A Survey on Active Queue Management Techniques

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Abstract

With the fast growth of current internet and service demand for multiple access has also been increased significantly. Therefore, there is huge traffic in the network which results in congestion where buffer management acts an important role. Earlier, drop tail and random drop were used as buffer management techniques with the TCP. Drop tail suffers from huge queuing delay, lockout, global synchronization problem. To overcome all these problems with earlier techniques active queue management(AQM) technique has been introduced. In active queue discipline packets are dropped or marked before buffer becomes full while in earlier technique does the same when buffer becomes full. We have various algorithms under the AQM as Random early detection(RED), Random Exponential Marking (REM), Blue and Stochastic Fair Blue (SFB), ARED, Re RED, PI controller, Robust random early detection (RRED), RED with Preferential Dropping (RED-PD) etc.

In this paper, we will perform the literature survey on the queue management and congestion control in the network.

Key Words: Queue Management (QM), Active Queue Management(AQM), RED, REM, Queue Length.

Introduction

Transmission control protocol (TCP), is mostly used protocol in current communication network and also over the internet, also controls the rate of transmission from the sender node across the network with end to end feedback, through inferred packet. With the exponential growth of users and accessing of the network, the data traffic is more and more, which results in congestion, the existing congestion control mechanism based on Jacobson [1] and its variants like Tahoe, Reno, New Reno etc. have become ineffective. Congestion occurs in the network, When the link bandwidth becomes larger than the capacity of router, this causes delay and subsequently packet drop occurs.

Drop Tel starts dropping of packet when the buffer is full, with the multiple TCP flow it causes global synchronization problem [2]. Newer technique for congestion control and avoidance required. So, in order to overcome this problem active queue management (AQM) [3] has been designed which notifies about the initiatory congestion proactively to the terminals. Active queue management (AQM) is mainly a technique based on router which is used to magnify the performance of TCP. Active queue management (AQM) is an effective congestion control mechanism that controls the queue size to ensure the high throughput, so that we can achieve effective congestion control and can get the quality of service(QoS).

Earlier AQM based technology for congestion control relies on classical control principle like Random Early Detection(RED) [4,5], proportional derivative (PD) control, proportional integral (PI), proportional integral derivative (PID) [6]. With the limitation of classical principles, the congestion control is not that much satisfied. To get better control, the modern control principles has been designed rapidly and many more methodology to control the congestion has been proposed like adaptive network congestion control [7,8], predictive congestion control [9], robust congestion control [10] etc. In these methods state feedback mechanism, has been introduced to improve the performance of the network.

Random Exponential Marking is a newly designed active queue management scheme have two main feature; first, Match rate clear buffer; it matches the user rates with network capacity regardless of the users count, while clearing buffer. Another, in REM, the marking probability between end to end system observed depends on sum of link congestion measures i.e. prices, in a simple and precise manner, termed as sum prices. This feature is required in that network where multiple congested links are followed by the users.

Literature Survey

Literature survey from various researcher related to queue management, AQM, congestion control and avoidance can be presented as: -

- S. Floyd and V. Jacobson. [4] first proposed that Random Early Detection gateways, are an effective mechanism for congestion avoidance at the gateway, in cooperation with network transport protocols. The gateway detects incipient congestion by computing the average queue size.

- Jacobson [1] proposed gateways to monitor the average queue size to detect incipient congestion, and to randomly drop packets when congestion is detected. These proposed gateways are a precursor to the Early Random Drop gateways that have been studied by several authors. RED gateways differ from the earlier Early Random Drop gateways in several respects: the average queue size is measured; the gateway is not limited to dropping packets; and the packet-marking probability is a function of the average queue size.

- Hashem [15] discusses some of the shortcomings of Random Drop and Drop Tail gateways, and briefly investigates Early Random Drop gateways. In the implementation of Early Random Drop gateways in, if the queue length exceeds a certain drop level, then the gateway drops each packet arriving at the gateway with a fixed drop probability. Hashem stresses that in future implementations the drop level and the drop probability should be adjusted dynamically, depending on network traffic.

- Ramakrishnan, K.K., and Jain, Raj [16] proposed DECbit scheme, a binary feedback scheme, the gateway uses a congestion indication bit in packet headers to provide feedback about congestion in the network. When a packet arrives at the gateway, the gateway calculates the average queue length for the last (busy + idle) period plus the current busy period. (The gateway is busy when it is transmitting packets, and idle otherwise.)

- Sally Floyd, Ramakrishna Gummadi, and Scott Shenker [17] solved the problem with minimal changes to the overall RED algorithm. To do so, they revisit the Adaptive RED proposal of Feng et al. They made several algorithmic modifications to fleg proposal, while leaving the basic idea intact. They found that the revised version of Adaptive RED, which can be implemented as a simple extension within RED routers, removes the sensitivity to parameters that affect RED’s performance and can reliably achieve a specified target average queue length in a wide variety of traffic scenarios.

