EF-AQM: Efficient and Fair Bandwidth Allocation AQM Scheme for Wireless Networks

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Abstract— **Heterogeneous Wireless Networks are considered nowadays as one of the potential areas in research and development. The traffic management schemes that have been used at the fusion points between the different wireless networks are classical and conventional. This paper is focused on developing a novel scheme to overcome the problem of traffic congestion in the fusion point router interconnected the heterogeneous wireless networks. The paper proposed an EF-AQM algorithm which provides an efficient and fair allocation of bandwidth among different established flows.**

Finally, the proposed scheme developed, tested and validated through a set of experiments to demonstrate the relative merits and capabilities of a proposed scheme.

*Keywords- **Wireless Network, Congestion Control, Active Queue Management, Random Early Detection.***

I. INTRODUCTION

Wireless communication technology is playing an increasingly important role in data networks. Wireless networks are usually connected to the internet via backbone gateway routers. The packet loss may occur at fusion points that connect the backbone network to the wireless networks.

However, in a wireless heterogeneous network, the loss occurs due to the channel nature and characteristics. For example, in IEEE 802.11 wireless networks, congestion may be defined as a state where the shared wireless medium is completely occupied by the nodes because of given channel characteristics in addition to external interference. The shared environment of the wireless medium causes a node to share the transmission channel not just with other nodes in the network, but also with external interference resources [1].

In reality that a wireless channel is shared by challenging neighbor nodes and the number of nodes sharing this channel may change all the time [2]. An additional reason is that the wireless link bandwidth is affected by many changing physical conditions, such as signal strength, propagation distance, and transmitter power. For example, an IEEE 802.11 node can modify its MAC-layer data rate dynamically according to different situations, which means the output bandwidth of this node and other neighbor nodes may also change .

In wireless networks throughput degradation can occur due to the sharing the lossy channel and packets collision. Slotted CSMA/CD is used to overcome a bit the collision occurrence at the lossy channel. Sending the frames at the slot start reduces the chance of frames' collision.

In addition, the using of a conventional mechanism in managing the traffic in inside the wireless gateway node causes an additional loss to truly arrived frames. Throughput degradation can occur also due to improper use of traffic management schemes at the fusion points of heterogeneous wireless networks [6]. For these reasons, an efficient mechanism for congestion control should be applied at the bottleneck nodes to overcome the additional loss in an accurate data.

In an IEEE 802.11 wireless network, the occurrence of high density nodes in a single collision domain can cause congestion, in consequence causing a substantial bottleneck gateway router [5]. Packet dropping, packet delays and session disruptions are a consequence of congested network.

Congestion control problem occurs when the demand on the network resources is greater than the available resources and due to increasing mismatch in link speeds caused by intermixing of heterogeneous network technologies. This congestion problem cannot be solved with a large buffer space. Clearly too much traffic will lead to a buffer overflow, high packet loss and large queuing delay. Furthermore, congestion problem cannot be solved by high-speed links or with high-speed processor, because the high-speed link connected via the high-speed switch with the low-speed links will cause congestion at the wireless fusion point of interconnection.

Drop Tail has been proposed in [4]. The most operational routers currently use Drop Tail coupled with FIFO (First in first out) scheduling scheme. In Drop Tail, all packets are accepted until the maximum length of the queue is reached and then dropping subsequent incoming packets until space becomes available in the queue.

Drop Tail is not appropriate as a feedback control system for high-speed networks because it sustains full queues and this may increase the average queuing delay in the network. More importantly, Drop Tail can cause a lockout due to traffic phase effects and the global synchronization, and thus results in low throughput. The lost packet from a Drop Tail queue will usually be retransmitted by TCP protocol via its retransmission timer. No congestion is detected until the buffer becomes full and the maximum congestion indicator is generated because all arriving packets are dropped. Then each source detects lost packets it will slow down the arrival rate of the sending packets until the queue will be less than the capacity of the link. No congestion indicator will be generated when the queue is not full, each source will increase until overflow happens again [11,12].

