Location-aware Long-lived Route Selection in Wireless Ad Hoc Network *

Dongkyun Kim†, Yanghee Choi† and C.K Toh‡

School of Computer Science and Engineering†
Seoul National University, Seoul, Korea
{pretty,yhchoi} @mmlab.snu.ac.kr

School of Electrical and Computer Engineering‡
Georgia Institute of Technology
cktoh@ece.gatech.edu

Abstract

Many routing protocols suitable for wireless ad hoc network have been proposed. However, most of them have focused on the reachability among nodes which want to communicate with each other. Actually, even if a route has been successfully acquired to be established, due to the node's mobility, there will be frequent route reconstructions, resulting in the need for a new partial or full route to the destination. Therefore, the selection of a long-lived route among multiple possible routes at the destination(if the source initiated on-demand routing protocol is applied to wireless ad hoc network) helps to reduce the number of route disconnections. In this paper, for deriving a long-lived route, we exploit location information obtained by GPS (Global Positioning System) and information of each node's radio transmission range. Additionally, in order to avoid excessive beacon signals used by the ABR(Associativity-Based Routing) protocol, only nodes on the acquired route exchange their beacon signals when detecting a route failure. Through simulation, we show that our proposed scheme is applicable to wireless ad hoc network.

Keywords : Wireless Ad Hoc Networks, Routing, Long-lived Route

1. Introduction

Wireless ad hoc network has no communication infrastructure, which means that all nodes are able to move around without the help of a fixed network such as wired base stations. This network is appropriate for battle field, disaster rescue, large scale wireless conference, etc. Recently, several protocols including routing protocol[1,2,3,4,5,6,7,8,11] and transport protocol[9] applicable to this wireless ad hoc network have been proposed by many research groups.

Most of routing protocols are categorized into two classes: (a) table-driven protocol and (b) on-demand routing protocol. In the table-driven approach, it is necessary that for avoiding stale routing information, a routing table is maintained consistently by periodic updates, resulting in much control overhead. However, in on-demand routing protocol, routes are created only when the source node requires it. Therefore, it takes longer time to get a route than table-driven approach because of the absence of routing information at each intermediate node even if it can avoid maintaining the routing table periodically. In table-driven approach, even if the routes are not required, the correct routing information should be always stable. In order to avoid this overhead, we take advantage of the source initiated on-demand routing protocol. For details, refer to [11] because these two approaches have their own advantages and disadvantages.

Generally, the source initiated on-demand routing protocol is performed in three phases: route discovery, route reconstruction, and route deletion. In route discovery, the source requiring a route to the destination broadcasts its route discovery packet to all neighboring nodes which forward the packet if they are not destinations in the network. In this way, the route discovery packet is flooded until the destination receives the packet. During this process, there exist various approaches for the maintenance of routing information at the intermediate nodes even if they are based on the source routing protocol. In the second phase, route

*This work was supported by the Brain Korea 21 Project and Agency for Defence Development and ACRC(Automatic Control Research Center), Korea.

reconstruction, since it is possible that the route is broken because of the node mobility during the session, a node detecting route failure should perform the route reconstruction process for acquiring an extended route to the destination. Finally, in route deletion, due to the route failure, the existing route should be changed. Therefore, a path from a node detecting a route failure (or the source) to the destination should be deleted before acquiring a new partial route.

Some research work[12] shows that location information obtained by GPS (Global Positioning System) can be used efficiently in wireless ad hoc network to avoid excessive flooding of route discovery packets for finding a route to the destination. However, such an approach does not attempt to acquire a stable route, but chooses the shortest path. We consider that it is more important to get a stable route since there can be frequent route disconnections due to the node mobility.

In this paper, we make use of location information and nodes' radio transmission ranges for deriving a long-lived route, resulting in the reduction of the number of route reconstructions. Prior to our proposed scheme, ABR (Associativity-Based Routing) protocol[11] presented the concept of a long-lived route. However, it relies on periodic exchange of beacon signals, which increases the consumption of battery power of the mobile node. Therefore, in this paper, we propose a new scheme to avoid the periodic exchange of beacon signals. In our approach, after acquiring a route, only nodes over the acquired path exchange the beacon signals for detecting a route failure.

2. Motivation

In source initiated on-demand routing protocol, a route discovery packet generated by the source arrives at the intermediate nodes and is forwarded to the neighbor nodes. In the sequel, a destination can receive multiple route discovery packets with different intermediate nodes. Therefore, the destination should select the best one among routes.

