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Reversing Ticket Based Probing Routing Protocol for MANET

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Abstract: - The delay-constrained maximum-bandwidth routing problem in mobile ad hoc networks (MANET) is to find the maximum bandwidth path which satisfies a given delay constraint. The challenge of solving this problem is that the networking information used for routing may be imprecise. The Ticket-Based Probing (TBP) routing algorithm provides a heuristic approach to solve the routing problem. In this paper we present a Reversing Ticket-based Probing (RTBP) routing protocol. RTBP has two novel features compared to the original TBP algorithm. The first feature is the use of one type ticket. By using just one type ticket, RTBP generates less ticket at path request phase and it reduces message overhead. The second feature is that if a ticket violates delay constraint, RTBP can reverse previous nodes to search the alternative paths. Through extensive simulations, it is shown that RTBP has fewer messages overhead than existing ticket based probing algorithms.

Key-Words: - MANET, routing, protocol, ticket based probing, wireless network.

1 Introduction

A MANET is a collection of self-organizing wireless mobile hosts that form a temporary network without an infrastructure. In such a network, each mobile node operates not only as a host but also as a router. Routing in a MANET has special challenges. Mobility of hosts, which causes topological changes of the underlying network, also increases the volatility of network information [1]. Because of its dynamic topology and imprecise available state information for routing, the design of routing protocol in MANET is different from other networks.

The primary goal of MANET routing protocols is to establish an efficient route between two nodes so that messages can be delivered in a timely manner. But connections with quality of service (QoS) requirement, such as multimedia applications with delay and bandwidth constraints, must be supported. Network control with QoS support is a key issue for multimedia applications in MANET. The key issue to support QoS is to select a path satisfying the QoS requirements [2]. Unfortunately, QoS routing in MANET is difficult because of imprecise network state information [9]. QoS routing should have the following features that traditional routing does not support: obtaining resource information from lower layers, offering bandwidth information to applications, and incorporating resource reservation schemes and predict route breaks [11].

The provision of QoS relies on resource reservation. Hence, the data packets are likely to flow along the same network path on which the required resources are reserved. The price paid, however, is that the overhead of QoS routing is likely to be higher than that in a wired network because the available state information is less precise, and the topology changes in an unpredicted way. For this reason, QoS routing algorithms for wired networks cannot be applied directly to ad hoc networks. In order to reduce message overhead, we propose an enhanced distributed QoS routing protocol for MANETs, named Reversing Ticket-based Probing (RTBP). RTBP has two novel features compared to the original TBP algorithms. The first feature is using one type ticket. By using just one type ticket, RTBP generates less ticket at path request phase and it reduces message overhead. The second feature is that if a ticket violates delay constraint, RTBP can reverse previous nodes to search the alternative paths.

The rest of paper is organized as follows. The related work is introduced in Section 2. The proposed RTBP routing protocol is presented in Section 3. The implementation and simulation results are provided in Section 4. Finally, Section 5 concludes the paper.

2 Related Work

QoS routing in MANET has been extensively studied by research community [3, 4, 5, 6, 7, 8]. In this section, we mainly introduce three most related work.

2.1 Ticket Based Probing (TBP)

Ticket based probing can be defined as an intelligent hop-by-hop path selection. With hop-by-hop routing, the task of route selection is shared among intermediate nodes between the source and the destination. There is no centralized computational burden on any node, which enables hop-by-hop routing to scale well [10].

To implement hop-by-hop routing, multiple paths routing is employed [6,7,8]. Multiple paths routing attempts to achieve a trade-off between success probability in route acquisition and protocol overhead. It works by searching multiple paths in parallel for a QoS path. In [6], Chen *et al*. designed a protocol named Ticket-Based Probing (TBP). TBP requires multiple routing daemons to run in parallel in the network, one for each of the concerned metrics, to obtain the distance from each node to all other nodes with respect to each of the metrics. To search for a QoS route, the source issues a fixed number of probe packets, each carrying a ticket. Each probe is in charge of searching for a path, if possible. The maximum number of probes at any time is bounded by the number of tickets.

A basic structure of TBP is ticket. A ticket is the permission to search one path. The source node issues a number of tickets based on the available state information. As a general rule, more tickets are issued for the connections with tighter requirements. When a connection request arrives at the source node, a certain number of tickets are generated, and probes are sent from the source toward the target to search for a low-cost path that provides the QoS requirement. Each probe has to carry at least one ticket. When an intermediate node receives a probe, it has to decide, based on its state: whether the received probe should be split and to which neighbor nodes the probe(s) should be forwarded. Since each probe searches a path, the maximum number of paths searched is also limited by the number of tickets. Ticket-based probing approach can handle different QoS constraints. Delay-constrained routing and the bandwidth-constrained routing are the most studied QoS routing problems.

