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Dynamic Bandwidth Shaping Algorithm for Internet Traffic Sharing Environments

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***Abstract*--For emerging Internet services and contents in the traffic-sharing environment of limited bandwidth capacity, an efficient method is required to manage the Internet-sharing problem and to improve quality of service (QoS) for high-demand bandwidth users. The results of our study show that dynamically delaying un-attended Internet usage activities, such as large file downloading, will drive more bandwidth usage optimization. Moreover, Internet users can reach higher speeds for high-priority activities (web browsing, emailing, small file transferring, etc.) when there is available bandwidth at times of low overall Internet resource usage. The results after implementing "Dynamic Bandwidth Shaping" show that about 40% of overall bandwidth utilization was improved; each client experienced higher Internet speed; and a majority of customer satisfaction ratings were improved under the experiment conditions.**

***Index Terms*-- Bandwidth shaping, Internet traffic control, Internet traffic sharing, Internet bandwidth allocation**

I. INTRODUCTION

Quality of Service (QoS) is one of the most important success criteria for Internet Service Providers (ISP) who own network infrastructures, such as transmission media for both wired and wireless networks, speed of communication (bandwidth) to the Internet, etc. In order to serve a high volume of Internet clients with limited resources, we need effective QoS management to cope with Internet traffic sharing.

True Corporation, one of the biggest ISPs in Thailand, has been using an Internet traffic sharing ratio of 1/50 for ADSL (Asymmetric digital subscriber line) in the consumer service sector, and a sharing ratio of 1/25 for the SME service sector. Sharing ratio is defined by the allocated bandwidth per number of subscribed Internet users. For example, if we allocate Internet speed at 4Mbps/1Mbps (downlink/uplink) for 50 Internet users, the highest speed that each user can reach is 4Mbps/1Mbps under the condition that there is only one user online. However, no sustained rate guarantees the Internet speed that a user receives at any given time. It depends on the overall bandwidth usage of the entire system.

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Data caching [1] and traffic limiting policy techniques [7] have long been applied for this problem and have proven mostly effective for large scale multi-Internet user schemes; for instance, 4 Gbps/1 Gbps can serve 50,000 subscribed users by using a 1/50 ratio rate at a fixed maximum bandwidth of 4Mbps/1Mbps per user (4Gbps/4Mbps * 50 = 50,000 users). From the experiences of ISPs in Thailand, the big bandwidth pool will relieve multi-user Internet sharing problems in most cases. Moreover, there are ongoing researches, such as "Improving User and ISP Experience through ISP-aided P2P Locality" [8] and "A possibility for ISP and P2P collaboration" [9], to solve this problem.

In addition, this paper will study the Internet sharing problems of small-scale networks, which have a very limited Internet bandwidth channel and number of users. Our interim study showed that a smaller bandwidth pool (about 2 to 9 Mbps) needs additional QoS techniques to deal with Internet traffic sharing. Without a traffic controller, a client's machine equipped with advanced downloading software, such as Bit-Torrent (Peer to Peer downloading application), will consume most bandwidth of the backbone capacity as depicted in Fig. 1 and yield a negative impact on other Internet users.

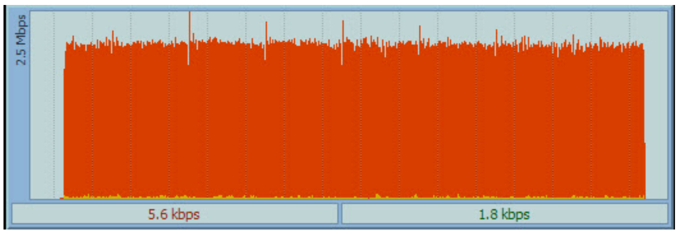

Figure 1, Internet traffic consumption without traffic sharing management (The red color indicates download)

II. FIXED BANDWIDTH SHAPING TECHNIQUE (FBS)

Most Internet Subscriber Gateway systems, both software and hardware boxes, such as IMS-I [2], Nomandix [3] and AntLab [4], supply each user with a Fixed Bandwidth Shaping technique (FBS), which is generally implemented by using the class-based queuing algorithm (CBQ) [6]. FBS will limit the bandwidth allocated to each user. An example of this is shown in the following configuration:

Main Internet link capacity:	4Mbps/1Mbps
Allocated bandwidth per user:	1Mbps/256kbps
Average concurrent users:	10 connections

The problem of this technique occurs when most of the connections use P2P downloading applications. In these cases, the main Internet link will reach its capacity at 4 concurrent connections. Blocking the P2P applications is an additional configuration which is required in order to

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achieve a good service for all the users. Nevertheless, there is no guarantee that all high bandwidth consumption applications can be blocked. Moreover, customer privilege to access those services should not be limited.

III. DYNAMIC BANDWIDTH SHAPING ALGORITHM (DBS)

***Hypothesis1**:* DBS will improve overall bandwidth utilization by approximately 15-30% compared with the fixed bandwidth shaping (FBS) technique.

