Developing an ICMP-Based Network Bandwidth Measurement

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1 INTRODUCTION

In recent years, Internet-based services have proliferated with the increase in network speed and the number of Internet users. We now have various network services based on peer-to-peer (P2P) networks, contents delivery networks (CDN), grid networks, and IP-VPN. These network services build original logical networks, called *overlay network* on top of the Internet Protocol (IP) network. In order to enhance the service qualities in an overlay network, it is essential to understand the resource status of the IP network and to utilize the network effectively. Network bandwidth is the most essential resource status parameter. When multiple peers hold the same resource in a P2P network, we can use network bandwidth information to choose a peer to retrieve the resource from. In a CDN, we can transfer data at low priority on the basis of bandwidth information so as not to affect high priority data transfer. Network bandwidth information can also be used for the determination of the failure point in a network.

Much research has already conducted on network bandwidth measurement. Inline measurement TCP (ImTCP) is a recently developed method for measuring available bandwidth [1]. ImTCP utilizes only TCP data packets and the corresponding acknowledgement (ACK) packets to measure the available bandwidth between the sender and receiver. Since ImTCP needs to modify sender-side TCP, it needs to modify the operating system kernel at the sender host. Therefore, ImTCP cannot be installed on operating systems whose kernel cannot be modified by a user such as MS Windows. Moreover, when a receiving host's delayed ACK option is in effect, ImTCP cannot obtain exact bandwidth measurements.

In this paper, we propose a new method to measure available bandwidth. Our method is designed as a standalone measurement tool. Based on the ImTCP algorithm, the proposed method measures available bandwidth using ICMP ECHO packets and ICMP ECHO REPLY packets and does not require modification to a receiver. Further, the proposed method does not need modifications to the operating system kernel at the sender host and can thus be installed on MS windows. When a receiver host receives an ICMP ECHO packet, an ICMP ECHO REPLY packet is sent immediately. Therefore, the proposed method works even when the delayed ACK option is in effect at the receiver host. In this paper, we describe the implementation of our method, and evaluate its performance on an experimental network.

The rest of this paper is organized as follows. In In Section 2, we explain the design of our method. In Section 3, we show the effectiveness of the proposed method by conducting a performance evaluation on an experimental network. Finally, in Section 4, we state our conclusions.

2 BANDWIDTH MEASUREMENT METHOD USING ICMP

In the proposed method, we measure available bandwidth by using ICMP ECHO packets and ICMP ECHO REPLY packets to overcome ImTCP's delayed-ACK limitation. A receiver host returns an ICMP ECHO REPLY packet immediately upon receiving an ICMP ECHO packet. Therefore, a sender host can always observe the arrival interval of ICMP ECHO REPLY packets. Moreover, we can transmit ICMP ECHO packets from an application at arbitrary times. Therefore, we can adjust the transmission interval without modifying the operating system kernel at the sender host. Therefore, the proposed method can be utilized in an operating system whose kernel is not user-modifiable.

The measurement algorithm of ImTCP searches for available bandwidth in a restricted search range. Therefore, the number of packets required for measurement of the proposed method is smaller than that for existing measurement methods. Based on the measurement algorithm of ImTCP, the proposed method also requires fewer packets for measurement than the existing measurement methods.

The proposed method terminates measurement when the search range, which contains the required value of available bandwidth, becomes sufficiently small. Let *upper* denote the upper limit of a search range, *lower* denote the lower limit, and *abw* denote the last measurement result. When the following inequality is satisfied, the proposed method terminates measurement and shows the current value of *abw* as the available bandwidth.

