A PREDICTION SCHEME TO ENHANCE THE ROUTING PROCESS IN GEOGRAPHICAL GPSR AD HOC PROTOCOL

Raed Saqour1), Mohamad Shanudin1), Mahamod Ismail2)

Abstract

Geographical routing protocols have been received serious attention due to their advantages as compared to conventional routing protocols. They require information about the physical position of nodes to be available. Commonly, each node determines its own position through the use of Global Positioning System (GPS) or some other type of positioning service. Greedy Perimeter Stateless Routing (GPSR) protocol, which is one of geographical routing protocols, limits the forwarding decision of the packet based on location information of the current forwarding node, its neighbors, and the final destination. Location information has some inaccuracy depending in the localization system and the environment. In this paper, we study the impact of mobility metrics (beacon interval, and node speed) on introducing location information error in GPSR protocol. We identify the effect of these metrics in GPSR as Neighbor Break Link (NBL) problem. Based on simulation analysis, we propose mobility prediction scheme-Neighbor Break Link Prediction (NBLP) to migrate the observed problem.

1. INTRODUCTION

Geographical routing protocols [1], [2] in ad hoc networks has been received serious attention due to their substantial advantages as compared to topology based routing protocols [3], being either proactive or reactive protocols. Geographical routing protocols eliminate some of the limitations of topology based routing by using location information.

In geographical routing protocols, the packet forwarding decision by a node is primarily based on the position of a packet's destination and the position of the node's immediate one-hop neighbors. Thus, nodes neither to store routing tables nor to transmit messages to keep routing tables up to date like other routing protocols.

While geographical routing protocols have been shown to be efficient with accurate location information, their performance in existence of information location inaccuracy will be degrade [4]. However, location information has some inaccuracy depending on the localization system and the environment. GPS location system has inheretent inaccuracy due to weak GPS signal (e.g., indoor), or when GPS receiver has to be avoided for cost or integration reasons [5]. The alternative solution proposed is to design location discovery algorithms that use measurements of distance between nodes and estimates of location of a small numbers of nodes to determine the locations [5], [6]. Distance measurement is also inheretent inaccuracy due to mobility of nodes during the beacon interval time.

In this paper, we analyze the effect of mobility metrics (beacon interval, and node speed,) in introducing a location error in GPSR geographical routing protocol. Based on the simulation results, Neighbor Break Link (NBL) problem which is due to link break connection with neighboring nodes is identified and discussed. In addition, we provide remedies for the identified NBL problem with a suggested NBLP scheme.

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[1] Faculty of Science & Information Technology, Universiti Kebangsaan Malaysia Bangi, Selangor, 43600, MALAYSIA {r_saqour2002@yahoo.com | msz@ftsm.ukm.my}
[2] Faculty of Engineering, Universiti Kebangsaan Malaysia Bangi, Selangor, 43600, MALAYSIA, mahamod@eng.ukm.my

We examine the following three main mobility metrics that cause the NBL problem and affect the performance of GPSR routing protocol:

- *Beacon Interval:* it's not possible to avoid the time gap between the measurement of a location and the time when the information is actually looked up for routing decision. This is because the time interval between location updates is generally longer than the inter-packet arrival times.
- *Node speed:* mobile node can move in different speed and the maximum node speed is one critical cause for the NBL problem.

The rest of the paper is organized as follows. In section 2, we provide background and the related works. In section 3, neighbor break link problem is identified. In section 4, the effect of mobility metrics - beacon interval, and node speed as a cause to NBL problem in GPSR routing protocol is analyzed and discussed. In section 5, NBLP scheme is introduced, and section 6, conclude the paper.

2. Background and Related Works

2.1 Greedy Perimeter Stateless Routing (GPSR) protocol

GPSR protocol [7], [8] is an efficient, localized routing algorithm in large-scale ad hoc wireless networks. Under GPSR protocol, a node makes routing decisions only based on the locations of its (one-hop) neighbors and the location of the destination node available using location service protocol like Grid Location Service (GLS), GPSR thereby avoiding the overhead of maintaining global topology information. In each step, a node relays a packet to the neighbor that has the shortest Euclidean distance to packet destination among all its neighbors.

