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FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME II

- Session 6 - Environmental Systems: Management and Optimisation
- Session 7 - New Methods and Technologies for Medicine and Biology
- Session 8 - Embedded System Design and Application
- Session 9 - Image Processing, Image Analysis and Computer Vision
- Session 10 - Mobile Communications
- Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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Technische Universität Ilmenau
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M. A. A. Kalil / N. Zamin Khan / H. Al-Mahdi / A. Mitschele-Thiel

Evaluation and Improvment of Queuing Management Schemes in Multihop Ad hoc Networks

ABSTRACT

Recent researches have observed inadequate performance in multihop ad hoc networks. Many factors lead to poor performance. Among those factors is an appropriate queue management scheme which is fair for all types of traffic. In multihop scenario, increasing the number of hops decreases the effective bandwidth. Longer hop flows suffer from unfairness problem as compared to shorter flows. This fact is undesirable in multihop ad hoc networks. In this paper, we evaluate different queueing management schemes and forwarding strategies for multihop networks. We show that queue management scheme, at intermediate nodes, have a great effect in limiting the performance of longer hop flows. Also, we propose an idea to improve the performance of multihop flows by fairly sharing the available buffer at each node.

I. INTRODUCTION

Multihop ad hoc network is a collection of mobile wireless nodes that dynamically form a network without any pre-existing infrastructure. This type of network is established when the source and destination are not in the transmission range of each other. However, in multi-hop networks, increasing the number of hops leads to decease in bandwidth. This leads to unfairness problem because longer hop flows suffer from low throughputs when compared with shorter hop flows. Many factors let this problem happen. Hidden and exposed terminal problems are one of those factors. Another important factor that causes this problem is the link layer buffer management scheme at the intermediate nodes. Current queuing management schemes do not take into account the number of hops a packet has traversed when inserting it into the link layer queue. This will lead to unfairness of flows spanning multiple hops. According to a lot of routing protocols, when a packet has to be forwarded by an intermediate node, the routing process sends the packet down to the link layer, which inserts this packet into the interface queue (IFQ). Generally, the link layer uses a drop tail queue management scheme in which newly arriving packets are dropped if the queue is full, regardless of the number of hops the packet has already traversed.

Most existing queue management schemes are not suitable for multihop ad hoc networks. They have been designed for controlling congestion in the Internet routers. For example, RED [1] was designed to control congestion and avoid queue buildups at Internet routers by measuring the average queue length. RED has some drawbacks, for example, RED fails to differentiate shorter flows and longer flows while dropping the packets, thus presenting unfairness. In [2], the authors have presented several queuing schemes at intermediate relay nodes for achieving fairness in multihop wireless networks. They suggested that each individual source should have a separate queue at all relaying nodes. Maintaining a separate queue for each individual source is a very difficult task. Recently, in [3], the authors developed analytical models for hop by hop congestion control in ad hoc networks and proposed layer 2 congestion control mechanisms for controlling the traffic load generated at the source nodes. However, the authors did not mention the role of link layer buffers. In [4], the authors have addressed the unfairness problem in multihop mesh networks by proposing an Inter-tap fairness algorithm in which the nodes exchange channel usage information and decide their maximal channel access times. However, the authors in [4] did not consider the link layer buffer management. In contrast, the main focus of our work is to evaluate the role of queue management schemes in the intermediate node and to present a queueing scheme to enhance the performance of IFQ in multihop ad hoc networks.

The rest of the paper is organized as follows. In section II, overview of queueing management schemes are discussed. Next, a description and analysis of unfairness problem is presented in section III. In section IV, the proposed scheme is presented. We conclude the paper in section V.

I. OVERVIEW OF QUEUE MANAGEMENT SCHEMES

In multihop ad hoc network, nodes may have to buffer messages and in case of congestion decide which messages to drop from its queue. They also have to decide which messages to forward to another node. In this section we describe the different queueing management schemes used in this paper for the evaluation.

