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Evaluating Performance of Broadband NetworkBased on Indexes of TCP Messages

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***Abstract*—Qos of broadband network is important. ISPs have some methods for evaluate it. But they are not efficient enough. This paper present a new method in which delay and scale of windows of TCP messages are used for evaluating performance of broadband. Comparison between delay or scale of window s of samples is the core idea of the method. There are two kinds of comparison.One is absolute terms of above-mentioned indexes,another is score,that is relative term. We can grade samples according to their scores. It is helpful for locating probably fault situation for ISPs.**

Keywords-QoS;Broadband;RTT;TCP;Scale of Window

I. INTRODUCTION

A. What is Broadband Access Network

The Internet known as the information superhighway, has indeed established a worldwide borderless cyber society. Nowadays, Internet is acknowledged worldwide as an essential component for electronic communication services. The rapid increase in the use of the Internet has changed the way we live, the Internet has become an important factor in people's daily life. Higher speed access network is necessary for huge amount of data.

Broad communication involves participants including users, ISPs and content providers. When users access Internet, the data will go through many parts of the network as showed in Fig. 1[1]. In fact, users' feeling about the Quality of Service (QoS) relates to ISPs' network, web sites, Content Delivery Network (CDN) servers and so on. However, occasionally the scenarios under which Internet is sold to customers is not fair and unfortunately Internet subscribers are not well informed on the InternetQoS provided to them by Internet service providers ISPs[2].

Usually, access network includes all line and equipment between Broadband Remote Access Server(BRAS) and hosts, as Fig. 1 shows. It is more and more difficult for ISPs to maintain the access network because of its more and more complexity. As reliance on Internet networks, in promoting socioeconomic development, increases the QoS of Internet networks also becomes very critical and important. How to evaluate effectiveness of a broadband access network is a hot topic. J. Sharad mentioned in an article[3]that we can track of the values of two important variables associated with a TCP connection: the sender's congestion window and the connection Round Trip Time (RTT). This paper will talk about them with other methods.

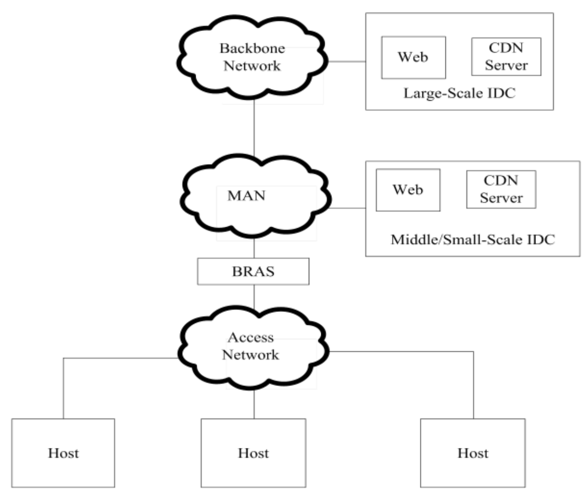

Figure 1. Structure of Broadband Network

B. An Existing Method

Monitoring RTT provides important insights for network troubleshooting and traffic engineering. The common monitoring technique is to actively send probe packets from selected vantage points (hosts or middleboxes).Active probing from selected vantage points for efficientRTTmonitoring of all the links and any round-trip path between any two switches in the network[4].

In a standard released by Ministry of Industry and Information Technology of the People's Republic of China concerns to measuring broadband access velocity. In the standard, a measure platform accesses to BRAS as showed in Fig.2[5]. Three models are presented including client speed-measurement, web page speed-measurement and control speed-measurement. The measurement process is described as follows. Firstly, users visit the special measurement web page, or use the measurement client to communicate with the measurement platform. Secondly, users download some special files from the platform. Lastly, the formula to calculate the access rate isEq.5

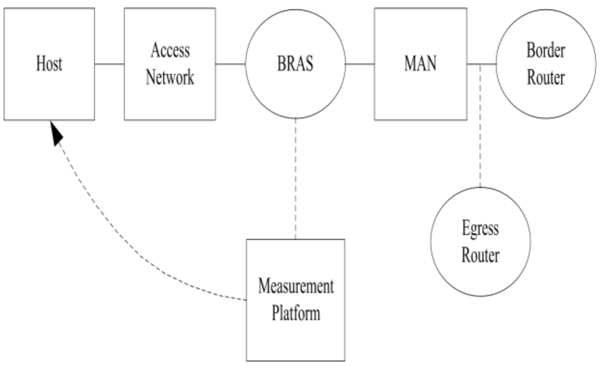

Figure 2. Architecture of Access Rate Measurement System

$$V = \frac{L}{T} \tag{1}$$

V (Byte/s) is the access rate, L (Byte) is the length of the downloaded file, and T(s) is the spent time for downloading the file.