978-0-7695-4158-7/10 $26.00 © 2010 IEEE
DOI 10.1109/CICSyN.2010.19

In the recent years, Active queue management (AQM) mechanisms have been proposed to provide an efficient queue management by selectively dropping/marking packets when congestion is anticipated so that TCP senders can reduce their transmission rate before an overflow occurs. AQM mechanisms are employed in the Internet by the routers to provide better stability, fairness, and responsiveness to dynamic variations in computer networks. Using queue management mechanisms in an efficient way will avoid the congestion collapse and lead to high link utilization.

In this paper, we present a novel buffer management approach for congestion control in a wireless network. This approach achieves both efficient and fair allocation of bandwidth among flows by randomly dropping frames and increases data throughput to the next hop.

The rest of this paper is organized as follows: In section II, the network model is presented. The proposed scheme is developed in section III. Extensive simulations and results are investigated in section IV. Section V concludes this paper.

II. Network Model

The network model considered in this paper will be explained in this section. IEEE 802.11 based wireless LAN networks have been chosen as a reference model of this investigation. A bottleneck wireless gateway router has been taking into account in this topology(Figure 1). A wireless channel ***L*** is shared by ***N*** challenging neighbor nodes and the number of nodes sharing this channel may change all the time. We suppose that all nodes use the same power and modulation methods. Figure 1 illustrates the wireless network model. The traffic model is shaped as follows. We assume that each node is transmitting HTTP packets of size S bits, and they are generated according to Markovian-Modulated Poisson Process MMPP with arrival rate λ.

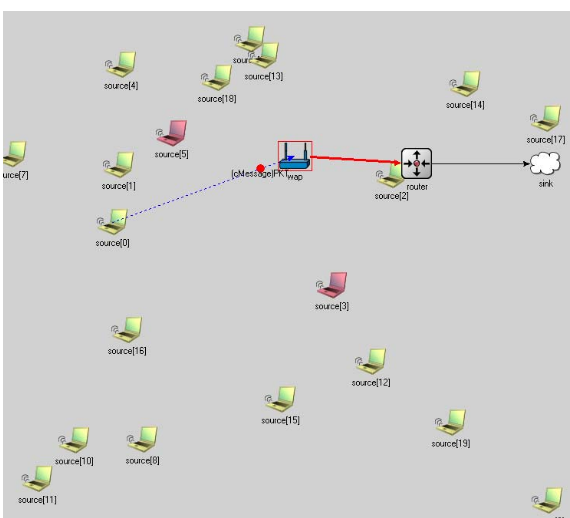

Figure 1. IEEE 802.11 Wireless network

The fusion point that connects the wireless network with wired network has a finite amount of buffer space, and this buffer is managed via an adaptive queue management scheme. In addition, the output link has a fixed bandwidth and connects the wireless network with Internet. But for a wireless network, for example in 802.11b, the node can dynamically change its MAC-layer data rate to 1, 2, 5.5, or 11Mbps. Consequently, when congestion is occurred the TCP is unable to maintain fairness and stability with improper estimation of the link capacity parameter. For this reason, the need for an adaptive and intelligent AQM algorithm to be implemented at the fusion point of a wireless network is critical and crucial.

The congestion sliding widow ***w*** is increased by one every round trip time if no congestion is detected, and it is reduced by half if a congestion is detected. This is called an additive-increase multiplicative decrease (AIMD) mechanism that represents the behavior of TCP flows, and it is described by the following nonlinear differential equation [9]:

$$\dot{w} = \frac{1}{r(t)} - \frac{w(t-1)}{2r(t-1)} p(t-1) \qquad (1)$$

Where ***r*** corresponds to the round-trip time (seconds) and ***p*** is representing the probability of packet drop/mark. In addition, the instantaneous queue can be expressed in the following equation:

$$\dot{q} = \frac{w(t)}{r(t)} N - C \qquad (2)$$

Where ***C*** is the link speed (packets/sec) and ***N*** load factor (number of TCP connections).

