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THE PERFORMANCE OF DCCP TCP-LIKE WITH INITIAL SLOW-START THRESHOLD MANIPULATION

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ABSTRACT. This paper investigates the performance of the implementation of modified initial slow-start threshold size in Datagram Congestion Control Protocol (DCCP) TCP-like (CCID-2) over long delay link network. TCP-like is one of a congestion control mechanism for DCCP which is suitable for the delivery of multimedia data with abrupt changes during the transmission. The scenario is set for long delay link network, where the impact of the modified slow-start threshold value in TCP-like is significant. As a result, we managed to reduce the time required to obtain the maximum throughput in TCP-like during in the slow-start phase. The result shows that with the correct manipulation of initial slow-start threshold size for TCP-like, it will give a significant improvement to TCP-like performance over long delay link where the maximum throughput during the slow-start phase can be achieved faster.

Keywords: DCCP TCP-like, slow-start threshold, congestion window

INTRODUCTION

As an option to User Datagram Protocol (UDP), DCCP is a new transport protocol for sending multimedia contents in the Internet nowadays. In addition, DCCP is an unreliable transport protocol which has built-in congestion control unlike UDP. With this feature, DCCP ensures that there is no bandwidth monopoly by certain transport protocol like UDP did for years. UDP has been proven that can eat up all the available bandwidth in the Internet while competing with other transport protocols such as Transmission Control Protocol (TCP) in carrying multimedia data in many situations.

The performance of DCCP is good while working in normal network scenario, i.e. short delay link network. As for long delay link network with higher Round-Trip Time (RTT), DCCP suffers from the bandwidth utilization during the beginning of the connection where longer time is taken to exceed the maximum bandwidth (Nor, Hassan, & Almomani, 2008).

This research is aiming in improving the performance of DCCP with TCP-like congestion control mechanism during slow-start phase of the connection for long delay link network. During the slow-start phase of the connection, the throughput is increasing exponentially until the current congestion window (*cwnd*) size exceeds the initial slow-start threshold size. With the idea of increasing the initial slow-start threshold size for more aggressive throughput grow in TCP-like, the initial slow-start threshold size has a significant effect to the performance of DCCP carrying multimedia data over large delay link. Initial slow-start threshold parameter is used by congestion control implemented in DCCP's TCP-like congestion control where all TCP congestion control implementations are required to support it. From our experiments, we found out that too small initial slow-start threshold value for large delay link makes the traffic throughput sent using DCCP requires longer time to become stable. The selection of suitable value of initial slow-start threshold is then vital to the stability of the network carrying streaming audio data over DCCP.

This paper is organized as follows: This section is followed by related work section regarding the works done by other researchers. The subsequent section explains about the transport protocols for multimedia data. Experimental setup section describes the simulation and performance metrics used. All the results are included in result section, and finally the conclusion section ends the paper.

TRANSPORT PROTOCOLS FOR MULTIMEDIA DATA

TCP (ISI-USC, 1981) has known to be a reliable transport protocol with congestion control for delivering data traffic. Moreover, TCP can deliver the best-effort services for error-intolerant and delay-tolerant data such as web, email, file transport, etc. All that features of TCP make it suitable for the delivery of important, mission critical, and error-free data which requires a reliable data connection.

On the other hand, TCP is not suitable to send multimedia data such as audio and video which request time-sensitive and error-tolerant transmission. For multimedia data transmission, UDP (Postel, 1980) is a suitable transport protocol and has been the favorite choice for decades among Internet users because it is a simple transport protocol and can comply with the transmission requirements. However, the extensive use of UDP can endanger and collapse the network because UDP is greedy protocol, which means that it will send data as much as it can without congestion control, and it is not friendly to other congestion controlled protocol such as TCP.

One of the solutions regarding this problem is the introduction of a new transport protocol for the delivery of multimedia data, DCCP (Kohler, Handley, & Floyd, 2006) which is unreliable like UDP, but has congestion control mechanism like TCP. Currently, DCCP has few congestion control mechanisms, i.e. TCP-like (Floyd & Kohler, 2006a) which follows the TCP Selective Acknowledgment (TCP SACK) (ISI-USC, 1981), TCP-Friendly Rate Control (TFRC) (Floyd & Kohler, 2006b) which follows the TFRC and TFRC-SP (Floyd & Kohler, 2007) which is a version of TFRC for small packet.

DCCP as defined by Internet Engineering Task Force (IETF) is well suited as a transport protocol for delivering multimedia data over wired or wireless networks. It supports bidirectional unicast connections of congestion-controlled unreliable datagram. DCCP is the right choice for applications that used to transfer huge amounts of data such as streaming multimedia data that can take advantage from control over the tradeoff between timeliness and reliability. It is also good for network health due to its built-in congestion control features.

