A STUDY OF VBR TRAFFIC TREATMENT IN A DIFFSERV DOMAIN

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Abstract

The unreliable network layer in the Internet has been a cause of concern for network managers and users. The unreliability manifests itself in terms of lost or delayed packets due to congestion or failure in the network. One of the causes of congestion is the inherent burstiness of network traffic. Traffic includes unpredictable large file or web page transfers as well as variable rate media streams. Traffic shaping means to smooth the traffic as a function of time. Many different schemes to perform shaping have been proposed. The target of such schemes is to increase 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 presents the results of an investigation into the effects of using various shapers and markers on VBR streams in a 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 unloaded and loaded traffic conditions to determine the effect on the level of congestion due to a particular scheme. 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.

1. Introduction

One of the causes of congestion in computer networks is the inherent burstiness of traffic. Traffic shaping means to smooth out the bursts of 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. Bursty traffic causes overflowing of router buffers and variable end-to-end delays. In order to avoid unmanageable bursts, an ISP (Internet Service Provider) may ask the customer to give a flow specification including the bounds on the rate of traffic entering the network. Flow specification agreement with an ISP is closely related to traffic marking and 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. Besides peak and average rates, flow specification may also include [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)

Diffserv (Differentiated services) model has been developed to make it easier for service providers to commit to and to fulfill such contracts with customers. Diffserv offers EF (expedited forwarding), AF (assured forwarding) and DF (default forwarding) behaviors to the traffic. A Diffserv domain at its edge may control the amount of 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 for using traffic shaping are to control access to available bandwidth and to regulate the flow of traffic in order to avoid congestion. Traffic shaping ensures conformance to policies and helps prevent packet loss making it important for real-time traffic such as audio and video [4]. In this paper, the effects of using various shaping and marking schemes on VBR traffic passing through a Diffserv domain are studied. Similar simulation based studies have been reported [5,6,7,8] in the literature, however their objectives are different. The targets of these studies include improving TCP completion time with TCP aware packet marking [5], comparing router mechanisms and marking schemes for bursty traffic [6], showing the effectiveness of Diffserv as a forwarding mechanism [7] and the effect of marking profiles and token bucket parameters on the offered service [8]. In our study, we analyze the results to determine suitable mix of shaping and marking schemes for VBR traffic passing as AF class in 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. Section 4 presents the simulation setup and discusses the results. We conclude by summarizing the contributions of this effort and point out some of the future extensions possible for this study.

2. 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:

2.1 Leaky and Token Buckets

Leaky bucket can be used as a policing device with a counter and as a shaper with the addition of a buffer. A source may maintain a finite queue of packets in the buffer for the network. When the queue becomes full, the newly arriving packets are discarded. Traffic is released into the subnet using a fixed rate thus converting an unregulated, bursty traffic flow into a regulated, smooth, predictable flow [2,3].

The leaky bucket shaper eliminates the burstiness in the input and produces a smooth output. For some applications, it is better to use token buckets so that limited bursts can pass through to the network. A token bucket is filled with tokens at a certain rate. A packet must grab and destroy tokens to leave the bucket. If there are not enough tokens available, packets wait in a queue. The size of burst allowed is proportional to the elapsed time before the burst. This scheme is a compromise between controlling congestion and fulfilling source needs [9].

2.2 Three-Color Markers

As described in [10], the Single-Rate Three-Color Marker (srTCM) meters an IP packet stream and marks its packets green, yellow, or red before admitting them to 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). The sizes are enforced through token buckets using CIR as filling rate. 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 where only the length, not the peak rate, of the burst determines service eligibility. The marker 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 [10,11].

The Two Rate Three Color Marker (trTCM) meters an IP packet stream and marks its packets red [12] if they exceed the Peak Information Rate (PIR). Otherwise they are marked yellow or green based on 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. In trTCM, the token buckets operate with different rates. The token bucket labeled P is filled with PIR (Peak Information Rate) until it reaches PBS (Peak Burst Size) and the token bucket C is filled with CIR (Committed Information Rate) until it hits the size of CBS(Committed Burst Size) [11]. When an arrived packet confirms to the CIR, tokens are removed from both buckets otherwise for yellow packets, tokens are only removed from P and for red packets, no tokens are removed.

