Enhancing AQM Performance on Wireless Networks

Gianluigi Pibiri, Ciarán Mc Goldrick, Meriel Huggard
School of Computer Science and Statistics
Trinity College Dublin, Ireland
Email: pibirig@tcd.ie, Ciaran.McGoldrick@tcd.ie, Meriel.Huggard@tcd.ie

***Abstract*—Congestion management is a key factor in the provision of acceptable levels of quality of service (QoS) on wired networks. However, the concept of congestion management does not translate easily into the wireless domain. Active Queue Management (AQM) solutions for congestion avoidance have proved effective in wired networks but have not gained much traction in the wireless world. Wireless AQM schemes need to be capable of being easily scaled in order to maintain the algorithm characteristics and improve their efficiency. The RED, REM and BLUE AQM schemes are considered from a wireless perspective and methods for improving their efficiency and performance in wireless networks are given.**

I. Introduction

Active Queue Management (AQM) [1] algorithms are designed to anticipate congestion and react in advance to prevent congestion collapse in the network. Some well-known AQM algorithms are RED [2], REM [3] and BLUE [4]. They start dropping packets before the queue becomes full but at a point where they estimate that the system is becoming congested. The extension of AQM to the wireless domain was detailed in [5], where active queue management is used to enhance the performance of IEEE802.11 [13]. In this work we devise strategies to conform some of existing AQM schemes to the original design when deployed in wireless IEEE802.11 networks.

II. Related Work

Many have sought to extend AQM algorithms and improve their performance; for example in IEEE802.11 networks Temporal Fair RED (TFRED) [14] uses the data transmission rate as a metric to decide if a packet is to be dropped or not. Exponential RED (ERED) [15] adopts a similar approach to TFRED, where a packet marking probability is calculated as an exponential function of the length of a virtual queue.

Other AQM schemes have the objective of achieving an acceptable level of fairness between the uplink and downlink. This is the case with VQ-RED [17] where virtual queues are used to guarantee fairness and reduce delay. Virtual queues have also been used for queue management in wireless infrastructure networks [18]. Another application of AQM on wireless networks is proxy-RED [16], where a gentle RED (ARED) is used between the gateway and the access point.

When considering the use of AQM in IEEE 802.11 [8] [7] CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) [13] networks the Theoretical Maximum Throughput (TMT) [6] has been identified [5] as a key input parameter.

In this study the focus is on improving the performance of AQM algorithms whe implemented in a wireless Access Point.

III. Problem Description

AQM algorithms play an important role in QoS provision through congestion avoidance in wired networks. In this paper we consider how existing AQM algorithms can be adapted and enhanced for use in a wireless access point (AP).

We adopt the same infrastructure network configuration as [5]: Each simulation starts with 10 unidirectional TCP flows from 10 sources to 10 destinations (Mobile Stations). Every 50 seconds 10 flows are added, up to a maximum of 30 sources and destinations. Then the flows are decreased by 10 every 50 seconds until we return to the initial configuration.

IV. The RED Algorithm

The RED [2] algorithm's goal is to maintain the queue length between two threshold values. The queue average (avg) is used to calculate a dropping probability to associated with each packet. An alternative average calculation, now considered obsolete, is the Holt-Winters procedure [10]. In this work a redesign of the average calculation using Holt's linear model or Double Exponential Smoothing [11] to forecast the queue length is proposed. Double exponential smoothing contains both a formula for the level (S_t) and a formula for the trend (b_t):

$$S_t = \alpha * Queue\_length + (1-\alpha)(S_{t-1} + b_{t-1}) \quad (1)$$

$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1} \quad (2)$$

where $0 < \alpha < 1$ and $0 < \gamma < 1$ are two small constants. The forecast is obtained by adding the level to the trend:

$$F_t = S_t + b_t \quad (3)$$

This approach is similar to [10] but there are some differences. Firstly we are using the forecast value as the average instead of using the level value. Secondly we use two small free constants (α and γ) for the level and trend instead of the one (α and $\frac{\alpha}{2}$) suggested in [10]. Forecasted RED is shown to match our expectations via simulation in ns-2 [9]. We have simulated both RED algorithms: traditional RED with the EWMA formula ($w_q = 0.002$) and RED with the forecast formula ($\alpha = 0.002$

