Fuzzy Logic for Bandwidth Allocator applies on IP Multimedia Traffic

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***Abstract*—In order to allocate the resource adaptively in computer network, some existing solutions and former work for traffic optimization based on fuzzy scheme has been introduced. As an alternative, we propose dynamic bandwidth and buffer allocation based on the number existing users connected within certain period according to ICMP traffic. Here, the propose rules is *better connection based on distance of visitors will be reserved better resource allocation*. Increasing network efficiency to deliver multimedia traffic is the main focus of our testbed.**

Keywords- fuzzy logic, bandwidth allocator, multimedia

1. INTRODUCTION

The one significant factor that influence the end-to-end quality in delivering multimedia traffic on computer network are bandwidth. Bandwidth fluctuation is important issue due to characteristic of multimedia traffic are real-time and delay sensitif. According to the reason above, this paper propose alternative solution to allocate resource of bandwidth and buffer via online measurement in certain interval according to the fuzzy rules *better connection based on distance of visitors will be reserved better resource allocation*.

Sensitive traffic change rapidly within short time intervals, it need efficient computation to be employed over small time interval. In our propose fuzzy rules, we dont determine fix parameters for the input, therefore the result can flexible adaptively according to the network performance, however there are some related issue should be taken into consideration such as filtering ICMP traffic, ability network to deliver multimedia application and other parameter issue in multimedia transport is jitter that we do not discuss it, here we only focus on dynamic bandwidth management.

Fuzzy dynamic bandwidth re-allocator has been studied and simulated in [1], it was propose dynamic bandwidth re-allocation focusing on content buffer. Other previous work related to the fuzzy logic controller in multimedia traffic has been studied in [2] and [3] which focused on congestion and queue control across IP networks, respectively. Another propose fuzzy logic that focus on cellular that related to multimedia traffic has been introduced in [4] and bandwidth allocation for wireless multimedia traffic by fuzzy logic in [5]. Above former work totally introduce different fuzzy input with our propose fuzzy logic model for traffic optimization management. On the previous work, they dont pay attention to the distance of visitors to the server across the network.

2. FUZZY CONTROLER AND TRAFFIC CONTROL

In this section, fuzzy controler is launched to provide efficient computation during short time interval for handling N number user's request access to the server during T interval time. And to produce the accuracy for the measurement, we provide three input network performance metric in general ICMP traffic that is round-trip time, the number of hop and loss ratio which is described in [6]. To adjust the requirement of the system, we modify ICMP source code with the purpose to remove error display that related to Type3, thus whenever ICMP fail in the middle of the network, the error message will not shown in STDOUT.

2.1 Fuzzy Controler

Our main goal is to optimize link capacity by designing buffer's weight for users during certain period and then allocate the bandwidth resource. Input parameter for fuzzy is ICMP network performance metric while the output parameter is bandwidth.

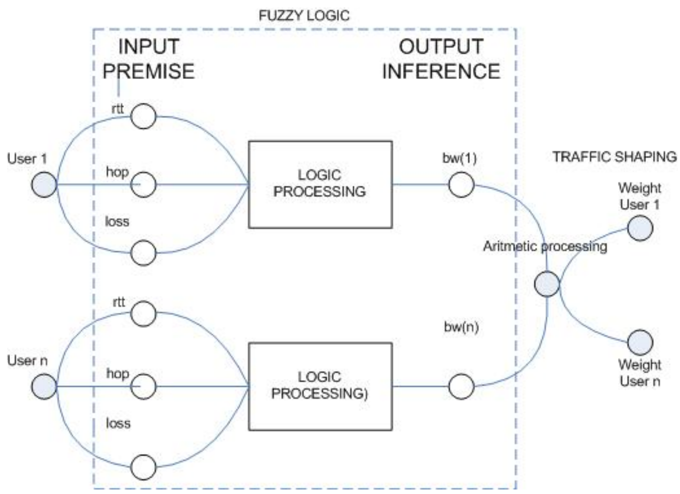

Figure 1. Fuzzy logic

rtt, *hop* and *loss ratio* are utilized as the INPUT, and then will be processed in the *logic processing* in order to obtain OUTPUT. The OUTPUT is *bw*.

Fuzzy logic consists of three part that is fuzzification, inference and defuzzification.

