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A Service Priority Differentiated Quality of Service Routing Protocol for MANET: Mobile *Ad hoc* Network

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Abstract: In allusion to the problem of load balance, differentiated priority of service and guaranteeing the QoS performance of high priority service, a new route protocol for MANET-MDSRP (Mobile Differentiated Service Route Protocol) was proposed. MDSRP makes use of a new kind of route metric, EWDM (Expected Waiting Delay Metric). With this new metric the MDSRP can measure and evaluate the end-to-end delay of every candidate route and offer different strategies for service with different priorities. According to this mechanism, MDSRP can also balance the traffic load of networks to avoid the congestion in regional area. Analysis and simulation results had shown the feasibility and effectiveness of MDSRP.

Key words: MANET, priority of service, end-to-end delay, QoS

INTRODUCTION

MANET (Mobile *Ad hoc* Network) is a kind of wireless network without fixed infrastructure and it is widely used in military, disaster emergency and the business communication networks.

Usually, the nodes in MANET are distributed in a huge expanse. The nodes of distant will suffer from lacking of effective radio link because of the environment. This will result in the multi-hop relay by the various nodes in end-to-end communication. According to the mechanism of route discovery, the routing technology can be divided into three main classes. They are active class, on-demand class and mixed-class routing technology.

In the on-demand routing technology, the node will not send out the “Hello” packets to seek for the routing path in passive manner until it meets the service need. The AODV (*Ad hoc* On-Demand Distance the Vector) protocol is a routing protocol of on-demand class which is most widely used and is the focus of the study on on-demand class of routing protocols currently. The on-demand class of routing protocols, which can reduce the routing overhead, are suitable for the bandwidth resources limited network, which is sensitive to the routing protocol overhead.

The basic mechanism of active class routing technology is that each node in the network will obtain the routing tables to other nodes by taking the initiative to exchange the routing information to all other reachable nodes periodically. As the periodically routing maintenance, the active class routing technology will increase the protocol overhead (Shanthi and Ganesan *et al*., 2008). TBRPF (Topology Dissemination Based on Reverse-Path Forwarding) and OLSR (Optimized Link State Routing) are all typical active class routing technology. In OLSR, an efficient mechanism, named MPR, (Multi Point Relay) was used to control the flood of information. And the MPR can help to control the overhead of the protocol effectively (Kajioka *et al*., 2008). So, OLSR is applicable to the complex networks with high node density and heavy traffic load.

The mixed-class routing technology is the integration of the active and the on-demand class routing technologies and it synthesizes the characteristics of both of them. The ZRP (Zone Routing Protocol) proposed by Beijar (2002) is a typical mixed-class routing technology.

The operation of the MANET is a highly dynamic process and the network topology may change at any time. More importantly, the MANET networks need to support many different types of communication services (data, voice and other multimedia services, etc.). And each type of communication services also has different QoS requirements. Therefore, besides the basic functions on routing, the MANET routing technology should also focus on QoS requirements of different services, such as offering optimal routing, balancing the network load, distinguishing different priorities and guaranteeing the QoS performance of high-priority service. However, there are more route protocol, such as AODV and OLSR, did not take the QoS support issues into account seriously during the protocol design. In the recent research, many

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scholars focused on how to improve and enhance the QoS support capabilities of relevant routing protocol. Roy *et al*. (2010) and Akhter and Sanguankotchakorn (2010) have given different methods to improve AODV. But all of them will still introduce large routing delay due to the basic routing mechanism of AODV and the mechanism is to seek and maintain routing information only when there was service needs. Compared with the on-demand class routing technology, the active class routing technology can avoid routing delay introduced by the passive routing manner effectively. Therefore, many scholars also committed to improve the QoS' ability of active class routing protocol. The research on the OLSR protocol is the most extensive. The improvement on selection algorithm of the MPR nodes was proposed by Khadar *et al*. (2010) and Leguay *et al*. (2006). Khadar *et al*. (2010) proposed to select the nodes with better link quality as MPR. And Leguay *et al*. (2006) had taken the bandwidth and latency into account in the selection of MPR. The simulation had improved that new MPR selection methods can optimize the routing discovery process of the OLSR protocol. New routing metric to improve network throughput and routing jitter performance was used by Kunavut and Sanguankotchakorn (2011) and Cao and Wu (2008). Not only is this necessary for the MANET can adapt to the mobile Internet in future, but also the key factor that makes the MANET differ from traditional wireless *Ad hoc* networks (Benyamina *et al*., 2011).