GPSR makes greedy forwarding decisions using only information about the position of immediate neighbors in the network topology as appears in figure 1. In figure 1, *x* receives a packet destined to *D*, *x*'s radio range is denoted by the dotted circle about *x*, and the arc with radius equal to the distance between *y* and *D* is shown as the dashed arc about *D*. *x* forwards the packet to *y* as *y* listed in *x* neighbors list as shown in table 1 and as the distance between *y* and *D* is less than that between *D* and any off *x*'s other neighbors. This greedy forwarding process repeats by nodes *y*, *k*, *z*, and *w* until the packet reaches the destination node *D*.

Node-id	Neighbor (x, y coordinates)
A	A (x, y)
B	B (x, y)
C	C (x, y)
F	F (x, y)
y	y (x, y)

Table. 1. Node x Neighbors List

The power of greedy forwarding to route using only neighbor nodes' positions comes with one attendant drawback: there are topologies in which the only route to a destination requires a packet move temporarily *farther* in geometric distance from the destination. A simple example of such a topology is shown in Figure 2. Here, *x* is closer to *D* than its neighbors *w* and *y*. Although two paths, $(x \rightarrow y \rightarrow z \rightarrow D)$ and $(x \rightarrow w \rightarrow v \rightarrow D)$ exist to *D*, *x* will not choose to forward to *w* or *y* using greedy forwarding. The protocol terms *x* as local maximum in its proximity to *D* and terms shaded region without nodes as void.

When greedy forwarding fails, the protocol using perimeter forwarding to forward the packet around void region. In perimeter forwarding, the protocol constructed planarized graph[3] for the nodes' neighbors and applied the right-hand rule to route the packet around void region. The right-hand rule states that when

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[3] Planar graph is a *graph* that can be drawn in the plane with no crossing *edges*,

arriving at node x from y, the next edge traversed is the next one sequentially counterclockwise about x from edge (x,y).

Network connectivity in GPSR protocol determined by simple beacon packet protocol, which provide all nodes with their neighbor's positions. Periodically, each node transmits a beacon packet containing only its own identifier (e.g., IP address) and its position, when any node receives a beacon packet from its neighbors; it creates or refreshes its neighbors list and uses this beacon packet information for future routing process.

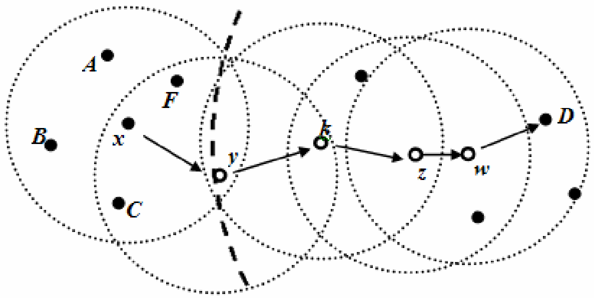

Fig.1. Greedy forwarding

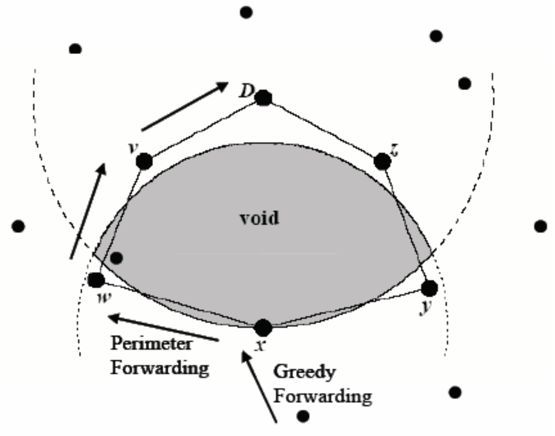

Fig. 2. Perimeter forwarding

2.2. Mobility Model

We use Bound Simulation Area (BSA) mobility model as a mobility model in this studying. BSA has the characteristics of temporal correlation for each node where a node's speed and direction depends on its previous movement history, and geographical restriction where a node's movement may be restricted due to obstacles, building, streets, or freeways. These two characteristics are considered as main characteristics of any realistic mobility model in ad hoc network comparing with widely used Random Waypoint mobility model [9].

In BSA Mobility Model as shows in figure 3, a relationship between the previous direction of travel and velocity of a mobile node (MN) with its current direction of travel and velocity exists [9]. A velocity vector $v = (v,\theta)$ is used to describe MN's velocity v as well as its direction θ, the MN's position is represented as (x, y). Both the velocity vector and the position are updated at every Δt time steps.