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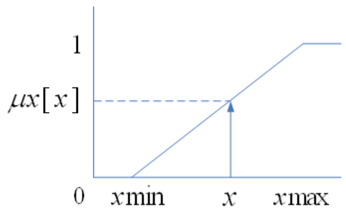
2.1.1 Fuzzification

The fuzzy parameter for minimum and maximum values for all the inputs such as rtt_{min}, rtt_{max}, hop_{min}, hop_{max}, $loss_{min}$ and $loss_{max}$. Those parameter above are obtained via online measurement active connections during certain interval.

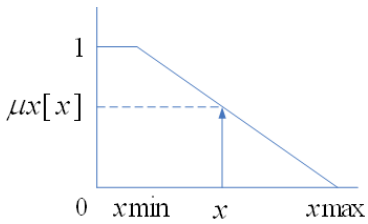
Membership function (μ) each of rules can be obtained according to Eq.(1) and Eq.(2).

Eq. (1)



$$\mu x[x] = \begin{cases} 0, & x \leq xmin \\ \dfrac{(x - xmin)}{(xmax - xmin)}, & xmin \leq x \leq xmax \\ 1, & x \geq xmax \end{cases}$$

Eq. (2)



$$\mu x[x] = \begin{cases} \dfrac{(xmax - x)}{(xmax - xmin)}, & xmin \leq x \leq xmax \\ 0, & x \geq xmax \end{cases}$$

2.1.2 Inference

The inference fuzzy in our propose model is described in table 1. The calculation of membership function for BIG, LARGE, HIGH and INCREASE refer to Eq.(1). And for LITTLE, FEW, LOW and DECREASE refer to Eq.(2).

TABLE I. INFERENCE OF FUZZY MODEL

Input (IF)			**Output (THEN)**
rtt	***hop***	***loss***	***bw***
LITTLE	FEW	LOW	INCREASE
LITTLE	FEW	HIGH	INCREASE
LITTLE	LARGE	LOW	INCREASE
LITTLE	LARGE	HIGH	DECREASE
BIG	FEW	LOW	INCREASE
BIG	LARGE	LOW	DECREASE
BIG	FEW	HIGH	DECREASE
BIG	LARGE	HIGH	DECREASE

Implication function (minimum) is occupied to calculate fire strength (α).

Eq. (3)

$$\begin{aligned}
\alpha_1 &= \mu rtt_{LITTLE} \cap \mu hop_{FEW} \cap \mu loss_{LOW} \\
\alpha_2 &= \mu rtt_{LITTLE} \cap \mu hop_{FEW} \cap \mu loss_{HIGH} \\
\alpha_3 &= \mu rtt_{LITTLE} \cap \mu hop_{LARGE} \cap \mu loss_{LOW} \\
\alpha_4 &= \mu rtt_{LITTLE} \cap \mu hop_{LARGE} \cap \mu loss_{HIGH} \\
\alpha_5 &= \mu rtt_{BIG} \cap \mu hop_{FEW} \cap \mu loss_{LOW} \\
\alpha_6 &= \mu rtt_{BIG} \cap \mu hop_{LARGE} \cap \mu loss_{LOW} \\
\alpha_7 &= \mu rtt_{BIG} \cap \mu hop_{FEW} \cap \mu loss_{HIGH} \\
\alpha_8 &= \mu rtt_{BIG} \cap \mu hop_{LARGE} \cap \mu loss_{HIGH}
\end{aligned}$$

To calculated bw_n as follows

$$\begin{aligned}
bw_1 &= bw_{min} + (\alpha_1 * (bw_{max} - bw_{min})) \\
bw_2 &= bw_{min} + (\alpha_2 * (bw_{max} - bw_{min})) \\
bw_3 &= bw_{min} + (\alpha_3 * (bw_{max} - bw_{min})) \\
bw_4 &= bw_{max} - (\alpha_4 * (bw_{max} - bw_{min})) \\
bw_5 &= bw_{min} + (\alpha_5 * (bw_{max} - bw_{min})) \\
bw_6 &= bw_{max} - \left(\alpha_6 * (bw_{max} - bw_{min})\right) \\
bw_7 &= bw_{max} - \left(\alpha_7 * (bw_{max} - bw_{min})\right) \\
bw_8 &= bw_{max} - \left(\alpha_8 * (bw_{max} - bw_{min})\right)
\end{aligned}$$

2.1.3 Defuzzification

The average of weight can be calculated according to defuzzifiction process.

$$bw_{avg} = \frac{\sum_{n=1}^{8} \alpha_n bw_n}{\sum_{n=1}^{8} \alpha_n} \tag{4}$$

Let *n* be number of the rules from section 2.1.2. Equation 4 is used for calculate fuzzy output. The output of fuzzy become input for traffic control (in section 2.2) to determine bandwidth allocation and user's weight.

