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設計與實作具服務品質保證之無線隨意行動網路的多徑繞徑協定

Design & Implement a Multi-Path QoS Routing Protocol in Wireless Mobile Ad Hoc Networks

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摘要：

A mobile ad hoc network (MANET) is one composed of a set of mobile hosts capable of communicating with each other without the assistance of base stations. This paper considers the QoS (quality-of-service) routing problem in a MANET, which is important for many real-time multimedia applications. We propose an on-demand protocol for searching for a multi-path QoS route from a source host to a destination host in a MANET, where a *multi-path* is a network with a source and a sink satisfying certain bandwidth requirement. Existing works all try to find a *uni-path* to the destination. The basic idea is to distribute a number of tickets from the source, which can be further partitioned into sub-tickets to search for a satisfactory multi-path. Through simulations, we justify that the value of our multi-path protocol is in its flexibility: (i) when the network bandwidth is very limited, it can offer a higher success rate to find a satisfactory QoS route than those protocols which try to find a uni-path, and (ii) when the network bandwidth is sufficient, it can perform almost the same as those protocols which try to find a uni-path (in both routing overhead and success rate). mobile ad hoc network (MANET),

關鍵字 ：

multi-path, quality-of-service (QoS), routing, wireless communication.

1. Introduction

Since MANETs are characterized by its fast changing topology, extensive research efforts have been devoted to the design of routing protocols for MANETs [2,3,9,10,11,12,14,17,18,19,21]. These works all address some of the following issues: how to discover a route from a source node to a destination, how to maintain a route while it is being used, and how to deliver data packets to the intended destination host. However, these protocols, when searching for a route to the destination, are only concerned with shortest-path routing and the availability of multitude routes in the MANET's dynamically changing environment. That is, only best-effort data traffic is provided. Connections with quality-of-service (QoS) requirements, such as multimedia with delay and bandwidth constraints, are less frequently addressed.

The purpose of this paper is to address QoS routing in a MANET environment. QoS routing has been studied extensively in the field of wireline networks [5]. Certainly, whether in a stand-alone MANET or in a MANET connected to a wireline network, QoS routing is still necessary. In this paper, we propose an on-demand protocol for searching for a multi-path QoS route from a source host to a destination host in a MANET, where a *multi-path* is a network with a source and a sink satisfying certain bandwidth requirements. Our protocol distinguishes from the work of [4] in that they try to find a *uni-path* to the destination based on a costly *reactive* approach (namely, DSDV [17]). The basic idea is similar to the work in [4] by distributing a number of tickets from the source. However, we allow a ticket to be further partitioned/split into sub-tickets to search for a satisfactory multi-path.

2. Background and Motivation

Existing ad hoc routing protocols may generally be categorized as *table-driven* and *on-demand*. Table-driven protocols attempt to maintain consistent up-to-date routing information from each node to every other node in the network (e.g., DSDV [17] and CGSR [6]). Contrarily, on-demand protocols create routes only when desired by the source node (e.g., DSR [12] and AODV [18]). A hybrid of these approaches is also possible (e.g., ZRP [10]). To assist routing, some protocols even adopt location information in their route discovery and maintenance procedures (e.g., LAR [13] and GRID [14]). However, all of these protocols are only concerned the existence of a route without guaranteeing its quality.

It is difficult to provide QoS in a MANET due to its dynamic nature. First, unlike wireline networks, precise network topology information is unavailable. Second, mobile hosts may join, leave, and rejoin at any time and any location; existing links may disappear and new links may be formed as mobile hosts moves. Hence, established paths can be broken at any time. In the following, we review the QoS routing protocol by [4]. Then we will motivate our work in this paper.

3. Our Multi-Path QoS Routing Protocol

3.1. Protocol Overview

Our protocol will follow an on-demand style to allocate bandwidth. So no global information will be collected in advance before a QoS route is required. A mobile host only knows the available bandwidth to each of its neighbors. When a source node S needs a route to a destination D

of bandwidth B, it will send out some probe packets each carrying some tickets. Each ticket is responsible of searching for a multi-path from the source to the destination with an aggregated bandwidth equal to B.