***Hypothesis2**:* DBS will gain a higher customer satisfaction rating compared with using FBS.

Definition:

Max speed: the maximum bandwidth that any particular user can reach over a given period of time. In other words, it is the maximum capacity of the main Internet link.

Sustain speed: The average maximum speed that is available to the entire system or user. In this experiment, it is about 90% of Max speed.

BW L1: The first level of bandwidth shaping defined by percentage of Sustain_speed. In this study, we use 100% of Sustain_speed.

BW L2: The second level of bandwidth shaping defined by percentage of Sustain_speed. In this study, we use 60% of Sustain_speed.

BW L3: The third level of bandwidth shaping defined by percentage of Sustain_speed. In this study, we use 30% of Sustain_speed.

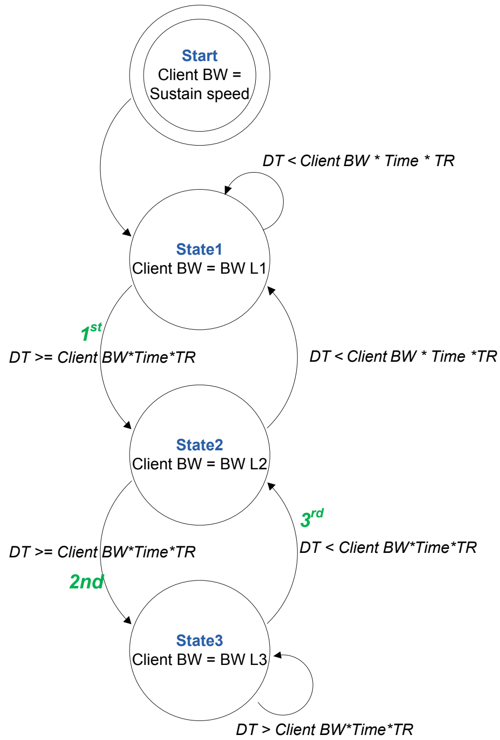
Interval time: The fixed period of time that DBS uses to check the total sum of bandwidth consumption of each user. In this study, we use 10 minutes.

Data transfer: The total amount of data transfer (kilobyte).

Client BW: The maximum bandwidth that any particular client can reach over a certain Interval time.

Ticker ratio: This ratio indicates when the Client_BW level should be increased (stepped up) or decreased (stepped down). In this study, we set it at 80%.

DBS Algorithm:



Time = Interval time, TR = Ticker ratio, DT = Data transfer

Figure 2, DBS algorithm

As depicted in the state machine in Fig 2, the DBS algorithm delayed un-attended Internet usage activities, such as large file downloading or P2P download applications. Allocated bandwidth (Client BW) was dynamically changed *(stepping up or down)* at every Interval time cycle.

After running the DBS algorithm against high demand downloading clients, we captured the bandwidth usage of each single user as illustrated in Fig 3. At the start state in Fig 2, the monitored client was automatically transferred to state1. Then, the downloading activities started.

At the first interval time (first 10 mins) in Fig 3, which corresponded to the 1st line in Fig 2, BW level 1 was allocated to the client. When the first interval time passed, DBS calculated the total data transfer (the red color area in Fig 3), which was greater than the condition *"Client BW * BW L1 * Ticker ratio",* and then the client's speed was DBS stepped down to BW level 2.

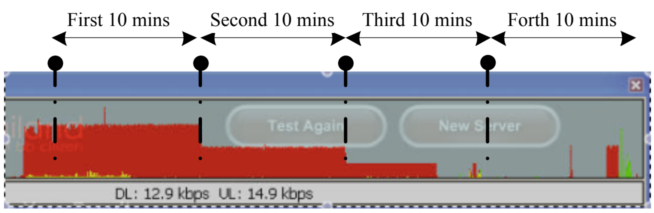


Figure 3, Bandwidth allocated to a single client by using DBS

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At the second interval time (second 10 mins), DBS again calculated the total data transfer, which was greater than the condition *"Client BW * BW L2 * Ticker ratio"*, and then the client's bandwidth was stepped down to BW level 3 corresponding to the 2nd line in Fig 2.

Once the client had finished the extended high-intensive data consumption and the next interval time (the fourth 10 mins) had arrived, DBS stepped up the client bandwidth to a higher speed (BW level 2) since the data transfer was less than the current given condition *"Client BW * BW L3 * Ticker ratio"*, which corresponds to the 3rd line in figure 2.

IV. Experiment results of DBS

The proposed technique was tested on 5 real site projects, with an average range of 7 to 65 concurrent Internet users (69 to 142 registered users), 3Mbps/1Mbps to 9Mbps/3 Mbps of Internet main link, and a variety of site projects, which were hotels, apartments and condominiums. All sites implemented wireless network IEEE802.11 b/g.

