GRGSPS – Geographic Routing based on Greedy Perimeter Stateless Position for Multi-Hop Mobile Ad-hoc Networks

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ABSTRACT: In Ad-hoc networks, we make the forwarding decisions based on the geographical position of the nodes. Each and every node knows its exact position of its one hop neighbour in order to forward packets. Driven by this issue, geographic routing has been introduced in mobile ad hoc networks and proved to provide drastic performance improvement over strictly routing by address-centric schemes. While geographic routing has been shown to be correct and efficient when location information is intended target, its performance accordingly to location errors is not well understood. In Geographic routing, Greedy Perimeter Stateless Position routing forwarding is used to select next hop forwarder with the largest positive progress towards the destination. We identify two main problems, named LOOP and LLNK, which are caused by mobility-induced location errors. In this paper, we study the effect of inaccurate location information caused by node mobility under a rich set of scenarios and mobility models. According by ns-2 simulations, we perform two mobility prediction schemes neighbour location prediction (NLP) and destination location prediction (DLP) to mitigate these problems.

Keywords: location errors, geographic routing, mobility prediction, GPSPR

1. INTRODUCTION

In anticipation of broader use of global positioning system (GPS) [1] and other schemes of localization, geographical routing is becoming a very attractive choice for routing in mobile ad hoc networks and also in sensor networks. Many geographic routing protocols [2, 3, 4, and 5] have been proposed and proved to provide drastic performance improvement over existing ad hoc routing protocols [6, 7, 8, and 9]. Not only the benefits attained from using geographic routing protocol but the location information itself is important and necessary for many applications.

In geographic routing, the packet forwarding decision is solely based on the location information of neighbours and a destination node at the moment of forwarding. Geographical routing protocols are being exhibited to be accurate and efficient with exact location information. The effect of location errors on geographical routing has not been extracted to our knowledge. This effect is exacerbated with node mobility and harder to resolve because each node may have a different level of location error according to its mobility level. Most previous studies on geographic routing have used the random waypoint mobility model that ignores movement relationship among nodes. In this paper we make avail the first study to (1) understand the effect of inaccurate location information caused by node mobility on geographic routing protocols under various mobility models, and (2) provide remedies for the identified problems with a suggested mobility prediction scheme. We examine the following three main factors that greatly affect the performance of geographic routing protocols:

(a) The freshness of location information: It is not possible to avoid the time gap between the measurement of a location and the time when the information is actually looked up for the routing decisions like the proactive and reactive routing protocols to the time spent for location information delivery and the time passed before the received information is used. The position freshness information is one of the most important factors that may cause errors in the cached location information.

(b) The mobile node speed in the network: Each mobile node can move at a different speed and the maximum node speed is another critical factor deciding the level of inaccuracy.

(c) The mobility pattern of mobile nodes: If the node movement exhibits a various pattern, the effect of the node’s mobility on the geographical routing protocol will be different. Four different mobility models [10] are adopted in our work: Random waypoint (RWP), Dual carriageway (FWY), Geographic (MH) and Reference Point Cluster Mobility (RPGM). Based on the results of simulation, two major types of problem are identified and discussed in this paper: Lost Link (LLNK) problem and...
LOOP problem. The LLNK is related to the link connection problem with neighbouring nodes, and the LOOP is related to the inaccurate location information of destination nodes caused by their mobility.

We present two mobility prediction (MP) schemes to address these problems: neighbour location prediction (NLP) and destination location prediction (DLP). We find that the performance of geographic routing is significantly increased with MP without any added communication overhead. We evaluate our proposed schemes through ns-2 simulations of the greedy perimeter stateless routing protocol, GPSPR [2, 11], using the IMPORTANT [10] mobility tool. The rest of the paper is organized as follows. In section 2, we provide background GPSPR and mobility models used. In section 3, the effect of node mobility on geographic routing is discussed based on simulation results. In section 4, two mobility-induced problems are identified. In section 5, mobility prediction scheme is introduced. In section 6, performance improvement is presented and section 7 summings-up the paper.