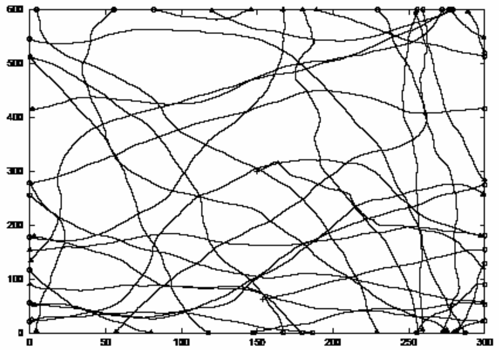

Fig. 3. Bound Simulation Area (BSA) Mobility Model

2.3. Related Works

There have been prior research efforts in the area of link break and prediction model. In [10], the authors proposed a mobility prediction scheme to enhance unicast and multicast routing protocols. The proposed scheme utilizes GPS location information that is piggybacking on data packets during a live connection and is used to estimate the expiration time of the link based on distance between two adjacent nodes while the data packet is being forwarded from the source to destination. Based on this prediction scheme, routes are reconfigured before they are disconnected, the mobility prediction scheme in [10] assumes constant node speed and movement direction, its effective when nodes exhibit a non-random traveling pattern. In [11], optimized dynamic source routing (DSR) protocol using mobility prediction scheme has been researched. The research advocates that in most existing protocols, a mobile host will keep using the route until the link is broken. It proposed a prediction protocol using power measurement of received packets to predict the topology change in order to perform a route rebuild prior to a link breakage; this was to avoid the data packets from being dropped. In [12], the proposed protocol was based on prediction of partitioning in ad hoc networks. The most recent research in mobility prediction was found in [13], they used information related to probability of link break in order to build a predication model that able to predicate when partitioning will occur and which link is critical using planar graph that represent the network.

In pervious studies, the authors concerned about link break and network partition that occurs between the source and destination. In additional, they built their prediction model based on signal strength. In this paper, the distinction from previous studies is the isolation of the neighbor break link effects of neighboring nodes. We are not concern with the route breaks link effects between the source and the distention node caused by intermediate nodes that other studies concern about and we built location based rather than signal based prediction scheme. We also concentrate our study in geographical routing protocols presented by GPSR protocol, which is not investigated like other proactive or reactive routing protocols [3].

In addition, [14] summarized the mobility metrics that impact routing protocols in mobile ad hoc network, these mobility metrics are the concern of our study. An analysis on the affect of mobility metrics on NBL problem is conducted. Only neighboring nodes considered are those within the node transmission range. Derived NBLP scheme is proposed according to our observations.

3. Neighbor Break Link Problem

In GPSR protocol, every node periodically within a time interval, broadcast a beacon packet within its own radio range. The beacon packet carries the node-id and the current location information (x, y coordinates) of the node. Every node, which receives a beacon packet within its transmission range creates a new entry into its neighbors list for the incoming node beacon packet and keeps information carried within incoming beacon packet on its neighbors list for later use in route process. In this way, all the nodes in the network will have the geographical location information about their neighbor nodes within its transmission range.

When the sender node wants to send a packet to a destination, its searches its neighbor list looking for the node that is closer to destination node. However, the selected next hop node may not exist within the radio range of the sender while it is listed as a neighbor in the neighbors list. This situation is defined as a NBL problem and can be affected by high node speed, and long beacon interval. When a node moves outward of the intended receiver, connection between the sender and the receiver can be broken.

Figure. 4 depicts the NBL problem; GPSR protocol defined the node y as forwarding node as it is listed in neighbors list of node x because of beacon packet heard from node y by node x at time t_1 and as it closer to destination node D. However, because the node speed, beacon packet interval of node y, when node *x* decides to forward the packet to *y* at time t_2, node *y* may will be in location L_{y2} which is not recognize by node *x* at the time of forwarding decision of the packet decided by node *x*, this lead to the dropping of a packet and affect the packets delivery and system throughputs performance.