To meet the need of the transmission characteristics of multi-priority traffic in the MANET, the MDSRP (Mobile Differentiated Service Routing Protocol), which is an active routing protocol, was proposed in this paper. The MDSRP uses new method on routing measurement, routing metrics and routing strategies for different priority traffic, which can balance the network load and guarantee the QoS performance of service with high priority.

DETAIL OF THE MDSRP

Most of relevant studies focused on how to improve the statistical average routing end-to-end delay performance. But fewer consider the priority distinction between different services and how to guarantee the QoS performance of high-priority service. Meanwhile, the mutual interference between the different routing services and network load balancing is also an important aspect of routing protocols' QoS support capabilities, which should be considered.

MDSRP had made two improvements in routing metric and routing calculation strategy based on traditional active routing protocols.

METHODS OF ROUTING MEASUREMENT AND ROUTING METRIC

In the active routing technology, routing protocols obtain routing information and calculate the routing table based on the collected routing information. When there are multiple routes exist between source and destination node, the routing protocol will choose the optimum route by measuring and comparing the different route. The routing measurement, in essence, is to give the measurement indicators for a route on the transmission performance or transmission costs, overhead and other factors as the fundamental basis on route selection. The metric which was widely used in MANET include number of routing hops (Hop Counts), the expected number of transmissions (ETX), the desired transmission time on the link (ETT), the weight cumulative expected transmission time (WCETT).

In the traditional active routing protocol, the Hop Counts are usually used as routing metric. The routing measuring mechanism based on this simple metric can not make a reasonable choice of route according to the current network traffic load on each node. And it can easily result in the congestion in the central area of the network and the emergence of the network "hot zone" (Song and Fang, 2006; Xiao *et al*., 2008). The phenomenon of congestion in the central area of networks is show in Fig. 1.

From Fig. 1, we can see that many routes will cross node N8, which will resulting the congestion around the area near node N8. Based on the considerations above, a new kind of routing measurement method which used Expected Waiting Delay Metric (EWDM) was proposed in this study. The EWDM from source node to the neighbor node i was defined as follows:

$$\text{EWDM}_i = \frac{1}{k}\sum_{j=1}^{k} d_j \tag{1}$$

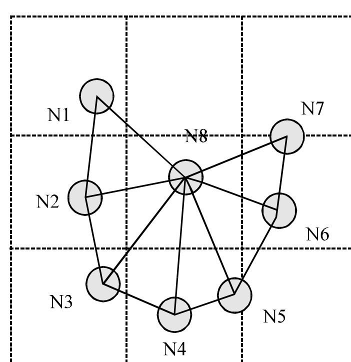

Fig. 1: The congestion in the central of networks

The d_j in the formula above means the waiting delay of the jth packets among the latest k packets cross node i. When the node stays in free, the EWDM will be set to a basic value which present the delay for forwarding a single packets. The value of EWDM measurement will be spread to the entire networks along with the topology information. When MDSRP calculate the route from source to the destination, it will calculate the EWDM of an entire route and choose the smallest one. The EWDM of an entire route from source node to destination node was defined as follows:

$$EWDM_{route} = \sum_{i \in route} \left(EWDM_i + \alpha \sum_{p \in \Delta i} EWDM_p \right) \quad (2)$$

The first part in the bracket means the EWDM of node i which belongs to the route. It can present the end-to-end EWDM without mutual interference from other service nearby. The Δ_i in second part means the neighbors area of node i. So the second part represents the present the mutual interference introduced by neighbors of node i. And α is the weighted coefficient, named Route Intra-Interfere Weight (RIW), which can decide the influence degree of the mutual interference. As α is bigger, the MDSRP will take more account of mutual interference around node i and choose a route keeping away the "hot zone". But when α is smaller or even zero, MDSRP will take little or even no account of mutual interference and choose a route concentrating on the source and destination.

To use the routing measurement methods based on EWDM, MDSRP will not only consider the selected route itself but also take the mutual interference between the service with adjacent routing in the network into account. And this mechanism will also balance the traffic load in the network efficiently.