2. BACKGROUND
In this section we elaborate detailed description of the geographical routing and models used for Mobility in our study.

2.1. Greedy Perimeter Stateless Position Routing (GPSPR)

GPSPR [2, 11] is a location-based routing protocol for wireless networks, and it consists of two packet forwarding modes: greedy packet forwarding and perimeter forwarding. The originator of the data generates a packet that contains the coordinates of the destination node. Initially, the packet is forwarded by greedy packet forwarding in which each node makes a localized routing decision based on the location information of its neighbour nodes as follows. Every node periodically broadcast a beacon packet within its own radio range which carries Present location information and a node-id. Each and every node receives beacon packet stores received information in the neighbour list. Every time a node forwards a packet, it calculates the distances from every neighbour node to the destination node. The neighbour node located closest to the destination node is selected as a next hop. With this localized routing decision for a packet can be dispatched to the node’s destination through the optimal path in the distance aspect. However, there are some situations called local maximum where a node cannot find any node located closer to the destination while there exist a detour through a neighbour located further from the destination than itself. When a node finds out a local maximum situation, the packet forwarding mode is changed to perimeter forwarding. Packets are traversed along the planar graph [2] until it reaches a node that is closer to the destination than the node where greedy forwarding was failed. Perimeter forwarding is used only when it reaches local maximum situation.

2.2. Mobility Models

We adopt a rich set of mobility models for our study. Some of the mobility patterns apart from the Random Waypoint (RWP) model that have been studied include the Dual carriageway, RPGM and Geographic. Each of these was chosen to replicate certain mobile node characteristics not previously captured by the RWP model.

2.2.1. RPGM.

Each cluster of nodes has a cluster head that determines the cluster’s movement behaviour. Initially, each member of the cluster is properly distributed in the neighbourhood of the cluster head. Each and every node has a direction and speed that is derived by randomly deviating slightly from that of the cluster head.

2.2.2. Dual carriageway Mobility Model.

This model emulates the movement behaviour of mobile nodes on a dual carriageway. An example of the dual carriageway model is shown in figure 2. Each mobile node is restricted to its lane on the dual carriageway and the velocity is temporally dependent on its velocity of the previous one. If more than one mobile node’s on the frequent dual carriageway lane are within the Safety Distance (SD), the velocity of the following node cannot exceed the velocity of preceding node. Due to the above association for the Dual carriageway mobility pattern is expected to have spatial dependence and high temporal dependence.

2.2.3. Geographic Mobility Model.

The Geographic model emulates the movement pattern of mobile nodes on streets defined by maps. An example of the Geographic mobility model is shown in figure 3. The mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At an intersection the mobile node’s can change the position to Right, left or possibly straight direction with probability aspects of 0.25, 0.25 and 0.5, respectively. the probability of moving left direction is 0.25 and the probability of moving right direction is 0.25. The velocity of a node at a time slot is dependent on its velocity at the previous time slot and is restricted by the velocity of the node preceding it on the same lane of the street, as in the Dual carriageway model. Thus, the Geographic mobility model is also expected to have high spatial dependence and high temporal dependence. However, it provides more freedom than the Dual carriageway model.
3. ANALYSIS OF THE EFFECT OF NODE MOBILITY

To estimate the effect of inaccurate information on the location caused by node’s mobility on the geographical routing protocol, we established various results varying the beacon interval by the Ns-2 Simulations.

and the maximum speed of mobile nodes for each model in mobility. GPSPR [2, 11] is selected for our simulation because it uses greedy forwarding with face routing, and was shown to perform correctly and efficiently with exact location information. It is a widely accepted protocol for geographic routing in mobile ad hoc and sensor networks.