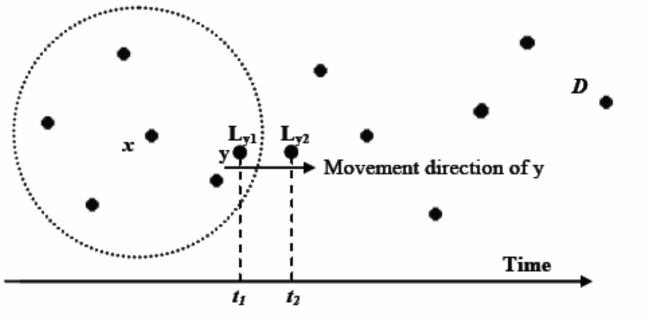

Fig.4. Neighbor Break Link (NBL) problem. t_1*: time instance of y last location heard by node x,* t_2*: time of packet forward decision made by node x.*

4. Mobility Metrics Effect in GPSR Protocol

In [14], the authors classified various mobility metrics that can affect routing protocols on mobile ad hoc network. In this paper, we investigate the influence of some of these mobility metrics in NBL problem in GPSR protocol.
After careful consideration of simulation environments like NS-2 and GloMoSim, we decided to build our discrete event simulator from scratch using Borland C++. The main reason for that is that none of the above mentioned simulators provided us with BSA mobility model wanted for this study. In addition, none of them give us the facilities to trace in details all the simulator behaviors.

To estimate the effect of inaccurate location information caused by node mobility metrics on the geographic routing protocol, we conducted simulation study varying the beacon interval, and the maximum node speed. GPSR [7], [8] is selected for our simulation because it was shown to perform correctly and efficiently with exact location information comparing with other routing protocols. We used selected simulation parameters similar to those used in [7], 100 nodes are placed randomly in a 1500m x 300m field and the combination of beacon intervals of 0.1, 0.25, 0.5, 1.0, 3.0, 4.0, 5.0 sec and maximum node speed of 10, 20, 30, 40, 50 m/sec are simulated. To filter out the noise in simulation results, ten different scenarios are generated for each distinct parameter setting and the results represent the average value.

We evaluate the performance of GPSR protocol based on the following metrics:
- *Packet Drop-Neighbor Break*: the number of data packets drop due to link break between the nodes and there neighbors during the packet forwarding process.
- *Delivery Ratio*: The number of successfully data packets delivered to destination over the total number of packets transmitted.
- *End-to-End Delay*: the average time delay for data packets from the source node to destination node.

4.1. Effect of Beacon Interval

To maintain connectivity in GPSR protocol, a node upon not receiving a beacon packet from a neighbor for longer than specific time interval, GPSR protocol assumes that the neighbor is no longer within transmission range and connectivity has been lost. One of the variables control the determination of network connectivity is a beacon packet interval [15]. Beacon packet interval specifies the maximum time interval between the transmissions of beacon packets between the nodes. The position a node associates with a neighbor becomes less current between beacon packets as that neighbor moves. The accuracy of the neighbors' Locations also decreases; old neighbor may leave and new neighbors may enter radio transmission range without recognizing that from nodes.

Figure 5 shows the simulation results on the effect of using different beacon interval on the neighbor link break occurrence. The number of packets' drops increase when the beacon intervals increase. BSA mobility model performs best when beacon interval is 1.0ms. When we analyze the reason for packet drops decrease before beacon interval 1.0ms, we found much more packet drops caused by node buffer overflow rather than beacon interval while packets drop with beacon interval 1.0ms and greater than it caused by node's neighbors location error and its increase with increasing in beacon interval.

Figure 6 shows the number of beacon packets drop caused by node buffer overflow in BSA mobility model. Congestion caused by more beacon packets decease until it's arrive its minimum value in beacon interval 1.0ms. In beacon interval 1.0ms and greater, not many beacon packets drop and this confirm the result shows in figure 5. The result shows that frequent beacon packets will not improve the performance of the protocol but it will make congestion in the network and wastage the network resources.