DropTail - is the most commonly used algorithm in the current Internet gateways. The main idea of this algorithm is to drop packets from the tail of the full queue buffer. Its

main advantages are simplicity, suitability to heterogeneity and its decentralized nature.
Random early drop (RED) - RED [1] is a queue management scheme that monitors and controls buffer occupancy. RED detects congestion by monitoring the average buffer size of the router. When the average buffer size is larger than the first threshold (minth) but lower than the second threshold (maxth), the incoming packets are dropped with probability *P*, which increases linearly as the average buffer size increases. When the average buffer size exceeds the second threshold (maxth), the router drops randomly chosen packets from within the buffer with probability one.
Fair queuing (FQ) [5] - The main idea of this algorithm is to divide the router buffer into sub-queues, one for each incoming traffic source (per-flow queuing). Then the router serves packets in the round-robin fashion (packet-by-packet round-robin scheduling). This algorithm, however, assumes the packet size is constant, and thus it fails to provide throughput fairness when packets have different sizes.
Deficit round robin (DRR) [6] - this algorithm was proposed to approximate the performance of FQ using a less complex computational structure. DRR serves sub-queues in the round-robin fashion. For each subqueue, a deficit counter (in bytes) is assigned. In each round of service, the deficit counter is incremented by a quantum (in bytes). Each sub-queue, when served, is allowed to send its packets one by one if the packet size is smaller than the deficit counter. The deficit counter is decremented by the packet size after a packet is sent. When the deficit counter is depleted, the DRR scheduler moves to the next sub-queue.
Virtual Queue Algorithm (VQ) [7] - In this scheme, a virtual queue is added in the link with the same arrival rate as the real queue. However, the capacity of this queue is smaller than the capacity of a real queue. When the virtual queue drops a packet, then all packets already enqueued in the real queue as well as all of the new incoming packets are marked until the virtual queue becomes empty again. The fixed size FIFO virtual queue seems to be a weakness of this algorithm.
Random Exponential Marking Algorithm (REM) [8] - this Algorithm is a technique for congestion control, whose main aim is to achieve a high utilization of link capacity, scalability, negligible loss and delay. It attempts to match user rates to network capacity while clearing buffers (or stabilize queues around a small target), regardless of the number of users.

From the above description of queue management schemes, we can conclude that none of those schemes take into account the number of hops the packet takes to reach its destination. They have been designed for controlling congestion in the Internet routers not working over multihop networks.

II. SIMULATION

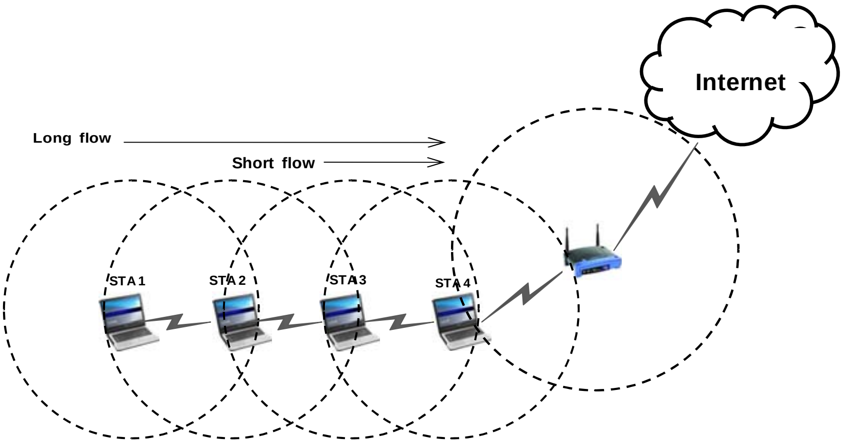

Figure 1. Simple multihop ad hoc scenario

In this section, we will illustrate the existing unfairness problem in multihop ad hoc networks. As we mentioned in section I, many factors let the unfairness problem happened. Our evaluation only focuses in link layer buffer management. To do that, we consider a four station communicate with each other using the legacy IEEE 802.11 based interface. Access Point (AP) serves as a gateway to connect other station to the internet.

