A Pseudo-distance Routing(PDR) Algorithm for Mobile Ad-hoc Networks

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Abstract: Previous routing algorithms for MANETs have focused on finding short-distance path(s) between communicating nodes. However, due to the dynamic and unreliable communication nature of MANETs, previously determined paths can easily become disconnected. Although dynamic routing can be used to circumvent this problem, determining a new route each time a packet needs to be sent involves a lot of overhead. An alternative form of dynamic routing involves maintaining valid routes in routing tables, which can be dynamically updated whenever network changes are detected. This paper proposes a new routing algorithm, referred to *pseudo-distance routing (PDR)*, that supports efficient routing table maintenance and dyamic routing based on such routing tables.

1. Introduction

Due to the limited communication range of wireless communication links and the mobility of the hosts, efficient routing is one of the main challenges for mobile ad-hoc networks (MANETs). To be truly effective, a routing algorithm for MANETs should support loop-free routing, quick convergence of the routing procedure, multiple paths to the destination, minimal-path routing, scalability, minimal overhead during the route discovery and maintenance phases, distributed execution and efficient maintenance of routing paths. This paper proposes a new routing algorithm, termed *pseudo-distance routing (PDR)*, that supports all of the above properties except minimal-path routing.

2. Model

A network is modeled as an undirected graph $G = (V, E)$ where V is a finite set of nodes that have unique identifiers (like MAC addresses) and E is a set of bidirectional communication links during a given time instant. Note that actual links in MANETs are not bidirectional. However by building a routing protocol on top of other protocols, as in the internet MANET encapsulation protocol (IMEP) [1], bidirectional communication links can be realized. A neighbor set of node i, written as N_i, consists of nodes that have a bidirectional link to node i. To provide loop-free and multi-path routing, we use the destination-oriented DAG concept defined in [2]. Then the routing problem becomes the problem of mapping a destination-oriented directed acyclic graph onto G while supporting the above properties. As in TORA [3], a link-reversal algorithm [2] is adapted to solve this problem.

The *pseudo-distance* of a node i to a node j is written as $PD_{i,j} =< \lambda, -\alpha, -\beta >$. λ is a distance metric between node i and j, α is the number of neighbors that have lower λ values than i and β is the number of neighbors that have the same λ value. Two types of links are identified. Primary links are mainly used to route packets along shortest-distance paths. Auxiliary links are used when all primary links are broken.

There are four cases to be considered when setting the directions of links in MANETs . For two neighbor nodes i and k, 1) if $\lambda_i > \lambda_k$ then node i sets its link as primary outgoing, 2) if $\lambda_i = \lambda_k$ and $-\alpha_i > -\alpha_k$, then node i sets its link as auxiliary outgoing, 3) if $\lambda_i = \lambda_k$, $-\alpha_i = -\alpha_k$ and $-\beta_i > -\beta_k$, then node i sets its link as auxiliary outgoing, 4) if $PD_i = PD_k$ and $i > k$ then node i sets its link as auxiliary outgoing. Each node i collects and maintains up-to-date $PD_{k,j}$ values for all $k \in N_i$.

Figure 1 shows an example of a destination-oriented DAG for destination node F using the pseudo-distance concept. Blue arrows represent primary links and yellow arrows represent auxiliary links. Example PD values are shown for each node. Note that the distance between two nodes is a multiple of δ, which is the default difference in λ between adjacent nodes. With this DAG, node E would select node B as its next hop because it has lower pseudo-distance than node G.

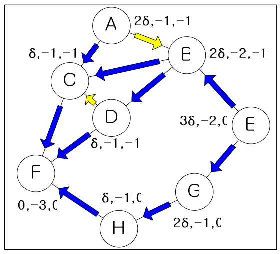

Figure 1. Destination-oriented DAG

3. Algorithm Description

3.1 Control Packets

To assign PD to all nodes in a MANET, a new algorithm is required. To assign and maintain PD values, three types of control messages are defined. 1) QRY is a route query message that is triggered when a node wishes to send packets to a destination node. QRY is forwarded toward the destination or any intermediate nodes that have route information. 2) REP, which contains pseudo-distance information, is the reply message for a QRY. REP is triggered by QRY if a node has route information (actually, a node that has a non-null PD) to the destination. REP may also be generated by another REP to forward routing information. 3)UPD is a route maintenance message used to reflect topological changes in a MANET. UPD is triggered when a local PD is changed. PD is changed when a node loses all of its outgoing links.

3.2 Route Discovery Phase

The algorithm consists of two phases. The first builds destination-oriented DAGs by assigning PD values to each node, and the second maintains the destination-oriented DAGs whenever there are topological changes in the MANET.

Initially, every node except the destination sets its own $PD_{i,j}$ to null. The destination node set its $PD_{i,i}$ to zero. When a node wishes to send packets to a destination, it broadcasts a QRY packet. An intermediate node with a null PD that receives the QRY rebroadcasts it. When a node with a non-null PD receives a QRY, it broadcasts a REP with its PD value. An intermediate node that receives a REP updates its PD value and broadcasts a REP with its PD value. Figure 1 shows an example of this process.