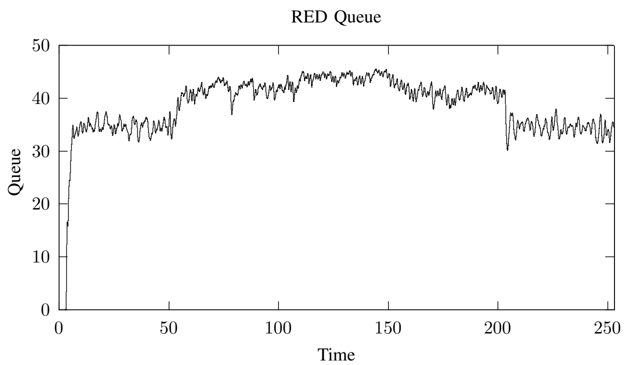

Fig. 1. RED average

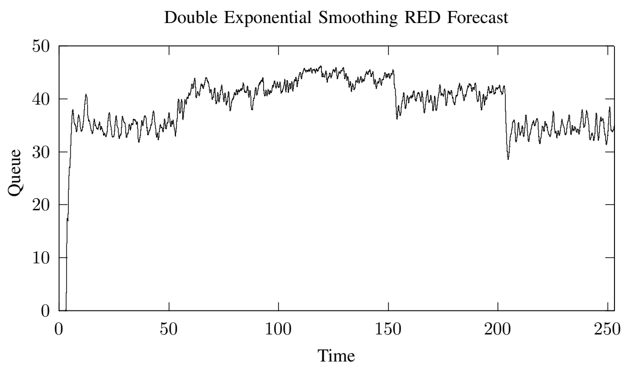

Fig. 2. Forecast RED average

and $\gamma = 0.0005$, determined experimentally). Figure 1 shows the EWMA simulation, and figure 2 shows the same simulation using the Forecast. In these simulations, the EWMA and the Forecast procedures have very similar performances in terms of packets transmitted, packets dropped and average queue occupancy. However, due to the choice of parameters and their ranges, the forecast results are shown to be more adaptable to a wider range of wireless scenarios. This increased adaptability can easily improve the algorithm performance.

V. The REM Algorithm

The Random Exponential Marking (REM) Algorithm [3] marks or drops the packets using a probability value calculated using a“price” variable. In the REM price calculation formula [3] there are two contributions: one from the queue weighted by α_l:

$$\alpha_l(b_l(t) - b_l^*) \tag{4}$$

and another from the throughput,

$$x_l(t) - c_l(t) \tag{5}$$

where: α_l is a constant > 0, $b_l(t)$ is the queue length at time t , $b_l^*(t)$ is the target queue length, $x_l(t)$ is the input rate and $c_l(t)$ is the available bandwidth. The difference ((4) - (5)) can be positive or negative.

We propose setting $c_l(t)$ to the Theoretical Maximum Throughput (TMT) [12], divided between the Mobile Stations and the AP. The values that (5) takes on are not continuous. One way to tranform it into a continuous function is to replace $x_l(t)$ with the EWMA normally used in wired networks for the RED algorithm [2]. w_q is subject to the same considerations as in [2].