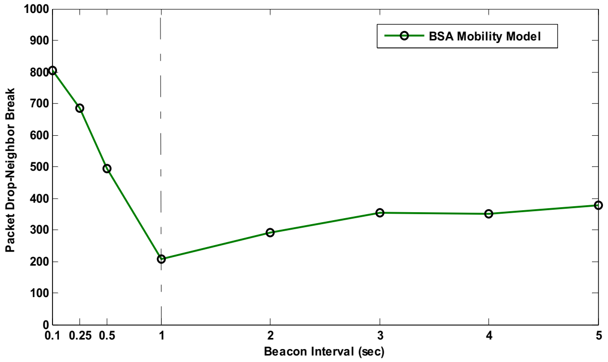

Fig. 5. Beacon interval effect

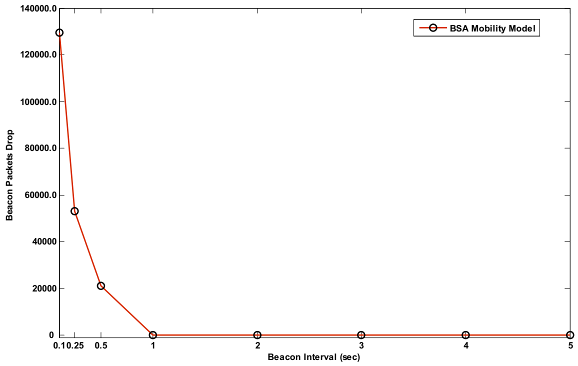

Fig. 6. Beacon packet drops varying beacon interval

4.2. Effect of node speed

Variation of the node speed means the change in the degree of node mobility that affects the error in node location information. The performance of GPSR protocol is fully related to the accuracy of node location, which effected by node speed.

Figure 7 shows the effect of node speed on the performance of GPSR protocol. The number of packet drops caused by NBL increase as the maximum nodes speed increase. BSA mobility model performs better in beacon interval 1ms in increasing node speed comparing with other beacon intervals, since the increase in beacon interval will result in increasing the packets drop.

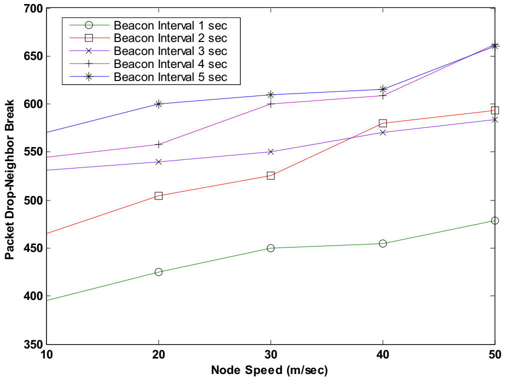

Fig. 7. Node speed effect

5. Mobility Prediction Scheme

In this section, suggested neighbor break link prediction (NBLP) scheme for GPSR protocol to overcome NBL problem is presented and discussed in addition to simulation result when using it. The proposed scheme is based on the physical concept of point's movements observed in [16]. The proposed prediction scheme does not require any additional communication between the nodes at the network.

In order to enhance the proposed prediction scheme to work, we need additional fields on the node neighbor list: we need two *x, y* co-ordinates for the neighbor nodes and beacon packet time when these *x, y* co-ordinates arrived. In addition, the second *x, y* co-ordinate also indicates υ to be the velocity of neighbor nodes at the second neighbor nodes location.

5.1 Neighbor Break Link Prediction (NBLP) Scheme

NBLP scheme is suggested as a solution to NBL problem. GPSR protocol will integrate the additional fields we mentioned to predicate the location of neighbor nodes to which it will pass the packet. The current location of closest neighbor node to destination will be predicted at the moment when the packet routing decision made by source node. Prediction is based on the recent (fresh) beacon information (co-ordinates and time) received from the neighbor nodes.

For now, we assume that a nodes move in a piecewise linear pattern, in other words, we assume that between successive update beacon packets, the nodes move in a straight line. In a piecewise linear motion pattern, two pervious updates are sufficient to predict a future location of the mobile nodes in the plane.

Let (x_1,y_1) at t_1 and (x_2,y_2) at t_2, where $t_2 > t_1$, be the latest two updates (beacon packet information) respectively from a neighbor node *B* to a particular correspondent node *A*, and let υ be the velocity *B* at (x_2,y_2), assume that also *A* wishes to predict the location (x_p,y_p) of node *B* at some instant time t_p in the future (at time node *A* decides to forward a packet to *B*). This situation is depicted in Figure 8.