Above-mentioned is a briefand direct way, and it is easy to draw a conclusion without complex devices. But this way has two shortcomings. At first, the conclusion cannot point out what is the main factor infecting the velocity. At last, too much platforms are not easy managing because there are many BRAS on the network.

II. A New Method

In this method, we can use some indexes of TCP messages including handshake-delay, wave-delay and scale of windows for measuring efficiency of the network. The following part will elaborate the method.

A. Handshake-delay and Wave-delay

1) Definition of Handshake-delay and Wave-delay

Su Q. and etc. mentioned some ways for measuring RTT in anarticle[6].According to their theories, we present two indexes, they are handshake-delay(T_1) and wave-delay(T_2)result from Eq.2 and Eq.3. And parameters being used for calculating them are shown in Figure 3. T_1 is handshake-delay of a upstream TCP message which is from Core Router (CR) to content server, for example, CDN.T_2 is Wave-delay of a downstream TCP message which is from CRto host, for example, PC[7]. We had capturedmessages in CR for a month.According to statistics and analysis, we divided T_1 and T_2into twelve intervals as Table 1 shown. T_1 and T_2 are defined as Eq.2 and Eq.3. Unit of them is millisecond.

$T_{hu}$is handshake-RTT of upstream, $T_{wu}$is wave-RTT of upstream, T_{hd} is handshake-RTT of downstream, and T_{wd} is wave-RTT of downstream. They can be calculated by time stamp of upstream or downstream. INT means bracket function. For instance, time stamp of downstream TCP message's ACK from content server minus time stamp of upstream TCP message's SYN from host can get T_{hu}.As shown in Fig. 3.

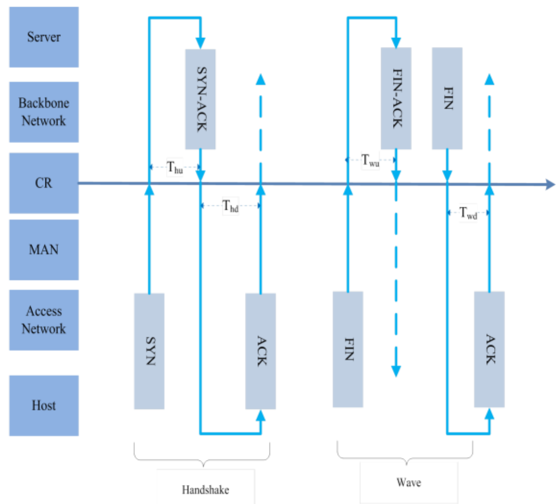

Figure 3. Definition of Delay

$$T_1 = INT\left(\frac{T_{hu} + T_{wu}}{2}\right) \tag{2}$$

$$T_2 = INT\left(\frac{T_{hd} + T_{wd}}{2}\right) \tag{3}$$

According to the value of T_N(including T_1 and T_2), T_N is divided into *i* intervals, $T_{N\text{-}i}$including $T_{1\text{-}i}$ and$T_{2\text{-}i}$ stands for the count ofT_N in No. *i* intervals in unit time. $T_{N\text{-}i}$ has no unit.

TABLE I. INTERVALS OF TN

T_N	<10	40	80	160
$T_{N\text{-}i}$	$T_{N\text{-}1}$	$T_{N\text{-}2}$	$T_{N\text{-}3}$	$T_{N\text{-}4}$

T_N	320	640	1280	2400
$T_{N\text{-}i}$	$T_{N\text{-}5}$	$T_{N\text{-}6}$	$T_{N\text{-}7}$	$T_{N\text{-}8}$

T_N	6000	18000	32000	>32000
$T_{N\text{-}i}$	$T_{N\text{-}9}$	$T_{N\text{-}10}$	$T_{N\text{-}11}$	$T_{N\text{-}12}$

For example, $T_{1\text{-}7}$ is 14 if 200 T_1 are recorded and 14 of them are between 1280ms and 2399ms in the unit time.

2) Analysis of Handshake-delay and Wave-delay

Probe at CR is able to collect aforesaid timestamp of TCP messages for calculating $T_{1\text{-}i}$ and $T_{2\text{-}i}$ in unit time. Then the statistics are inserted into a database consists of quintuples.

These quintuplesare defined according to a TCP message's parameters including source IP, source port, destination IP, destination port and name of the service. These parameters are easy being captured by probes based on Field Programmable Gate Array(FPGA).Table II shows THE data structure.