2.2 Traffic Control

In order to allocate buffer according to the weight each of user's flow, we borrow Weighted Fair Queue (WFQ) or Packet-by-packet Generalized Processor Sharing (PGPS) which has been studied in [7]. According to fuzzy output from section 2.1.3, we calculate the value of the bandwidth each of user's flow and determine the weight for its relative share of the bandwidth.

$$bw_{user(n)} = \frac{bw_{avg}\,(user_n)}{\sum_{n=1}^{m} bw_{avg}} * bw_{max} \tag{5}$$

$$weight_{user(n)} = \frac{bw_{user(n)}}{bw_{max}} * 100\% \tag{6}$$

Here, notation of $user(n)$ is user n*th* and total of user is m. bw_{max} is maximum bandwidth of the server and the bw_{avg} is the output of fuzzy. Finally, $bw_{user(n)}$ can be calculated and *weight* can be obtained to allocate buffer's weight.

For special issues, if all the users have the same one or two of input parameter or have same both of them, for example same *hop* and *loss* or both of them, then those parameter no need to use for fuzzy computation due those values can't be used to determine minimum and maximum values of the fuzzy input. We experiences in our testbed, all users *loss* are zero. Then we only use *rtt* and *hop* as fuzzy input.

3. System Testbed

In this section, we construct topology and procedure send/ receive control information between users and the server across computer network.

The service in this system tested is multimedia progressive download. Table II summaries the specification of the video clip.

TABLE II. A Spesification of The Video used in The Testbed

Items	Parameters
File type	VLC media file (.FLV)
File size	24Mbytes (25174747 bytes)
Time length	00:05:02
Resolution	640 x 360
Video format	MPEG4 Video (H264)
Audio format	AAC 44100Hz stereo

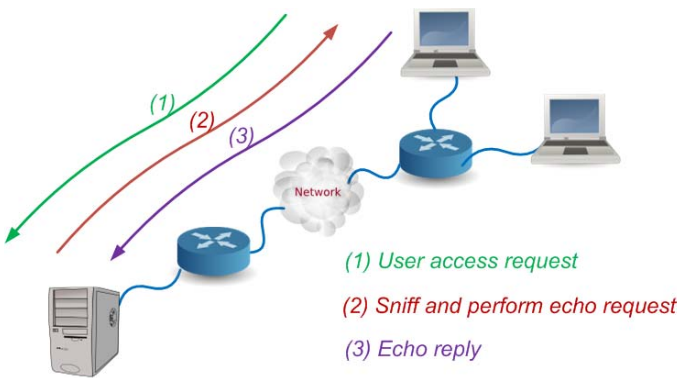


Figure 2. System testbed procedure

As can be seen in Figure 2, first, user send an access request. Second, the server perform traffic sniffing to obtain IP Address and then sending ICMP echo request to the user. Here, ICMP source code is bit modified to adjust requirement of this system by removing error display to STDOUT that related to Type3. Last, user replied it by sending ICMP echo reply which bring three network performance metric. Five ICMP samples is taken during every measurement. For certain failure condition such as firewall, the last node can be traced by the server will be user's node.

3.1 Design Scenario

In order to verify proposed method, two scenarios are provided.

3.1.1 Scenario 1

Random users location in scenario 1 in order to represent common topology on computer network.

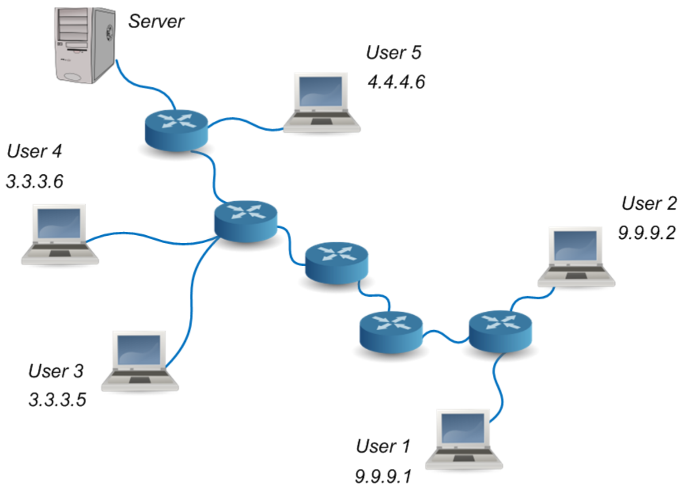


Figure 3. Topology of scenario 1

Figure 3 consists of an application multimedia server which is accessed by five users in the same period of time. According to the distance location to the server, the shortest path is User 5 and the longest path is User 1 and User 2 while Users 3 and User 4 are located in the middle of the network testbed.