MDSRP DETECT MESSAGE FORMAT DESIGN

MDSRP detect the adjacent nodes by exchanging the detected messages and the EWDM on relevant link periodically. Through the periodic exchanging of the detected message, MDSRP can achieve the topology message within two-hops. To communicate with distant nodes, the topology message, which is based on the exchanging of detected message, should be spread to the entire network to establish the routing table for network wide. The format of detected message was shown in Fig. 2.

8 bits	8 bits	8 bits	8 bits
Source address of detect message			
Type of massage	TTL	Length of massage	
Resered	Period	Sequence number	
Address of neighbor node 1			
MPR indicator	EWDM of neighbor node 1		
Address of neighbor node 2			
MPR indicator	EWDM of neighbor node 2		
....			

Fig. 2: The format of detect message

The period defined the interval of detecting message. And the MPR indicator shows whether the neighbor node is selected as the MPR of the source node. The sequence numbers show whether the current detected message is new. When a node received a new detected message, MDSRP will refresh the routing table with Dijkstra Algorithm.

ROUTING STRATEGY FOR THE PRIORITY DISTINCTION

By adjusting the Route Intra-Interfere Weight (RIW) in EWDM, the MDSRP proposed in this paper can offer distinct routing strategy for different service according to its priority. The illustration of routing strategies for the priority distinction in MDSRP was shown in Fig. 3.

We supposed that there was an existing service from N6 to N8, which will bring mutual interference to the nodes nearby. At same time N1 want to initiate an new service to N5. Actually, N1 had two route choices. One is show in dashed arrow named R1, which will suffer from the mutual interference but is shorter. The other is show in solid arrow named R2, which will suffer little mutual interference but is longer.

The traditional routing protocol like OLSR will choose the shortest route rigidly, which is R1, without considering the QoS requirements of service with different priority. In addition, this will introduce mutual interference between the new service and the existing service.

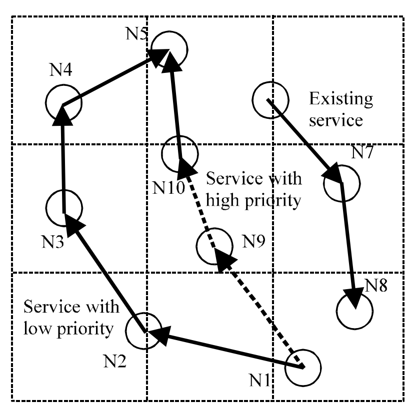

Fig. 3: Illustration of routing strategies for the priority distinction in MDSRP

However, strategy that is more flexible will be taken by MDSRP for service with different priority by adjusting the Route Intra-Interfere Weight α.

According to the formulation (2), MDSRP will firstly evaluate the EWDM of R1 and R2:

$$\begin{aligned} EWDM_{Ri} &= EWDM_{N9} + \alpha \sum_{p \in \Delta N9} EWDM_p \\ &+ EWDM_{N10} + \alpha \sum_{p \in \Delta N10} EWDM_p \end{aligned} \tag{3}$$

Where:

$$\begin{cases} \Delta N9 = \{N2, N3, N10, N6, N7, N8\} \\ \Delta N10 = \{N3, N4, N5, N6, N7\} \end{cases} \tag{4}$$

$$\begin{aligned} EWDM_{R2} &= EWDM_{N2} + \alpha \sum_{p \in \Delta N2} EWDM_p \\ &+ EWDM_{N3} + \alpha \sum_{p \in \Delta N3} EWDM_p \\ &+ EWDM_{N4} + \alpha \sum_{p \in \Delta N4} EWDM_p \end{aligned} \tag{5}$$

Where:

$$\begin{cases} \Delta N2 = \{N1, N3, N9\} \\ \Delta N3 = \{N4, N9, N10\} \\ \Delta N4 = \{N5, N10\} \end{cases} \tag{6}$$

When comes the high priority service, MDSRP will turn down the value of α when calculating the route. This can reduce the influence introduced by existing service nearby effectively.

When $\alpha \to 0$:

$$\underset{\alpha \to 0}{EWDM_{R1}} = EWDM_{N9} + EWDM_{N10} \tag{7}$$

and:

$$\underset{\alpha \to 0}{EWDM_{R2}} = EWDM_{N2} + EWDM_{N3} + EWDM_{N4} \tag{8}$$

So the MDSRP will select R1 for the services with high priority, as the R1 take fewer hops for the service with high priority, making it reach the destination directly without detour.