In ABR[11], a long-lived route is selected based on the information of tick counts obtained by periodically exchanged beacon signals among adjacent nodes. The long-lived route decreases the possibility of route failure which results in performance degradation due to frequent breakage of the data transmission. However, unnecessary exchange of beacon signals can be avoided if the beacon signals are exchanged among only nodes over a given path through the route discovery process. In this paper, unlike ABR, we take advantage of location information obtained by GPS and node's radio transmission ranges for selecting a long-lived route as well as avoid excessive beacon signals.

3. Proposed Approach

3.1. Assumptions

From GPS, each node obtains its own location information(latitude (x) and longitude (y)), but not other nodes' location information. In addition, it is assumed that each node knows its current radio transmission range. By using these information, each node estimates how long the route will last until route failure.

3.2. Location-aware route discovery

A source generates a route discovery packet that contains source position information(X_s, Y_s) and its current transmission range (R_s). This packet is propagated to all neighbor nodes as in other source-initiated on-demand routing protocols. This is repeated until the destination receives the discovery packet. During the process, node B receiving the route discovery packet from node A performs the following process (Figure 1). :

1. By using the previous node (A)'s location information (X_a, Y_a) and its radio transmission range (R_a) recorded in the route discovery and receiving node (B)'s locati on information (X_b, Y_b) obtained by GPS, calculate FML(Forward Movement Limit) = R_a - distance(A, B), where distance(A, B) = $\sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$.

2. Similarly, by using receiving node (B)'s location information and radio transmission range (R_b), calculate BML(Backward Movement Limit) = R_b - distance(A, B).

3. Derive a NML(Normalized Movement Limit) = (FML*BML)/(FML + BML).

4. Compare the derived NML with the NML stored in the route discovery packet. Select the minimum value as the propagated NML stored in the route discovery packet.

5. Forward the route discovery packet to neighboring nodes.

An NML should be derived because FML and BML may be different since time allows all nodes to have different randio transmission ranges due to the consumption of battery power. When a destination receives a route discovery packet, the packet contains a minimum NML calculated over the route. Since there are many routes between the source and destination, the destination collects multiple route discovery packets traversing different routes. Since a minimum NML contained in the route discovery packet

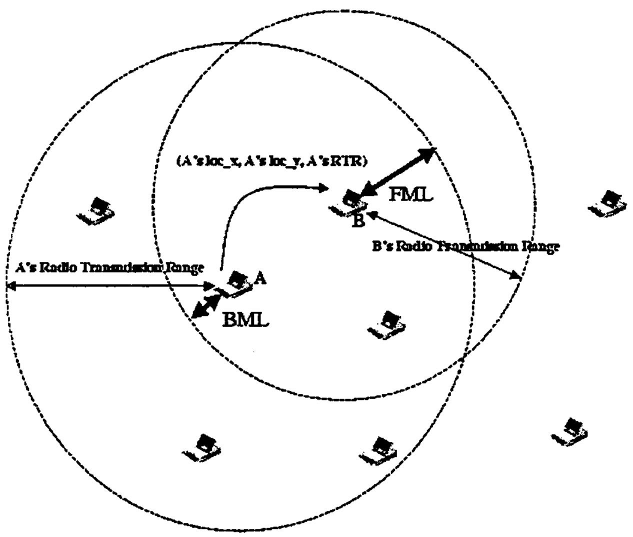

Figure 1. The Computation of FML and BML

can represent the unstability level of a link over a route, the route with the highest NML among multiple routes is selected. In addition, since the length of the path is also meaningful for getting higher throughput because of small delays, among the routes with the minimum hop counts, the route with the highest NML is selected.

Consider two pairs of (FML, BML), (5, 2) and (4,4). In case that BML is 2, the route is less stable than the case that BML is 4. Therefore, we should obtain a normalized value. In the pair (5,2), NML = 10/7, whereas in the pair (4,4), NML = 16/8. It means that the higher NML is, the more stable is the route.

3.3. Selection of the best route

We can consider several solutions for deriving a stable route as two categories : Using only distance information among nodes, and using locations and radio transmission ranges.

If only distance information among nodes is used, we can consider two schemes as follows. However, since these schemes don't consider the radio transmission ranges of all nodes, they experience many route failures.

- Using Accumulated Distances between nodes: Each route discovery packet contains accumulated distance information between intermediate nodes (d_i). In this case, the best route = minimum of d_i, $i \in$ all paths collected by the destination. However, in this case, since we don't make use of each node's radio transmission range, it is possible that there are frequent route disconnections because of node mobility. Since there can be some nodes far from each other even if there exist some nodes so close to each other, the minimum accumulated distance cannot reflect the route stability correctly.
- Using Min_Max distance: We can list each link-distance between two nodes(Instead of listing link-distances, we can easily obtain the maximum link-distance over a given path). A maximum link-distance(Max_Link_Dist) on a given path increases the possibility of route disconnections. Therefore, in order to reduce the number of route failures, a path with the minimum value among each path's Max_Link_Dist values can be selected as the best route. However, since the radio transmission ranges are not considered, this solution also experiences a similar route unstability like the solution mentioned above.