3.1.2 Scenario 2

Concentrate users location in scenario 2 is focused on testing effect best-effort on IP network, thus although the number of *hop* are same, but some user's node have different *rtt*.

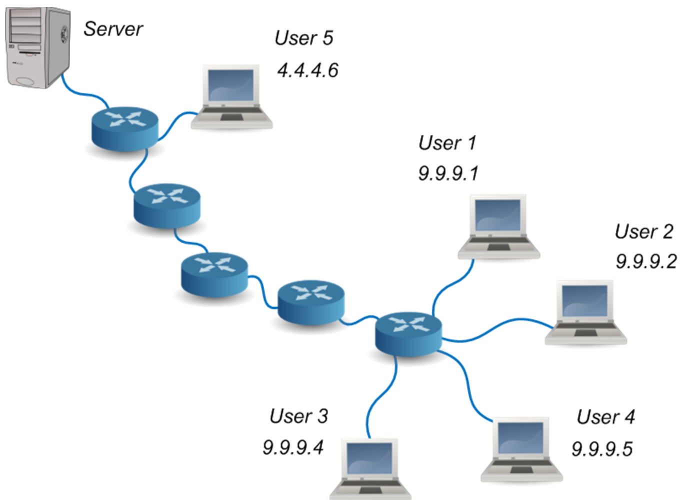


Figure 4. Topology of scenario 2

Figure 4 focus on the longest path with collected users. Four users have same *hop* from the server, however effect of best-effort influencing along the path. Here dynamic parameter input for fuzzy according to online measurement are tested.

3.2 Experiment Result and Analysis

The value of minimum and maximum parameter input of fuzzy logic (rtt_{min}, rtt_{max}, hop_{min}, hop_{man}, $loss_{min}$ and $loss_{max}$) are obtained based on online measurement of ICMP traffic.

The 5 samples are taken every 30 second. The value of minimum and maximum parameter output of fuzzy logic (bw_{min} and bw_{max}) are set on pre-configuration. For satisfaction and suitable to the scenario 1 and 2, we therefore set the bw_{min} 700kbps and bw_{max} 3500kbps.

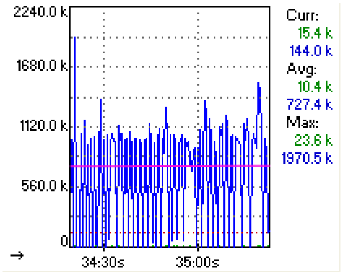


Figure 5. Output bandwidth of scenario 1, without allocation

Figure 5 is bandwidth throughtput without traffic shaping. It showed that the average requirement during playing pseudo-streaming up to 727kbps for user's satisfaction in our testbed.

3.2.1 Experiment Result for Scenario 1

TABLE III. RESULT OF SCENARIO 1 (RANDOM TOPOLOGY)

IP Address	rtt (ms)	hop (n)	Loss ratio (%)
9.9.9.2	2.35	6	0
3.3.3.5	1.02	3	0
4.4.4.6	0.60	2	0
3.3.3.6	0.92	3	0
9.9.9.1	1.42	6	0

IP Address	weight (%)	bandwidth (kbps)
9.9.9.2	14	504
3.3.3.5	20	703
4.4.4.6	29	1007
3.3.3.6	22	765
9.9.9.1	15	521

Table 3 show the result of online measurement scenario 1. The best connection belong to IP Address 4.4.4.6 with *rtt*=0.60ms and *hop*=2. According to those input above, then 4.4.4.6 obtain best weight of the buffer=29% and the bandwidth allocation=1007kbps. Otherwise the poorest connection is IP Address 9.9.9.2 with *rtt*=2.35ms and *hop*=6, then it will be allocated worst weight of the buffer=14% and bandwidth=504kbps. For 9.9.9.2, although the allocation is lowest than the bandwidth requirement during playing pseudo-streaming (±727kbps), but in WFQ when other connection do not use the link capacity which is allocated to them, then the link can be shared to other connection.

