On Shaping and Handling VBR traffic in a Diffserv domain

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ABSTRACT

One of the causes of congestion in computer networks is the inherent burstiness of network traffic. Traffic includes unpredictable file or web page transfers as well as variable rate media streams. Traffic shaping means to smooth the traffic as a function of time. Shaping and congestion control is very important especially in cases where Variable Bit Rate (VBR) traffic streams are passing through the network.

Many different schemes to address this issue have been proposed. The target of such schemes is to maximize the amount of the traffic that can be supported while maintaining the required quality of service and to reduce the amount of congestion in the network.

This paper investigates the effect of using various shapers on VBR streams on the overall diffserv domain. Simulations are conducted using NS-2 simulation platform applying VBR streams that are shaped using TB and dual-TB shapers followed by srTCM, trTcm and TSWTCM markers. The shaped traffic is applied across a diffserv domain under normal traffic conditions to determine the effect on the level of congestion due to a particular shaper use. Generally in TB shapers, changing the bucket size affects the burstiness of the traffic while changing the queue length affects the delay of the traffic. Applying different traffic parameters (w.r.t. applications) and connecting them to various shapers provides a suitable burst size and delay for each application and allows different coloring of packets. The most suitable shapers generate maximum number of green packets thus reducing the potential of congestion in the network.

INTRODUCTION

One of the causes of congestion in computer networks is the inherent burstiness of traffic. Traffic shaping means to smooth, or otherwise alter, the offered traffic as a function of time, thus reducing the peaks that cause congestion. Smooth traffic is easier to deal with as compared to bursty traffic. A subnet may be able to handle on the average 10 million packets in an hour, but it probably can't handle 10 million packets in one minute and nothing for the next 59 minutes [1]. Flow specification agreement with an ISP is closely related to traffic shaping. A flow specification describes what kind of traffic will be sent into the network and what QoS (quality of service) is expected from it. Some of the QoS parameters are [1,2,3]:

- Loss sensitivity (number of lost bytes per unit of time)
- Loss interval (the unit of time for calculating loss)
- Burst loss sensitivity (how long of a loss burst can be tolerated)
- Minimum delay (The allowed delay ignored by the application)
- Maximum delay variation (the variance or jitter in the inter-packet delay)
- Quality of guarantee (how important the flow spec is to the application)

A Differentiated Services (diffserv) domain at its edge may control the amount of Assured Forward (AF) traffic that enters or exits the domain at various levels of drop precedence. Such traffic conditioning may include traffic shaping, discarding packets, increasing or decreasing the drop precedence of packets and reassigning of packets to another AF class. However, the traffic conditioning actions must not cause reordering of packets of the same microflow.

The primary reasons to use traffic shaping are to control access to available bandwidth, to ensure conformance to policies and to regulate the flow of traffic in order to avoid congestion. Also traffic shaping helps prevent packet loss making it critically important for real time traffic such as audio and video [1]. In this paper, we study the effect of shaping and marking on VBR traffic that passes through a diffserv domain. The remaining paper is divided into three sections. In the next section, we summarize various shaping and marking schemes that have been in use and some schemes that have evolved recently. In section 3, the characteristics of time-sensitive traffic are discussed and in section 4 the simulation setup and results are discussed.

TRAFFIC SHAPING AND MARKING SCHEMES

Bursty traffic has been a cause of congestion and packet loss in the networks. One of the earliest traffic policing and shaping schemes is known as the leaky bucket that was standardized by the ATM forum. Later variants like token bucket were developed to allow bursts within certain limits to pass through. Recently a number of traffic shaping and marking schemes have been proposed and most of them build on leaky and token buckets. We summarize traffic shaping and marking schemes below:

Leaky Bucket

Leaky bucket was proposed by Turner in 1986 to regulate the traffic from a source. It can be used as a policing device with a counter and it can be upgraded to a shaper with the addition of a buffer. When used as a shaper, a source in the network may contain an interface with a leaky bucket, i.e. a finite internal queue. All the packets to be transmitted by the host are included in the queue. At a given time, the queue may be empty, partially filled or full. When the queue becomes full, the newly arriving packets are discarded. The buffer may drain onto the subnet either by some number of packets per unit time or by some number of bytes per unit time (helpful if packets vary greatly in size). Simply we can say that it is a buffer that converts an unregulated, bursty traffic flow into a regulated, smooth, predictable flow. The buffer is inserted between a traffic source and the subnet and it acts like a single server queue with a finite queue length. [2,3].

