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Autonomous routing control protocol for mobile ad-hoc networks

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Abstract: A clustering scheme for ad hoc networks is aimed at managing a number of mobile devices by utilizing hierarchical structure of the networks. In order to construct and maintain an effective hierarchical structure in ad hoc networks where mobile devices may move at high mobility, the following requirements must be satisfied. The role of each mobile device for the hierarchical structure is adaptive to dynamic change of the topology of the ad hoc networks. The role of each mobile device should thus change autonomously based on the local information. The overhead for management of the hierarchical structure is small. The number of mobile devices in each cluster should thus be almost equivalent. This paper proposes an adaptive multihop clustering scheme for highly mobile ad hoc networks. The results obtained by extensive simulation experiments show that the proposed scheme does not depend on mobility and node degree of mobile devices in the ad hoc network, which satisfy the above requirements.

1. INTRODUCTION

A mobile ad hoc network is formed by a group of wireless stations without infrastructure. There is a growing need to support real time traffic in mobile ad hoc networks. This, However, is very challenging because mobile ad hoc networks represent dynamic nature, which causes unexpected network congestion as illustrated in Fig. [1]. In this figure, we can see that network congestion is induced when a mobile station moves, which may consequently cause high delay and low throughput. Consequently, the QoS guarantee of real time flows is violated.[2]

In this paper, we propose a DiffServ module to support differentiated service in mobile ad hoc networks through congestion control. Our DiffServ module uses the periodical rate control for real time traffic and the best effort bandwidth concession when network congestion occurs. The organization of this paper is as follows. In Section 2, we describe congestion detection and congestion control mechanism performed at our DiffServ module. In Section 3

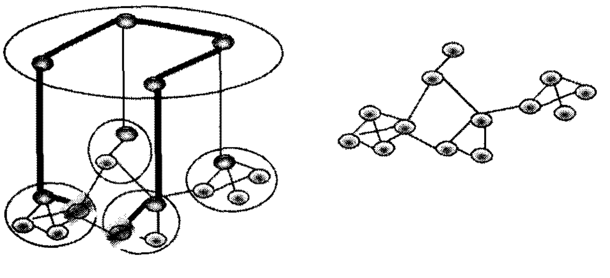

Fig. 1. Congestion control in mobile ad hoc networks

2. MOBILE AD HOC NETWORKS

The most dominant factor of packet transfer delay in networks is queuing delay. So, delay and jitter are minimized when queuing delays are minimized. The intent of the EF PHB is to provide a PHB in which EF marked packets usually encounter short or empty queues. EF Service should provide minimum delay and jitter.
According to RFC 3246 which discusses the departure time of EF traffic, a node that supports EF on an interface I at some configured rate R must satisfy the following condition for the j-th packet:

$$d(j) \le F(j) + E \qquad (1)$$

where d(j) is an actual departure time, F(j) is a target departure time, and E is a tolerance that depends on the particular node characteristics. E provides an upper bound on (d(j)-F(j)) for all j.

F(j) is defined iteratively by

$$F(0)=0, \quad d(0)=0 \quad \textit{for all } j>0: \qquad (2)$$

$$F(j)=\max[a(j), \min(d(j-1), F(j-1))]+\frac{L(j)}{R}. \qquad (3)$$

where a(j) is an arrival time, and R is the EF configured rate.

The rate at which EF traffic is served at a given output interface should be at least the arrival rate, independent of the offered load of non-EF traffic to that interface [4]. The relationships between EF traffic's input rate and output rate in each node are represented in the following three cases:

In case (I), it is difficult to support EF service because of the higher queuing delay. In case (II), the queuing delay is minimal so that high quality is provided to EF traffic.

Non-EF traffic, however, is starved. Also, the delay and throughput of EF traffic can fluctuate because the output rate of EF traffic is disturbed. Finally, case (III) is considered as an ideal case for EF traffic. We assert that the input and output rate of EF traffic should be the same.

A path of real time traffic is established by the QoS extensions [4] of routing protocols such as AODV and OLSR. QoS routing protocols find an optimal path in meeting the delay and bandwidth requirements of real time traffic.