TABLE II. DATA STRUCTUREOFTN STATISTICS

Time Stamp	IP_{Source}	P_{Source}	$IP_{Destination}$	$P_{Destination}$	Service Name
2 Byte	4 Byte	4 Byte	4 Byte	4 Byte	20 Byte
	Quintuple				

T_1	T_2
12 Byte	12 Byte

Note: Structure of T_1 and T_2 is shown in Table I

Calculating accumulative total probability distribution of $T_{1\text{-}i}$ and $T_{2\text{-}i}$ as Eq.5

$$T_{S-N} = \sum_{i=1}^{12} (T_N)_i \tag{4}$$

T_{S-N} (N=1 or 2) is the sum of T_1 or T_2 in a quintuple in unit time.

$$P_{N-m-t} = \frac{\sum_{i=1}^{m} T_{N-i}}{\sum_{i=1}^{12} T_{N-i}} * 100\% \tag{5}$$

P_{N-m-t} (N=1 or 2) is accumulative total probability distribution of $T_{N\text{-}i}$ in *m* intervals,and T_{N-i} (i= 1 ~ 12) is the probability distribution of No.*i* interval.

Table III demonstrates how to use Eq.5.

TABLE III. THE DISTRIBUTION OF T2

T_2	<10	40	80	160
$T_{2\text{-}i}$	65	40	18	20
$P_{2\text{-}m\text{-}t}$	31.55%	50.97%	59.71%	69.42%
T_2	320	640	1280	2400
$T_{2\text{-}i}$	9	6	12	16
$P_{2\text{-}m\text{-}t}$	73.79%	76.70%	82.52%	90.29%
T_2	6000	18000	32000	>32000
$T_{2\text{-}i}$	12	7	1	0
$P_{2\text{-}m\text{-}t}$	96.12%	99.51%	100.00%	100.00%

$T_{N\text{-}A}$is defined as Eq.6 and score of $S_{N\text{-}k\text{-}t}$ is defined as Eq.7.$T_{N\text{-}A}$ means average of $T_N$and $S_{N\text{-}k\text{-}t}$ means the score of time delay of No. *k*sample.

$$T_{N-A} = \frac{\sum_{k=1}^{n} (T_{S-N})_k}{n} \tag{6}$$

$T_{1\text{-}A}$ is average T_1 of *n* samples,*n* is the number of samples with same destination IP, same destination Port and same name of the servicebut different source IP. $T_{2\text{-}A}$ is average T_2 of *n* samples,*n* is the number of samples with same BRAS or same port of BRAS, or same VLAN of portbut different source IP. $T_{S\text{-}N}$comes from Eq.4

$$S_{N-k-t} = \frac{100 * (I - \sum_{m=1}^{I} P_{N-m-t})}{I * x} + 100 * \frac{1-x}{2} \tag{7}$$

$S_{N\text{-}k\text{-}t}$(*N*=1 or 2) is the score of No. *k* sample. P_{N-m-t} results fromEq.5. *I* and *x* are parameters. Because there are 12 intervals for $T_{1\text{-}i}$ ($T_{2\text{-}i}$), so I equals 12. In addition, shorter time-delay means better QoS, so *x*=-1. For example, in the specified time, if the accumulative total probability distribution of $T_2$is shown in Table 3, the score of No. *k* sample is 75.5.

According to Eq.2 and Eq.3, T_1indictsefficiency of transferring data of uplink from CR to content server and T_2 indicts efficiency of transferring data of downlink from CR to host in the unit time. Two parameters could beused for evaluating the QoS. The comparison between $T_N$and $T_{N\text{-}A}$(from Eq.6), the comparison between T_N from different IP, different BRAS, different VLAN etc. in same time quantums, the comparison between T_N in different time quantums is helpful to locate the situation of fault. For the same reason, the comparison between $S_{N\text{-}k\text{-}t}$(from Eq.7) is helpful to locate the situation of fault. For example, if user-a blame to the speed when he was playing an online-game, we can score speed of users-b who playing same game on same server in the same VLAN-a during the same time. If a and b's scores were almost same, and users-c who playing same game on same server in others VLAN-b acquire higher score. So we can draw a conclusion that there may be something wrong with VLAN-a. Conversely, if user-a's score was obviously lower than users-b's , we can find maybe something wrong with user-a's equipment. Moreover, if user-a acquire different scores when he played same game on same server, without reconfiguring his equipment, in different time quantum. We can draw a conclusion that the difference dues to time but not equipment.

B. *Scale of Windows*

1) *Interview*

When CRs communicate with content servers or host, they can use sliding windows scheme in order to enhance efficiency of per TCP connection. Larger windows means more effective[7]. That is to say, more data can be transferred in unit time[8]. So we can grade scale windows according to their score, using similar method to mentioned-above.

2) Definition of Scale of Windows

$W_1$is defined as scale of windows of upstream TCP messages and $W_2$is defined as scale of windows of downstream TCP messages in a quintuple[9]. They also are divided into 12 intervals according to our statistics and analysis base on captured packets in CR for a month, as shown in Table IV.W_{N-i} including W_{1-i} and W_{2-i} stands for the count of W_N in No. *i* intervals in the unit time. Neither of $W_N$and W_{N-i}has unit.