2.2 Delay-Constrained Routing with TBP

For a connection whose delay requirement is smaller, more tickets are issued to increase the chance of finding a feasible path. There are two types of tickets that have different purposes: *yellow* and *green* tickets. The purpose of yellow tickets is to increase the probability of finding a feasible path. Hence, yellow tickets (or more precisely, the probes carrying them) prefer paths with smaller link delays. The purpose of green tickets is to increase the probability of finding a low-cost path. Green tickets prefer the paths with smaller link costs.

The number of tickets is aggregation of the number of yellow tickets and the number of green tickets. The number of yellow tickets and number of green tickets are determined based on the delay requirement.

When a node forwards the received tickets to its neighbors, the tickets are distributed unevenly among the neighbors, depending on their chances of leading to low-cost feasible paths. A neighbor having a smaller end-to-end delay to the destination should receive more tickets than a neighbor having a larger delay; a neighbor having a smaller end-to-end cost to the destination should receive more tickets than a neighbor having a larger cost. Note that some neighbors may not receive any tickets because the node may have only a few or just one ticket to forward.

If the best expected delay from a neighbor to target violates the delay requirement, there is no need to send any ticket to this neighbor. If the node does not find a neighbor that provides delay constraint, it invalidates all received tickets and discards them. The distribution of yellow tickets is completely based on delay, and the distribution of green tickets is completely based on cost.

The routing process terminates when all probes have either reached the destination or been dropped by the intermediate nodes. In order to detect the termination, the intermediate nodes send the invalidated tickets to the destination. Therefore, all tickets will arrive at destination finally. The routing process is terminated after destination receives all valid and invalid tickets.

A probe accumulates the cost of the path it traverses. If multiple probes with valid tickets arrive at the destination, the path with the least cost is selected as the primary path, and the other paths are the secondary paths, which will be used when the primary path is broken due to the mobility of intermediate nodes [6].

2.3 Modified Ticket Based Probing (MTBP)

The MTBP routing protocol is very similar to the TBP protocol. The system model, calculation of number of tickets and distribution of probes of MTBP and TBP are identical. MTBP routing protocol is designed for only delay-constrained routing. MTBP routing protocol is intended to reduce message overhead per connection. Aiming to reduce message overhead, some modifications on TBP protocol were done in [7].

Firstly, the routing process ends at destination in two ways, first after all tickets reach destination, or second if a timeout occurs. In MTBP, all invalid probes are discarded by intermediate nodes, instead of sending them over network to their destination.

The second modification is about the data structure of probe. MTBP protocol uses a new field representing the hotness of this probe (degree of importance of the message to be sent after route is determined). The other fields of modified ticket based probe are the same as the ticket based probe. The hotness degree could be based on applications running on nodes or node priorities.

3 Reversing Ticket Based Probing

In TBP and MTBP, there are two types of tickets that have different purposes: yellow and green tickets. Yellow tickets are used to increase the probability of finding a feasible path. Green tickets are used to increase the probability of finding a low-cost path. The numbers of yellow and green tickets are determined based on the delay requirement. Yellow tickets (or more precisely, the probes carrying them) prefer paths with smaller delays. But green tickets prefer the paths with smaller costs. After all probes reach the destination node, several paths may be found. Some of these paths satisfy delay constraint and the rest are lowest cost paths that may have larger delay and hence have less chance to satisfy the delay constraint. In this case, the paths that do not satisfy delay constraint are not useful for determining delay-constrained path. If there is no feasible path for delay constraint among paths of green tickets, all the paths of green tickets have no value to determine a delay constraint path and it causes unnecessary processing time and message overhead.

In proposed RTBP protocol, there is only one type ticket. The purpose of the ticket is to maximize the probability of finding a feasible path with high-bandwidth. This is one of the primary differences of RTBP from TBP and MTBP. Instead of using two types of tickets, one type ticket is used and the ticket has not only delay information but also bandwidth information in it. The number of tickets is determined based on the delay requirement and tickets prefer paths with smaller delays. A probe accumulates the delay and bandwidth of path it traverses. If multiple probes arrive at the destination, the path with the maximum bandwidth is selected as the primary path because all paths provide delay constraint.