The proposed DiffServ module exists in the IP layer together with routing protocol as illustrated in Fig. 2. There is an interface between the DiffServ module and MAC for their interoperation. The DiffServ module controls the output rate of traffic using a MAC delay or bandwidth usage provided through the interface. The objective of our DiffServ module is guaranteeing the QoS requirement of already established real time traffic. The DiffServ module has two main roles: IP Infusion has implemented RFC 3270 as an extension to its ZebOS RSVP-TE Module to provide a flexible DiffServ over MPLS solution. This extension enables RSVP-TE to set up a DiffServ LSP using RSVP signaling.

A DiffServ Object is added to the RSVP Path message and passed on to the next node. ZebOS DiffServ supports both EXP-Inferred-PHB Scheduling Class LSP (E-LSP) and Label-Only-Inferred-PHB Scheduling Class LSP (L-LSP). The ZebOS DiffServ Module enables network traffic to be specified and prioritized by class so that certain kinds of traffic, for example voice traffic, get precedence over other types of traffic. DiffServ employs a sophisticated policy to determine how to forward network data, so it is more advanced than earlier QoS or Type of Service (ToS) protocols.

It periodically regulates the output rate of real time traffic to meet bandwidth requirements. In other words, the output rate is maintained the same as the input rate. This rate maintenance provides not only the ideal EF service as previously described but also a stable throughput and delay of real time traffic.

When congestion occurs, the bandwidth of best effort traffic is conceded to real time traffic in order to prevent the QoS requirement penalty. illustrates the conceding of best effort bandwidth to real time traffic.

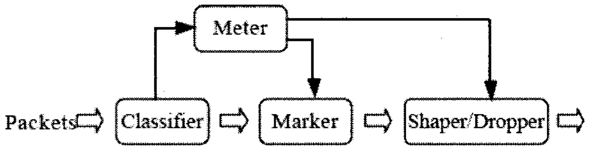

Fig. 2. DiffServ module

If queues remain short and empty relative to the buffer space available, packet loss and queuing delay is kept to a minimum. Since EF traffic usually encounters short or empty queues, and node mobility induces obscurity of queue utilization, the conventional congestion detection method using a queue threshold value or queue overflow is not appropriate for mobile ad hoc networks. For this reason, in our scheme, congestions are detected by monitoring when the delay and bandwidth utilization of real time packets exceed a given threshold.

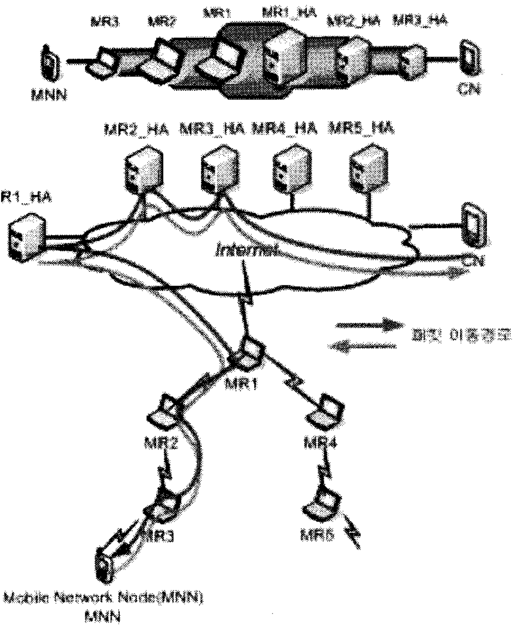

Fig. 3. Congestion control in mobile ad hoc networks

When a node detects congestion, it sends out congestion notification messages in the direction of the source node of the real time flow as illustrated in Fig.3. The notification messages are broadcast because of wireless medium characteristics. First, one-hop upstream nodes receiving the notification messages concede the bandwidth allocated for their best effort flows to their real time flows to relieve a congested situation. At this time, if the congestion is resolved, all congestion control processes end and congestion notification messages are no longer relayed in the direction of source nodes. If the congestion is not relieved, however, the congestion notification messages are continuously relayed in the direction of source nodes. So, two-hop, three-hop, …, upstream nodes receiving the notification messages reduce their output rates of their best effort flows. Through this process, if the congestion is solved all processes successfully end, and if the congestion is not solved the notification messages are continuously relayed in direction of source nodes until congestion is solved. So, light congestion is simply relieved at one-hop upstream nodes, but the heavy congestion is relieved after many upstream nodes reduce their best effort output rates.