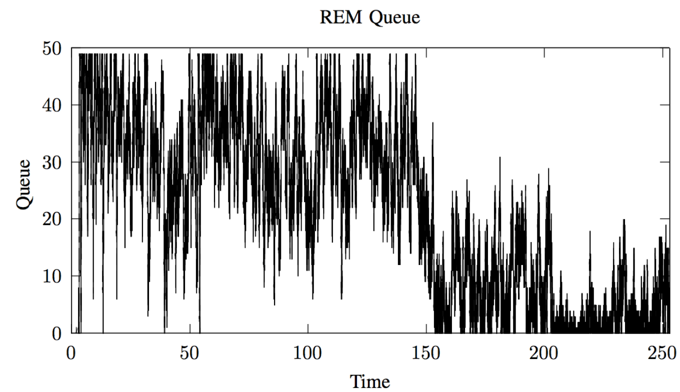

Fig. 3. REM instantaneous Queue with $c_l(t) = 0$

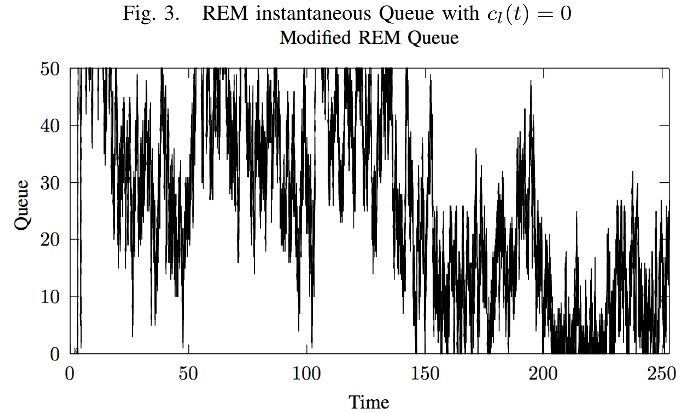

Fig. 4. Modified REM instantaneous Queue with $c_l(t) = 3.5Mbps$ and $w_q = 005$

We evaluated the solution proposed in the same environment used for RED above. Figure 3 shows the instantaneous value of the queue for a REM simulation when $c_l(t)$ is set to 0. While Figure 4 shows the instantaneous queue length in a simulation of the modified REM using the EWMA to calculate $x_l(t)$, and with $c_l(t)$ set to TMT ($3.5Mbps$ in this case).

We can see that the modified REM with $w_q = 0.005$ (upper limit) uses the queue in a more efficiently manner than REM does. The performance in terms of successfully transmitted packets is better for the modified REM (+3.6%) than for REM. Also the number of dropped packets is lower for the modified REM (-9%) than for REM. By contrast the average queue length is less for REM (22.67 packets) than for modified REM (28.28 packets).

VI. The BLUE Algorithm

The BLUE [4] algorithm drops or marks the packets using a drop probability. The probability increases or decreases based on “packet loss and link utilization” [4]. The probability is updated after a sampling time ($freeze\_time\_$). Figure 5 shows

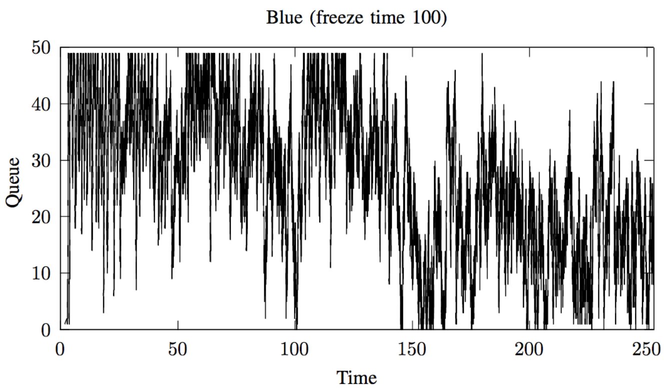

Fig. 5. Blue instant queue ($freeze\_time\_ = 100ms$)

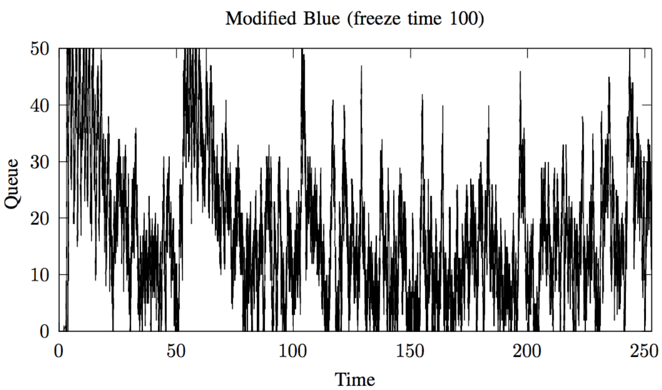

Fig. 6. Modified Blue Instant queue $freeze\_time\_ = 100ms$

the instantaneous queue length in a simulation of the Blue algorithm in an AP. The parameters limits have to obey the guidelines in [4] and they have to be set according to the traffic mix. If we want to obtain a function that varies according to traffic changes this suggests that the most appropriate value for δ is as a function of the queue length. We propose the following function:

$$\delta(q) = \gamma \left(\frac{1}{1 + e^{\frac{q}{\alpha}}} \right) \tag{6}$$

where q is the actual queue length, γ is a constant scalar value, and α is a constant used to change the curvature of the graph. The function can be easily changed from linear to exponential by simply changing the value of α. Figure 6 show the simulation results obtained with the modified BLUE with a lower queue saturation and smaller amplitude oscillations than with the traditional BLUE algorithm. Also it clearly show peaks in reaction to an increase in the number of sources.

VII. Conclusion and Future Work

In this paper we considered how three of the most common AQM algorithms, designed to work in wired networks, can be adapted for use in wireless networks that are experiencing AP bottlenecks due to rapid changes in network traffic. This scenario is typical of an Access Point on an infrastructure wireless network.

We conclude that the traditional approach to AQM algorithm design and parameterisation needs to be reconsidered in light of the inherent features of wireless networks. We are now concentrating our research on new methodologies for the design of AQM algorithms for future wireless networks.

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