- Santosh M Nejakar et al. [18] proposed a simple modification to the RED AQM algorithm in order to account for the presence of both input and output queues in the switch. The weighted sum of input and output queue lengths are specifically used as the congestion measure instead of just the output queue length. The average backlog in the switch is significantly reduced in the low speedup region by using our modified algorithm as compared to RED without this modification.

- Mahmoud et al [19], proposed a controller technique for early stage congestion detection at the router buffer in the networks. The proposed technique extends the well-known Gentle Random Early Detection (GRED) algorithm. The proposed technique uses the average queue length and the delay rate as input linguistic variables for a fuzzy logic system. The utilized fuzzy logic system produces a single output that represents a packet dropping probability, which in turn control and prevent congestion in early stage.

- S. Athuraliya et al. [14] proposed REM for wired and wireless networks, and targets both a desired queue size and high link utilization. There are two extreme asymptotic regimes for sizing router buffers: the currently deployed bandwidth-delay rule, and a small buffer regime.

Active Queue Management

AQM technology is mainly designed for congestion avoidance, i.e., AQM detects the congestion and notifies to the sender before it occurs. Congestion will occur in this but they will be detected early. The sender will be notified by marking the packets using ECN [17] bit or by dropping the packets. The ECN bit is mainly used to notify the end system about the congestion. For the further improvement in performance a new method called fast congestion notification(FCN) has been designed which notifies about the congestion in a faster way and controls the router efficiency.

Many active queue management schemes have been proposed in past and many recently for the TCP that improves the performance will study here about RED, GRED, Re-ARED, NLRED, AVQ, PI, REM.

A. Random Early Detection

Random Early Detection [4] is widely used Active Queue Management technique [11] which is based on queue length. RED is mostly used in TCP and is recommended by IETF. With the arrival of each new packet in the queue, the average queue length is calculated(avg_l) and is compared with two pre-fixed threshold values i.e. min_{th} and max_{th}. If avg_l is smaller than minth then packet is queued. If avg_l falls between min_{th} and max_{th} then with a certain probability P_a, the packets are queued which is the function of avg_l and with probability $(1-P_a)$ the packet are dropped. If the avg_l exceeds the maxth then the packets are dropped. The probability P_a varies between the 0 and max_p (Maximum drop probability).

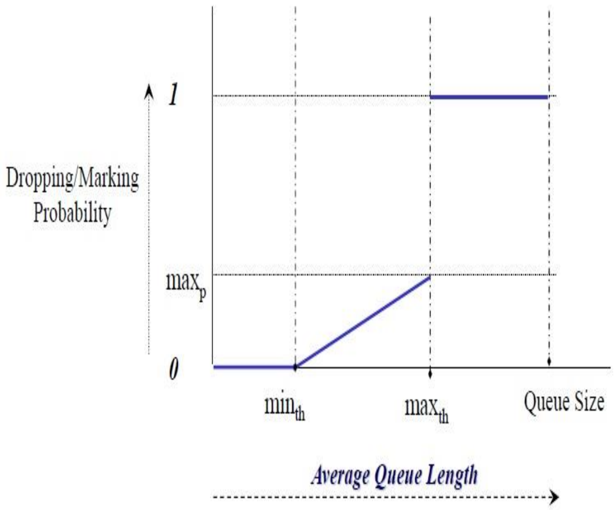

Figure 1: RED Router Mechanism

B. Gentle RED (GRED)

In this variant of RED, when the avg_l i.e. average queue length exceeds maxth the packet dropping probability increases linearly or gently to 1 as avg_l exceeds twice of max_{th}, unlike RED, which directly jump to 1 [11].

C. Adaptive RED (ARED)

Another variant of RED algorithm is Adaptive RED(ARED) [12] that have low delay and high throughput by defining average queue size with $q_{min} + 0.4\ (q_{max} - q_{min})$, $q_{min} + 0.6(q_{max} - q_{min})$). With additive increase and multiplicative decrease policy the control parameter is modified that maintains the stability in average queue length. The maximum probability P_{max} can be given as:

When $P_{max} < 0.5$
Then $P_{max} = P_{max} + \alpha$, $q_{avg} > q_{target}$
When $P_{max} \geq 0.01$
Then $P_{max} = P_{max} * \beta$, $q_{avg} < q_{target}$

D. Nonlinear RED

Nonlinear RED [13] is another modification over original RED algorithm in which nonlinear quadratic packet drop function is used instead of linear function for dropping the packets when avg_l is in between min_{th} and max_{th}.