As mentioned above, when a destination receives a route discovery packet, the packet contains the list of NMLs calculated and appended to the route discovery packet, or the minimum NML among the links over the given path. Since there are many routes with different intermediate nodes, the destination collects multiple routes for selecting the best route (the most stable route) during a given time.

- Using Accumulated NML: Similar to the case using Accumulated Distances between nodes, since some links can have very high NML values and some links can have very small NML values, to just accumulating NMLs calculated at intermediate nodes and to select the route with the maximum value of the accumulated NMLs among the collected routes as the best route cannot reflect route stability correctly due to the high differences among NMLs. Therefore, in this paper, we make use of the following strategy.
- Using Max_Min of NML: We can list each NML of intermediate nodes in the route discovery packet(Instead of listing NMLs, we can obtain the minimum NML as the route discovery packet is propagated.). A minimum NML among the listed NMLs on a given route represents a link which has the hightest probability of route failure(We call this minimum NML M_NML). Therefore, it is possible that the route with maximum M_NML is selected among the possible routes with different M_NMLs. This stragegy makes the best use of the route stability by using location information and radio transmission ranges.

3.4. Avoiding Excessive Beacon Signals

For the first time, the concept of a long-lived route is introduced in ABR protocol. ABR selects a long-lived route

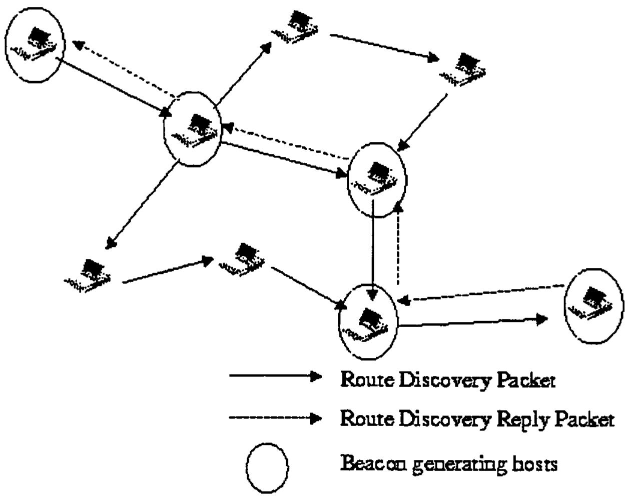

Figure 2. Exchanged Beacon Signal among Nodes on the Acquired Path for Detecting Route Failures

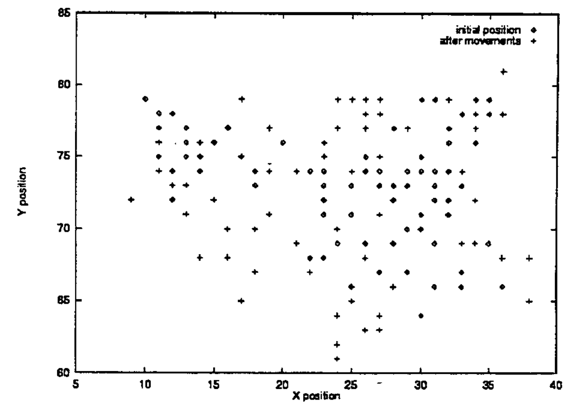

Figure 3. Initial Topology of Wireless Ad Hoc Network

based on the accumulated tick counts over a wireless link among nodes. Therefore, each link between two nodes has its tick counts which are obtained by exchanging periodical beacon signals from each other. During a route discovery process, the route discovery packets which arrive at the destination have the list of tick-count values at visited links. Among the collected routes, a route having the highest tick-count value is selected as the best path. In this paper, we don't need to use periodic exchange of beacon signals with each other of all adjacent nodes which is used for measuring link stability in ABR. Since the beacon signals are used for detecting route failures on the acquired path, only nodes on the acquired route have only to generate and exchange their beacon signals for detecting a route disconnection, resulting in reducing the power consumption more than the case where all nodes always maintain their link associativity at link level as in ABR. As shown in Figure 2, in order to detect a route failure, after selecting the best route, the route discovery reply packet is propagated on the reverse path of the selected path and each intermediate node keeps track of its up-link node and down-link node. If there is no beacon signal from a up-link or down-link during a given period, a node declares a route failure and performs route discovery process as defined in ABR protocol [11].