3.3 Route Maintenance Phase

A route maintenance phase is triggered by a node when it loses all of its outgoing links. If short-distance routes are to be maintained, then each node must modify its pseudo-distance when it loses all primary outgoing links. If a node i loses all primary outgoing links directed toward destination j, then it checks whether it has auxiliary links. If node i has auxiliary links, it modifies its PD to convert auxiliary links into primary outgoing links and sets its $\lambda_{i,j}$ to $\lfloor \lambda_{i,j} + \{\lambda_{i,j} + \min(\lambda_{k,j})\}/2 \rfloor$ for all $k \in N_i$, where $\lambda_{k,j} > \lambda_{i,j}$. If a node i does not have any auxiliary links, it modifies its $\lambda_{i,j}$ to $\min(\lambda_{k,j}) + \delta$ for all $k \in N_i$. Also, if node i receives UPD from a neighbor node k, it updates its $\lambda_{i,j}$ to $\lambda_{k,j} + \delta$ if $\lambda_{i,j} - \lambda_{k,j} > \delta$.

Figure 2 shows route maintenance phase when a link between node A and B is broken. When node B detects an event that causes it to lose all outgoing links, it modifies its own $PD_{B,A}$. Node B finds $\min(\lambda_{i,A})$ for all $i \in N_B$, where $\lambda_{i,A} > \lambda_{B,A}$. Because node B has one auxiliary link, it modifies its $\lambda_{B,A}$ to $\delta + (1/2)\delta$ and updates its corresponding $< -\alpha, -\beta >$ to $< -1, 0 >$.

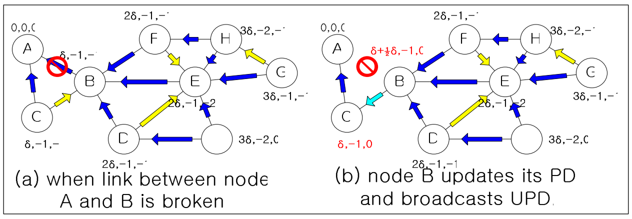

Figure 2. An example of the route maintenance phase.

Figure 3 shows another example of the route update phase. Suppose that node E moves toward the right. It may lose all outgoing links. Because node E does not have any auxiliary links, it recomputes $\lambda_{E,A} = \min(\lambda_{i,1}) + \delta = 4\delta$ and updates its corresponding $< -\alpha, -\beta >$.

3.4 Comparison of PDR to TORA

In the example of Figure 2, PDR requires only a single step in order to converge during the route maintenance phase. However, TORA [3] requires seven steps.

Figure 4 shows routing paths used by PDR and TORA. Part (a) of Figure 4 shows the initial routes used by PDR when $\delta = 4$ and (b) shows the initial routes used by TORA for the same MANET. Suppose that the link between node

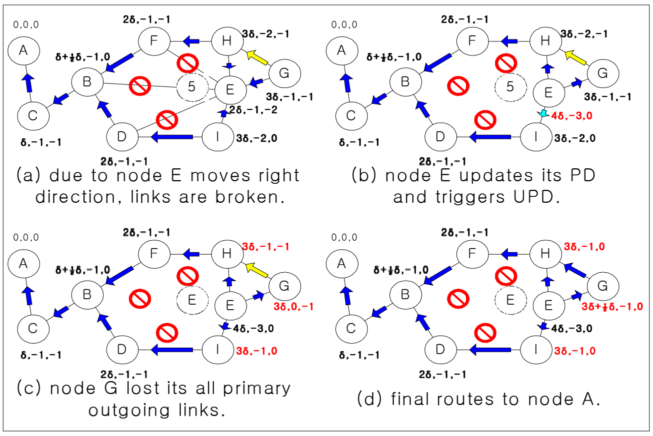

Figure 3. The other example of route maintenance phase

E and node F becomes disconnected. Route maintenance is then performed. This results in $PD_{E,F} =< 12, -1, 0 >$, $PD_{B,F} =< 10, -1, 0 >$ and $PD_{D,E} =< 8, -1, 0 >$ in PDR. If the link between node E and node F is later re-established, then node E modifies its pseudo-distance to find shorter paths. As $\lambda_{E,F} - \lambda_{F,F} > \delta$, node E modifies its pseudo-distance to $< 8, -1, 0 >$ as shown in Figure 4(b). PDR provides a 2-hop-

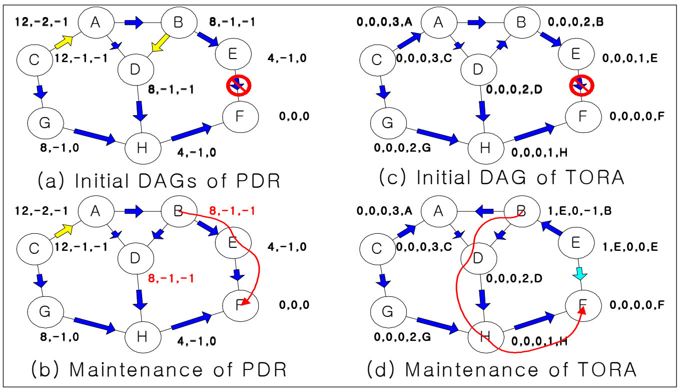

Figure 4. Comparison of PDR with TORA.

distance path from B to F, but TORA can not because the "height" does not decrease in TORA.

4. Discussion

This paper proposes a new routing protocol termed PDR that provides efficient, multiple paths to each destination. Analysis of example cases shows how PDR can maintain routing table information more efficiently than TORA while using shorter routes than TORA. For more detailed performance comparisons, simulation experiments are currently being conducted using the NS-2 simulator.

References

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