Fifty nodes are placed randomly in a 1500m x 300m field and the combination of beacon intervals of 0.25, 0.5, 1.0, 1.5, 3.0, 6.0 sec and maximum node’s speed of 10, 20, 30, 40, 50 m/sec are being simulated. The IMPORTANT mobility tools presented in [9] are used to generate the mobility models. To filter out the noise in results of simulation, we exhibit another five scenarios are developed. They represent the average value for each for each distinct parameter setting and the results. We introduce various metrics to correct the performance of the routing protocol in several aspects.

(a) Accomplished Delivery Rate (ADR): the number of packets successfully delivered to the destination node over the total number of packets transmitted.

(b) Lost Transmission Rate (LTR): the number of transmission efforts made for dropped packets during the delivery over the total number of packet transmission.

(c) Number of Lost Links (LLNK): the number of lost link problem observed during the packet forwarding. ADR represents the level of reliability in packet delivery, while LTR represents the level of lost resources in the wireless network. While considering energy-constrained in wireless networks the latter metric is particularly important.

4. IDENTIFIED PROBLEMS (CAUSED BY MOBILITY)

Inaccurate location information caused by node mobility produces bad performance of geographic routing protocol as we have shown. Through further analysis we identify two main problems that account for the degradation performance namely LOOP and LLNK problems as mentioned below.

4.1. Lost Link (LLNK) problem

Greedy forwarding mode in GPSPR always forwards a packet to the neighbour that is located closest to the destination node. Each node searches its neighbour list to find a node that meets this condition and forwards a packet to this selected next hop neighbour. However, the selected next hop node may not exist within the radio range while it is listed as a neighbour. This situation is defined as lost link (LLNK) problem and can be caused by one of the following two reasons:

(1) Node mobility: There is a higher probability of packet transmission failure if greedy forwarding is used to forward the packets. With small outward node’s movement of the intended receiver and establish relationship between the receiver and the sender can be broken.

(2) Asymmetry in a communication link: GPSPR assumes link symmetry between neighbouring nodes. However, this may not be true in many real wireless network environments. Asymmetric communication links exist when there are nodes with different radio range of radio signal accordingly to the effects of node mobility or environment. These problems are justified in figure 3.

4.2. LOOP problem

With GPSPR, a packet is forwarded towards the coordinate of the destination stored in the packet header and node’s identification is being meaningless until the packet reach the node’s destination by greedy forwarder routing. Let us assume while the destination node moves away from its original location and another becomes a node located closest to the destination’s original coordination. These current circumstances are misunderstood as local maximum by GPSPR protocol and the perimeter mode forwarding are being used to resolve these problems. However packets normally get dropped unless the destination node doesn’t come back to near the original location and becomes the closest node to the destination location of the packet. Perimeter forwarding generates wasteful loops in this situation, and we label these situations of LOOP problem are shown in figure 4.

5. MP: Improvement on geographic routing

We introduce a mobility prediction (MP) scheme for geographic routing that does not require any additional communication or serious calculation. There have been some prior research efforts for mobility prediction. In [13], a mobility prediction scheme in wireless networks and its application to several protocols like unicast [14, 15] and multicast [16] are being introduced. The mobility scheme suggested is occupied to calculate the duration of a link connection time. Route expiration time (RET) before the predefined route becomes unavailable can be attained based on the valid
link duration, better packet delivery and reduced overhead are achieved.

The mobility prediction scheme in [13] assumes clock synchronisation in the network and constant node speed and movement direction. The suggested scheme is effective when nodes exhibit a non-random traveling pattern. Similarly, [17] suggests a mobility prediction scheme that proactively constructs a route for robust and efficient packet delivery. Virtual grid space, where every node stays inside, is introduced and a unique grid-id is given for each grid. The movement pattern of a node is identified based on the previous node movement represented by a sequence of grid-ids stored in the movement of node’s cache. Recent movement of node is compared with detected movement pattern via pattern matching to predict the next node movement. Probability of next node movement is calculated and used to cope with node mobility beforehand. Assumptions on virtual grid space and the non-negligible amount of required computation, communication and storage limit the applicability the proposed scheme. Our mobility prediction scheme is composed of two prescriptions to identified problems listed in section 4. Suggested schemes are neighbour location prediction (NLP) and destination location prediction (DLP).