RELATED WORK

TCP-like congestion control is designed for the abrupt changes data with higher buffer size and the data is sent as fast as possible. Same as in TCP, the congestion control mechanism in TCP-like consists of slow-start and congestion avoidance. The *cwnd* size increases exponentially in slow-start phase where it increases linearly in congestion avoidance phase.

The study of the friendliness of DCCP towards TCP was done by Shahrudin et al. (Nor, Hassan, Ghazali, & M. Arif, 2010) which shows that DCCP can coexist with TCP and sharing the bandwidth fairly, not like UDP which is unfriendly to TCP.

Since DCCP is a new transport protocol, most of the research works of DCCP is related to its performance (Azad, Mahmood, & Mehmood, 2009; Bhatti, Bateman, & Miras, 2008;

Chowdhury, Lahiry, & Hasan, 2009). Nevertheless, since TCP-like congestion control mechanism follows the TCP standard, the improvement works on the TCP regarding slow-start threshold (Kaiyu, Yeung, & Li, 2005; Marchese, 2001; Rung-Shiang, Hui-Tang, Wen-Shyang, & Ce-Kuen, 2005) and TCP-like (Chaintreau, Baccelli, & Diot, 2002; Seung-Gu & Jong-Suk, 2000; Zhao & Song, 2009) are related to DCCP TCP-like as well. Shahrudin et al. also did a work on the initial slow-start threshold for DCCP TCP-like in delivering VoIP over long delay link (Nor, et al., 2008).

The slow-start phase in TCP-like, as well as in TCP, can be whether at the beginning of the connection, or when reconnection establishment after idle time due to no data transmission or inactive connection. In normal case, the initial slow-start threshold size is 20 packets for DCCP. The unit packet is used in DCCP in contrast of byte in TCP because DCCP is a datagram transport protocol whereas TCP is a byte stream transport protocol.

In our research for long delay link, TCP-like congestion control mechanism for DCCP is selected because it outperforms TFRC in terms of time taken to achieve the maximum throughput (Nor, Hassan, Ghazali, & M. Arif, 2010). This improvement is done during slow-start phase, where another improvement for TCP-like is done in congestion avoidance phase long delay link as done by Shahrudin et al. in (Nor, Hassan, Ghazali, & M. Kadhum, 2010) and resulted in better and smoother throughput.

EXPERIMENTAL SETUP

The experiments have been carried out by means of simulation with the simulation topology as shown in Figure 1. The network simulation topology uses classic dumbbell topology. Dumbbell topology is a very common topology that has been used in many TCP network simulations. For all the experiments, the simulations consist of a DCCP TCP-like sender and a standard TCP sender, or TCP New Reno in particular, because TCP New Reno is one of the most popular TCP variant used in the Internet nowadays. At the receiver's side, there are DCCP TCP-like and TCP receivers. All the senders and receivers are connected to the routers through 100 Mbps links with 1 ms propagation delay.

Figure 24. Simulation Topology.

In our simulation environment, we have simulated DCCP as a competing protocol to TCP, so that we can see how the other protocol such as DCCP behaves when they coexist with TCP. The utilization of bandwidth by these two competing protocols is set into a scenario so that a DCCP sender will fully utilize the 2 Mbps bandwidth with the sending rate of 2 Mbps Constant Bit Rate (CBR) traffic. CBR is used as a multimedia traffic and its packet size is 500 bytes. In this case, TCP sender sends the file transfer data using File Transfer Protocol (FTP) application. Unlike DCCP, where the transmission bit rate can be set by the application like CBR, the maximum bit rate occupied by FTP application on TCP will be calculated by the transport protocol itself based on the link bandwidth provided, packet size, propagation delay, etc. From the simulation results, we will see the effect of the manipulation of initial slow-start threshold size on DCCP TCP-like.

The network topology used in our simulation includes two interconnected routers, R1 and R2 with queue size of 20 packets. For the router to router connection, a long delay bottleneck link is set to have a bandwidth of 2 Mbps with 300 ms propagation delay. This long delay bottleneck link can be used as an emulation of satellite or wireless links with a fixed forward link delay of 300 ms and fixed return link delay of 300 ms. This assumption is reasonable based on Henderson and Katz (Henderson & Katz, 1999) for the satellite link. There is also research done by other researchers that use this assumption for a long delay link (Sathiaseelan & Fairhurst, 2006). In addition, we considered that the bottleneck link has enough bandwidth allocation for the data transfer to flow from the sender to the receiver. For simplicity, instead of using other types of queue management such as Random Early Detection (RED), the type of queue management used in this link is Drop Tail, which implements First-In First-Out (FIFO). For the simulation experiment, the network simulator *ns-2* ("The VINT Project. The Network Simulator - ns-2,") is chosen together with DCCP module (Mattsson, 2004).