On a ticket/sub-ticket arriving at a node, if the node is not the destination, some bandwidth of a qualified outgoing link will be reserved for this ticket and then the ticket will be sent out through that link. Since we allow a multi-path from S to D, if no link with a sufficient bandwidth exists, the ticket may be split into multiple sub-tickets, each being responsible of searching for a multi-path with a certain portion of bandwidth B. The destination node will, if possible, receive multiple tickets or sub-tickets. It will then pick one ticket or a set of sub-tickets forming a whole ticket and send a reply to the source node. On the reply’s way back to the source, the bandwidths reserved by the earlier probes will be confirmed. A reservation that is not confirmed after a time-out period will be released. Below we will discuss our multi-path QoS routing protocol in more details.

3.2. Ticket Format

For each bandwidth request, a number of tickets may be sent. In the rest of the discussion, we will call a ticket that has never been split a *whole-ticket*, and one that has been split a *sub-ticket*. However, both whole-ticket and sub-ticket will be called a ticket. As shown below, this can be told from a ticket’s content. A ticket will be denoted by $T(S, D, x, y, RID, TID, B, b)$. The meanings of the parameters in the ticket are as follows.

- S: the source host.
- D: the destination host.
- x: sender of the packet carrying the ticket.
- y: receiver of the packet carrying the ticket.
- RID: identity of a bandwidth request. This is unique for each QoS route request.
- TID: identity of a ticket. This is unique for each ticket.
- B: the required bandwidth of the multi-path from S to D.
- b: the required bandwidth of the multi-path from y to D. (So, if this is a sub-ticket, then $b < B$.)

3.3. Ticket Splitting and Inheritance Relation

As mentioned earlier, on a ticket reaching a node from which there is no outgoing link with a sufficient bandwidth, it may be split into several sub-tickets each responsible for searching for a multi-path with a partial bandwidth. The correctness of our protocol relies on a special representation of ticket identity (TID). The format of TID is a sequence of numbers separated by periods, i.e., $i_1.i_2..i_k$. When a ticket is initiated at the source node, it will be given a unique identity i_1 (unique under the same RID). When an intermediate host receives a ticket (whole-ticket or sub-ticket) with identity TID, it may decide to split the ticket into sub-tickets. If so, each sub-ticket will be given an extension number appended after TID. Specifically, let the ticket be split into k sub-tickets. These sub-tickets will be given identities $TID.1$, $TID.2$, …, $TID.k$. This is illustrated in **Fig1**

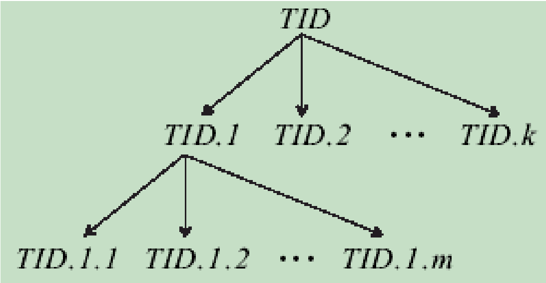

Figure 1 Representation of ticket identities after a ticket is split twice.

It is critical in our yet-to-be-presented protocol to determine the relationship between tickets. Let $head(T)$ be the first number in a ticket T. Consider two tickets $T_1(\ ,\ ID_1,\ldots)$ and $T_2(\ ,\ ID_2,\ldots)$. If $head(TID_1) = head(TID_2)$, then they are two sub-tickets of the same whole-ticket. If TID_1 is a sub-string of TID_2, then T_1 is a sub-ticket split from T_2. If $head(TID_1) = head(TID_2)$ but none of them is a sub-string of the other, then they belong to the same whole-ticket, but none of them is an ancestor of the other. These relationships are important in our protocol. We point out some crucial points below. In **Fig2(a)**, tickets T_1 and T_2 are two distinct tickets belonging to the same request. When they reach the same intermediate node Y (perhaps at different time), it is not necessary to reserve separate bandwidths for them because they represent the same request. Only a bandwidth of $max(b_1, b_2)$ has to be reserved. In **Fig2(b)**, tickets T_1 and T_2 are two sub-tickets belonging to the same whole-ticket. In this case, a total bandwidth of $b_1 + b_2$ has to be reserved at the intermediate host B. In **Fig2(c)**, tickets T_2 and T_3 are two sub-tickets belonging to the same whole-ticket T_1, but T_2 is a sub-ticket split from T_1. In this case, a loop is detected and we should discard T_2.