Upon receipt of a probe, an intermediate node decides, based on its state: 1) whether the received probe should be split, and 2) to which neighbor nodes the probe(s) should be forwarded. The goal is to collectively utilize the state information at the intermediate nodes to guide the limited tickets (the probes carrying them) along the best paths to the destination, so that the probability of finding a high-bandwidth feasible path is maximized.

RTBP routing protocol is composed of three main stages: 1) determination of the number of tickets for the initial probes, 2) distribution of the probe copies with tickets towards specific neighbors, and 3) path selection.

3.1 Determining the number of tickets

Different numbers of tickets are assigned to different connections based on their delay requirement. For a connection whose delay requirement is larger and can be easily satisfied, one ticket is issued to search a single path; for a connection whose delay requirement is smaller, more tickets are issued to increase the chance of finding a feasible path.

Let s, o, D, ΔD be the source, the destination, delay requirement, and delay variation respectively. The number of tickets N_0 is then a function of D, $Ds(o)$, and $\Delta Ds(o)$. There are three scenarios as follows:

- If $D \geq D_s(o) + \Delta D_s(o)$, then $N_0 = 1$. Because D is equal to or greater than the largest possible end-to-end delay, a single ticket will be sufficient to find a feasible path.
- If $D_s(o) - \Delta D_s(o) < D < D_s(o) + \Delta D_s(o)$, then $N_0 = \lceil (Ds(o) + \Delta Ds(o) - D) / 2\Delta Ds(o)\Phi \rceil$, where Φ is a system parameter specifying the maximum allowable number of tickets. It shows that more tickets are assigned for smaller D.
- If $D < D_s(o) - \Delta D_s(o)$, then $N_0 = 0$. Because D is even less than the best-expected end-to-end delay, such a tight delay requirement will not be satisfied. The connection request is rejected.

3.2 Distribution of Probe Copies

When a node forwards the received tickets to its neighbors, the tickets are distributed unevenly among the neighbors, depending on their chances of leading to reliable high-bandwidth feasible paths. A neighbor having a smaller end-to-end delay to the destination should receive more tickets than a neighbor having a larger delay. Note that some neighbors may not receive any tickets because the node may have only a few or just one ticket to forward.

Candidate neighbors. If $N_0 = 0$, the connection request is rejected. Otherwise, probes carrying the tickets are sent from *s* to *o*. A probe proceeds only when the path has a delay of no more than *D*. Hence, once a probe reaches *o*, it detects a delay-constrained path. Each probe accumulates the delay of the path it has traversed so far. More specifically, a data field, denoted as delay(*p*), is defined in a probe *p*. Initially, delay(*p*) := 0. Whenever *p* proceeds for another link, delay(*p*) is updated by adding the delay of that link.

If no neighbor node provides delay constraint, the node sends the probe back to previous node. Every node that gets the turning back probe calculates the delay of probe. If this delay is smaller than the half of delay constrained, the node determines whether the probe has new neighbor nodes for sending probe. Every node has the information of the probe id and nodes that this probe was sent to. This information remains for certain time at the node.

When a node sends back probe to one of previous nodes, the previous node determines whether the probe is sent to new neighbor node or it is discarded. If previous node has more neighbors that provide constraints, it sends probe to it. Otherwise the probe is discarded. Sending probes back is one of the main differences with the other ticket based probing protocols. If $R_{ip}(o) \neq 0$, then for every $j \in R_{ip}(o)$, *i* makes a copy of *p*, denoted as p_j. Let p_j have $N(p_j)$ tickets. Next we present how to calculate $N(p_j)$.

Calculating and Distributing Tickets. Basically, $N(Pj)$ is determined based on an intuitive observation: a probe sent toward the direction with a smaller delay and bigger bandwidth should have more tickets. In MTBP tickets are distributed according to not only delay but also bandwidth of path. This is one of the main differences of RTBP from TBP and MTBP. Let $B_j(o)$, *Y* and *Np* be the bandwidth from *i* to *j*, the system parameter for delay efficiency over bandwidth ($0.5<Y<1$), and the number of tickets of probe *p* respectively.

$$N(P_j) = \left(\frac{(delay(i,j)+D_j(o))^{-1}}{\sum_{j'\in R_i^p(o)} (delay(i,j')+D_{j'}(o))^{-1}} \times \mathrm{Y} + \frac{\min\{bandwidth(i,j), B_j(o)\}}{\sum_{j'\in R_i^p(o)} \min\{bandwidth(i,j'), B_{j'}(o)\}} \times (1-Y)\right) N(p)$$

3.3 Path Selection

The routing process is terminated when all probes have either reached the destination or been dropped by the intermediate nodes. In order to reduce overhead, the invalidated tickets are discarded by intermediate nodes instead of sending them to the destination. Probes may be discarded by intermediate nodes and probes may be destroyed according to the conditions of transmission and environment so there is a certain time-timeout that the destination node has to wait receiving for all probes after which the destination node considers rest of not received probes as lost or discarded. The routing process is terminated after timeout.