III. EF-AQM Scheme

EF-AQM scheme has been designed and analyzed in terms of feedback control theory (Figure 2). The advantages of using control theory are to increase the speed of response and to bring further improvement to the system robustness and stability. These advantages can be achieved by regulating the output queue length around a target value Q_{ref}. An important goal of the AQM design is to stabilize the queue length $q(t)$ at a given target Q_{ref} , so that the magnitude of the error signal.

$$e(t) = Q_{ref} - q(t) \qquad (3)$$

is kept as small as possible.

The output of the EF-AQM controller represents the dropping probability and is simplified as:

$$y(k) = y(k-1) + K_0(e(k) - e(k-1)) + K_1 T e(k-1) \qquad (4)$$

where T is the sampling period time, K_0 and K_1 represent the tuning parameters of the controller.

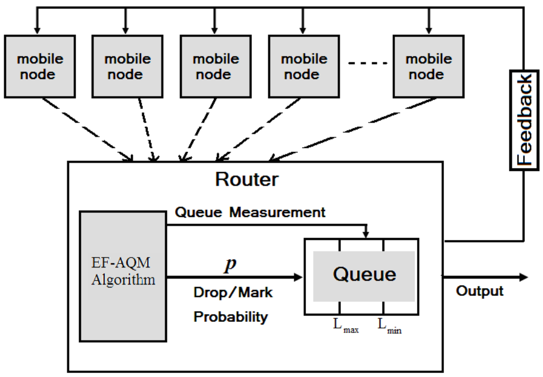

Figure 2. EF-AQM as a feedback control system

The dropping probability is calculated according to the intelligent controller, and it is considered as a function of the difference between the current value of the queue length and the reference queue length. Our aim is to compute this dropping probability $p_d(t)$ such that it will keep the instantaneous queue length close to the target queue. Therefore, the dropping probability $p_d(k)$ can be achieved as:

$$p_d(k) = \begin{cases} 0 & y(k)<0 \\ y(k) & 0<y(k)<1 \\ 1 & y(k)>1 \end{cases} \quad (5)$$

The dropping probability is calculated at every packet arrival. The reason for randomizing the packet drops is the hypothesis that users generating more traffic would have a greater number of packets dropped. The same as in Random Early Detection (RED) [7], if the average queue length exceeds a minimum threshold L_{min}, incoming packets are dropped/marked with a probability that it is a linearly increasing function of the average queue length. When the average queue size exceeds a maximum threshold L_{max}, the router is likely to incur congestion, and all incoming packets are dropped/marked. When it is between, a packet is dropped with a probability ***p*** which represents the output of EF-AQM controller.

IV. Performance Evaluation

To validate the performance and the robustness of the proposed EF-AQM algorithm for wireless network, we simulated it using OMNET++ platform [10] with highly bursty traffic. Different scenarios have been chosen to validate the proposed algorithm with different number of flows. The parameters used in EF-AQM simulation are: N = 10,20,30 and 40 flows, L_{max} = 500 packets, L_{min} = 100 packets, *packet length* = 100 bytes, IEEE 802.11 *propagation delay* = 10 *ms.* Probability based dropping p_{max} =0.2 and the target queue length is $(L_{max} + L_{min})/2$.

A. Throughput

As shown in Figure 3, EF-AQM has offered higher throughput as compared to the classical algorithm Drop Tail and RED for the 10, 20, 30 and 40 flows respectively. It is observed that although the number of TCP flows has increased, EF-AQM has offered higher throughput for different control approaches and reach (100%) for the smaller flows. This due to the stability of EF-AQM in maintaining the queue length which makes it more stable around the target queue and shrunk in width; thereby packet dropping is less despite of increasing the number of TCP flows.

