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Inter-flow fairness support and enhanced video quality delivery over multi-hop wireless networks☆

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ABSTRACT

Due to intra-flow and inter-flow interference problems, the throughput performance decreases dramatically in a multi-hop wireless network. These two kinds of bandwidth unfair sharing problems could cause serious collisions and congestion, hence affecting the performance of multi-hop wireless networks. That is to say, data packets that need to traverse more hops to arrive at the destination will get lower throughput and result in the inter-flow fairness problem. Furthermore, the quality of video transmission is especially poor in traditional multi-hop wireless network environments. Therefore, in this paper, we propose a virtual queue management scheme that does not require the modification of any communication protocol. According to the number of flows, it adjusts the queue management scheme to achieve each flow's fair sharing of channel resource. It also improves the quality of video transmission. Through NS2 simulations, the results show that our proposed scheme can mitigate the inter-flow fairness problem and effectively improves the quality of video transmission.

1. Introduction

In recent times, the rapid development and deployment of the IEEE 802.11 Medium Access Control (MAC) wireless local area network protocol in conjunction with the increasing number of handheld consumer electronic devices that offer wireless network functions, such as smartphones, tablets, and digital cameras, are driving the popularization and growth of wireless networks. Various devices in a wireless network environment can extend the range of the network by relaying information to one another. However, this requires network architecture that allows nodes to act as relays between the transmitting and receiving ends. Wireless networks with this type of architecture are called Multi-hop Wireless Networks (Fig. 1). In the last few years, with the evolution of wireless networks and greater bandwidth, the applications of multi-hop wireless networks have become quite diverse. Instances include vehicular ad hoc networks (VANET) [1], [2], wireless mesh networks (WMN) [3, 4], and wireless sensor networks (WSN) [5–8]. Wireless nodes compete with one another for routes. The transmission throughput at each node is limited by the bandwidth of the original channel as well as nodes neighboring the site of the transmission.

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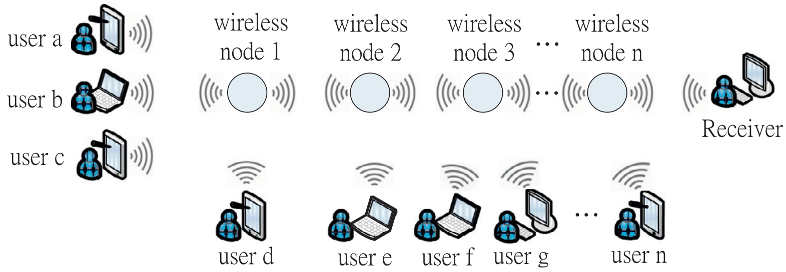

Fig. 1. Multi-hop wireless networks.

When packets are from the same flow and compete for channel access with neighboring nodes, this is known as intra-flow contention. On the contrary, if packets are from different flows, the phenomenon is called inter-flow contention.

Intra-flow contention refers to competition among nodes for channel access rights to transmit packets of a particular data flow. The physical position of each node affects its opportunity for obtaining channel access rights and causes unfairness of access among nodes. Inter-flow contention refers to competition among nodes for channel access rights to transmit packets belonging to different data flows. Due to competition, throughput as measured at the receiving end varies according to data flow and, hence, leads to the inter-flow fairness problem.

The aim of this paper is to examine the fair sharing of network resources and the quality of video transmission in multi-hop wireless networks. There are two cases when data packets are transmitted in multi-hop wireless networks: data packets need to traverse a large or a small number of hops to reach the destination. The transmission throughput in case the packets need to traverse more hops is worse. This is because the packets that need to traverse more hops require greater effort to compete for channel access and queue space in intermediate nodes. Furthermore, when competing for channel access and queue space, packets may be dropped due to transmission collisions or overflow of the queue space in intermediate nodes. As a result, packets that need to traverse more hops have a lower probability of successfully arriving at the destination. In other words, either throughput is lower or the quality of the delivered video is poor as a consequence.

Due to these fairness problems, wireless network environments with more hops can be less effective at data transmission. Past research on fairness in multi-hop wireless networks and quality of video transmission includes work by Zhai et al. [9], who proposed a backward pressure scheduling method to solve inter-flow contention conditions. In their scheme, a backward pressure threshold is assigned to each flow. When a node transmits a request to send (RTS) packet, the receiving node replies with a negative clear-to-send (NCTS) packet if it is above the backward pressure threshold. Thus, the transmitting node knows that traffic is congested in the network, and passes this information to the source node. The source node then delays data flow transmission to help reduce the congestion. When the channel is available to transmit, the receiving end informs the transmitting end of this by sending a clear to send (CTS) packet to the transmitting end that includes the source address and the flow ID. A limitation of this scheme is that it requires that each node change its communication protocol.

Cho et al. [10] proposed a Multi-interface Multi-channel (MIMC) method that uses multiple channels to avoid interference and modifies RTS packets to achieve multi-hop reservation. This reduces delay and improves transmission throughput. A limitation of the method is that it requires investment in additional hardware.

Hoblos [11] proposed an Adaptive Contention Window Algorithm (ACWA) to improve transmission fairness and increase channel throughput. It is based on the negative correlation between packet transmission success and the number of intermediate nodes. A greater number of intermediate nodes correspond to a lower probability of successful transmission. The scheme assigns smaller contention window (CW) values to nodes with a greater number of intermediate nodes between them and their respective destinations as well as nodes that experience less interference from hidden nodes. The lower CW values provide more transmission opportunities to these nodes, which increases fairness and channel throughput. A limitation of the technique is that immediately following a change in network topology, the CW values need to be recalculated. This complicates calculations and imposes an additional burden. Moreover, it is difficult to detect hidden nodes in a dynamic environment.

Tamang and Sanguankotchakorn [12] proposed an Adaptive Dynamic Mapping Algorithm (ADMA) to protect the transmission of video frames. In this algorithm, certain video frames are protected depending on their category and importance. Video frames are assigned increasing levels of protection as they move closer to their destinations. Video frames with high importance have a low probability of being dropped, whereas those assigned low importance have a high drop probability. This strategy is used to improve the quality and throughput of video transmission. However, it does not consider data flow other than that involved in video transmission; nor does it address the inter-flow fairness problem. For example, there is no discussion of cases where video and ordinary data flow simultaneously occur.

Wan [13] proposed a Dynamic Frame Assignment Algorithm (DFAA) involving a fuzzy logic controller (FL controller) whereby video frames are protected differently based on type, priority, relative queuing delay (D_R), and queue length. Different care delays are executed as well. The more important video frames and those with shorter delays are placed in an