In order to see the effect of link layer buffer queue, we use the scenario illustrated in Figure 1. In this scenario, STA1, STA2, STA3 and STA4 try to connect to the internet. But, only STA4 is in the transmission range of the access point. So, the other station will use it as a gateway. We assume that all stations use IEEE 802.11 DCF operating at 2 Mbps with RTS-CTS handshake enabled. By implementing this scenario in Network Simulator (NS2) [9] and monitoring the data packets sent from each station, we conclude that the IFQ plays an important role in the performance of multihop networks and leads to unfairness problem. For example, STA1 transmitted 4576 CBR packet, only 1276 are forwarded by STA2, while the remaining packets are dropped due to lack of buffer space at the link layer. STA2 sent 4148 CBR packet, only 914 are forwarded by STA3.

Figure 2, illustrates that. From this figure, we conclude that IFQ plays an important role in the performance of multihop ad hoc networks. Also, we simulate this scenario with different queueing policies such as RED, REM, DRR and VQ and we conclude that the effect of each of those queueing management schemes is approximately the same.

They fail to present fairness to longer hops when it is compared with shorter hops packets.

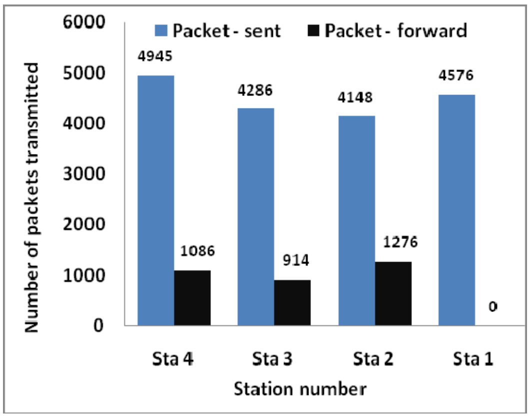

Figure 2. Packet transmitted by each station MAC layer

III. OUR PROPOSED SCHEME

In this section, the proposed scheme will be presented. The packets received to each node will be classified as follow:

- Packets with a large number of hops to reach its destination (class-1) and
- Others with a small number of hops (class-2).

All types compete for the available finite buffer space at nodes. The number of hops can be determined from the routing table at each node. In this paper, without loss of generality, it is assumed that the class-1 packets are more important than class-2 packets, but this fact may change according to the load of the traffic.

Dynamic Buffer

In this scheme, each node has a finite buffer with fixed size of C places where each one can hold one packet. The C places are divided into two regions, by threshold k, where $k< C$. As mentioned before, each node receives two different classes: class-1 and class-2. If a class-2 packet arrives at the node and the buffer occupancy is less than k, then the packet can be accepted. If the buffer occupancy is greater than or equal to k, then the class-2 packet can be accepted with probability α. Otherwise, the packet is rejected and lost. If a class-1 packet arrives at the node and the buffer occupancy is less than C, the class-1 packet is accepted, otherwise, it is rejected. Here, we rank the size buffer for class-1 and class-2 types as follows:

- Rank-1: assigns buffer for both classes.
- Rank-2: assigns buffer for class-1 and assigns buffer for class-2 with probability α.

For example, a class-2 will first try Rank-1, if unavailable, it tries Rank-2, if unavailable, it will be rejected and lost. The value of α can be adjusted depending on the traffic load. For example, if we put $\alpha=0$, we give the class-1 packets a good chance to find a free space in the buffer. In other word, if the class-1 traffic is high, we can make the value of probability α close to zero.

IV. CONCLUSION

In this paper, we have evaluated different queueing management schemes in multihop ad hoc networks. From the evaluation presented in this paper, it is evident that the queueing management schemes in IFQ at intermediate relay ad hoc nodes, can greatly impact the performance of longer hops over shorter hops in multihop ad hoc scenario. We proved that by evaluating different queueing management schemes such as droptail, RED, VQ, DRR and REM.

We evaluated the performance of those queueing management schemes through a simulation study using network simulator 2 (NS2) in a multihop ad hoc network scenario. This scenario consists of five nodes in linear topology. Also, we presented a simple and effective solution for improving the performance of multihop flows by fairly sharing the available buffer at each intermediate node among all the active source nodes whose flows are being forwarded. Evaluation of the proposed scheme using ns2 and mathematical methods will be done in the future work.

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