The Time Sliding Window Three-Color Marker (tswTCM) [13] performs marking 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.

3 Time sensitive traffic characteristics

We can classify the network traffic into time sensitive traffic (hard real-time traffic, soft real time traffic) and best-effort Traffic. Hard real time traffic requires strict guarantees on delay (e.g. video conferencing). Soft real time traffic also has delay bounds that need to be met, but these bounds can be slightly exceeded and some packet loss can be tolerated [14]. 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.

Some applications generate the traffic in fixed rate. An example is digital telephony where each conversation generates a constant bit rate (CBR) equal to 64 Kbps. In practice, most of the applications generate variable bit rate (VBR) streams. VBR traffic is characterized by variations in the amount of information transmitted per unit time. Burstiness (degree of variation in bit rate) is different from one application to anther. Burstiness of a stream can be characterized with MBR (Mean Bit Rate) and PBR (Peak Bit Rate) and their ratio [15].

One of the most important parameters to consider in real time communications is the *delay jitter*. When a stream of packets traverses the network, each packet may experience different end-to-end delay due to buffering in routers. This variation in delay is called jitter. Generally speaking the jitter increases when the traffic become burstier [16]. For traditional non-real-time applications, such as ftp and telnet, the delay jitter does not have an adverse effect because the application can wait random amount of time for the data to be put together. Real-time applications such as audio and video however, have to recreate the original data stream at receiver by playing back the data after fixed delay offset from the original departure 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 [17].

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. 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 [18]

4 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. For example, in trTCM, 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 a burst of an arbitrary size 'B', it can be divided into three segments, Bg, By and Br

the green segment is given by:

$$\mathbf{Bg = (t_B *L/ t_L)} \qquad (1)$$

the yellow segment would be:

$$\mathbf{By = (t_B *(L/ t_P - L/ t_L))} \qquad (2)$$

and the remaining portion of the burst is red, given by:

$$Br = B - (Bg+By)$$

Substituting the values of Bg and By, we get

$$Br = B - ((t_B *L/ t_L) + (t_B *(L/ t_P - L/ t_L)$$

Simplifying,

$$\mathbf{Br = B - (t_B *(L/ t_P)} \qquad (3)$$

If the marking is accompanied with segmentation of packets based on these boundaries, a much better network behavior may result. However, segmentation has its own overhead and it has been eliminated in IPv6. Therefore, this scheme may have to be restricted to the current IPv4 networks.

The time sliding window marker (tswTCM) does not use token bucket. It is based on computation of average rate using a constant size of time window (w) added with elapsed time (t) for receiving the current burst. The metering and marking in tswTCM are related through the CTR (committed target rate) and MTR (maximum target rate). Thus for a burst of an arbitrary size 'B' received during 't' interval,

If B/CTR <= (w + t), then the burst is colored green,
Else if B/MTR <= (w + t), then the burst is colored yellow,
Else the burst is colored red.

In this work, we have used various shapers and meters/markers to determine their effect on VBR traffic. VBR traffic flows 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 and Figure 2. A source node transmits VBR stream into the network through the ingress router of a Diffserv domain. This node connects through a bottleneck link to the core router. The core router connects to the egress router that in turn connects to the destination host. All intermediate links inside the domain have dsRED (Diffserv Random Early Detection) [19] scheduling and these are set at 1.5Mbps with the bottleneck link between ingress and core having a capacity of 0.8Mbps. The dsRED can implement multiple physical RED queues along a single link and multiple virtual queues within a physical queue, with individual set of parameters for each virtual queue. 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 bytes, burst time 500ms, idle time 0ms and rate 1000kbps. This stream is generated using the on-off model with exponential distribution with mean packet size of 100 bytes and burst time of 500ms. 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. Later, single and dual token bucket shapers are used in conjunction with these marking schemes to determine the overall effect on the traffic stream in terms of number of green packets and number of packets discarded. A second stream is introduced that consists of CBR traffic and extensive measurements are conducted to find out the overall performance of the marking and shaping schemes. Using Nortel patch for diffserv and Nortel's scripts, we use the CIR as 100000, CBS as 2000 and EBS as 3000 whereas PIR is set at 200000 and PBS at 3000.