TABLE IV. INTERVALS OFWN

W_N	0	500	1000	1500
W_{N-i}	W_{N-1}	W_{N-2}	W_{N-3}	W_{N-4}

W_N	2000	2500	3000	7500
W_{N-i}	W_{N-5}	W_{N-6}	W_{N-7}	W_{N-8}

W_N	11520	16000	32000	>32000
W_{N-i}	W_{N-9}	W_{N-10}	W_{N-11}	W_{N-12}

For example, W_{1-7}equals500 if 2000 TCP connections of upstream are recorded and 500 of their scale of windows are between 2500 and 3000 in the unit time.

3) Analysis of Scale of Windows

We construct a table similar to Table II shown as Table V.

TABLE V. DATA STRUCTUREOFWN STATISTICS

Time Stamp	IP_{Source}	P_{Source}	$IP_{Destination}$	$P_{Destination}$	Service Name
2 Byte	4 Byte	4 Byte	4 Byte	4 Byte	20 Byte
	Quintuple				

W_1	W_2
12 Byte	12 Byte

Now we can use Eq.8 for calculating the count of windows in a quintuple in unit time .

$$W_{S-N} = \sum_{i=1}^{12} W_{N-i} \tag{8}$$

We can acquire the accumulative total probability distribution of W_{N-i}in *m* intervals, as Eq.9 shown

$$P_{N-m-w} = \frac{\sum_{i=1}^{m} W_{N-i}}{\sum_{i=1}^{12} W_{N-i}} * 100\% \tag{9}$$

P_{N-m-w} (N=1 or 2) is accumulative total probability distribution of W_{N-i} in *m* intervals,W_{N-i} (i= 1 ~ 12) is the probability distribution of No.*i* interval.

Table VI demonstrates how to use Eq.9.

$W_{N-A}$is defined as Eq.10 and score of S_{N-k-w} is defined as Eq.11. W_{N-A} means average of $W_N$and W_{N-k-w} means the No. *k*sample's score of scale of windows .

$$W_{N-A} = \frac{\sum_{k=1}^{n} (W_{S-N})_k}{n} \tag{10}$$

W1-A is average W1 of n samples,n is the number of samples with same destination IP, same destination Port and same name of the service but different source IP. W2-A is average W2 of n samples,n is the number of samples with same BRAS or same port of BRAS, or same VLAN of port but different source IP. WS-N comes from Eq.8.

We also are able to calculate score of scale of windows for any sample based on Eq.11 similar to Eq.7.

$$S_{N-k-w} = \frac{100 * (I - \sum_{m=1}^{I} P_{N-m-w})}{I * x} + 100 * \frac{1-x}{2} \tag{11}$$

But it is important that *x*=+1in this scene because scale of windows and efficiency of network is positive correlation. This is different from delay. The latter is negative correlation.There is an example in Table VI similar to TableIII.

In Table VI, the values of P_{2-m-w} are as same as them in Table III, but the score of the scale of windows is only 24.5. We can estimate such a result because it is obviously that about one third of samples' scale of windows equals 0 in unit time. That means congestion during that time quantum[10] .

Thus comparison between $W_N$and W_{N-A}, the comparison between W_N from different IP, different BRAS, different VLAN etc. in same time quantums, the comparison between W_N in different time quantums is helpful to locate the situation of fault. For the same reason, the comparison between score of scale of windows is also helpful to locate the situation of fault. The example is similar to which are mentioned-above and it is not necessary to repeat.

TABLE VI. THE DISTRIBUTIONOFW2

W_2	0	500	1000	1500
W_{2-i}	65	40	18	20
P_{2-m-w}	31.55%	50.97%	59.71%	69.42%
W_2	2000	2500	3000	7500
W_{2-i}	9	6	12	16
P_{2-m-w}	73.79%	76.70%	82.52%	90.29%
W_2	11520	16000	32000	>32000
W_{2-i}	12	7	1	0
P_{2-m-w}	96.12%	99.51%	100.00%	100.00%

III. CONCLUSION

Delay and scale of windows are two important index when TCP messages are transferred on the Internet. This paper puts forward a new method using them for evaluating the QoS of broadband network. Following steps describe the method. Firstly, TCP messages in CR are captured. Secondly, delay and scale of windows are calculated. Thirdly, data from step 2 are used to calculate $T_{N\text{-}A}$,$W_{N\text{-}A}$and scores of T_N or W_N. Lastly, comparison between T_Ns, $W_N$sand scores can be used to locate fault.

But there is a problem should overcome. Though 20 Bytes are distributed to service name in quintuples mentioned in Table II and Table V, it is difficult to classify different services. Next we should devote our energies to abstracted huge amount of services to a limited quantity.

In addition, there are others indexes should be used for evaluating performance, for example, zero-windows delay. Because indexes relate to each other, we had better research more methods considering interdependencyof indexes.

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