5.1. Neighbour Location Prediction (NLP)

A neighbour location prediction scheme is introduced as a solution to the LLNK problem. To avoid the bad next-hop node selection, which may result in LLNK problems, the current locations of neighbour nodes are estimated at the moment of packet routing with NLP decision. Predictions are based on the latest beacon information received from neighbour nodes. The neighbour list includes the following additional fields for neighbour location estimation: last beacon time (LBT), node speed in the direction of x-axis (Sx) and y-axis (Sy). When a node receives a new beacon from a neighbour, the current time is stored in LBT together with the location of the neighbour. The beacon receiver searches its neighbour list for previous beacon information from the same neighbour. If previous beacon information from the same neighbour is found in the neighbour list, current node speed of the neighbour, which consists of Sx and Sy, is calculated when it receives a new beacon packet from the same neighbour as follows. The previous location and beacon time of a neighbour stored in the neighbour list is denoted by \((x_1,y_1,LBT)\) and the same information found in the last beacon packet for the same neighbour is denoted by \((x_2,y_2,LBT)\). The current node speed \(Sx\) and \(Sy\) of the neighbour is calculated as follows:

\[
Sx = \frac{(x_2-x_1)}{LBT-PBT} \\
and \quad Sy = \frac{(y_2-y_1)}{LBT-PBT}.
\]

The current location of a given neighbour node \((Xest, Yest)\) is estimated whenever a node looks up a neighbour list for routing decision based on the calculated node speed and the amount of time passed since LBT:

\[
Xest = x_2 + Sx \times (Current\ Time - LBT) \\
Yest = y_2 + Sy \times (Current\ Time - LBT)
\]

Our linear location prediction scheme is simple, but very reasonably when the beacon interval and the time since \(LBT\) are reasonably small. Transmission range information of each node is also incorporated in our NLP scheme to avoid the problem caused by asymmetric link resulted from inherent difference in transmission power among deployed nodes.

We assume each node knows (or estimates) its approximate radio range and does not forward a packet to a neighbour node that is currently located outside of its range based on the estimated position to avoid LLNK. With NLP, a packet is forwarded to a neighbour node that meets the following two conditions:

- A neighbour node that has a closest distance to a destination node from the estimated location of a neighbour node, and
- Distance to a neighbour node is less than the transmission range of a forwarding node. By incorporating the transmission range information and using the estimated neighbour location information attained from this simple calculation, the LLNK problem identified from previous simulation is greatly reduced for all mobility model in our simulation. The percentages drop in the number of LLNKs is 17.5% for RWP, 15.2% for FWY, 14.3% for MH, and 6% for RPGM mobility models.

5.2. Destination Location Prediction (DLP)

The second part of our mobility prediction scheme is a solution to the problem of LOOP which leads out to be the most dangerous problem for greedy forwarding. A great number of packets get dropped even when those are delivered to a neighbour node of the destination node. Packet drop after forwarding it to a neighbour of a destination node is the most undesirable thing to do with packet routing because it means more wastage of energy and bandwidth in the network.

\[
\text{Successful Delivery Rate with various prediction schemes}
\]

To avoid this kind of problem and to increase the chance of packet delivery for the case when the destination node is moved out of its original location, a destination location prediction (DLP) scheme is proposed as a second part of MP. With DLP, each node searches its neighbour list for the destination node before it makes a
packet forwarding decision based on the location information of the destination. If the destination node exists in the neighbour list and located within the transmission range of the packet holder and then packet is proceeded directly to the destination node without further calculation for finding a closest neighbour to the destination.

