QoS Implementation and Evaluation for Mobile Ad hoc Networks

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Abstract. Future mobile Ad hoc networks (MANETs) are expected to be based on all-IP architecture and be capable of carrying the multitude of real time multimedia applications such as voice, video and data. It is very necessary for MANETs to have an efficient routing and quality of service (QoS) mechanism to support diverse applications. In this paper, we propose a novel node-disjoint Multipath QoS Routing protocol for supporting DiffServ (MQRD). Simulation results show that MQRD achieves better performance in terms of packet delivery ratio and average delay.

1 Introduction

With the rising popularity and development of wireless network based on all-IP architecture and multimedia applications, potential uses of MANETs in military and civilian life are attracting more and more researchers' attentions on QoS support. QoS provisioning in MANETs faces a number of technical challenges because of the network restrictions such as dynamically and unpredictably variable topology resulting from nodal mobility and bandwidth constraints caused by the shared wireless medium.

For the current Internet there are two different models to obtain a QoS guarantee: the Integrated Services (IntServ) [1] and Differentiated Services (DiffServ) [2]. IntServ uses the RSVP protocol [3] to carry the QoS parameters from the sender to the receiver to make resource reservations along the path. IntServ/RSVP provides for a rich end-to-end QoS solution, by way of end-to-end signalling, state-maintenance (for each RSVP-flow and reservation), and admission control at each network element. DiffServ on the other hand, does not have any end-to-end signalling mechanism and works on a service level agreement between the provider and the user. Multiple flows in DiffServ model are mapped to a single service level and state information about every flow need not be maintained along the path.

IntServ-based model on per-flow resource reservation is not particularly suitable for MANETs because of the frequently changing topology and limited resources in MANETs, resulting in more signalling overhead and unaffordable storage and computing process for mobile nodes. DiffServ-based is a lightweight model using a relative-priority scheme to soften the hard requirements of hard QoS models like IntServ. The service differentiation is based on per-hop behaviours (PHBs) [4], so no flow

Li X. and Cuthbert L. (2005).
QoS Implementation and Evaluation for Mobile Ad hoc Networks.
In *Proceedings of the 2nd International Workshop on Ubiquitous Computing*, pages 82-87
DOI: 10.5220/0002576200820087

states need to be maintained within the core of the network. Thus the model could be a potential QoS model in MANETs.

The current existing solutions for QoS provisioning in MANETs are mainly based on the IntServ or DiffServ model. AQOR [5] uses a reservation-oriented method to decide admission control and allocate bandwidth for each flow. INSIGNIA [6] employs an in-band signalling protocol rather than out-of-band signalling protocol as RSVP to decrease reservation overhead. FQMM [7] is designed to provide QoS in ad hoc networks by mixing the IntServ and DiffServ mechanisms. High priority applications are provided by IntServ per-flow QoS guarantee, while lower priority applications are provided with per-class differentiation based on DiffServ. SWAN [8] is based on reservation-less approach. By avoiding signalling, it simplifies the whole architecture and provides a differentiation between real-time and best effort in spite of not being able to guarantee the QoS needs of each flow for the whole session due to frequently changing topology and limited wireless bandwidth restriction.

Multipath routing allows the establishment of multiple paths between a single source and single destination node during a single route discovery. Some multipath routing protocols [9,10] in MANETs have been proposed to provide load balancing, fault-tolerance and higher aggregate bandwidth as well as eliminate route discovery latency after a link break by making use of the availability of multiple route paths. However, these multipath routing protocols lack QoS support in the process of transmission of data packets.

In this paper, we present a novel node-disjoint Multipath QoS Routing protocol for supporting DiffServ (MQRD), which combines DiffServ and a multipath routing protocol, Node-Disjoint Multipath Routing (NDMR) [9], for QoS provisioning in MANETs.

2 MQRD

Although NDMR provides node-disjoint multipath routing with low route overhead in MANETs, it is only a best-effort routing approach, which is not enough to support QoS. DiffServ is an approach for a more scalable way to achieve QoS in an IP network. It could be a potential QoS model in MANETs because it acts on aggregated flows and minimises the need for signalling. However, one of the biggest drawbacks of DiffServ comes from the fact that the QoS provisioning happens separate from the routing process.

