Inter-Domain Admission Control (IDAC) Algorithms for End-to-End IP QoS

Joyce. Y. Wu
EE Eng. Dept. University College London, London WC1E 7JE, Email: j.wu@ee.ucl.ac.uk

Abstract: The inter-domain congestion is the bottleneck to provide end-to-end Quality-of-Service (QoS) for IP networks. Congested links will result in delay and packet loss. Admission control can be used to reduce network congestion and to increase bandwidth utilisation; therefore, it is an important mechanism for IP network QoS provisioning. In this paper, we will investigate the concept of effective bandwidth, develop and discuss three Inter-Domain Admission Control (IDAC) algorithms for IP networks.

1. Introduction

Today's Internet only provides best-effort service, such as file transfer and email, there is no QoS guarantee. Due to the explosive growth of Internet users, the Internet became the ubiquitous communications infrastructure, which will be used to carry QoS sensitive traffic such as voice and video. These real time services require very strict QoS in terms of delay, packet loss and jitter. In order to guarantee required QoS over the Internet, the Internet Engineering Task Force (IETF) working groups have developed the QoS framework InterServ and DiffServ to address IP QoS.

In order to implement these mechanisms and to meet the user Service Level Agreements (SLAs), firstly, we have to decide how the bandwidth is provisioned and allocated to the QoS guaranteed traffic flows to meet the QoS requirements. This is referred to *bandwidth allocation mechanism*. In IP network, in order to meet the QoS requirements, the bandwidth could be provisioned either **deterministically** or **statistically.** The deterministic bandwidth allocation approach requires that the peak rate of the connection be reserved for a particular source. All packets from a flow will satisfy given worst-case end-to-end delay bounds and no packets are dropped in the network. This approach provides the highest level of QoS guarantee; however, it wastes the bandwidth significantly since it is based on the worst-case scenario. Therefore, this is the most expensive approach to offer QoS, and will result in inefficient bandwidth utilisation. On the other hand, the statistical bandwidth allocation approach is based on the **statistical knowledge** about the users and the system and makes use of statistical multiplexing gain. With this approach, the required bandwidth can be reduced substantially (it depends on how bursty the traffic is) while still guarantees acceptable QoS. Secondly, in order to meet the users QoS requirements, we have to avoid overloading the network, and prevent the network from congesting, while try to maximize the usage of the network resources. So we need to have a mechanism to determine whether a traffic flow should be admitted or rejected according to the SLA and the network condition, this process is called admission control. Admission control can be based on network measurement [3] or network polices [1] to manage the traffic flows.

In literature there are some different admission control mechanisms [1-4]. However, they are all focused on the customer-to-ISP level, i.e., they are all intra-domain admission control schemes. No work has been done on the transit level inter-AS level so far. In this paper, we will develop three IDAC algorithms for end-to-end IP QoS and compare their performances.

The rest of the paper is organised as follows. Section 2 discusses the need of admission control. Section 3 presents three IDAC algorithms. Section 4 is the performance evaluation for the IDAC algorithms regarding bandwidth utilization and unserved number of requests. Concluding remarks and further work are given in section 5.

2. The Need of Inter-Domain Admission Control

Why do we need inter-AS admission control schemes on the ISP-to-ISP transit level? The idea is that ISPs/ASs need to agree on how much QoS-based traffic they will exchange. When a transit ISP has several customer ISPs, all of whom have agreed traffic quantities to forward through the transit domain according to SLAs, so how the downstream bandwidth should be allocated? If we use deterministic approach, the bandwidth required to meet the QoS will be significant. If statistical multiplexing is employed, while there are no admission control schemes on the transit level, the potential congestion will be obvious. This is because the statistical multiplexing bandwidth allocation is based on the statistical knowledge, it assumes that the traffic is a random process and distributed over the network. In some cases, e.g., if all the stub domains' traffic flows are coming towards a single link on the transit domain, there may be congestion on this link even if each of the stub domains does not exceed its agreed capacity. In this situation, the static SLA can not provide any QoS guarantee. And also, the intra-domain admission control can not detect the congestion, since none of them exceeds its contracted capacity. The network congestion will result in packet loss and delay, and the overall QoS will be deteriorated. So in order to deliver end-to-end QoS, it requires management on the links between ASes. This will avoid the congestions on the links between ASes. So there is a clear need to have an admission control on the transit level to avoid the congestion.