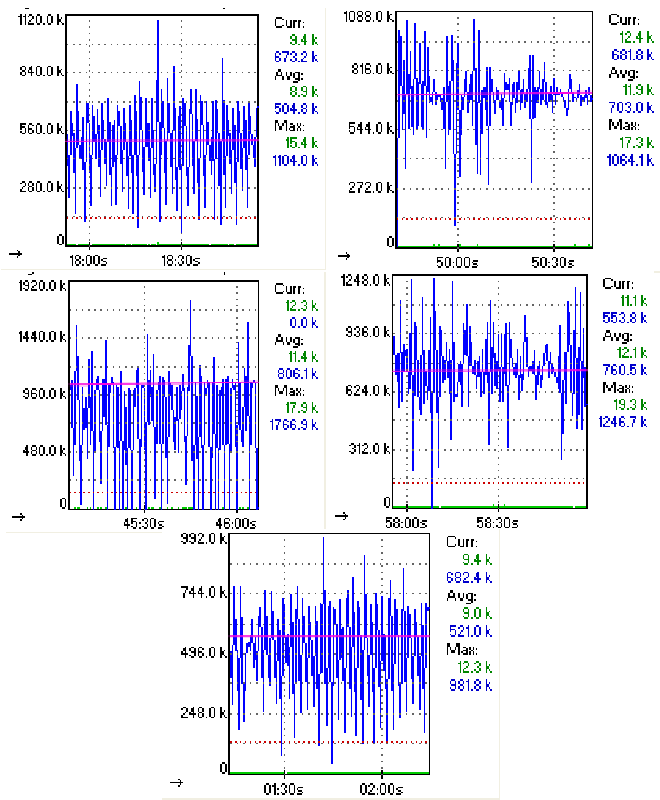


Figure 6. Output bandwidth of scenario 1

Figure 6 describe result of the bandwidth throughput scenario 1. At the right side each of figure, we can see notation *Avg* that represent average throughput bandwidth each of user from scenario 1. And also the figure above showed that fluctuation of the bandwidth can be shaped.

User 9.9.9.2 need 407 second to play pseudo-streaming while User 4.4.4.6 need 51 second.

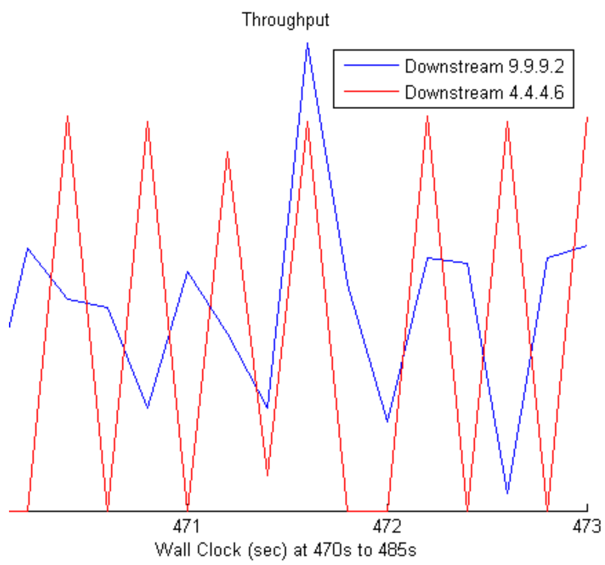


Figure 7. Throughput User 9.9.9.2 and 4.4.4.6 at 470s to 485s

Figure 7 is bandwidth throughput User 9.9.9.2 (worst) and 4.4.4.6 (best) at second 470 to second 485. For best connection (4.4.4.6), the download rythme is consistent periodically. Even it can perform faster download the streaming frame and then stop download when playing the movie. It is opposite to the worst connection (9.9.9.2) which still download while playing in the same time, this condition is triggering buffering event.

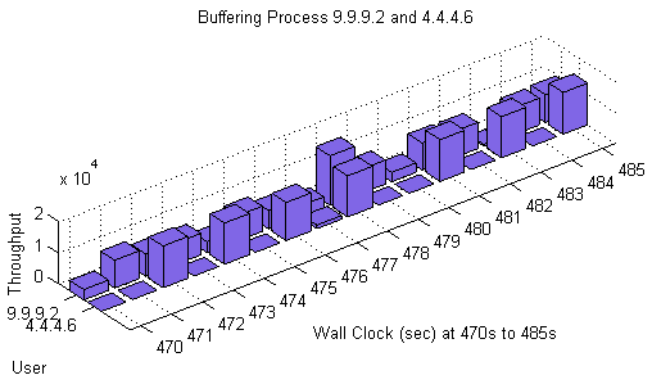


Figure 8. Buffering Process User 9.9.9.2 and 4.4.4.6 at 470s to 485s

Figure 8 is explain more clearly of buffering process during playing the movie at second 470 to second 485. It can be seen that 4.4.4.6 throughput is consistent periodically, it doesnt have buffering experience which unsatisfy the user's opinion. The condition which need pay attention is when downloading while playing on the same time in peak rate of link capacity, it can be seen at User 9.9.9.2, sometimes it experience buffering events.

