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RESEARCH ARTICLE

Analysis of Buffer Sizing in Core Routers and Investigating Its Impact on Flow of Files

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Abstract— Buffer sizing has received a lot of attention recently since it is becoming increasingly difficult to use large buffers in high speed routers. TCP dictate buffer size in the routers must be in the order of band width delay(C*RTT) Product. It can be scaled down to (C*RTT/Square root (N)) or O (1) with N long lived connections on the internet. In this paper, we re-examine the buffer-size requirements of core routers when flows arrive and depart. We are arriving at two insights. First, when the core to access speed ratio is large O (1) buffer size is efficient in a network. Second, the two parameters buffer sizes and number of flows in the system should not be treated as individual quantities.

Key Terms: - Buffer sizing; core routers; core-to-access speed ratio

I. Introduction

High speed internet uses large buffers to store all the packets at the time of congestion which happens when the packet can be send out of the port as fast as they arrive. As derived by the rule of thumb the buffer size of the router is (C*RTT) (here RTT, is the average two delay between traffic senders and receivers and C, is the output link band width) for TCP type resources[8] We are going for high speed routers to save the packets at the time of congestion. But it not always a good choice because of the following reasons 1) Queuing delay 2) Complexity 3) Cost 4) Power Consumption. Buffer sizes can be scaled down to O (C*RTT/square root (N)) with N long lived connections on the network It can be further scaled down to O (log W). Here the traffic becomes smoother when the packets of individual one are spaced out when they are multiplexed.

We have to make an assumption that there are N long lived flows in the network. The number of long lived flows in the network was not allowed to vary with time. The performance metric that we used to study the impact of Buffer Sizing on end-user performance is the Average Flow Completion Time (AFCT). It is the commonly used metric when there are a fixed number of flows.

The main contributions are,

There is a vast disparity between Operating speeds of core router and access router (roughly three to four orders of magnitude). During flow arrivals and departure we show that core-router are rarely congested even at high loads of 98%.Since there is no congestion at core routers flows are largely limited by their access speeds. From this our results agree with [13] which states that core router should be scaled down to O (log (Ca*RTT)) where Ca is the capacity of access router.

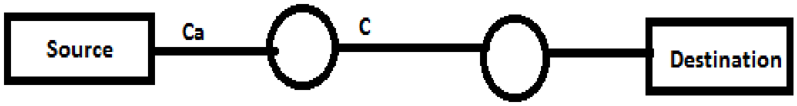

Figure.1 Active Flows

We study the impact of small buffers on a single congested link when access limitations are absent. In this system very few active flows are present at even high loads. The fact is that TCP approximates Processor sharing when file sizes are large [4].For example even at 90% loading the probability that more than 40 flows are active is 0.004. Scaling down the buffer sizes degrades the overall performances; hence this idea does network here.

A key feature of our model is that it captures the dependence between core buffer size and the number of flows in the network. The paper [5] contains new section on modelling networks where all the flows are small in size relative to the capacity of the link.

In paper [6] it was shown that core routers without access speed limitations need O(C*RTT) for a high link utilization. But with access speed limitations small buffers are efficient to maintain the link utilization.

II. Routers in Access-Limited Networks

In this module we will study the networks where the core router speed is several orders of magnitude than the access router speed. Thus in access-limited networks core routers are less congested i.e. number of packets dropped in core router is less than number of packets dropped in access router. Buffer size requirements are derived for this network with fixed number of flows to achieve high link utilization. We model the packet arrival and departure using Poisson process. Since core routers are less congested buffer size of core router does not effect on AFCT of the flows, thus small buffers are sufficient.

Example: Let the core router access the network via access router whose capacity is about 2Mb/S. Let the packet size be 1000B and RTT=50ms. The Band width delay product C*RTT=625 packets. Consider N=60. The amount of buffering to achieve high link utilization is given in (Fig 3). The loss probability at the core router is not more than 0.01. The loss probability is shown as a function of the core-router buffer size for various values of core-router link utilization. This is shown in (Fig 2). Even at 95% efficiency we require a buffer size not more than 40 packets at the core router. Thus it states that even at high link utilization small buffers are sufficient.

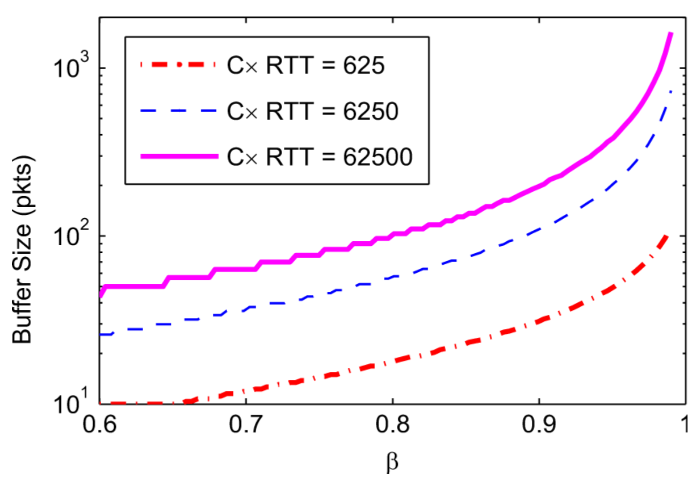

Figure.2 Amount of Buffering required to maintain the target

III. Routers in Unlimited Access-Networks

In this section we will study the impact of small buffers in the network when there are no access speed limitations. It means that each flow in a network can use the large fraction of capacity of the link. However small buffers are efficient for an un-congested network, we have to study the impact of small buffers in a highly congested network.