2.1 Integration of NDMR and DiffServ

Both of NDMR and Diffserv operate at the network layer, so it is easy to work naturally together. Although NDMR was designed without taking QoS into consideration, it and DiffServ could be complementary techniques that can be implemented in MANETs to support an end-to-end QoS solution. When used together, DiffServ provides the standardized QoS mechanisms and NDMR provides node-disjoint multipath routing techniques increasing the network resource optimization and decreasing routing overhead.

2.2 QoS and Resource Management of MQRD

Effective QoS mechanism can be used to provide better service to certain flows in the environments of limited wireless bandwidth. In MQRD this is done by either raising the priority of a flow or limiting the priority of another flow. In order to support service differentiation, scheduling and queue management are thought to be two important aspects of resource management. The former is done by the scheduler which decides the opportunities of flows for link access and the latter holds the valid packets when necessary drops some packets from the buffer in case of network congestion.

Priority Scheduling. In MANETs, when a mobile node is receiving traffic faster than it can transmit, the node may buffer the extra traffic until bandwidth is available. In MQRD, priority queuing is used to build a priority scheduler. The priority scheduler includes two queues: a high-priority queue and a low-priority queue. The high-priority queue must be emptied before packets are emptied from low-priority queues.

Although DiffServ has a lot of classes defined, the most essential use of DiffServ is to provide support for the two most common applications:

(A) Voice, Video traffic. (B) Best effort data.

Let us denote the two classes as A and B. Class A applications require generally low loss, low latency and assured bandwidth service, so packets of class A are classified as Expedited Forward (EF) traffic. Class B is classified as Best Effort (BE) traffic which offers a lower priority service. Our priority scheduler (see Fig. 1) is designed to transmit any available Class A packets ahead of Class B packets. On the other hand, Class B packets are not sensitive to delay, as the application which they service are primarily HTTP and FTP sessions.

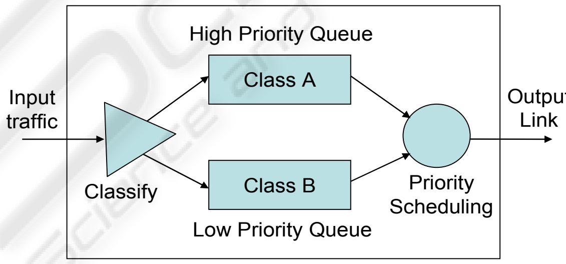

Fig. 1. Priority Scheduler

Queue Management. While the scheduling does play a big role in the QoS provided by the network, it is only effective if there is sufficient queue space to hold incoming packets. Because queues are not of infinite size, they can fill and overflow. When a queue is full, any additional packets cannot get into the queue and will be dropped. This is a tail drop. The issue with tail drops is that the router cannot prevent this packet from being dropped (even if it is a high-priority packet). So, the purpose of queue management is to make sure the queue does not fill up so that there is room for high-priority packets.

The random early detection (RED) algorithm [11] is implemented to avoid congestion before it becomes a problem. The minimum threshold specifies the number of packets in a queue before the queue considers discarding packets. The probability of discard increases until the queue depth reaches the maximum threshold. After a queue depth exceeds the maximum threshold, all other packets that attempt to enter the queue are discarded.

2.3 Load Balance and Congestion Avoidance

As mentioned before, MQRD can discover multiple node-disjoint route paths with low routing overhead, so it can provide load balancing and higher aggregate bandwidth. Load balancing function can be triggered to avoid congestion by spreading the traffic along multiple routes when RED algorithm judges the queue depth to reach the minimum threshold at which the queue begins to consider discarding packets. The mobile node needs to send a Congestion Notification packet (CN) to the source of the data packet along the reverse route path. When the source receives the CN, it distributes part of traffic to the other node-disjoint routing paths. In this way congestion and bottleneck are avoided or alleviated.

3 Simulation Model

OPNET 8.1 Modeler [12] was used to create a simulation environment to develop and analyze the proposed node-disjoint Multipath QoS Routing protocol for supporting DiffServ (MQRD) and compare performances with NDMR, which does not take QoS into account.

The random waypoint model [13] is used to model mobility. Each node starts its journey from a random location to a random destination with a random velocity of 0-20 m/s. Field configuration of 1000m x 1000m field with 50 nodes is used and each node uses the IEEE 802.11[14] with a 250m transmission radius. Traffic sources with 512 byte data packets are CBR (constant bit rate). The source-destination pairs are spread randomly over the network and the number of sources is varied to change the offered load in the network.

