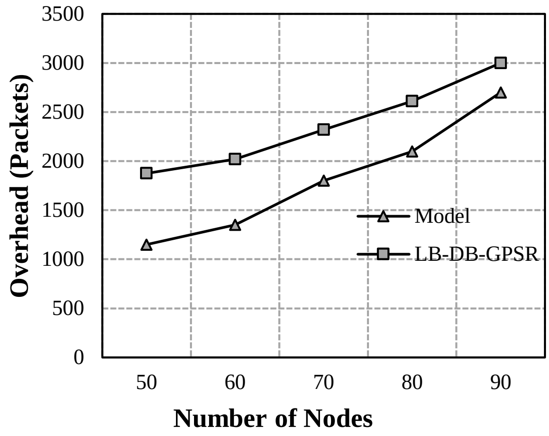

Fig.5. Number of Nodes vs. Overhead

6. CONCLUSION

This study has proposed the MObility pattern free Dynamic and Effective Location update (MODEL) protocol for maintaining the trade-off between the beaconing overhead and neighbor list accuracy in frequent location changing network using beaconing importance and prediction method. By calculating the self and neighbor stability based on the mobility of nodes, the beaconing importance can be estimated. The prediction-error allows those nodes with high beaconing importance which elevates the beaconing interval resulting in low overhead. This work has simulated using NS2 to evaluate the comparative performance of LB-DB-GPSR and the proposed MODEL.

Introducing the Dynamic Acceptance Error Rate (DAR) based on a fuzzy algorithm allows the boundary nodes to update the location dynamically and accurately. This escalates the possibility of selecting the best boundary node as a greedy node during data forwarding. The DAR supports the accurate neighbor list maintenance and overhead reduction even in the highly Adynamic network, thereby it can be evaluated that the Throughput of the proposed system called MODEL and its performance.

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