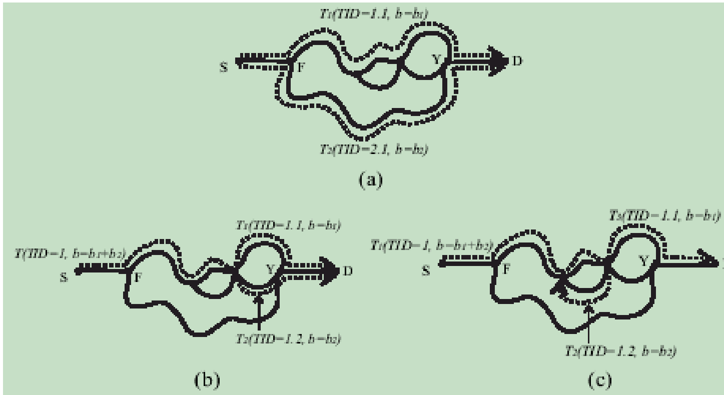

Figure 2 Three possible relationships between tickets: (a) T_1 and T_2 are irrelevant, (b) T_1 and T_2 are irrelevant siblings, and (c) T_2 is T_1's sub-ticket. Note that all these tickets share the same RID.

3.4. Loop Avoidance

To prevent loops from happening, we can let a mobile host collect tickets issued by its neighboring hosts, even if the tickets are not intended for itself. This is possible in a MANET due to the radio's broadcasting nature. For example, in Linux, this could mean that mobile hosts turn on their "listening" mode. Specifically, the following rules are used. A host always listens to the medium and collects all tickets issued by its neighbors, no matter if they are intended for itself or not. Now suppose a host receives a ticket T_1 destined to itself. The host will not forward T_1 or sub-tickets of T_1 to those neighbors who have ever sent a ticket T_2 such that T_1 is a sub-ticket of T_2 (by telling their ticket id's). For example, in **Fig 3**, host A sends B a ticket, B splits the ticket into two sub-tickets and forwards them to C and E. On C receiving the sub-ticket (with $TID = 1.2$), it will avoid forwarding the sub-ticket to A if it ever heard A's earlier ticket (with $TID = 1$).

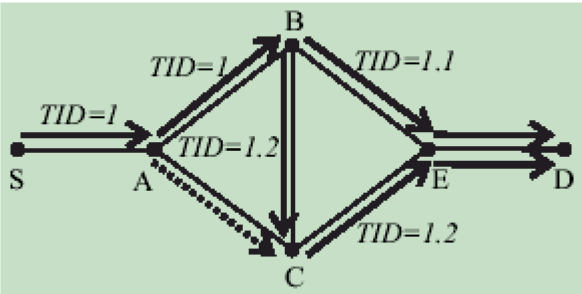

Figure 3 Loop avoidance in forwarding tickets.

Also note that the purpose of the above loop avoidance rules is to increase the success probability of route discovery. It will not affect the correctness of our protocol. This implies that it is alright for a host to miss some tickets issued by its neighbors (perhaps due to collision or mobility).

3.5. Route Reply

The purpose of route reply is to confirm the bandwidth reservations that we made in the previous section. Whenever a ticket reaches the destination , can check whether all sub-tickets under the same have been received or not. This can be done by summing up their total bandwidths and comparing it to the requested total . If a satisfactory multi-path has been found, we can send out the reply packets. Each of these reply packets should carry a sub-ticket under the same to the host where it was sent (this can be tracked back using the receive set). Also, for each sub-ticket being sent, the corresponding entries in the receive set and the listen set should be deleted. These route reply packets should travel backward to confirm the reserved bandwidths, until the source host is reached. The operations in the intermediate hosts are the same as the above. Our earlier records in the send sets and receive sets will be able to help the reply packets to track back correctly to the source .

4. Conclusions

We have proposed a multi-path QoS routing protocol for finding a route with a bandwidth constraint in a MANET. As opposed to the proactive routing protocol [4], our protocol is based on an on-demand manner to search for a QoS route, so no global link state information has to be collected in advance. Our protocol flexibly adapts to the status of the network by spending route-searching overhead only when the bandwidth is limited and a satisfactory QoS route is difficult to find. Simulation results have demonstrated the effectiveness of our protocol.

5. References

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