Control theoretic approach for the Reduction of RTT in a distributed system

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***Abstract*—In a distributed system, the demand for live content over the network has increased multifold, throwing open the challenge of meeting the stringent quality of service(QoS) parameters such as delay, loss rate etc. In interactive applications, the in-time response is very important to render a pleasant user experience. In such scenarios, the round trip time (RTT) represents the lower bound on the response time and directly affects the performance of the system. RTT plays a crucial role in shaping the network traffic as it encompasses all the parameters such as buffer dynamics and transmission window. The traffic shaper essentially controls this parameter directly or indirectly. In this paper, a method has been described to reduce the RTT.**

***Index Terms*—Active queue management, Artificial neural networks, Packet Delay, Round Trip Time.**

I. Introduction

In a network, reduction of RTT effectively puts a higher bound on the bandwidth supported for a given packet loss. Thus the throughput can be increased if RTT can be made small. In order to make it happen, a feedback control signal indicating the status of the network is provide to the data sources.

In Random early detection (RED) the probability of packet loss [1] is used as the feedback signal. In the proposed scheme, a predicted version this signal is taken with time shifts as the feedback signal. It is as though the RTT is reduced. .

As the RTT gets reduced or probability of cell loss decreases, the throughput increases. With the usage of predicted packet drop as the control signal, both RTT as well as the cell loss get reduced, resulting in an increased throughput. The predictor works with in the source and controls the transmission rate efficiently.

The RTT is an important state variable in this system. This includes the delay around the feedback loop, as well. The RTT varies primarily as a function of the buffer fill levels in the network path, along which the data travels. The longer the packets must wait in buffers, the longer it takes for them to traverse that path. A significant increase in RTT indicates the network congestion.

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The importance of limits on RTT is highlighted in the next section. The performance with the proposed controller is demonstrated in section III with simulation experiments. Section IV concludes.

II. Importance of limits on RTT

The roundtrip delay of packets in a network comprises of the delay in the forward path, delay in the feedback path and the associated minimal packet processing time after which the response originates from the feedback path. Thus reduction in the packet delays attribute to the reduction in RTT straightaway. In a conventional traffic controller, RTT is small; the source transmission rate quickly increases to its former level and increases the congestion [2]. This calls for a new contrasting approach where the loss probability does not increase with the fall in RTT. It is achieved with shifts given to the predicted version of the loss probability or the feedback signal [3]. A new class of neural networks called differentially fed artificial neural networks (DANN) is used for the prediction of the signal [4]

At a given arrival rate, the streams with different RTTs may be in different phases. i.e. increase or decrease the transmission rates. The number of packets a data source pump in to the network is smaller if the other streams that compete with the source have shorter RTTs. This makes the frequency of limit cycles more and amplitude lesser. It reduces the variance.

The variance of the aggregate traffic, on the other hand, is a function of the variance of all the individual streams and is dominated by the stream with the highest variance.

III. Impact of shifted feedback on RTT and stability

In the closed loop control system, meddling with the RTT will have a profound impact on the stability of the system. The predicted feedback signal is generated at the traffic source. The source can conveniently make use of the predicted signal to compute the window size for the subsequent transmissions. Hence, as seen by the source, it is as though the RTT is reduced. The small signal fluid model for the feedback control signal gives the closed-loop system transfer function as [5]

$$T(s) = \frac{\frac{1}{s}.k}{1+\frac{e^{-s.t_d}}{s}.k} \tag{1}$$

Where $s=\sigma+j\omega$ and k is the system gain. The characteristic equation of this system is

$$s + e^{-st_d} k = 0 \quad (2)$$

$$\sigma + ke^{-\sigma t_d} \cos(\omega t_d) = 0 \quad (3)$$

$$\omega - ke^{-\sigma t_d} \sin(\omega t_d) = 0 \quad (4)$$

As the parameters K and t_d are increased, at some point, the right-most pole will travel from the left hand plane into the right-hand plane, resulting in an unstable system. At the point at which this pole is on the imaginary axis, $\sigma = 0, \omega = \pm k$

$$t_d = \frac{\pi}{2k}$$

The system is stable when

$$k - t_d < \frac{\pi}{2} \quad (5)$$

As the delay or the gain is increased, the system can become unstable. For a stable congestion-control, it is important for the stability of this feedback system to be invariant to the delay, and the gains in the loop, due to different network topologies. The time shift given to the predicted version of the feedback signal is equivalent to reducing the delay value. Hence, shifts improve the stability and achieve it quickly.