Token Bucket

The leaky bucket shaper enforces a rigid output pattern at the average rate, no matter how bursty the traffic is. It eliminates the burstiness in the input and produces a smooth output. For many applications, it is better to allow output to speed up somewhat when a large burst arrives, so a variant of leaky bucket was developed. This variant is the token bucket. Instead of having fixed output rate regardless of variations in the traffic rate, the bucket is filled with tokens at a certain rate. A packet must grab and destroy a token to leave the bucket. If there are not enough tokens available, packets are not discarded rather they wait for an available token. If a burst arrives, it is allowed to pass through if enough tokens have accumulated in TB. Therefore the amount of burst allowed would be proportional to the elapsed time before the burst. This scheme is a compromise between controlling congestion and fulfilling source needs. [2, 3, 5].

Single-rate three-color marker (srTCM)

As described in [6], the Single-Rate Three-Color Marker (srTCM) meters an IP packet stream and marks its packets green, yellow, or red before admitting them in a diffserv domain. Marking is based on a Committed Information Rate (CIR) and two associated burst sizes, a Committed Burst Size (CBS) and an Excess Burst Size (EBS). A packet is marked green if it doesn't exceed the CBS, yellow if it does exceed the CBS, but not the EBS, and red otherwise. The srTCM is useful, for example, for ingress policing of a service. In such a policing scheme, only the length, not the peak rate, of the burst determines service eligibility. The meter can operate in color blind mode in which it assumes that the packet stream is uncolored, or in color aware mode in which the meter assumes that the packets have already been colored by some previous entity. The color is coded in the DS field of the packet in the PHB specified manner [7].

The behavior of the meter is specified in terms of its mode and two token buckets, which both share the common rate CIR. After the meter the marker should reflects the metering result by setting the DS field of the packet to a particular codepoint. In case of AF PHB, the color can be coded as the drop precedence of the packet [6].

Two-rate Three-Color Marker (trTCM)

The Two Rate Three Color Marker (trTCM) meters an IP packet stream and marks its packets either green, yellow, or red [8]. A packet is marked red if it exceeds the Peak Information Rate (PIR). Otherwise it is marked either yellow or green depending on whether it exceeds or doesn't exceed the Committed Information Rate (CIR). The trTCM is useful, for example, for ingress policing of a service, where a peak rate needs to be enforced separately from a committed rate. The difference in the metering behavior between srTCM and trTCM is that in the case of the trTCM, the token buckets operate with different rates. The token bucket labeled P has PIR (Peak Information Rate) and the token bucket C has CIR (Committed Information Rate). PBS (Peak Burst Size) is used as the size of the bucket P and CBS is used as the size of the bucket C. The token buckets P and C are initially (at time 0) full, i.e., the token count Tp (0) = PBS and the token count Tc (0) = CBS. Thereafter, the token count Tp is incremented by one PIR times per second up to PBS and the token count Tc is incremented by one CIR times per second up to CBS. [7]

Rate Adaptive Shaper

Rate Adaptive Shapers (RAS) can be used in combination with the single rate Three Color Markers (srTCM) and the two rate Three Color Marker (trTCM) [9]. The main objective of the shaper is to produce at its output a traffic that is less bursty than the input traffic, but the shaper avoids discarding packets in contrast with classical token bucket based shapers. The shaper itself consists of a tail-drop FIFO queue that is emptied at a variable rate. The shaping rate, i.e. the rate at which the queue is emptied, is a function of the occupancy of the FIFO queue. If the queue occupancy increases, the shaping rate will also increase in order to prevent loss and too large delays through the shaper. The shaping rate is also a function of the average rate of the incoming traffic. There are two types of rate adaptive shapers defined. The single rate rate-adaptive shaper (srRAS) will typically be used upstream of a srTCM while the two rates rate adaptive shaper (trRAS) will usually be used upstream of a trTCM.