Testing project no.2 (a case from 5 projects)
Site configuration:
Internet maximum speed = 6 Mbps (download speed)
Number of monitored clients = 35 (from 76 registered users)

Prior to the experiment, this site was facing problem of bandwidth congestion due to fixing the bandwidth per each user at 2 Mbps and the main Internet link was full most of the time. Therefore, a lower fixed bandwidth (1 Mbps) was set for all users; however, most of the customers complained that the speed was lower and the overall Internet bandwidth utilization was not as efficient as depicted at the left area (FBS configuration – week#53) of figure 4.

In this experiment, each user was allocated a speed by using the following DBS schemes:

DBS1 configuration (Week#1-Week#2)
BW level 1 = 2 Mbps
BW level 2 = 1.2 Mbps (60% of BW level 1)
BW level 3 = 0.6 Mbps (30% of BW level 1)

DBS2 configuration (Week#3)
BW level 1 = 3 Mbps
BW level 2 = 1.8 Mbps (60% of BW level 1)
BW level 3 = 0.9 Mbps (30% of BW level 1)

Overall bandwidth utilization of DBS was compared to FBS as depicted in Fig 4. The DBS1 configuration was activated after the end of week#53 (first red line form the left). The results (upper graph in Fig 4) show that bandwidth utilization increased by approximately 50% in both week#1 and week#2. Furthermore, most clients could reach higher speeds by implementing DBS (double the maximum speed of FBS).

After adjusting DBS1 to the DBS2 configuration at the end of week#3, we noticed that bandwidth utilization increased by more than 10% compared to DBS1. In addition, clients could reach 3 Mbps of maximum speed. However, as we notice from the graph, DBS2 makes the bandwidth slightly more congested in peak hours, resulting in unstable Sustain_speed for some users.

The number of concurrent online clients was stable at about 10 to 25 clients throughout the monitoring period as depicted in figure 4.

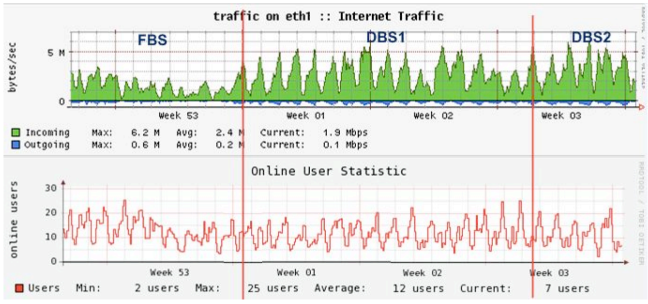

Fig 4, DBS implementation result against FBS (testing site no.2)

A customer satisfaction survey of 105 people (60 professional workers, 39 college students and 6 self-employers) was conducted.

For the question "*Was the Internet speed faster on web browsing and emailing?*", 54 (51.43%) of the total clients gave a high rating; 24 people (22.86%) didn't feel any improvement; and 27 people (25.71%) though that they got a slower Internet speed.

For the question "*Was the Internet speed faster on file downloading?*", 67 people (63.81%) though that they could download files faster; 9 people (8.57%) didn't feel any improvement; and 29 people (27.62%) though that file downloading needed a longer time.

V. Discussion

Clients with relatively lower bandwidth consumption tended to experience a faster service for downloading tasks, such as e-mailing and web browsing, because their total bandwidth consumption activities were not intensive enough for the DBS to step the allocated speed down. However, serious download clients faced slower speeds (BW level 2 and level 3) for their overall Internet usage because of their always-on peer-to-peer downloading programs.

However, the results of this study may not reveal all the aspects of DBS affects on bandwidth utilization that a longer period of testing would show.

In order to gain more bandwidth utilization of the entire system, additional DBS configurations could be formulated such as adjusting the speed for BW level 2 and level 3 or changing the Interval time. However, the BW levels should be individually calibrated for each project site in order to find the optimal level of bandwidth utilization under the condition that overall utilized bandwidth will not reach the maximum speed of the main Internet link for most of the time.

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Theoretically, DBS can be incorporated with a HTB (Hierarchical Token Bucket) technique [5] and it would provide more detailed control for traffic sharing management. However, it is hard to find common test cases that can provide actual comparisons between DBS and HTB performance.

VI. CONCLUSION

Hypothesis1: "*DBS will improve overall bandwidth utilization by approximately 15-30% compared with the fixed bandwidth shaping (FBS) technique*"

In actual results, DBS improved overall bandwidth utilization by approximately 40% compared with the fixed bandwidth shaping (FBS) technique under the condition that the double and triple speed of FBS was allocated to DBS's clients.

Hypothesis2: *"DBS will gain a higher customer satisfaction rating against using FBS."*

DBS gained a higher customer satisfaction rating from more than 50% of the number of users compared with FBS regardless of the quality of wireless media connection.

VII. FUTURE WORK

In this paper, we implemented and tested only downlink DBS. DBS for uplink could be considered for future experiments. Furthermore, a longer period of monitoring time *(months and year)* would reveal more extensive analysis results and provide a better understanding for adjusting the DBS algorithm. Also, applying the DBS technique over HTB [5] is planned.

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