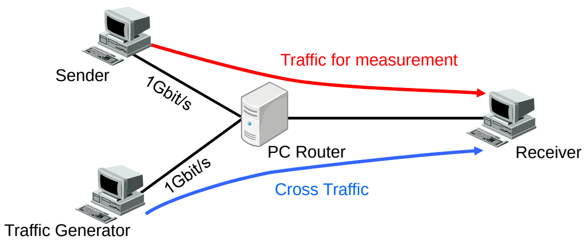

Figure 1: Experimental network

$$upper - lower < \alpha \times abw$$

ICMP is abused in many cases as means of attacking server, as in the Ping flood attack where an aggressor brings a server down by transmitting ICMP ECHO packets in large quantities to the server. When a lot of ICMP ECHO packets are received in a short time, many servers are configured to filter out these packets. Therefore, when measuring available bandwidth using ICMP, we must limit the number of ICMP ECHO packets transmitted. In the proposed method, we set an idle period (during which measurement is not conducted) after each measurement that is equal to two round-trip durations. This prevents the transmission of a lot of ICMP ECHO packets in a short time. Moreover, setting the idle period eliminates the effect of the packets transmitted for the last measurement on the network.

3 PERFORMANCE EVALUATION

Fig. 1 shows the experimental network, which is constructed from a PC router running DummyNet, a traffic generator, a sender, and a receiver. ImTCP estimates the tendency of the receiving interval of measurement packets using two thresholds, PCT and PDT. In this paper, PCT is configured to 40 and PDT is configured to 30. Further, we set the number of subdivisions of a search range K to four, the number of packets for measuring the sub-range n to 10, and the parameter for end of measurement α to 0.05.

The measurement methods transmit packets over a network for measurement. In other words, they give load to a network. The amount of data used for measurement is an essential index of the measurement methods. In addition, compared with the physical bandwidth, the time granularity of the available bandwidth variation is very small. Therefore, the time for measurement is important. We first evaluate the amount of data and time required for measurement. In this evaluation, the bandwidth between the PC router and the receiver is varied from 1 [Mbit/s] to 5 [Mbit/s] using DummyNet. We took 10 readings at each setting. We also took readings using PathLoad [2], which is the conventional available bandwidth measurement method, for comparison.

Fig. 2 shows the distribution of the relative error between measured available bandwidth and actual available bandwidth and the total amount of data for measurement sent to the receiver. From Fig. 2, it is observed that the measurement error of the proposed method is 0.1 or less, much smaller than that of PathLoad. The minimum and maximum amounts of data transmitted by the proposed system are 162 [Kbyte], and 1134 [Kbyte], respectively. When using PathLoad, the corresponding values are 2163 [Kbyte] and 3324 [Kbyte]. In most cases, it is observed that the proposed method transmits only a small amount of data for measurement. Even in the worst case, the total amount of data that the proposed method requires for measurement is 1134 [Kbyte]. We note that the minimum amount of data required by PathLoad is 2163 [Kbyte].

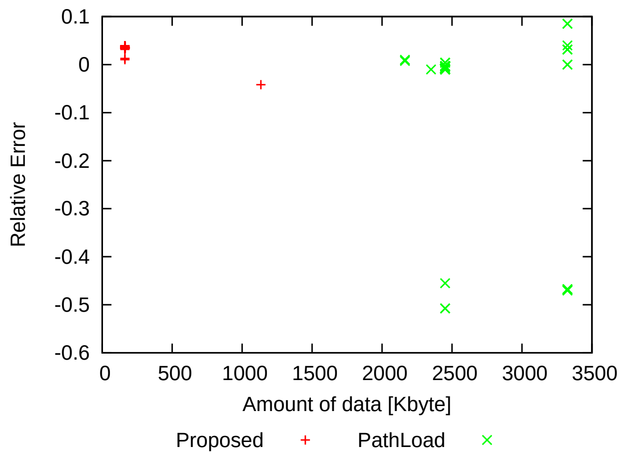

Figure 2: Distribution of the relative errors between measured and actual bandwidth and the total amount of data

4 CONCLUSION

In this paper, we proposed a new available bandwidth measurement method based on the measurement algorithm of ImTCP, an inline network measurement method. The proposed method solves the limitations inherent to ImTCP. We evaluated the proposed method in an experimental network, and showed that the proposed method requires smaller amounts of data and less measurement time compared to PathLoad.

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