We will look at this problem more closely from the model in the following.

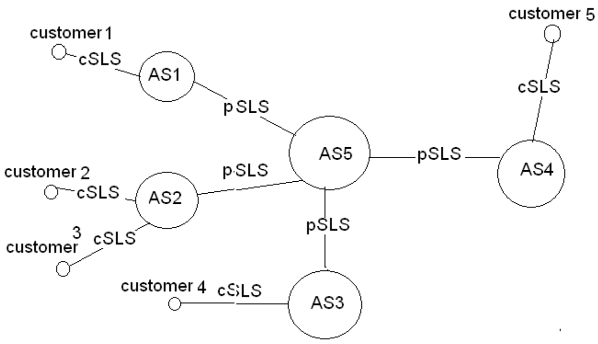

Fig. 1. Customer-ISP relationship model

In Figure 1, AS1, AS2, AS3 and AS4 are stub domains/ASes, AS5 is a transit domain. AS1, AS2, AS3 and AS4 need to have a service level agreement (SLA) with transit domain AS5 on how much QoS-based traffic they will exchange. For example, for links AS1-AS5, AS2-AS5 and AS3-AS5, if the down stream bandwidth is 10 units on each of them, for the link between AS5-AS4, how is the bandwidth allocated? As we said in section 1, in IP network, to meet the QoS requirements, the bandwidth could be provisioned either **deterministically or statistically.**

Bandwidth allocation schemes: The first option is to use deterministic approach. This can give hard guarantees, but it is inefficient and unscalable for large transit ISPs. This is because if the transit domain has a significant number of customer ISPs, the sum of the bandwidth could be a very large number. Hence, it is not scalable. Also, since the traffic is a random process, it is unlikely all the traffic will be working at the peak rate at all the time, so in most of the time, most of the link capacity will leave unutilized. It is very inefficient. The second option is to use statistical multiplexing. The second approach is more efficient in bandwidth utilisation, but congestion and QoS deterioration may occur if all tributaries generate full capacity traffic at the same time. In order to avoid congestions, admission control is needed. Therefore, the second approach with admission control is the best choice.

IDAC algorithms prevent the customer ISPs from increasing their transmission rate too fast or injecting large amount of traffic into the network. IDAC algorithms can also detect the customer ISPs' bad behaviour.

3. Inter-domain Admission Control (IDAC) Algorithms

In this section, we will develop three **IDAC** algorithms. Our **IDAC** algorithms should be the best trade-off between bandwidth utilisation and QoS deterioration. The more traffic is injected into the network, the higher utilisation of the network resources, but the more likely deterioration of the QoS of the traffic delivered by the network. The effective bandwidth is the parameter representing the trade-off between bandwidth utilisation and QoS deterioration. Effective bandwidth can be used to dimension link capacity. In the following, first, we will briefly discuss effective bandwidth concept, then we will present three IDAC algorithms.

3.1 Effective Bandwidth

Effective bandwidth is a value between the average and peak traffic rate on a particular link. The burstier the traffic is, the closer of the effective bandwidth is to its peak. There are a number of methods to approximate effective bandwidth, e.g., [5-6].

Additive property is an important characteristic of effective bandwidth, i.e., the sum of the effective bandwidths of two independent traffic flows equals the effective bandwidth of their superposition.
So, if we denote Y as bandwidth required for all the QoS traffic flows on the egress link, we can get Y as follows:

$$Y = \sum_{j=1}^{N} E_j(P_l) \qquad (1)$$

Where E_j is flow *j*'s effective bandwidth with loss probability P_l, *N* is the number of customer ISPs multiplexed flows, *Y* is the required effective bandwidth for *N* traffic streams.