Time Sliding window

The Time Sliding Window Three Color Marker (TSWTCM) is designed to mark packets of an IP traffic stream with red, yellow or green color [10]. The marking is performed based on the measured throughput of the traffic stream as compared against the Committed Target Rate (CTR) and the Peak Target Rate (PTR). The TSWTCM is designed to mark packets contributing to sending rate below or equal to the CTR With green color. Packets contributing to the portion of the rate between the CTR and PTR are marked yellow. Packets causing the rate to exceed PTR are marked with red color. The TSWTCM has been primarily designed for traffic streams that will be forwarded based on the AF PHB in core routers [10].

TIME SENSITIVE TRAFFIC CHARACTERISTICS

We can classify the network traffic into time sensitive traffic (hard real-time traffic, soft real team traffic) and best-effort Traffic. Hard real time traffic requires strict guarantees on delay and generally must be lossless (e.g. video conferencing). Soft real time also has delay bounds that need to be met, but these bounds can be slightly exceeded. Many soft-real time application can also tolerate a small amount of packet loss [12]. Best-effort or data traffic has no delay requirements but short average delay is desired. Data traffic requires lossless transmission but reliable delivery is usually handled in higher layer protocols. From bit rate point of view, we can classify the traffic into the following two categories:

Constant Bit Rate (CBR)

Some applications generate the traffic in fixed rate. An example is digital telephony where each conversation generates a constant bit rate equal to 64 Kbps.

Variable Bit Rate (VBR)

In practice, few applications generate CBR. Most of the applications generate variable bit rate streams. Such traffic is characterized by changing of the amount of information transmitted per unit time, i.e. the bit rate. The degree of variation in bit rate (i.e. burstiness) is different from one application to anther.

Some important characteristics of network traffic are burstiness and delay variations. *Burstiness* means having a more or less variable bit rate within a stream. The metrics to characterize the burstiness of a stream are:

- The peak within a short period of time
- The mean bit rate (MBR): the number of bits in the stream averaged over long period of time
- The peak bit rate (PBR): the maximum number of bits in the peak duration
- The ratio between the MBR and the PBR (burstiness ratio) [13]

One of the most interesting parameters to consider when supporting real time communication is the *delay jitter*. Delay is the time that the packets spend travelling from the transmitting end-system to receiving end-system. When a stream of packets traverses the network, each packet may experience different delay due to buffering in routers. This variation in delay is called jitter. Generally speaking the jitter increases when the traffic become burstier [14]. For traditional non-real-time applications, such as ftp and telnet, the packets received have to be put in order by the upper layer protocols. The delay jitter does not affect the application adversely as the application can wait random amount of time for the data to be put together. The variation in delay has little impact on these applications as the performance is largely dominated by average delay that the packets have experienced. Real time application such as audio and video however, have to faithfully recreate the original data stream at receiver by playing back the data after fixed delay offset from the original departure time. If some packets arrive before their turn, these packet may have to wait in the receiver's buffer in order for the packets with longer delay to arrive before their play out time. Delay jitter, in such applications, leads to unacceptable presentation quality. Therefore the upper bound on the delay jitter is much tighter. For voice and TV-quality video, the delay jitter must be less than 10 ms and delay jitter in compressed video must also be less than 1 ms [15]

In order to support real time traffic, we need a mechanism to prioritize data. This is done by classifying traffic into service classes based on expected traffic patterns. Each service class has a data priority level and associated guarantees. Applications that need real time guarantees first need to classify their traffic into one of the available service classes based on their expected traffic behavior before requesting a QoS guarantee from the network. Real Time Variable Bit Rate (RT-VBR) is for applications that generate a bursty traffic load requiring low delay. Sources indicate their peak traffic rate (in bytes/sec) and their maximum burst size (in bytes). The network gives a guarantee on the peak rate and tries to minimize packet delay and packet delay variation. The maximum burst size is defined as the maximum amount of traffic from a source within any 10ms interval. It may be explicitly set by a source, or implicitly set by the network to be equivalent to the traffic generated in any 10ms interval assuming a constant flow at the peak traffic rate. Bursts exceeding the maximum burst size or traffic beyond the peak rate contract may be dropped [16]

EXPERIMENTAL SETUP, RESULTS AND DISCUSSION

Traffic shaping using token buckets in various combinations depends upon two important parameters. The bucket size represents the maximum amount of burst that can be transmitted forward of the shaper into the network domain. Bursts arriving into nodes that already have traffic backed up would suffer packet loss and delay jitters. Therefore an optimum size of bucket will go a long way in ensuring minimum loss and jitter. The other parameter governing the behavior of the shaper is the token generation rate of the bucket. This rate is effectively the long term average rate produced by the shaper and it can be used by bandwidth management tools to efficiently allocate resources to flows.