Whenever destination receives a valid probe, a feasible path is found, which is the one the probe has traversed. In order to record the path: the path in the probe is recorded itself.

A probe accumulates the maximum achievable bandwidth of the path it traverses. If multiple probes with valid tickets arrive at the destination, the path with the highest bandwidth is selected as the primary path, and the other paths are the secondary paths, which will be used when the primary path is broken due to the mobility of intermediate nodes. After the primary path selection, a confirmation message is sent back along the path to the source and reserves resources along the way.

3.4 Data Structure

The data structure of a probe p is shown in Table I. The last five fields, path, *N*(*p*), delay(*p*), bandwidth(*p*), and direction are modified as the probe traverses. Tickets are logical tokens, and only the number of tickets is important: there can be at most *N*(*p*) new probes descending from *p*, choose paths based on delay.

Table I: Data Structure

id	Unique identifier for connection request
s	Source node
o	Destination node
D	Delay requirement
N_0	Total number of tickets
path	Path that traversed by this probe
N(p)	Number of tickets that this probe has
bw(p)	Maximum achievable bandwidth of probe
delay(p)	Accumulated delay of probe
direction	A Boolean field that shows whether the probe turns back or forwards

4 Simulation and Results

In order to compare the performance of RTBP, extensive simulations were conducted to compare the performance of RTBP with TBP, and MTBP. Two performance metrics, success ratio, and average message overhead are used. In this simulation, the network topology and simulation environment are the same as in [6, 7]. Sending a probe over a link is counted as one message. Hence, for a probe that has traversed a path of *h* hops, *h* messages are counted.

4.1 Success Ratio

Success ratio is the ratio between the total numbers of connection requests of the network to the number of accepted connections in a certain portion of time. Simulation results have suggested that TBP, MTBP and RTBP achieve the same success ratio. Two examples are given in Figs. 1 and 2.

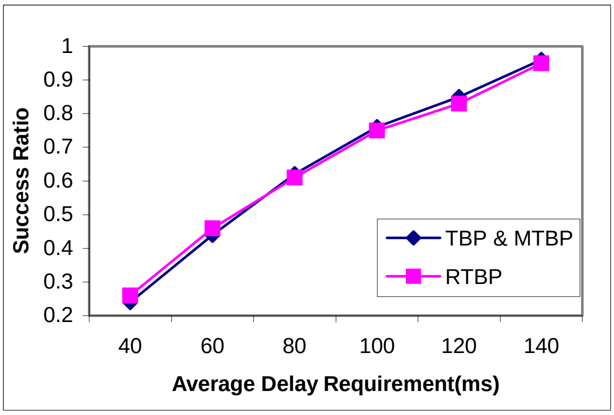

Fig. 1. Success ratio for imprecision rate 5%.

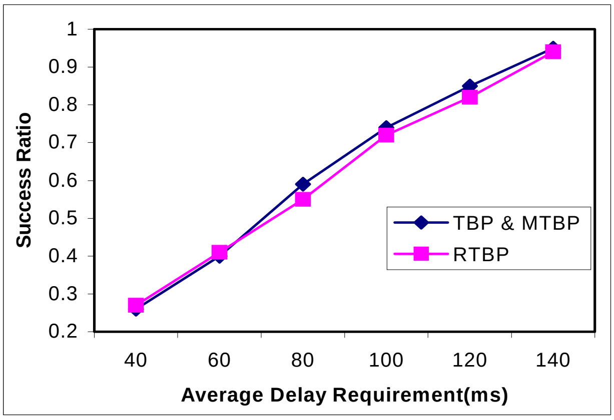

Fig. 2. Success ratio for imprecision rate 10%.