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 results in maximum packet loss. In terms of delay jitter, trTCM measures 4.76ms, srTCM measures 4.97ms and tswTCM gets 5.11ms with tswTCM slightly exceeding the other two schemes for the VBR stream considered.

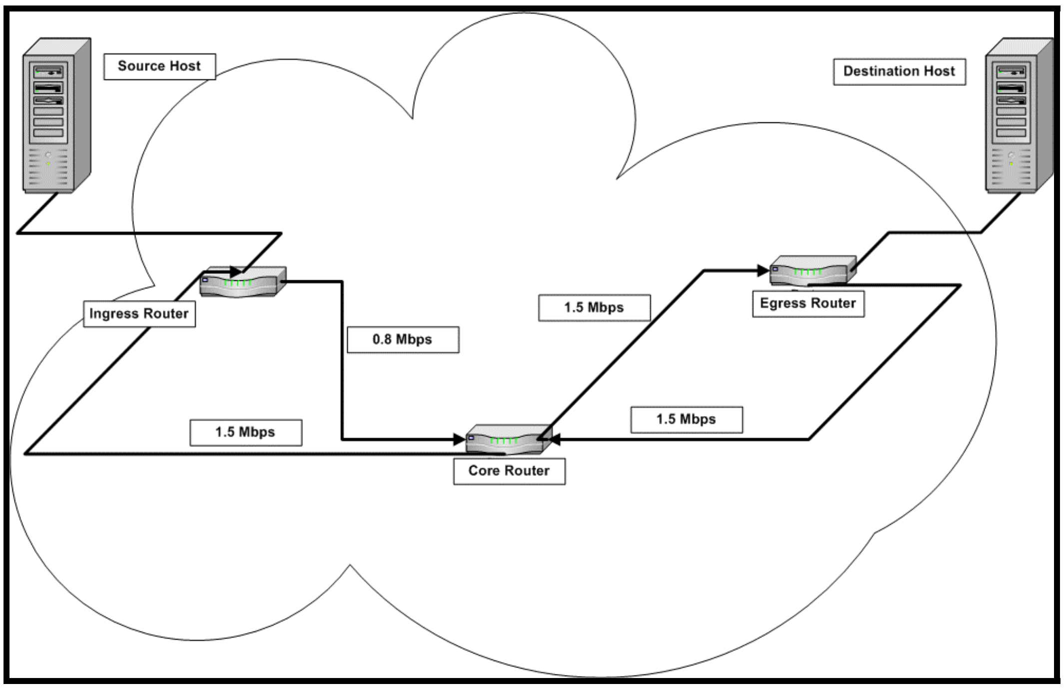

Figure 1: The Simulation Setup for VBR Stream Shaping and Marking Experiments

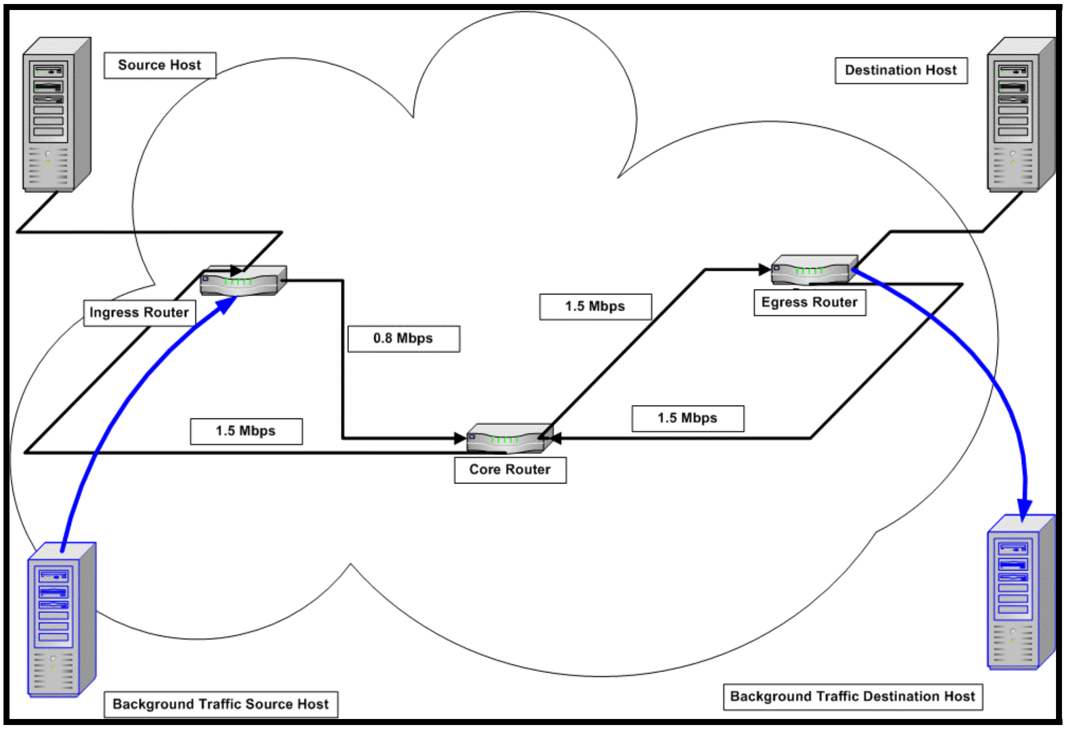

Figure 2: The Simulation Setup for VBR Stream Shaping and Marking Experiments With background traffic

Table I: VBR Traffic Marking

	TOTAL	GREEN		YELLOW		RED	
		Total	Dropped	Total	Dropped	Total	Dropped
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 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.

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

	TOTAL	GREEN		YELLOW		RED	
		Total	Dropped	Total	Dropped	Total	Dropped
SrTCM	100000	11130	0	30	0	88840	11270
TrTCM	100000	11130	0	11121	0	77749	11251
TswTCM	100000	11323	0	11423	0	77254	11340

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. Another token bucket is added 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. These experiments are conducted 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.

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

	TOTAL	GREEN	YELLOW	RED

		Total	Dropped	Total	Dropped	Total	Dropped
SrTCM	100000	11784	0	30	0	88186	5969
TrTCM	100000	11784	0	11774	0	76442	5944
TswTCM	100000	12018	0	12044	0	75938	5963

In the next set of experiments, we introduce a background source generating CBR traffic at the rate of 1Mbps through the path shared by VBR stream and measure the green, yellow and red packets and the number of discarded packets for both the flows. Nine sets of results are obtained covering srTCM, trTCM and tswTCM marking without shaping, with single token bucket shaping and with dual token bucket shaping. Figures 3 through 5 show the number of green packets generated by all schemes for the VBR traffic under study. It can be seen that the number of green packets is increased considerably with 2TB (dual token bucket) shaping. With 2TB, significant reduction in loss percentage is measured for all three markers. Summarizing the results, it was determined that tswTCM outperforms srTCM and trTCM in generating maximum number of green packets and reducing the loss to a minimum. However, tswTCM performance penalty is in the increased delay jitter. For non-realtime multimedia applications that operate with buffers at the receiving end, tswTCM can generate the most network friendly traffic that may experience least loss but increased delay jitter under overloaded network conditions. With the admission control deployed in network management tools, it is expected that the network may not reach an overloaded state and thus the delay jitter will not degrade the performance of tswTCM.