When a burst of traffic exceeds preset limits, the network needs to identify the offending portion so that in case of congestion, the offending portion can be delayed or discarded. Usually CIR (Committed Information Rate) determines the part of the burst that is well behaved and is colored green. PIR (Peak Information Rate) determines occasional peaks that can be tolerated and colored yellow. Anything beyond PIR determines the portion that is in violation of the agreed limits and colored red. Given the CIR and PIR, it is not difficult to calculate the parts of a burst with green, yellow and red colors. Let us assume that the token bucket contains a buffer of size 'L' bytes and it can be filled in time 't_L' at the committed information rate (CIR) of 'L/ t_L' and in time 't_P' at the Peak information rate (PIR) of 'L/ t_P' where $t_L > t_P$. If a burst of size 'B' bytes arrives within a certain time period 't_B', it will occupy a certain area in the buffer. The CIR is 'L/ t_L' and if $B/ t_B <= L/ t_L$, it will pass through into the network without any delay in the shaper. Thus for any burst of an arbitrary size 'B', the green segment equals ($t_B * L/ t_L$). The yellow segment would be ($t_B *(L/ t_P - L/ t_L)$) and the remaining portion of the burst would be colored red.

In this work, we have used various shapers and meters/markers to determine their effect on VBR traffic. In order to get meaningful results; we set up the VBR traffic to flow through the diffserv domain with or without shaping. The VBR traffic is programmed to cause congestion in the network so that the effect of shaping can be determined. We are interested in knowing that how much of the traffic can make it to the egress without getting discarded and what is the average delay suffered by the VBR stream as congestion builds up in the network. The experimental setup is shown in Figure 1. A source node 'S' transmits VBR stream into the network through the ingress node 'e1' of a diffserv domain. This node connects through a bottleneck link to the core router 'c1'. The core router 'c1' connects to the egress node 'e2' that in turn connects to the destination node 'D'. All intermediate links inside the domain have dsRED scheduling and these are set at 1.5Mbps with the bottleneck link between e1 and c1 having a capacity of 0.8Mbps. The source and destination nodes are linked to the domain with 10Mbps capacity links having DropTail queues. The VBR stream has its packet size at 100, burst time 500ms, idle time 0ms and rate 1000kbps. Firstly, we use srTCM, trTCM, and TSWTCM schemes and we measure the number of packets generated, number of packets discarded and how many of them are colored green, yellow, and red. Then we use shapers in conjunction with these marking schemes and determine the overall effect on the traffic stream in terms of number of green packets and number of packets discarded. Shapers used consist of single and dual token buckets.

Table I shows the number of green, yellow and red packets generated when srTCM, trTCM and tswTCM schemes are used. It was determined that tswTCM generates the maximum number of green packets and the minimum number of red packets. However, it causes maximum packet loss. In terms of delay jitter, trTCM measures 4.76ms, srTCM measures 4.97ms and tswTCM gets 5.11ms again showing tswTCM's performance to be inferior to the other two schemes for the VBR stream considered.

Table II shows the results when a TB shaper is used in combination with each one of the marking schemes with the token generation rate at 900k, Bucket size 2500 bytes and queue length set at 10000 packets. The number of packets colored green increases for all schemes because the traffic has been shaped before it is marked. It is determined that tswTCM again generates maximum number of green packets and minimum number of red packets. However using tswTCM, we experience discarding of maximum number of packets. In terms of delay jitter, trTCM measures 4.24ms, srTCM measures 4.29ms and tswTCM gets 4.49ms again showing tswTCM's performance to be inferior to the other two schemes for the VBR stream considered.