E. Re-ARED

Re-ARED [12] is the variant of ARED that improvs the performance of ARED with low delay and high throughput and defining average queue size with [q_{min} + 0.48 (q_{max} - q_{min}), q_{min} + 0.52(q_{max} - q_{min})).

F. Random Exponential Marking

REM [12] is very similar to RED except the way congestion is measured and with a different marking probability function. These differences with RED leads to the two main features below:

I. Match Rate Clear Buffer

It matches the user rates with network capacity regardless of the users count, while clearing buffer. The first idea of REM is to stabilize both the input rate around link capacity and the queue around a small target, regardless of the number of users sharing the link.

REM explicitly controls the update of its price to bring about its first property. Precisely, for queue l, the price $p_l(t)$ in period t is updated according to:

$$p_l (t + 1) = [p_l(t) + g(al(bl(t) – b^*l) + xl(t) – cl(t))]$$

where g > 0 and al > are small constants and [z]+ = max {z, 0}. Here bl(t) is the aggregate buffer occupancy at queue l in period t and b*l ≥ 0 is target queue length, xl(t) is the aggregate input rate to queue l in period t, and cl(t) is the available bandwidth to queue l in period t. The difference xl(t) – cl(t) measures rate mismatch and the difference bl(t) – b*l measures queue mismatch. The constant al can be set by each queue individually, and trades off utilization and queuing delay during transient. The constant g controls the responsiveness of REM to changes in network conditions. Hence, from above Equation, the price is increased if the weighted sum of rate and queue mismatches, weighted by al, is positive, and decreased otherwise.

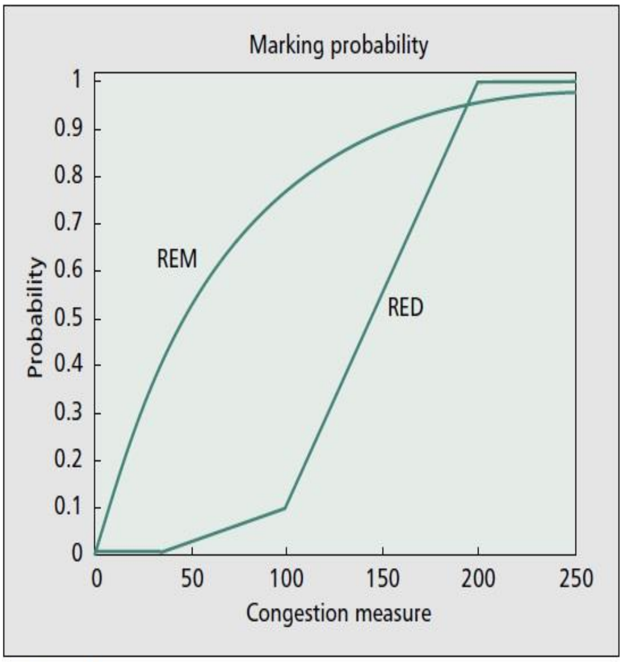

Figure 2: Marking probability of (gentle) RED and REM.

II. Sum Prices

The second idea of REM is to use the sum of the link prices along a path as a measure of congestion in the path, and to embed it in the end-to-end marking probability that can be observed at the source. The marking probability between end to end system observed depends on sum of link congestion measures i.e. prices, in a simple and precise manner, termed as sum prices. This feature is required in that network where multiple congested links are followed by the users.

G. Proportional Integral (PI)

PI [6] is designed to improve the stability in earlier AQM techniques such as RED by using control-theoretic approach. To get the stability in PI average queue length is decoupled from the marking probability. At any time marking probability p(t), is the function of difference between current queue length, $q_i(t)$, and target queue length, $q_t(t)$ and marking probability at time (t −1), p (t −1). This can be expressed as $p(t)=a(q_i(t)−q_t(t)) − b (q_i (t −1) −q_t (t −1)) + p(t−1)$, where a and b are the PI coefficients.

Conclusion

The study and research of queue management continues to be an active area for the researchers. The most asked question in queue management is about the buffer size and in particular likelihood of networks with small buffer length, now gives us a new stage among which queue management strategy could be assessed.

In this survey paper, we have studied about the active queue management techniques and their many variants. First, I surveyed the earlier queue management techniques such as Drop Tel, Random Drop. Then, I came to the active queue management techniques such as RED, REM, ARED, Re-ARED, GRED, NLRED, PI mechanism.

Many study and experimental results show that RED gives better performance in comparison with other techniques such as REM, PI, Drop Tel, Random Drop because it maintains stable queue size. Also, RED achieve higher throughput, low delay and have more stability than other techniques. RED is having many variants, out of which NLRED gives better performance with respect to queue size and average throughput.

Acknowledgement

I want to thank my guide Prof. Ashok Kumar Behra and the management of Bhilai Institute of Technology, Durg, India; for their inspiring encouragement and support towards the completion of this survey.

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