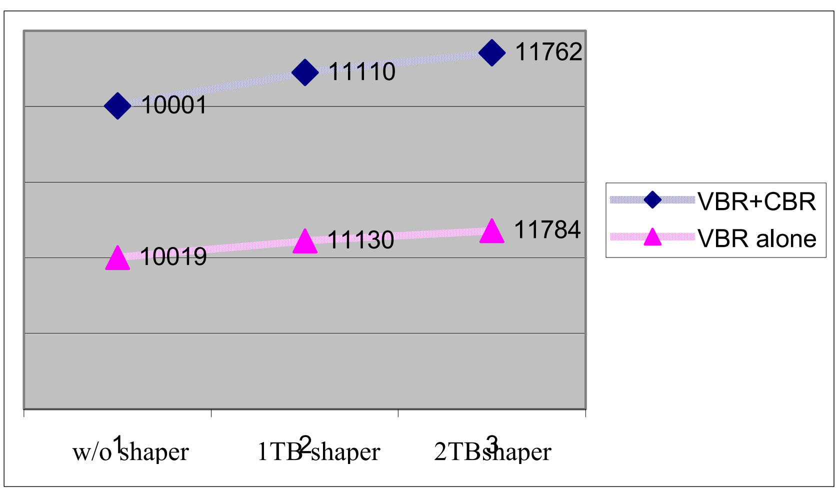

Figure 3: The srTCM green packet generation for the VBR stream

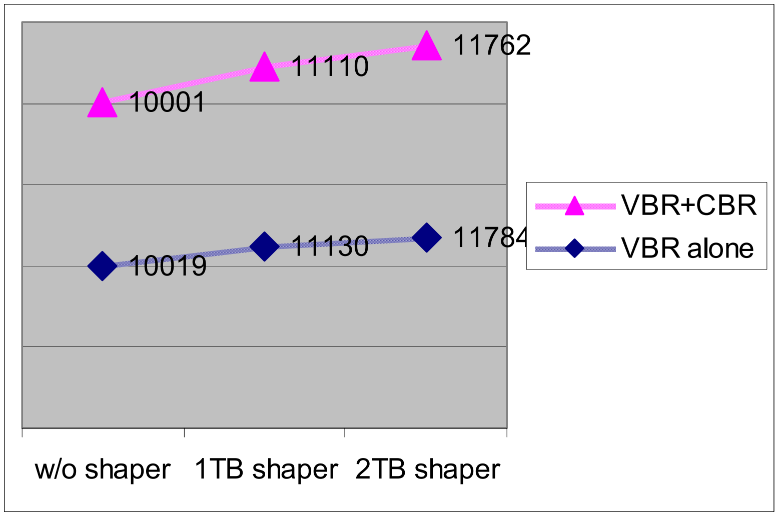

Figure 4: The trTCM green packet generation for the VBR stream

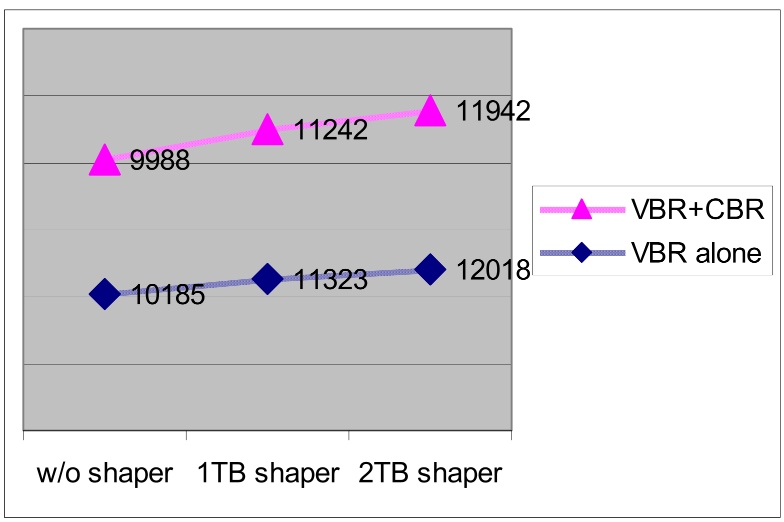

Figure 5: The tswTCM green packet generation for the VBR stream

5. 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 enters the core of the domain. The results show that the lowest loss ratio and maximum number of green packets are obtained when the VBR stream is shaped with dual token bucket shaper and marked using tswTCM scheme. However, increased delay jitter was observed with the tswTCM marking following 2TB shaping. The increased value of delay jitter for tswTCM is because of the fact that its marking is based on the effective rate which keeps changing for the VBR traffic. Thus we have variable marking resulting in variable queuing delays in the routers. It is expected that the delay jitter will not jeopardize the performance of tswTCM with the admission control mechanisms in place. For example, consider the transmission of stored MPEG compressed video. The server generates a VBR stream that can be passed through dual token bucket shaper and tswTCM marker in the ingress node, resulting in lowest loss and highest number of green packets. We have also contributed an analytical study of the granularity of the markers. It is shown that the markers may color the whole packet red although various segments of the current packet may belong to different colors. This problem can be solved easily in current IPv4 networks by segmentation of the current packet based on the equations developed in section 4. This work can be extended by including more shapers and implementing admission control mechanisms to measure the loss percentage, number of green packets generated and the delay jitter. This work was carried out in the network research lab of the faculty of Engineering in International Islamic University Malaysia.

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