For the dual token bucket shaper, we use two token buckets in series. The traffic parameters, the topology and the first token bucket parameters are the same. We add another token bucket with token rate 850k, bucket size 1600 bytes and queue length 6000 packets. We chose these parameter values in order to get a better performance as a shaped stream without any loss of packets is being applied to the second bucket. We run this experiment for srTCM, trTCM, and tswTCM. Table III summarizes the results with dual token bucket shaping. Overall, the number of green packets increases for all marking schemes and delay jitter reduces. The performance of tswTCM is better in terms of more green packets and less red packets. Also the traffic colored by srTCM experiences a delay jitter of 3.4ms, trTCM gets a jitter of 3.38ms and tswTCM has a delay jitter of 3.31ms recorded.

CONCLUSION

We have investigated the effect of shaping and marking on a VBR stream when it passes through a diffserv domain. The experimental setup under NS-2 simulation platform included a diffserv domain with marking and shaping applied to a VBR stream before it is admitted into the core of the domain. The results show that the lowest delay jitter and maximum number of green packets are obtained when the VBR stream is shaped with dual token bucket shaper and marked using tswTCM scheme. Such a setup would be useful in handling stored MPEG compressed video in a diffserv domain because an increase in delay jitter would adversely affect this stream. Future work will include implementing more shapers and measure their effect on the loss percentage and delay jitter. This work was carried out in the network research labs of Intl' Islamic University Malaysia and supported by a grant through IRPA, Malaysia.

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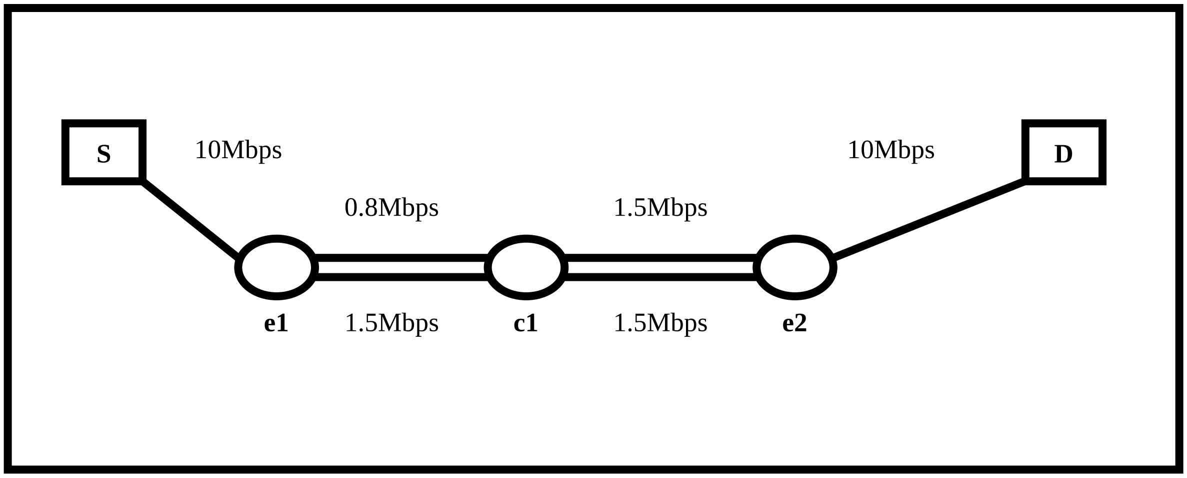

Figure 1: The Simulation Setup for VBR Stream Shaping and Marking Experiments

Table I: VBR Traffic Marking

	TOTAL	GREEN		YELLOW		RED	
		Total	Drop	Total	Drop	Total	Drop
srTCM	100000	10019	0	30	0	89951	20278
trTCM	100000	10019	0	10010	0	79971	20118
tswTCM	100000	10185	0	10357	3	79458	20307

Table II: VBR Traffic Marking After Shaping With TB-Shaper

	TOTAL	GREEN		YELLOW		RED	
		Total	Drop	Total	Drop	Total	Drop
srTCM	100000	11130	0	30	0	88840	11270
trTCM	100000	11130	0	11121	0	77749	11251
tswTCM	100000	11323	0	11423	0	77254	11340

Table III: VBR Traffic Marking After Shaping With Dual TB-Shaper

	TOTAL	GREEN		YELLOW		RED	
		Total	Drop	Total	Drop	Total	Drop
srTCM	100000	11784	0	30	0	88186	5969
trTCM	100000	11784	0	11774	0	76442	5944
tswTCM	100000	12018	0	12044	0	75938	5963