4. Simulation Environment and Results

We developed an event-driven simulator suitable for wireless ad hoc networks. Initially, 70 nodes are assumed to be spread in the plane ($1000m$ x $1000m$)(Figure 3). Each node can move randomly into all directions. We make use of source initiated on-demand routing protocol. Additionally, our route reconnection process is based on ABR protocol which is one of source initiated on-demand routing protocols. We assume that all nodes' radio transmission ranges are the same for simplicity of simulation and avoiding the existence of unidirectional links. Therefore, the nodes located within a radius of radio transmission range of a node are its neighboring nodes.

As mentioned above, we don't use periodic exchange of beacon signals for deriving a long-lived route because we take advantage of location information and radio transmission ranges. In this paper, beacon signals exchanged among nodes are used for detecting a route failure. In order to detect a route failure, the only nodes on the acquired route are supposed to exchange their beacon signals. During a given time, if an adjacent node cannot hear any beacon signal, it can consider that there exists a route failure between two nodes.

We assume that a propagation delay of a link is 0.01 seconds and each node's radio transmission range is 30 meters.

At first, we compared our approach with the pure shortest path scheme that does not consider route stability. The destination, after receiving the first route discovery packet, waits for 1 second[1] to collect other incoming route discovery packets for selecting the best route. In the pure shortest path scheme, a destination simply selects the shortest path. The number of route reconstruction is measured as the overall node mobility increases. The simulation result in Figure

[1] This value can be adapted according as a system parameter. This is an arbitrary value in this simulation.

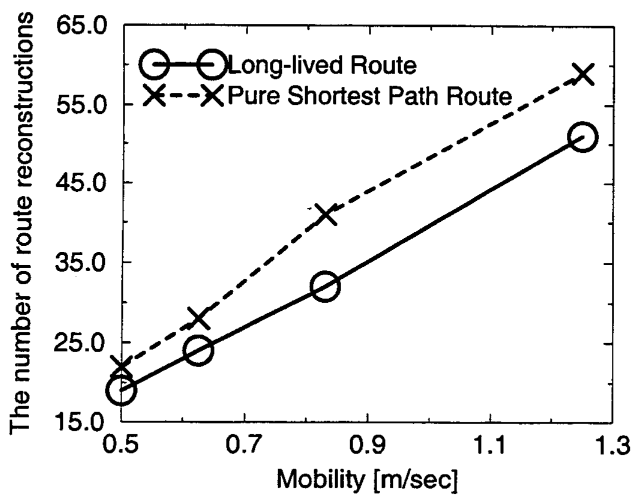

Figure 4. Comparison of the Number of Route Reconstructions : Pure Shortest Path vs. Long-lived Route

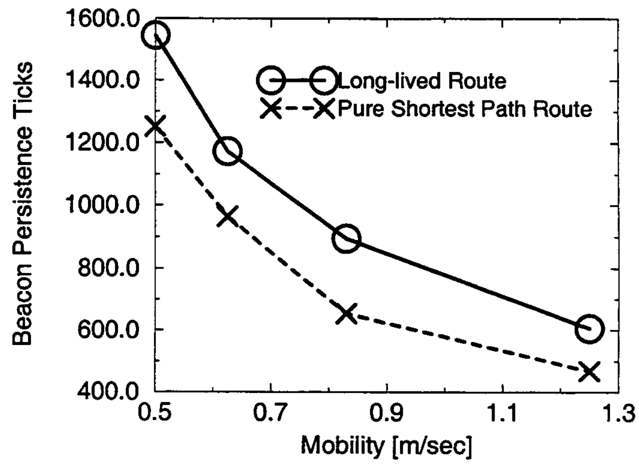

Figure 5. Beacon Persistence Ticks according to the Mobility

4 shows that the frequency of route reconstructions in our scheme is much less than the pure shortest path scheme.

In our proposed scheme, we intend to avoid unnecessary excessive beacon signals. Assuming the beacon period of one second, a link is considered broken if no beacon signal is received after five seconds. We measure how long a node keeps generating its beacon signals until it experiences a route failure caused by node mobility. It is easy to see that the Beacon Persistence Ticks(the average number of beacon signals between successive route failures) decreases as the node mobility increases. The Beacon Persistence Ticks is a measure of route stability. Compared to the pure shortest path scheme, our scheme improves the Beacon Persistence Ticks by 20 % as shown in Figure 5.

Finally, we varied the radio transmission range and observed its effect on route reconstruction. Increasing the radio transmission range means that a destination can be reached in less hops than a small radio transmission range. In addition, since there are more neighboring nodes, the destination have more opportunity to select more stable routes. As shown in Figure 6, the number of route reconstructions of our location-aware long-lived route selection approach shows better performance than that of simple shortest path.