4.2 Message Overhead

Figs. 3 – 5 compare the average message overhead of the three protocols. Here the average message overhead is defined as the ratio of the total number of control messages sent divided by the total number of connection requests. It can be seen that the proposed protocol has the lowest message overhead for each imprecision rate. When delay requirement is small, message overhead of three protocols is nearly the same. In case delay requirement is too small to be satisfied, most of connections can be rejected. Therefore, a few tickets are assigned for small delay requirement and message overhead is the same for three protocols or very close. When delay requirement increases, some tickets are assigned for nearly all connections and total connection messages increases. In this case, RTBP has fewer messages overhead because RTBP generates less ticket at initial phase.

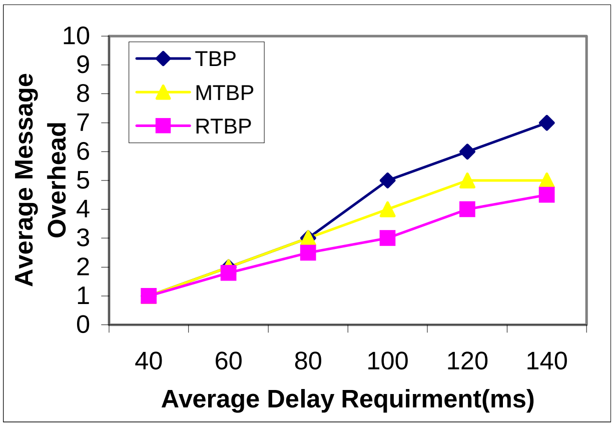

Fig. 3. Message overhead for imprecision rate 5%.

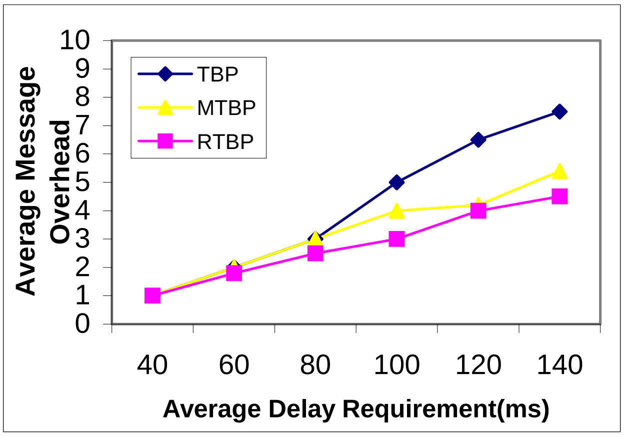

Fig. 4. Message overhead for imprecision rate 10%.

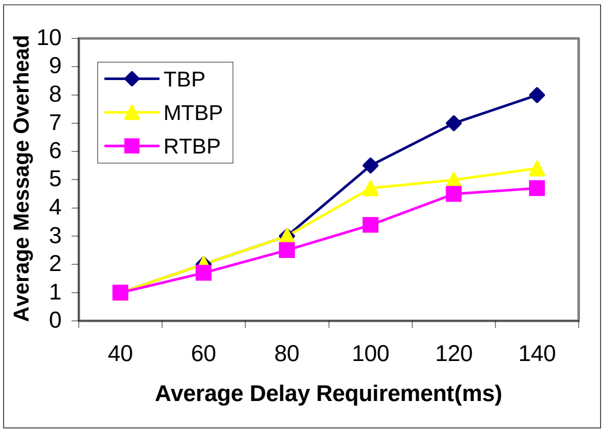

Fig. 5. Message overhead for imprecision rate 25%.

5 Conclusion

In this paper, a Reversing Ticket Based Probing (RTBP) routing algorithm for mobile ad hoc networks is proposed. RTBP inherits ideas and advantageous properties of original ticket based probing routing algorithm, besides the message overhead reduction and some modifications. RTBP has two main differences from existing ticket based probing protocol. The first difference is about ticket type. In TBP and MTBP, there are two types of tickets that have different purposes. In RTBP, there is only one type ticket. The second difference is about the direction of node traverse. When a probe violates the delay constrained, it can reverse the previous node and search alternative paths. Therefore the maximum number of paths searched can be more than the number of tickets. Simulation results showed that success ratio of proposed protocol is nearly the same as TBP and MTBP. But it can be a little better or worse up to imprecision rate and delay requirement. The main goal of RTBP is to perform less overhead and same success ratio with TBP and MTBP. Simulation results show that RTBP has fewer messages overhead than TBP and MTBP do because it uses one type ticket. RTBP has same success ratio with TBP and RTBP.

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