From Figure 8, using similarity of triangles *KLM* and *KNO*, we get:

$$\frac{y_2 - y_1}{y_p - y_1} = \frac{x_2 - x_1}{x_p - x_1} \qquad (1)$$

If we want to predict the location of node *B* at y-axis, we can solve for y_p from equation 1,

$$y_p = y_1 + \frac{(x_p - x_1) - (y_2 - y_1)}{(x_2 - x_1)} \qquad (2)$$

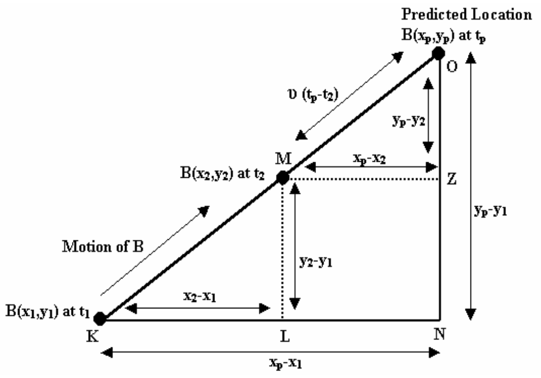

Fig. 8. Prediction of node B location at a given time in the future using last two-location information.

Using equation 2, node *A* can predict location of node *B* at y-axis (y_p) if it knows x_p, which in turn can be calculated as follows, using similarity of triangles *KLM* and *MZO* from Figure10, we get:

$$\frac{y_2 - y_1}{y_p - y_2} = \frac{x_2 - x_1}{x_p - x_2} \qquad (3)$$

If we use Pythagors' theorem at the triangle *MZO*, we get:

$$\upsilon^2 (t_p - t_2)^2 = (x_p - x_2)^2 + (y_p - y_2)^2 \qquad (4)$$

Substituting for $y_p - y_2$ from equation 3 into 4, we get:

$$\upsilon^2 (t_p - t_2)^2 = (x_p - x_2)^2 + \left[\frac{(y_2 - y_1)(x_p - x_2)}{(x_2 - x_1)}\right]^2 \qquad (5)$$

Solving for x_p in equation 5, we get:

$$x_p = x_2 + \left[\frac{\upsilon(t_p - t_2)(x_2 - x_1)}{\left[(x_2 - x_1)^2 + (y_2 - y_1)^2\right]^{1/2}}\right] \qquad (6)$$

The NBLP mechanism is work as follows: source node stores 2-points location information for its neighbors' nodes in addition to velocity of its neighbors at the second location point. When the source node has a packet to forward it to a destination using its neighbors, it first uses the information available in its neighbor list to predict the location of its neighbor nodes using the equations 2 and 6 mentioned above, where x_p and y_p are predicted location of neighbor nodes at *(x, y)* co-ordinates and t_p is the time when the node decides to forward a packets to one of its neighbor nodes. The current location of a given neighbor nodes (x_p, y_p) is predicted whenever a node looks up a neighbors list for routing decision made by source node based on the calculated nodes location. The source node now can calculate its distance from the predicted neighbor nodes location using the Pythagorean Theorem,

$$D_p = \sqrt{x_p^2 + y_p^2} \qquad (7)$$

Where D_p is the predicted neighbor nodes distance from source node. It assumed in our calculation to estimate neighbor nodes location that the velocity of the neighbor nodes movement is constant between two beacon packets and neighbor nodes keep moving in straight-line motion pattern. Each node here can predict its neighbor nodes location and it does not forward a packet to a neighbor node that is currently located outside of its transmission range (D_p > node transmission range) based on the predicted position to avoid NBL.

By using NBLP, the source node has the ability to avoid forwarding the packet to a node that is located outside its transmission range even though it is still listed in its neighbors list as a neighbor node.

5.2. Simulation Results with NBLP Scheme

Figure 11 and 12 shows end-to-end delay when we varying beacon interval and node speed with and without NBLP scheme. The end-to-end delay is less even with longer beacon interval and higher node speed. The actual reason for that is explained by IEEE 802.11 standard [17], according to the standard, a maximum number of retransmissions are allowed before the packets is dropped, if the sender does not receive the ACK frame within time interval for the packet it sent, it retransmit the packet until it receives ACK frame or throws it away after maximum number of retransmissions. The NBL problem causes the packet to retransmit several times to the neighbor that is listed in neighbors list but out of transmission range before the sender consider the neighbor can't be reach. The packet retransmission caused the packet to have additional propagation, transmission, and processing delay. By using the NBLP scheme, we avoid the packet to have these additional delays.

Another result shows in figure 9 and 10 is that even when using the NBLP scheme; the end-to-end delay is still considerably increase, this due to when the beacon interval and node speed increase, the probability of node sending two beacon packets will be decrease since the node may pass the boarder of other nodes transmission range sending just one beacon packet, this will result to miss used the NBLP scheme by sending node.