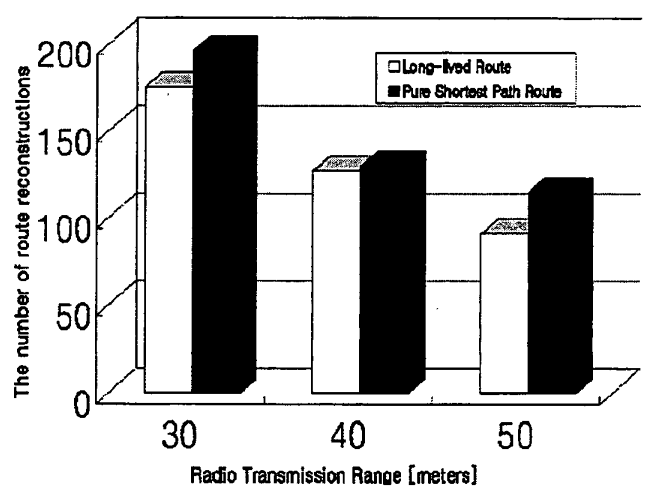

Figure 6. Route Reconstruction according to Varied Transmission Ranges

5. Conclusions

Most routing protocols in wireless ad hoc network have focused on the shortest route from the aspect of throughput due to a short delay. However, since there are frequent route failures because of node mobility, it is more important for getting a stable and long-lived route. In the literature, ABR protocol makes use of long-lived route based on the periodically exchanged beacon signals. In ABR, even if there are no nodes which want to communicate with other nodes, they should generate beacon signals, resulting in the consumption of battery power. Additionally, since node's mobility is unpredictable, there are always the possibilities of route failures.

In this paper, a long-lived route is derived by using location information and radio transmission range. Furthermore, for detecting a route failure, the only nodes on the acquired path exchange beacon signals periodically. The simulation shows that the number of route reconstructions can be reduced due to route stability. In the future, the behavior of data traffic under our proposed scheme such as throughput will be evaluated. Additionally, the influence of variable radio transmission ranges will be studied.

References

[1] C. Perkins and P. Bhagwat, "Highly Dynamic Destination Sequenced Distance Vector Routing(DSDV) for Mobile Computers," Proc. ACM SIGCOMM Symposium on Communications, Architecture and Protocols, 1994.

[2] D.B. Johnson and D.A. Maltz, "Dynamic Source Routing in Ad Hoc Wireless Network," Mobile Computing, edited by Tomasz Imielinski and Hank Korth, Chapter 5, Kluwer Academic Publishers, 1996.

[3] M. Gerla and J.T. Tsai, "Multicluster, mobile, multimedia radio network," Wireless Networks, Vol. 1, pp. 255-265, 1995.

[4] P. Krishna, M. Chatterjee, N.H. Vaidya and D.K. Pradhan, "A Cluster-based Approach for Routing in Ad-Hoc Networks," Second USENIX Symposium on Mobile and Location-Independent Computing, 1995.

[5] D.K.Kim, S.J.Ha and Y.H.Choi, "K-hop Cluster-based Dynamic Source Routing in Wireless Ad-Hoc Packet Radio Network," IEEE VTC,1998.

[6] Z.J.Haas and M.R. Pearlman, "The Zone Routing Procotol (ZRP) for Ad Hoc Network," draft-zone-routing-protocol-00.txt, Novemeber,1997.

[7] Z.J. Haas, "A New Routing Protocol for the Reconfigurable Wireless Networks," ICUPC, 1997.

[8] D.K. Kim, S.J. Ha and Y.H. Choi, "Cluster-based Dynamic Source Routing Protocol in Wireless Ad-Hoc Network with Variable-sized Clusters and Variable Transmission Ranges," IEEE VTC, 1999.

[9] K.Chandran, S. Raghunathan, S. Venkatesan, and R. Prakash, "A Feedback Based Scheme For Improving TCP Performance In Ad-Hoc Wireless Networks," ICDCS 1998.

[10] E.M. Royer, C.-K. Toh, "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks," IEEE Personal Communications, April 1999.

[11] C.K. Toh, "Associativity Based Routing For Ad Hoc Mobile Networks," Wireless Personal Communications Journal, Special Issue on Mobile Networking & Computing Systems, Vol. 4, No. 2, March 1997.

[12] Youngbae Ko and N.H. Vaidya, "Location-Aided Routing (LAR) Mobile Ad Hoc Networks," MOBICOM '98.