Performance Modeling of Differentiated Service Network with a Token Bucket Marker

Hongjun Su
Department of Electrical & Computer Engineering
University of Dayton, Dayton, OH 45469-0226. (suhongju@flyernet.udayton.edu)

Mohammed Atiquzzaman
School of Computer Science
University of Oklahoma, Norman, OK 73019-6151. (atiq@ou.edu)

1 Introduction

The current Internet does not provide Quality of Service (QoS) to real-time applications such as audio and video. Differentiated Service (DiffServ)network [1] is currently being developed by IETF to add QoS to the current Internet without fundamental change to the current Internet protocol. Diffserv distinguishes between edge and core networks/routers. DiffServ pushes all complex tasks, such as administration control, traffic classify, traffic monitor, traffic marking etc., to edge network where per flow based schemes can be used without any scalability problem. Traffic passing through the edge network is classified into different service classes and marked with different dropping priorities (such as In/Out packets). Core routers implement active queue management schemes and provide service differentiation to the traffic according to preassigned service classes and dropping priorities carried in the packet header.

Recent research results have shown that the service goals promised by the DiffServ AF PHB are not likely to be achieved in many situations [2, 3, 4]. This is due to TCP's congestion control algorithm which results in a saw-tooth like data transmission pattern resulting in unfairness among connections. Subscribers with larger profiles will not be likely to achieve their desired rate [2, 3, 4]. To determine the performance of DiffServ, it is important to develop mathematical models to help us understand the behavior of the DiffServ network under TCP congestion control algorithms. The authors in [3] model only the TCP congestion avoidance phase, while [4] considers both TCP congestion avoidance and retransmission caused by time-out. Both of them include the effect of Committed Information Rate (*CIR*) in their model. They achieved similar results and conclusions. However, none of above studies [4, 3] considered the effect of the marker setting on the performance of DiffServ.

2 Proposed Model

In this work, we develop a simple but effective model which incorporates the effect of both Committed Information Rate (*CIR*) and the maximum allowed burst size (B), the two parameters required for a Token Bucket Marker in a DiffServ edge router. In contrast to previous studies, our proposed model considers the marker at the edge network, the queue in the core network, and the number of flows in a traffic aggregate.

Like previous researchers, we assume that loss in the DiffServ network is low to middle, and is periodic. It is well known that under this assumption, the TCP's congestion control window follows a perfect saw-tooth like pattern. Although the assumption maybe not true in the real world, simulation results shows good accordance, and the resulting performance model is simple and intuitive. The model will help us to determine the effect of the token bucket parameters on the performance of DiffServ. We also assume that all TCP connections from a source goes to the same destination (i.e., all connections have the same Round Trip Time RTT) and Maximum Segment Size (MSS). Under this assumption, all flows from one source will share the network resource (such as service profile, Token Bucket, etc.) fairly and will suffer the same loss. Different sources can however have different number of flows with different RTT and MSS settings. The achieved bandwidth (BW) under the perfect TCP response assumptions [3, 5] can be shown to be:

$$BW = \sum_{i=1}^{n} \frac{MSS * c}{RTT_i * \sqrt{p_i}} = \frac{n * MSS * c}{RTT * \sqrt{p}} \tag{1}$$

where n is the number of flows from a source, and p is the probability of packet loss in the network.

The *objective of this paper* is to determine the relationship between packet loss probability and the Token Bucket parameters. By examining the relationship between TCP's congestion window change and Token Bucket buffer parameters, we can determine the In packet (P_{MIn}) and Out packet (P_{MOut}) marking probabilities which are functions of *CIR* and Token Bucket Size *B*. The total packets loss probability in the core network can then be expressed as:

$$p = P_{MIn} * p_i + P_{MOut} * p_o = p_i + P_{MOut} * (p_o - p_i) \tag{2}$$

where p_i and p_o are loss probabilities in the core network for In and Out packets respectively. p_i and p_o can be measured by many network tools.