When comes the low priority service, MDSRP will turn up value of α when calculating the route. In the calculation process, MDSRP will take full account of the mutual relationship between the new services and the existing services nearby.

As there was an existing service from N6 to N8, but the other nodes were free. So there were:

$$EWDM_{(N6,N7,N8)} >> EWDM_{\overline{\{N6,N7,N8\}}} \tag{9}$$

Simultaneous Eq. 3-6 and 9, we can conclude that:

$$\underset{\alpha \to 0}{EWDM_{R1}} >> \underset{\alpha \to 0}{EWDM_{R2}} \tag{10}$$

So the MDSRP will select R2 with low priority, as the R2 can avoid the area with heavy traffic load and select the route cross the area with light traffic load though detoured.

Adopting the routing strategy for the priority distinction can guarantee the QoS performance of service with high priority effectively. At the same time, it also can make the low priority service avoid the area with heavy traffic load, balancing the traffic load in networks and avoiding network congestion. More importantly, routing strategy for the priority distinction can save valuable network resources for the service with high priority.

ANALYSIS AND SIMULATION

In this study MDSRP protocol was accomplished in the Qualnet simulator. The performance of MDSRP was evaluated on throughput and end-to-end delay under same scenarios comparing with original OLSR. The main reference of the scenario is in the Table 1.

The comparison of performance on throughput with MDSRP and original OLSR was shown in Fig. 4.

Under the same scenario and service model, the performance on throughput of original OLSR was nearly 300 kbps. But when we used MDSRP, the performance on throughput rose up to 350 kbps, which was 50 kb sec^{-1} higher than OLSR about 16%.

Figure 5 has shown the comparison of performance on end-to-end delay between OLSR and MDSRP. The end-to-end delay is defined as the average of time delay experienced by the latest m packets, which is:

$$Delay_t = \frac{1}{m} \sum_{k=1}^{m} d_{k/t} (1 \le k \le m) \tag{10}$$

where, $d_{i/t}$ is the time delay experienced by the kth packet close to current time.

Table 1: Main reference of the scenario

Simulator	Qualnet V5.0
Boundary	120×120 km
Mobility model	Random mobility model average velocity: 5,10, 15 m sec^{-1}
Number of nodes	36
Topology	Initialized with square matrix
Service model	CBR
Packet length	400 Byte
Transmission range	24 km
Band width on link	2 Mb sec^{-1}
Simulation time	900 sec
MAC protocol	Dynamic TDMA
Network protocol	MDSRP , original OLSR
Simulation time	900 sec