In order to investigate the usage of network ability, the number of EF (Expedited forwarding) sources with 80kbit/s (20pkt/s) bandwidth requirement is varied from 5 to 20 in intervals of 5. 20 other nodes are randomly chosen to send background BE (Best Effort) traffic with 2pkt/s. Simulations are run for 800 simulated seconds.

4 Simulation Results

Comparing Fig. 2 and Fig. 3, we can find that the packet delivery ratio of MQRD has better performance than that of NDMR with the increase in the number of EF sources.

In order to show clearly and compare simulation results of different type of packets, packet delivery ratios of EF packets, BE packets and ALL packets (combination of EF and BE packets) are depicted respectively in the two figures. Fig. 3. shows that EF packets have higher delivery ratio than BE packets because priority scheduler is used in MQRD. When the number of EF sources increases, NDMR drops a larger fraction of the packets than that of MQRD. The reason is that there exists more congestion in mobile node buffers when the number of EF sources increases.

From Fig. 4 we can see that EF packets and BE packets in NDMR have little difference in End-to-End average delay. The reason is that there is no priority policy to deal with the incoming EF and BE packets in mobile nodes. Fig. 5 shows that EF packets of MQRD has a much lower average delay than BE packets because priority scheduler in MQRD makes EF packets be forwarded more quickly. With the increase in the number of EF sources average delay of BE packets in MQRD increases more quickly than that of EF packets. The reason is that an increase in the number of EF sources leads to higher network load traffic. Because of the limitation of a constrained wireless bandwidth, BE packets that will be sent or forwarded have to stay in buffers and wait for a longer time to get a radio channel available than EF packets in order to avoid traffic congestions.

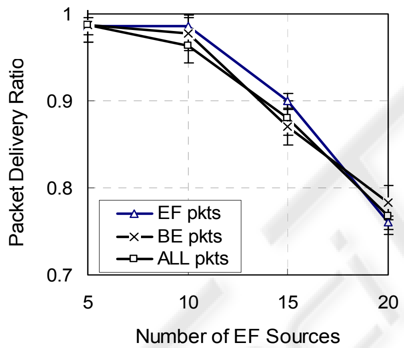

Fig. 2. Packet Delivery Ratio of NDMR

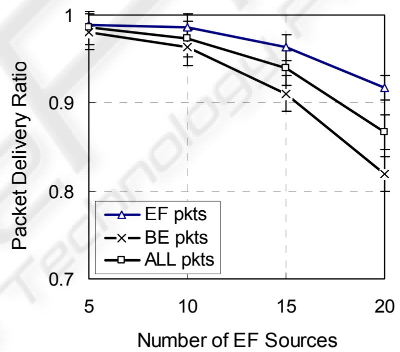

Fig. 3. Packet Delivery Ratio of MQRD

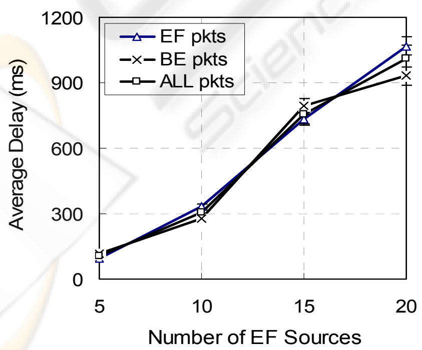

Fig. 4. Average Delay of NDMR

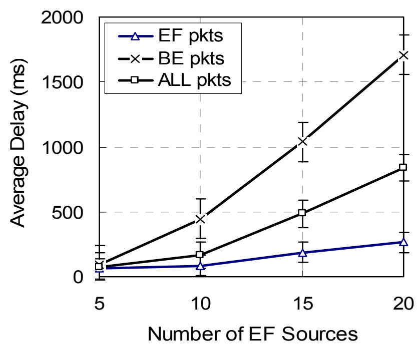

Fig. 5. Average Delay of MQRD

5 Conclusions

In this paper, we have introduced a practical QoS provisioning which makes DiffServ over node-disjoint multipath routing protocol for MANETs to overcome the shortcomings of the best-effort model. We also present a solution about a reliable multipath routing and resource management for QoS issues of real-time multimedia applications in ad hoc networks. The performance evaluation and comparison between NDMR and MQRD are studied by extensive simulations using OPNET Modeler. Simulation results show that MQRD achieves better performance than NDMR by providing end-to-end QoS support in MANETs. We can conclude that MQRD has a good potential to serve as a QoS model to provide real-time multimedia applications under the dynamically changing environment of ad hoc networks.

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