Substituting Eq. (2) into Eq. (1), we can determine the relationship between the bandwidth and Token Bucket Marker.

$$BW = \frac{3}{4} * CIR + \frac{3}{4} * \sqrt{2 * \left[\frac{n * MSS * B}{RTT^2} + (\frac{n * MSS}{RTT * \sqrt{p_o}})^2\right]} \tag{3}$$

The above equation is derived under the condition of nearly provisioned network (i.e., the network utilization is in the range of about 50% − 80%) and with a relative small Token Bucket setting. We feel that most of the well engineered network should operated in this region. Note that we also assumed the packet dropping probability of In packets to be zero. This is true for a network operated in this region. Simulations also prove that the loss of In packets is very low under for this nearly provisioned network.

From Eq. (3) we can easily see that the excess bandwidth is shared among different flows. Moreover, for all sources having the same settings, sources with more flows will grab more of the excess bandwidth. Eq. (3) also shows that only 3/4 of the source's desired service rate is guaranteed; the rest depends on the parameter settings. So, there is a possibility that some sources with small number of flows will not be able to to achieve their desired bandwidth, while sources with a lot of flows will get more bandwidth than their subscription. This causes unfairness problem. To verify the validation of our model, we used NS-2 to simulate a simple DiffServ network using Token Bucket Marker and RED with In/Out (RIO) router. Simulation results confirmed the accuracy of our model under different network conditions [6]. For nearly provisioned network condition, the results from simulation and model are almost same.

3 Results and Conclusion

From our simulation and model analysis, we find that for a DiffServ network with a token bucket marker, the performance is flow based instead of aggregated based. For a largely over provisioned network, all aggregates can achieve their profiles, however, the excess bandwidth is shared among flows. For a near provisioned network, the aggregates with more flows in it will more likely to achieve their desired bandwidth. For aggregates with same flows in them, a small service subscriber will more likely to achieve their service goal. For a under provisioned network, the differentiation among different subscribers is totally lost, the network is reduced to current Internet, the performance is totally flow based. This flow based phenomena will cause fairness problem for different service subscribers. Form the simulations and model, we also find that there is a tradeoff between the token bucket size (B) and the probability of packet dropping. Under some threshold, increasing token bucket size B will increase the achieved bandwidth, however, the dropping probability of packet dropping at the core network also increase. This is due to larger B setting introducing larger traffic burst.

Our simple but accurate performance model can help us to fully understand the behavior of TCP in the DiffServ network. Observed that DiffServ network with a token bucket marker has the flow based phenomena, we are current working on a new marker proposal that will let to a more aggregate originated DiffServ network. We hope it can solve, at least alleviate, the flow based unfairness problem in the DiffServ network.

References

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Mohammed Atiquzzaman
School of Computer Science
University of Oklahoma, Norman, OK 73019-6151
Email: atiq@ou.edu

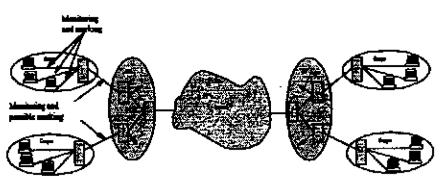
Hongjun Su
Department of Electrical & Computer Engineering
University of Dayton, Dayton, OH 45469.
Email: suhongju@flyernet.udayton.edu

Quality of Service in Internet

- Present day Internet does not offer QoS to real time applications.
- Previous approaches to QoS in Internet
  - ATM: did not reach the desktop
  - Integrated Services: scalability problem
- Differentiated Service (DS) network is being developed to provide a scalable solution to QoS in Internet

DiffServ Network Architecture

- Edge Network
  - Traffic classification, monitoring (Token Bucket), marking, etc.
- Core Network
  - Queue Management, scheduling, service differnetiation, etc.



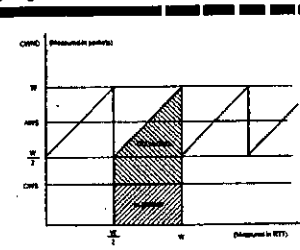
Objectives of this study

- Problems with DiffServ
  - QoS with DiffServ may not be achieved
  - Unfairness: connections with larger profiles may not be able to achieve their target bandwidth
- Objectives
  - Develop a model to study the impact of the Token Bucket parameters on the QoS obtained by TCP connections.
  - Model tested by comparison with simulation results from *ns*.
- Contributions of this study
  - Our proposed model considers marker at the edge network, queue in the core network, and number of flows in a traffic aggregate; previous studies considered them separately.