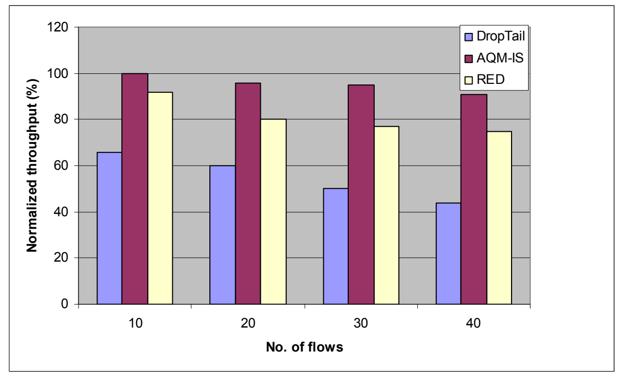

Figure 3. Throughput comparison for different flows

B. Queuing Delay

The queuing delay is considered as one of the important metrics in performance evaluation of any AQM controller. Figure 4 shows that the queuing delay of the proposed EF-AQM is very small compared other approaches for a variety of flows. It is noted that the queuing delay becomes constant for EF-AQM controller despite increasing traffic load or changing the type of data traffic. For other schemes, the delay is continued to increase when changes occur in any of the network parameters.

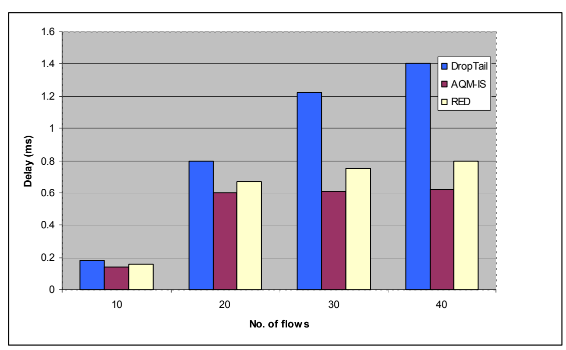

Figure 4. Delay comparison for different flows

C. Queue length

Figures 5 Shows the instantaneous queue length evolution comparison under the EF-AQM approach compared with RED for the number of TCP flows equal to

20, 30 and 40 respectively. It can be seen that the instantaneous queue length of the EF-AQM is stable and oscillate around the target queue length. While the instantaneous queue length of the RED algorithm is still fluctuated away from the target queue length as the number of TCP connection increased due to the sensitivity of RED to any change in its parameters. It is worth noting that the EF-AQM scheme with adaptive tuning parameters is the most stable control scheme as compared to the others; demonstrates steadiness mode despite higher number of TCP flows.

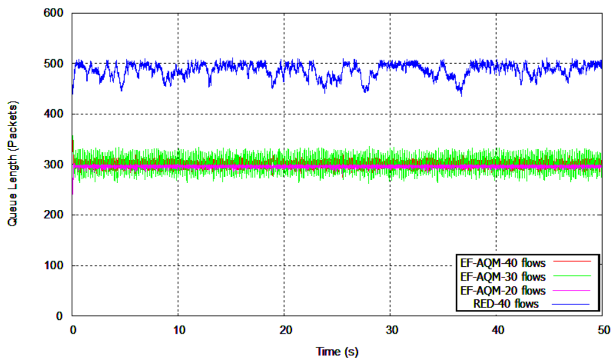

Figure 5. Instantaneous queue comparison for different flows

V. Conclusion

This paper presented an efficient and fair bandwidth allocation AQM algorithm to overcome the problem of congestion control in heterogeneous wireless network. It has been demonstrated that the new EF-AQM has achieved desirable properties such as robustness and fast system response, as compared to the traditional DropTail and RED. Finally, a set of experiments has been provided to demonstrate the efficiency of the proposed design approach. It is noted that the proposed EF-AQM design approach performs significantly better than many well-known schemes, and guarantees the robustness of the controller. elp your readers, avoid using footnotes altogether and include necessary peripheral observations in the text (within parentheses, if you prefer, as in this sentence).

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