The throughput is measured between Router 1 and Router 2 where the DCCP TCP-like and TCP flows compete with each other on the long delay link. The TCP connection is monitored while it coexists with DCCP connection.

Experiment 1 is carried out to show how friendly the DCCP TCP-like is when it coexists with TCP flow on a fully-utilized bandwidth link. For this purpose, the simulation duration is increased to 1000 seconds. The simulation time for experiment 2 is set to 200 seconds because this period is long enough to get the whole picture of the performance of TCP-like which is affected by the initial slow-start threshold size. Four different initial slow-start values are used, i.e. 20, 50, 100 and 200 packets. In our case, the slow-start phase that we will investigate happens at the beginning of the connection. In all the simulation experiments, the FTP application using TCP is started first, i.e. at time 0.5 seconds, whereas the CBR application for DCCP TCP-like is started at time 10 seconds. We assume that 10 seconds is enough to allow the TCP data flow to utilize the bandwidth without any contention with another flow, so that we can see the effect on throughput of having other flows joining the bottleneck link after that.

All the performance metrics used in this research are throughput and packet loss. The measurement of the packet drop percentage are from the simulation time at 20s to 180s for more precise average value, which is not including the setup and tear-down times of the connection. On the other hand, the instant throughput is calculated from the simulation and plotted in the throughput graph. Other performance metrics such as delay and jitter are not taken into account since all measurements are taken at the beginning of the connection, i.e. during slow-start phase. The delay and jitter are suitable to be measured for the entire connection when the throughput has gained the maximum and stable state.

RESULTS

In our finding, we have shown that TCP-like with the manipulation of initial slow-start threshold size can improve the performance of the TCP-like in terms of faster time required to obtain the matured throughput during slow-start phase over long delay link network. The slow-start phase can be in action during the initial connection establishment or reconnection after idle time. This modified mechanism for TCP-like can minimize the time required during slow-start phase, i.e. faster to achieve the stable maximum throughput.

Experiment 1

This experiment is to show how DCCP is friendly to TCP. As shown in the topology in Figure 1, TCP and DCCP flows are sharing the same fully utilized bottleneck link. The throughput graph in Figure 2 shows that DCCP can share the bandwidth fairly with TCP on a fully utilized link.

Figure 25. Throughput of TCP-like vs. TCP.

It is noticed that the throughput of the DCCP TCP-like is in the range from about 1 to 1.7 Mbps in zigzag form. This is due to the congestion control behavior of TCP-like which is implementing Additive-Increase Multiplicative-Decrease (AIMD) based on the congestion control of TCP SACK. As for TCP, the average bit rate for TCP data flow is fluctuating around 300 kbps because the TCP throughput is limited by buffer size and Round-Trip Time (RTT).

Experiment 2

This second experiment is to find the optimum value for initial slow-start threshold size in DCCP with TCP-like congestion control mechanism. The graph in Figure 3 shows four different times taken to exceed the maximum throughput with different initial slow-start threshold size, i.e. 20, 50, 100 and 200 packets. For normal initial slow-start threshold size, where the size is 20, it can be seen that it exceed the maximum bandwidth at about the simulation time of 160 ms, whereas for the initial slow-start threshold size of 200 packets, the maximum throughput is gained at time of about 100 ms. This is because the increase of throughput is exponential during slow-start phase, i.e. until its current *cwnd* exceeds the initial slow-start threshold size. After that, the congestion avoidance phase will be entered where the throughput is increasing linearly.

It shows that with the initial slow-start threshold of high value, in this case of 200 packets, the maximum throughput can be obtained faster. The values of initial slow-start threshold of higher than 200 packets do not give any better result. The optimum value of 200 packets for the initial slow-start threshold size has given the best performance in this research in terms of throughput.

Figure 3. Throughput of Various Initial Slow-start Size for TCP-like

From the experiment result for packet loss as given in Table 1, the percentage of packet loss or Packet Loss Ratio (PLR) is 0.0277% for initial slow-start threshold size of 200 packets, which is within the specification by ITU-T. ITU-T recommendation G.1010 (ITU-T, 2003) states that PLR must be less than 1% for video data.

Table 1. Packet Loss

Initial Slow-start Threshold size (packets)	Packet loss (%)
20	0.0014
50	0.0015
100	0.0107
200	0.0277

CONCLUSION

In our finding, we have shown that with the correct selection of initial slow-start threshold size, we can enhance the performance of the DCCP TCP-like in terms of faster time required to obtain the maximum throughput during slow-start phase for long delay link network. TCP-like with such initial slow-start threshold size can minimize the time required during slow-start phase, i.e. faster to achieve the maximum stable throughput with acceptable packet loss. The implementation can be made during slow-start phase, i.e. whether during the initial setup connection or during the reconnection after timeout where slow-start phase will be in action. It is also shown that the implementation over long delay link still maintain the friendliness of DCCP TCP-like towards TCP.

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