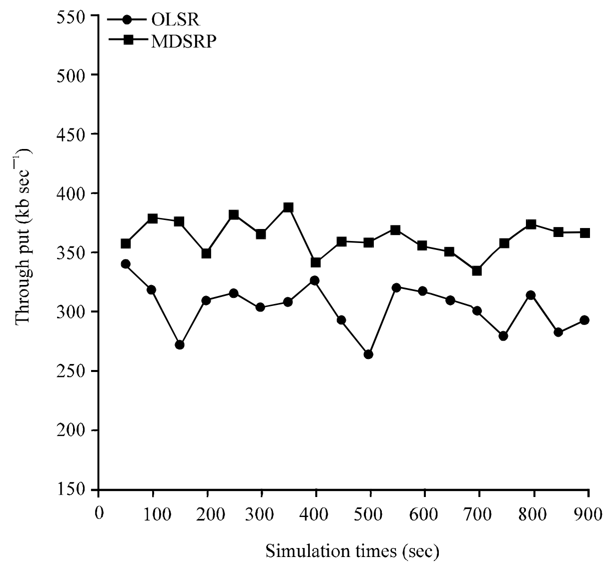

Fig. 4: The comparison of performance on throughput

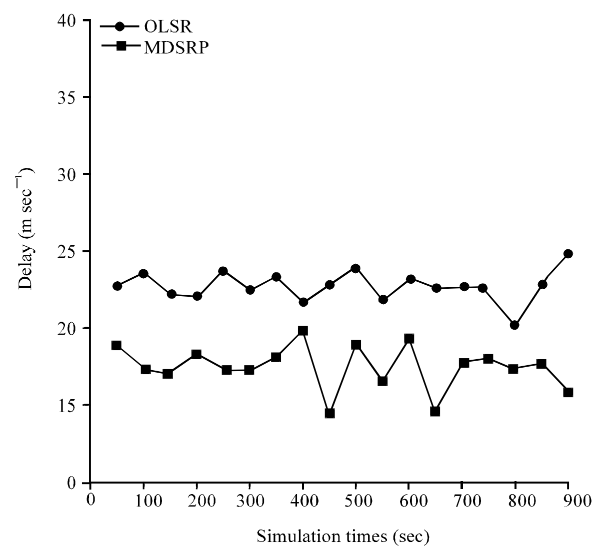

Fig. 5: The comparison of performance on end-to-end delay

The end-to-end delay was about 23 msec when using original OLSR. But the end-to-end delay was about 18 ms using MDSRP which was 5 ms less than original OLSR. The reason for this result is that the original OLSR only consider the shortest distance from view on topology of networks. Moreover, it may allow many services converge to a small area in the network, make them disturb each other, resulting in the congestion. Different from original OLSR, MDSRP can make effective coordination between different services and choose different routing path to avoid the crosscutting between them. Although MDSRP maybe make some services to pay a cost of more hops, it

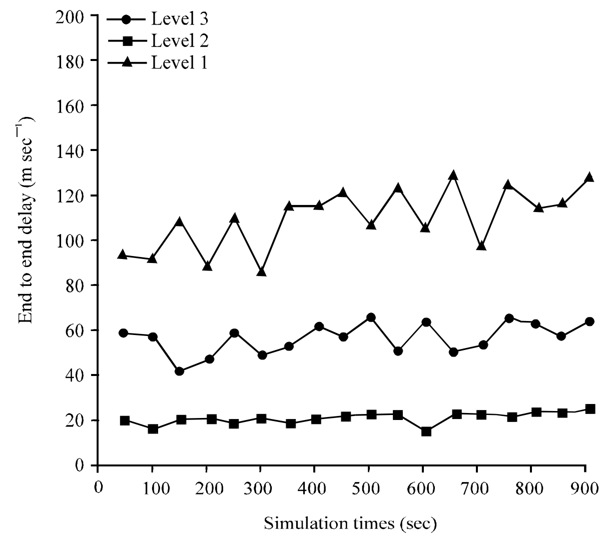

Fig. 6: The performance of services with different priority levels on end-to-end delay

can allow more business to transmit in the network simultaneously without disturbing each other. This will reduce the queue waiting time on the relay nodes and then reduce the end-to-end transmission delay on the entire routing path.

To verify and test the routing strategy for the priority distinction introduced by MDSRP, three kinds of services with different priority were installed in the same scenario in order to compare the performance of them on end-to-end delay. The priority of level 1 service was the highest. To guarantee the performance of level 1 service, MDSRP set the Route Intra-Interfere Weight α to 0.1 reducing the interference from other services. The priority of level 2 service was lower, so the MDSRP set α to 0.3, which is bigger than the value of level 1. The priority of level 3 service was the lowest and set α to 0.8, which is the biggest. During the route calculating, MDSRP will seriously consider the interference from other services. The result was shown in Fig. 6.

In Fig. 6, we can see that the end-to-end delay of service with priority level 3 was the longest with serious jitter, beyond 110 ms; The end-to-end delay of service with priority level 2 was smaller which was about 55 ms; The smallest end-to-end delay belong to service with priority level 1 which was nearly 20 ms was much more steady.

It is obviously that the higher priority service will have smaller EWDM as MDSRP set small Route Intra-Interfere Weight α for it. So when the services with different priority get together, MDSRP will force the services with lower priority to change the routing path, give out the transmission channel to services with higher priority. And this will guarantee the performance of high priority service on end-to-end delay.

CONCLUSION

A service priority differentiated routing protocol, named MDSRP is proposed in the paper. This protocol has used a new kind of methods to rout the measurement and the metric indicators EWDM. By means of EWDM, MDSRP can offer different routing strategies for services with different priority to guarantee the QoS' performance of high priority services by adjusting the Route Intra-Interfere Weight α. And MDSRP can also balance the traffic load in networks. The simulation result had shown that MDSRP is an effective routing protocol to differentiate the different service priority and guarantee performance of high priority services on end-to-end delay. And MDSRP can also optimize the network resources.

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