3.2.2 Experiment Result for Scenario 2

TABLE IV. RESULT OF SCENARIO 2 (CONCENTRATE TOPOLOGY)

IP Address	rtt (ms)	hop (n)	Loss ratio (%)
9.9.9.1	1.64	6	0
4.4.4.6	0.67	2	0
9.9.9.4	1.51	6	0
9.9.9.5	1.47	6	0
9.9.9.2	1.99	6	0

IP Address	weight (%)	bandwidth (kbps)
9.9.9.1	15	538
4.4.4.6	35	1229
9.9.9.4	16	554
9.9.9.5	16	564
9.9.9.2	18	615

Table 4 show the result of online measurement in scenario 2. The best connection belong to IP Address 4.4.4.6 with *rtt*=0.67ms and *hop*=2, it will be allocated weight=35% and bandwidth=1229kbps. The users in network segment 9.9.9.0 have different value of *rtt* although have same number of *hop* from the server. Its proved that TCP/IP characteristic is best-effort. Here, four users in network 9.9.9.0 have weight and bandwidth less than 4.4.4.6 due to larger of *rtt* and the number of *hop*.

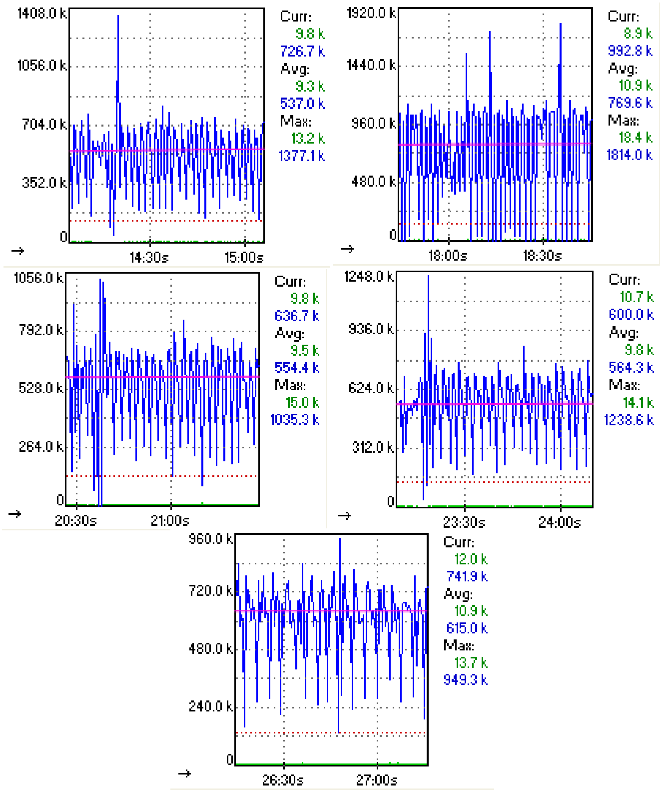


Figure 9. Output bandwidth of scenario 2

Figure 9 show result of the bandwidth throughput in scenario 2. The explanation is similar to scenario 1. The scenario 2 is just to prove that our fuzzy calculation is fulfill to our propose rules.

4 CONCLUSION

In this paper, alternative bandwidth allocator using fuzzy logic is introduced. The proposed model is implemented on computer network to manage resource bandwidth and network buffer adaptively during serving multimedia application. The motivation behind this testbed is to optimize link capacity also update bandwidth and buffer frequently depend on distance of visitors along the network path to fullfill requirement multimedia service. However another network performance metric such as network jitter and also resource guarantee in the middle network should be taken into consideration since integrated service does not implemented in the system testbed. All the parameter inputs are taken during online measurement, therefore the server is expected can adaptive quickly to allocate the resource according to network condition.

We introduce fuzzy rule *better connection based on distance of visitors will be reserved better resource allocation*. The propose rule above is the basis of management bandwidth in this testbed to deliver multimedia service across computer network.

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