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A link layer adaptive pacing scheme for improving throughput of transport protocols in wireless mesh networks

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Abstract

In this paper, we study the performance of a static multihop wireless network, specifically that of the backhaul network of a two-tier Wireless Mesh Network (WMN) operating on IEEE 802.11 Medium Access Control (MAC) protocol. The performance of an IEEE 802.11 based backhaul network is greatly affected by the MAC contention and congestion in the network. If the sources pump data into the network than can be supported, loss rate increases due to MAC contention and congestion in the network. This also leads to the problem of unfairness among flows. In this paper, we propose a Link Layer Adaptive Pacing (LLAP) scheme that adaptively controls the offered load into the network. This improves the performance of higher layer protocols without any modifications to them. Our LLAP scheme estimates the four hop transmission delay in the network path without incurring any additional overhead (Control packets) and accordingly paces the packet transmissions to reduce MAC contentions in the network. We implement the LLAP scheme in ns-2.29 network simulator and extensively study its performance for both User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) traffic in different network scenarios. In all the cases, our scheme shows a significant improvement in the performance of both UDP and TCP traffic.

Keywords: Wireless mesh networks; Medium access control; IEEE 802.11 standard; TCP and UDP traffic; Congestion and contention

1. Introduction

Wireless mesh networking has emerged as a promising technology to meet the challenges such as providing flexible, adaptive, and reconfigurable architecture while offering cost-effective solutions to service providers, in next generation wireless networks [1]. In a Wireless Mesh Network (WMN), the backbone mesh network formed by a set of mesh nodes is a static multihop wireless network. The clients (for example, in a community WMN) are connected to the edge mesh nodes of the backbone network. Some mesh nodes, called gateway nodes in the backbone network, provide Internet connectivity to the clients of the WMN. The multihop backbone wireless network has to be utilized efficiently in order to improve the overall performance of the network. In a two-tier WMN architecture, the

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communication of a client with a mesh node and that between mesh nodes is carried out using either a different technology or different channels so that both are independent. Most of the Internet based applications use Transmission Control Protocol (TCP) as a transport protocol, since it provides end-to-end reliable transmission of data. Many applications such as audio and video streaming use User Datagram Protocol (UDP) as a transport protocol, since they require faster delivery of data rather than reliable transmission. As WMN is used as backbone network for accessing the Internet as well as for community networking, the traffic in WMNs is from numerous applications which use different transport protocols (both reliable and unreliable transport protocols).

As applications such as audio and video streaming coexist with TCP traffic, improving only the performance of TCP protocol may not improve the overall performance of the WMNs. As the performance of TCP is greatly affected by the packet losses in the network, reducing the losses will improve its performance considerably. In wired networks, packet loss is mainly due to the buffer overflow at the intermediate routers. But in the case of multihop wireless networks, packet loss could also occur due to erroneous wireless channels, MAC contention, unstable network conditions, and mobility of nodes (in Mobile Ad hoc Networks). Bursty nature of the traffic also increases MAC contention and packet losses in the network due to self contention (packets of the same flow collide with each other) thereby affecting the performance of flows in a multihop wireless network. As TCP uses window based congestion control, it generates bursty traffic and leads to self contention.

It is shown in the literature that, in IEEE 802.11 based multihop wireless networks, if the interference range is twice the transmission range, the contention in the network path can be reduced by evenly spacing the packet transmissions with 4-hop transmission delay (FHD) at the source node [2]. The FHD is defined as the time for transmitting a packet from a node to the 4th hop node on the downstream path. The spacing between packet transmissions can be done at the transport layer by properly estimating the FHD of the network path. Although, this may provide a separation (delay) between successive transmission of packets for each flow at the higher layer, due to very high contention in the network or traffic from the multiple flows, there may not be such a separation at the Medium Access Control (MAC) layer in reality.

In WMNs, a number of clients can generate TCP and UDP traffic which goes in the same multihop path from an edge node to another edge node or from an edge node to the gateway node. Hence, all the packets going in a path have to be scheduled with an interval of FHD to reduce the contention between the packets, thereby achieving better channel spatial reuse. This spacing of packet transmissions is required in multihop wireless networks irrespective of higher layer protocols used when the flows are running for more than four hops. In this work, we aim to reduce the MAC layer contention by using an adaptive pacing mechanism at the link layer. Our proposed Link Layer Adaptive Pacing (LLAP) scheme tries to reduce the contention in the network by properly scheduling the packets at edge nodes thereby increasing the channel spatial reuse in the network.

We use a cross-layer approach for scheduling of packets and estimation of FHD in a path. Our approach estimates the FHD in a path by measuring the queuing and *transmission delay*[1] incurred at the bottleneck node in a distributed manner. The main contributions of this paper are as follows:

- A performance study of multihop wireless networks for both UDP and TCP traffic.
- The new LLAP scheme to reduce the MAC contention in the network for achieving better channel spatial reuse.
- The estimation of FHD in a path in a distributed manner without additional control packet exchanges between the edge nodes.

The rest of the paper is organized as follows. Section 2 discusses the related work in the literature and provides the motivation for our work. Section 3 gives a class of networks considered for our study. Section 4 describes the problem with multihop wireless networks for both UDP and TCP traffic. In Section 5, we describe the design and implementation of our LLAP scheme. In Section 6, we demonstrate the responsiveness of our LLAP to congestion in the network. In Section 7, we evaluate the LLAP scheme for both UDP and TCP traffic in different network scenarios. Finally, we conclude the paper in Section 8.

[1] Transmission delay is the sum of channel access time and transmission time.