As the RTT gets reduced, they become more negative and driven well inside the s-plane making the system more stable. It is for the same reason, the amplitude of transients of the queue i.e. Q fluctuations get reduced with increase in the shift or reduction in RTT. Also, the settling time gets reduced and stability is achieved faster since the poles move farther from the imaginary axis.

The settling time is then $1/\omega$ and increases with reduction in RTT or increase in the shift. Thus, effective decrease of RTT due to prediction of the feedback signal increases the frequency of the congestion avoidance cycle giving enough scope for immediate corrections. The shifts provide the appropriate feedback matching with the characteristics of the network.

With shifts the RTT reduces giving high frequency components to the spectrum. This keeps the autocorrelation small making the variance of the queue or delay constant most of the time. The shifts given to predicted feedback signal should reduce the variance. Alternative interpretation is that the higher time shifts are equivalent to giving higher order feedback.

In a normal scenario, for RED, the RTT increases quickly with load. However the reverse happens with the proposed method. This is possible again with shifts. It is reflected in the simulation results. Figure 1 and figure 2 show the reduction in the delay with increase in the load. The simulation has been carried out in MATLAB version 6.

40 FTP sources that exist as background traffic and 20 HTTP sources that start at t=0 and go off at t=70 are considered. The transient response gets advanced with increase in order of shift. After some time the average delay again starts increasing. However, in any case it will be less than the delay without prediction.

The RTT may be written as $(Q/C)+rt_o$, rt_o being the propagation delay and C being the output data rate that is by and large a constant unless the Q is empty(in which case output rate is the same as the input rate). It has two parts- a variable part and a fixed part with respect to the shift. The three signals-Q, p and RTT behave similarly with shift.

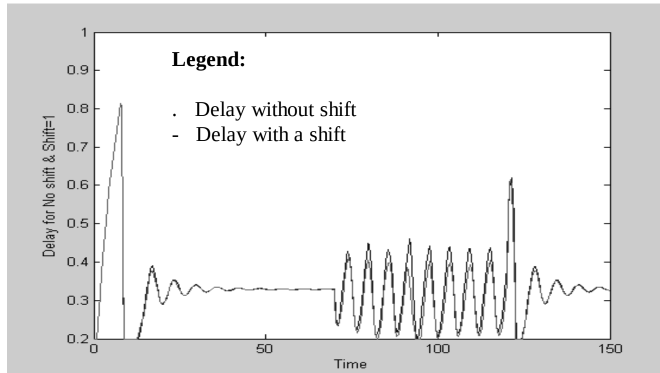

Fig 1 Delay for a shift=1. Load =20.

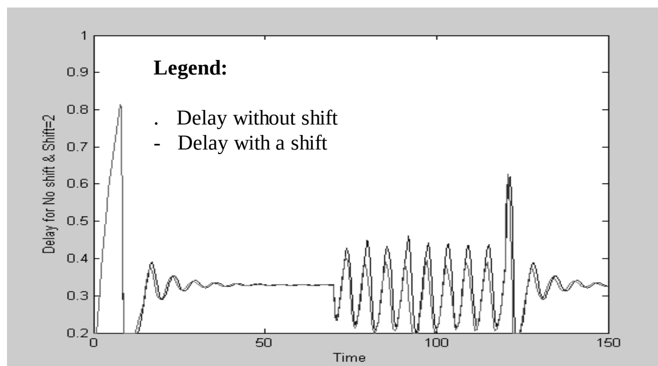

Fig 2. Delay for a shift=2. Load =20.

IV. CONCLUSION

Packet roundtrip time plays a significant role in dictating the performance and quality of service of the interactive applications in a distributed system. The two components of RTT –forward data packet delay and the feedback congestion notification delay are to be controlled separately. A controller is required to shape this value with in the safe margins. The stability of this controller improves by using the predicted signal rather than the actual one for the congestion notification in the network. The quantum of improvement is linked to the amount of time shift provided to the feedback signal.

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