In earlier model of access limited networks, the system is designed such that throughput of TCP was roughly equal to access speed and thus the impact of RTT on TCP throughput was irrelevant. Since we were considering a network with unlimited access capacity the queuing delay at the core routers affects the overall throughput. There is no longer an assumption that core routers are less congested. We here split RTT in to Propagation delay and Queuing delay. We have to model the packet arrival process using a stochastic process with a larger inter arrival time variance than a Poisson process. We use a diffusion approximation to study the resulting queuing Process. We calculate AFCT as a function of buffer size at various loads. At 80% load AFCT increases by an order of magnitude when small buffers are used.

Thus, we conclude that whenever core routers are severely congested, it is not possible to use small buffers at the routers. In fact, we require O(C*RTT) buffers in order to maintain good performance to the end-users.

IV. SHORT FLOWS

The first two models explain the impact of flow arrivals and departures by considering the long flows. We here will consider the scenarios where all the file sizes are relatively short when compared to core router speeds. We study the model in two steps.

A) Loss probability as a function of Buffer Size

Consider all the flows are relatively short when compared to the Router capacity. Let us assume that all the flows are always in slow start phase to get a conservative estimate on buffer size. In the Slow-start phase, the window size is doubled when ack packet is received. The file transfer will be completed in RTT if no packet loss occurs. At core router large number of such ack packets are multiplexed.

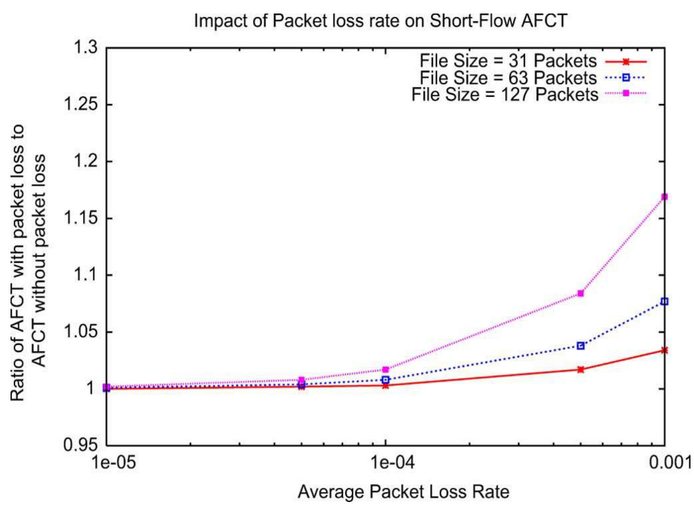

Figure.3 Average packet loss rate

B) Impact of Buffer Size on Short Flow AFCT

Packet losses cause short flows to terminate slow-start and start congestion-avoidance phase. This increases the flow completion times significantly. Thus the impact of packet loss on flow completion times is evaluated. The graph (fig 3) plots the AFCT for short flows under various packet loss rates and flow sizes. Consider the flow consists of 127 packets each of size 1KB. The graph demonstrates even at the packet loss of 0.01%, the performance degradation is 17% for 127 packets. This is not a worst scenario. The buffer size needed will be approximately 1500 packets.

V. SIMULATION RESULTS

This module tests the accuracy of various models discussed in previous modules.

A) Access-Limited Networks with Long Flows

In this simulation we study the effect of buffer sizing where access-limited capacity is very small when compared to core router capacity. Consider a dumb bell shaped network topology. File transfer requests arrive according to Poisson process. These flows access the network via access routers whose capacity is varied between 2 to 10 Mbps, then transmit the data. The core-router capacity is varied between 100 to 500 Mbps. The two-way propagation delay is uniformly distributed between 40-60 ms. We set the packet size to 1000B. It has been observed that Internet traffic is heavy- tailed (see for example, [1], [2], and [7]). A bounded Pareto (b.p.) distribution can be used to capture the heavy tailed property of the Internet traffic [10]. The result of the simulation predicts that the core router will experience very little congestion when the access speeds are small. Furthermore, even when the external load is 80%, there is little degradation in throughput with small buffers.

B) Buffer Sizing for long flows

We study the scenario in which the access routers do not limit the transmission rate of the TCP. Consider the access speed to 30 Mbps. Due to the window control flow mechanism, any TCP connection cannot transmit more than 64 packets. The simulations results predict when small buffers are used in such networks degrade the performance significantly. When the system load is 0.8, the AFCT can be decreased nearly 85% by increasing the buffer size from 20 to 1000 packets. Similarly, as seen in the simulations, the average throughput increases by about 400% with the increase in the buffer size.

C) Buffer Sizing for Short Flows

We consider a single link accessed by many flows. Flows arrive according to the Poisson process. Consider mean file size to be 64KB and RTT be 200ms. The simulation result showing AFCT as a function of buffer size. The AFCT does not change significantly when the buffer size is varied from 500 KB to 8 MB. This result is independent of both the link capacity and the RTT. A buffer size equal to 0.5% of the band-width delay product is sufficient to ensure optimal AFCT.

VI. CONCLUSION

In this paper we have developed simple models to provide buffer sizing guidelines for high speed routers. The key factor is the core-to- access-speed ratio which determines the buffer sizing guidelines. This parameter along with the buffer size determines the number of flows in the network. Thus the fundamental fact which is conveyed is that number of flows and buffer size should not be treated as independent quantities. Even at 98% utilization, the core router may contribute very little to the overall packet loss probability seen by a source if the core-to-access-speed ratio is large.

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