3. SIMULATION

We evaluated our mechanism via simulation. Fig. 4 illustrates the network model used in the simulation. In this figure, three nodes simultaneously access a channel in order to communicate with a congested node. It is assumed that a contention-based service by the IEEE 802.11 Distributed Coordination Function (DCF) channel access mode is used to contend for the medium for each packet transmission. Each node is modeled as a perfect output buffered device, that is, one which delivers packets immediately to the appropriate output queue as illustrated in Fig. 3.

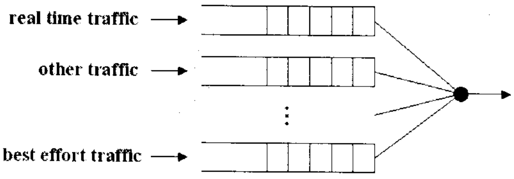

Fig. 4. Model of node with prioritized queues

The focus of the experiments is whether our DiffServ module guarantees the QoS requirements of real time traffics as the best effort traffic load is increased.

Fig. 4 show throughput and delay, respectively, when the output rate of real time traffic is maintained the same as the input rate. The input rate of real time traffic is 0.5Mbps that represents a bandwidth requirement. In the experiment, the best effort traffic load continuously increased while the rate of real time traffic is maintained at 0.5 Mbps. As a result of experiment, the throughput of the best effort traffic increases up to some point and after that point, is saturated to almost 4 Mbps. Furthermore, the delay of the best effort traffic suddenly increases after the saturation point. We can see that the throughput of real time traffic is maintained successfully meeting the bandwidth requirement. The delay performance of real time traffic also shows a relatively stable pattern. Assuming that the bandwidth requirement is 0.5 Mbps and the node-to-node delay requirement is 5 ms, then the network is not congested. A congestion control mechanism for real time traffic is not needed.

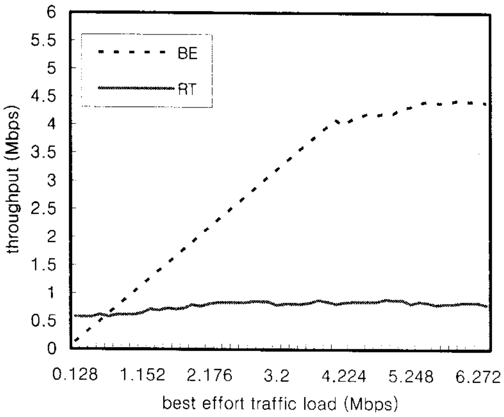

Fig. 4. The throughput when the real time bandwidth requirement is 0.5 Mbps

If the bandwidth requirement of real time traffic is changed to 2.833Mbps, however, we can observe congestion as shown in Fig. 5. In this case, the bandwidth requirement of real time is satisfied when the offered loads of best effort are relatively low. As the best effort traffic load increases, however, the throughput of real time traffic decreases and the delay also terribly increases, which induces the QoS violation of real time traffic.

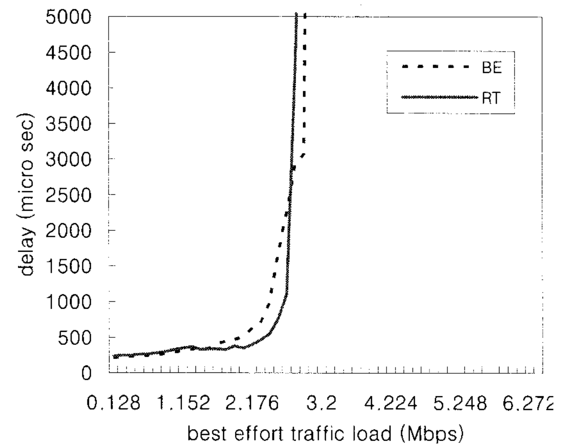

Fig. 5. The delay with no congestion control when the real time bandwidth requirement is 2.833 Mbps