LOOP problems can be overcome by utilizing the identification information of nodes as well as location information. Figure 5 shows the performance improvement achieved with both NLP and DLP. Estimated location information by NLP is used when a packet holder verifies the existence of the destination node within its communication range in MP. Significant amount of lost packets and lost network resources can be saved by avoiding misjudgement on the maximum situation for local network. Geographical routing can also maximize the node’s mobility in a positive way while reducing the problem of it using DLP.

6. Simulation Results with MP

With MP (NLP plus DLP), the amount of Lost transmission (LTR) is reduced 18.6% for RWP, 37.2% for FWY, 15.2% for MH, 16.5% for RPGM, and the ADR levels up even with higher mobility and longer beacon interval. Figure 6 clearly shows the effect of MP on the performance of geographic routing protocol. The impact of faster node movement and infrequent beacon interval has greatly reduced after applying MP to GPSPR. ADR is improved 12.3% for RWP, 26.9% for FWY, 14.7% for MH, and 19.8% for RPGM. To identify the actual effect of each component in MP, the causes of packet drops in our simulations are analyzed.

As discussed earlier, NLP is a scheme to reduce the number of LLNK caused by inaccurate neighbour location information. Broken link connection delays the packet forwarding process of the queue, when packet drops occurred by the delay in ARP process (indicated by ARP in the ns-2 trace file) are closely related to LLNK problem.

DLP is a scheme introduced to fix LOOP problem identified in section 4.2. Figure 12 shows example improvements achieved with DLP in the number of packet drops caused by no route (NRTE) and TTL expiration (TTL). Packet drops caused by routing loop (LOOP) and MAC layer callback timer (CBK) are also closely related to LOOP problem and exhibit similar improvement in our simulations with DLP.

7. CONCLUSION AND FUTURE WORK

In this paper, we have presented the effect of inaccurate location information caused by node mobility in geographical routing protocols and identified two problems majorly caused by node mobility: LLNK and LOOP problems. We also propose a mobility prediction scheme to address these two revealed problems.

For our simulation we chose three main factors,
(1) Maximum speed of the Node
(2) Interval of the beacon
(3) Pattern for the mobility that affect the performance of geographic routing to clarify the effect of these factors on the performance of location based routing protocols.

The general effects from varying maximum node speeds and beacon intervals are similar for all the studied mobility models. However, the levels of effect are somewhat different. Increased node mobility causes more effect on FWY and MH models for mobility. Longer interval of the beacon deteriorates the performance of RWP and RPGM slightly increased more and these
differences are attributed between the difference of mobility models. Our proposed mobility prediction scheme is comprised of neighbour location prediction (NLP) and destination location prediction (DLP) schemes.

Each component is introduced to settle down LOOP and LLNK problem with NLP then number of lost link problems been significantly decreased by estimating the actual location of neighbour nodes based on latest movement and by excluding nodes located outside of a sender’s radio transmission range. With DLP, unnecessary packet drops near the destination can be avoided, and the positive side of node mobility is exploited as well as negative effect is mitigated. With the combination of these two schemes in GPSPR, the performance in both ADR and LTR is gradually increased. For model we got the best improvement of 27% more packets are delivered to the destination, and 37% of Lost transmission effort is reduced with suggested mobility prediction scheme in our simulations. Other than the saved network resources with MP, we could pursue further saving. As seen in figure 4, the negative effect of increased beacon time is alleviated even with high level of node’s mobility. Economically beacon exchange can be achieved with MP when the small loss in the level of reliability is less significant than the level of wastage in network resource (e.g., sensor networks).

In our future work, we aim to collect supplementary information from previous node movements to build a more sophisticated mobility prediction schemes. Location estimation scheme will be combined with stability factor for each link to help the sender make better routing decisions and applied for location services [18] as well as other geographic routing protocols. We also plan to investigate the relationship between node density and the performance of geographic routing protocol under more realistic mobility models.

REFERENCES

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