Modeling Assumptions

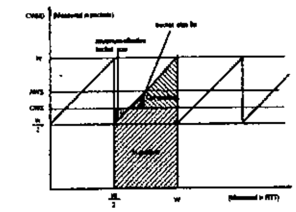
- TCP congestion window obeys a prefect saw-tooth like pattern.
- The loss at the network is middle and random.
- All flows in an aggregate fairly share its achieved bandwidth.
- All flows in an aggregate share the token bucket fairly.
- Packets in an aggregate have the same round trip time (RTT).

Largely Over Provisioned Network



$$BW = \sum_{i=1}^{n} \frac{MSS * c}{RTT_i * \sqrt{p_i}} = \frac{n * MSS * c}{RTT * \sqrt{p}}$$

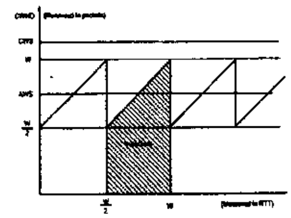
Nearly Provisioned Network



$$BW = \frac{3}{4} * CIR + \frac{3}{4} * \sqrt{2 * \left[\frac{n * MSS * B}{RTT^2} + \left(\frac{n * MSS}{RTT * \sqrt{p_0}} \right)^2 \right]}$$

Mohammad Atiquzzaman, University of Oklahoma,
Email: atiq@ieee.org

Largely Under Provisioned Network

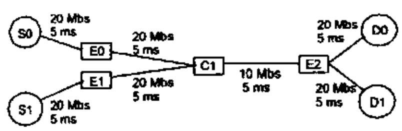


$$BW = \frac{n * MSS * c}{RTT * \sqrt{p_i}}$$

Mohammad Atiquzzaman, University of Oklahoma,
Email: atiq@ieee.org

Simulation Topology

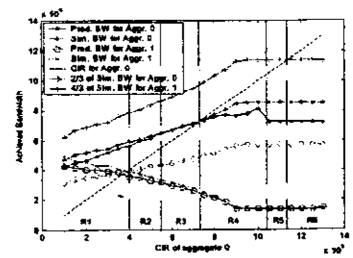
- NS-2 Network Simulator
- Use Token Bucket Marker at Edge
  - B=30,000 byte
- Use RIO at Core
  - {20,40,0.1} for Out profile packets
  - {40,80,0.02} for In profile packets



Mohammad Atiquzzaman, University of Oklahoma,
Email: atiq@ieee.org

Achieved Bandwidth Versus CIR

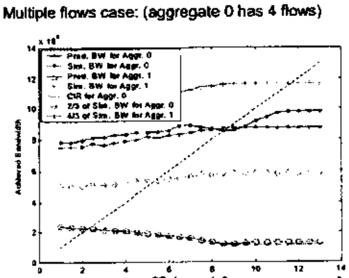
Single flow case



Mohammad Atiquzzaman, University of Oklahoma,
Email: atiq@ieee.org

Achieved Bandwidth Versus CIR

Multiple flows case: (aggregate 0 has 4 flows)



Mohammad Atiquzzaman, University of Oklahoma,
Email: atiq@ieee.org

Conclusion

- The achieved bandwidth of DiffServ with a token bucket marker is flow based rather than aggregate based.
- For over provisioned network, excess bandwidth is shared among flows.
  - Aggregates with more flows will receive more bandwidth.
  - For aggregates with same flows, the small profile aggregates will more likely to achieve their service profile.
- Further Information:
  - Mohammed Atiquzzaman, Web: http://www.cs.ou.edu/~atiq/, Email: atiq@ou.edu, Tel: (405) 325 8077, Fax: (405) 325 4044.
  - Hongjun Su, Email: SuHongJu@flyernet.udayton.edu, Tel: (937) 229 4529.

Mohammad Atiquzzaman, University of Oklahoma,
Email: atiq@ieee.org