3.2 Admission Control Algorithms

The admission control decision will be made by comparing the instantaneous load request with the current available bandwidth. The new request(s) will be accepted if and only if:

$$B_{req} + B_{used} \leq Y \qquad (2)$$

B_{req} is the requested bandwidth, and B_{used} is the currently used bandwidth. We have implemented three different IDAC algorithms: **(a)**. First come first served; **(b).** Serve the smallest bandwidth request first; **(c).** Serve the largest bandwidth request first. Their performances are discussed in section 4.

4. Performance Evaluations

Java 2 Standard Edition is the platform used to write simulation programs. The IDAC algorithms are implemented in a Java class called IDAC. A Link class is also developed. The Link class has peak, effective bandwidth, traffic, delay, and buffer size etc properties; it also has relevant methods to calculate effective bandwidth, to generate fixed or random traffic requests, and to set or get the data member of the class.

4.1 Network Scenarios

Suppose that the traffic of ten 155Mbps links will be forwarded to one large egress link, also suppose each 155Mbps link has a mean traffic rate of 50Mbps and an effective bandwidth of 65Mbps (between their mean value 50Mbps and peak rate 155Mbps), Each 155Mbps link is independent to each other, and traffic is randomly generated (with mean value of 50Mbps). Fig. 2 shows traffic profile of the egress link, whose traffic profile is similar to each of the ten 155Mbps links. According to additive characteristics of effective bandwidth, the egress link should reserve an effective bandwidth of 650Mbps to accommodate the injected traffic. Simulation shows, with this amount of effective bandwidth, in 10000 observed time instances, there are about 155 times that some bandwidth requests can not be served. This also means that, in about 98.5% times, all bandwidth requests will be served. When the sum of requested bandwidth is larger than 650Mbps, IDAC algorithms will decide which requests will be served according to the IDAC algorithms as discussed in section 3.2.

4.2 Performances of Three IDAC Algorithms

In this section, we will evaluate the performance of the three IDAC algorithms by comparing the bandwidth utilisation over various transmission rates. We also want to test the fairness of the IDAC algorithms. Throughout the experiments, we will use bandwidth utilisation and unserved number of requests as metrics. Fig. 3 and 4 show 9 time instances when the requested bandwidth is larger than 650Mbps. From Fig. 3 & 4, we can see that in terms of bandwidth utilization, LTF (Largest Traffic First) is the best, and it is much higher than STF (Smallest Traffic First), however, LTF also has the largest number of unserved requests, we can also see that in terms of number of unserved requests, STF is the best. FCFS (First Come First Served) is the quickest and the fairest among three algorithms. With STF, if the sum of requested traffic is constantly over 650Mbps, the largest bandwidth may not have the chance to be served, since priority will be given to smaller bandwidth requests. LTF also suffers from the similar problem. In addition, both LTF and STF need to sort the bandwidth request first, so, there may be a scalability problem with them as sorting may take some time. The optimal IDAC algorithm should serve as many requests as possible with the largest possible bandwidth utilization. It is clear that the time it takes to find the optimal schedule is longer than the decision time of any FCFS, STF and LTF.

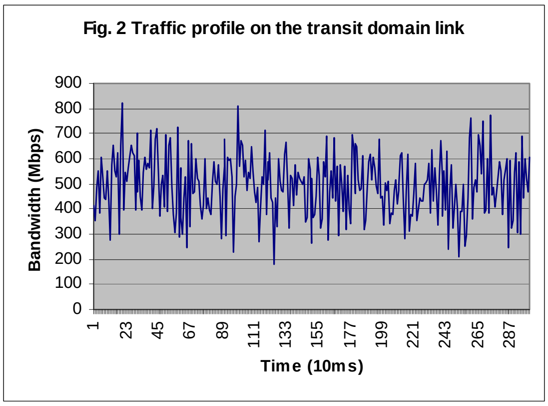

Fig. 2 Traffic profile on the transit domain link (effective bandwidth 650Mbps)