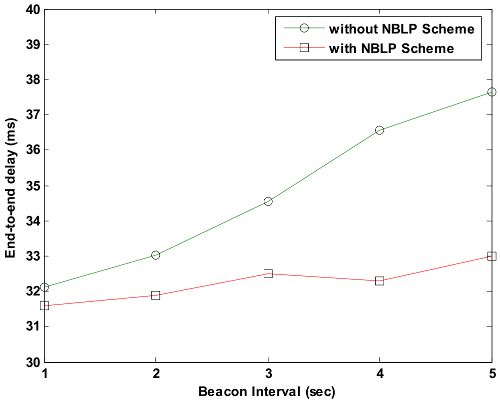

Fig. 9. End-to-end delay varying beacon interval

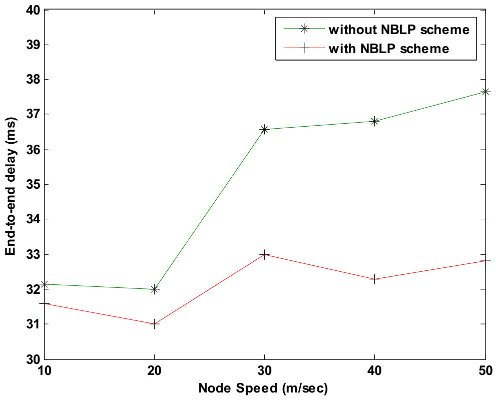

Fig. 10. End-to-end delay varying node speed

Figure 11 and 12 shows the delivery ratio when we varying beacon interval and node speed with and without NBLP scheme. The delivery ratio is up even with longer beacon interval and higher node speed. To identify the actual reason for this improvement, as discuss earlier, the NBLP scheme is used to reduce the number of NBL problem caused by inaccurate neighbor location information. NBLP scheme is used to blacklist neighbor nodes that are estimated to be out of the communication range at the moment of packet forwarding. In this way, we avoid to send the packets listed at nodes' neighbors list if it out of node transmission range which caused the delivery ratio to be higher.

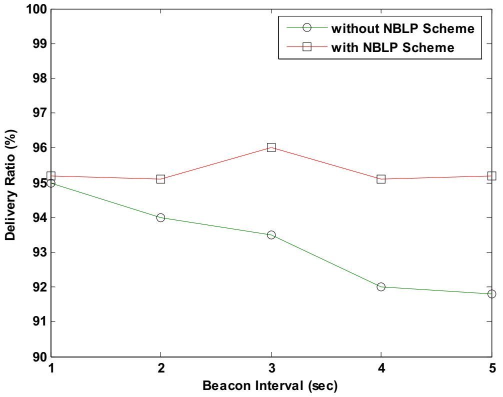

Fig. 11. Delivery ratio varying beacon interval

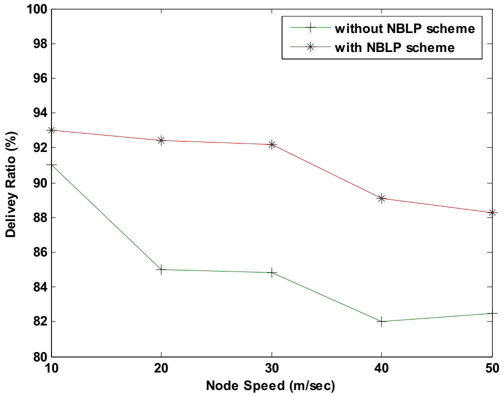

Fig. 12. Delivery ratio varying node speed

6. Conclusion and Future Work

In this paper, we study the effect of inaccurate location information caused by mobility metrics, node speed, beacon interval in geographical GPSR mobile ad hoc network routing protocol. We identified the problem of NBL and discussed the mobility metrics that cause NBL problem. We also proposed a prediction scheme to overcome NBL problem: NBLP scheme. By using NBLP scheme, the source node has the ability to avoid forwarding the packet to a node that is located outside its transmission range even though it is still listed in its neighbors list as a neighbor node, which leads to improve the delivery ratio and the end-to-end delay. In our future work, we aim to improve NBLP scheme by considering the node direction and history movement and build more sophisticated prediction scheme based on nonlinear motion in addition to study the NBL problem under other mobility models.

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