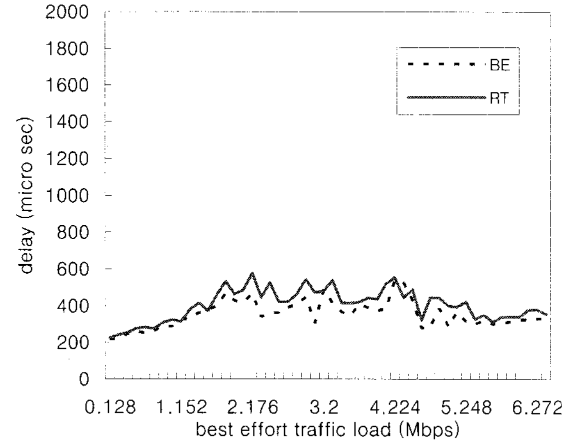

Fig. 6. The delay with congestion control when the real time bandwidth requirement is 2.833 Mbps

Fig. 6. show the throughput and delay performances with our congestion control mechanism. When the bandwidth requirement of real time traffic is 2.833Mbps, the throughput of real time traffic is stably maintained at 2.833Mbps and the delay is also maintained at stably low values as a result of the best effort bandwidth concession. In Fig. 6, the crooked points represent that congestion control is performed. Whenever congestion is detected, the bandwidth of best effort traffic is conceded to real time traffic through its rate reduction. As previously described, congestion is detected by a delay threshold value of real time packet.

4. CONCLUSION

In this paper, we proposed DiffServ module, supporting service differentiation in mobile ad hoc networks through rate regulation and congestion control. In our scheme, for real time traffic, we regulated its output rate the same as the input rate. This regulation produced stable throughput and delays. The congestion was detected by measuring the delay or bandwidth utilization of real time traffic and comparing it with some threshold values. The congestion was controlled by conceding the best effort bandwidth to real time traffic. We verified our DiffServ mechanism through simulation. The experiment results showed that our mechanism could offer stable throughput and stably low delays for real time traffic.

References

[1] M. Z. Win and R. A. Scholtz, "Impulse radio: How it works," IEEE Communication Letter, vol. 2, no. 2, pp. 36-38, February 1999.

[2] I. D. O'Donnell, M. S. W. Chen, S. B. T. Wang, and R. W. Brodersen, "An integrated, low power, ultra-wide band transceiver architecture for low-rate, indoor wireless systems," Proc. IEEE Workshop Wireless Communication & Networking, Pasadena, USA, September 2002.

[3] S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, and W. Weiss, "An architecture for differentiated services," IETF, RFC 2475, Dec. 1998.

[4] Gahng-Seop Ahn, Andrew T. Campbell, Andras Veres, and Li-Hsiang Sun, "Supporting service differentiation for real-time and best-effort traffic in stateless wireless ad hoc networks," IEEE Trans. Mobile computing, vol. 1, July-Sept. 2002.

[5] A. Stolyar. Maximizing queueing network utility subject to stability:

Greedy primal-dual algorithm. *Queueing Systems*, 50(4):401–457, 2005.

[6] A. Stolyar. On the asymptotic optimality of the gradient scheduling algorithm for multiuser throughput allocation. *Operations Research*,53:12 – 25, 2005.

[7] L. Tassiulas and A. Ephremides. Stability properties of constrained queueing systems and scheduling policies for maximum throughput in multihop radio networks. *IEEE Transactions on Automatic Control*,37(12):1936 – 1948, December 1992.

[8] M. Z. Win and R. A. Scholtz, "Impulse radio: How it works," IEEE Communication Letter, vol. 2, no. 2, pp. 36-38, February 1999.

[9] I. D. O'Donnell, M. S. W. Chen, S. B. T. Wang, and R. W. Brodersen, "An integrated, low power, ultra-wide band transceiver architecture for low-rate, indoor wireless systems," Proc. IEEE Workshop Wireless Communication & Networking, Pasadena, USA, September 2002.

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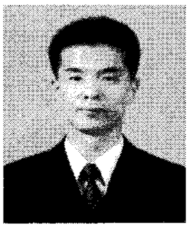

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