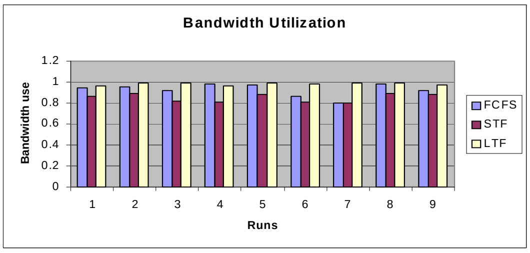

Fig. 3 Bandwidth utilization

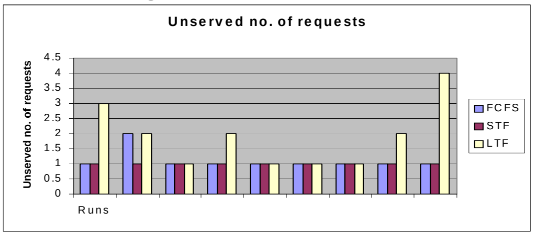

Fig. 4 Unserved number of bandwidth requests

The statistics of bandwidth utilisation and unserved number of bandwidth requests for three algorithms are summarised in Table 1. The statistics are obtained using 155 runs.

Table 1 Summary of performance

Algorithms	Bandwidth Utilisation (mean)	Bandwidth Utilisation (standard deviation)	Unserved no. of request (mean)	Unserved requested bandwidth (mean)
FCFS	0.929	0.0535	1.335	112.4
STF	0.862	0.0558	1.116	155.9
LTF	0.986	0.0132	2.219	75.2

5. Conclusions and Future Work

This paper shows that admission control can be used to achieve good bandwidth utilization and avoid network congestion. Three IDAC algorithms are developed and their performances are compared. LTF provides the best bandwidth utilization, STF delivers the minimum unserved bandwidth requests (therefore, it can satisfy as many customers as possible), FCFS is the quickest and fairest, in terms of bandwidth utilization, its performance is between STF and LTF. The optimal admission control algorithm should meet as many requests as possible while maximising bandwidth utilization. The further work will include the investigation of the optimal IDAC algorithm, and its scalability. How bandwidth request on each link can be best estimated/measured will also be studied.

Acknowledgement: The author would like to expresses her gratitude to her supervisor Prof. Chris Todd. She also thanks David Griffin and Jonas Griem for stimulating discussions. Thanks also go to EPSRC for providing funding for her study.

References:

[1] E. Mykoniati et al, "Admission Control for Providing QoS in IP DiffServ Networks: the TEQUILA Approach", IEEE Communications, special issue on QoS Advances: the European IST Premium IP Projects, Vol. 41, No. 1, pp. 38-44, IEEE, January 2003

[2] E. knightly and N. Shroff, "Admission control for Statistic QoS: theory and practice," *IEEE Network*, Vol. 13, No. 2 Mar 1999, pp. 20-29

[3] S. Jamin, P. Danzig, S. Shenker, and L. Zhang, "A Measurement-Based Admission Control Algorithm for Integrated Services Packet Networks," *IEEE/ACM Trans. Networking*, vol. 5, pp. 56-76, Feb. 1997

[4] J.Qin, E Knightly, "Measurement-based admission control with aggregate traffic envelopes," *IEEE/ACM Trans. Networking*, April 2001.

[5]C. Courcoubetis and R. Weber, "Effective bandwidths for Stationary Sources," *Probability in Eng. and Info. Sci.*,Vol. 9, No 2, 1995, pp. 285-94.

[6] R. Guerin, H. Ahmadi, and M. Naghshineh, "Equivalent Capacity and Its Applications to Bandwidth Allocation in High-Speed Networks," IEEE JSAC, Vol. 9, Sept. 1991, pp. 968-81.