Analysis of congestion control techniques for time critical applications

Afeefa Qureshi[1], Ariba Qamar[1], Imtiaz Ali Halepoto[2], Sana Ashfaque[1], and Monika Lohana[1]

[1] Department of Computer Science, QUEST Nawabshah Pakistan
[2] Department of Computer Systems Engineering, QUEST Nawabshah Pakistan
halepoto@quest.edu.pk

Abstract. The social media video apps such as TikTok require a smooth data transmission. Such type of applications are time sensitive and could not tolerate much delay in transmission caused by the algorithms of the protocol. For example, algorithms for congestion control and reliability check. TCP and UDP protocols are used on todays Internet. TCP is a reliable transport layer protocol with congestion control mechanism, which deliver the data in ordered manner and retransmit the data in case of error. Therefore, TCP needs improvement to be used for such type of applications where reliability could be compromised for high performance. UDP is suitable for time sensitive apps but it has no mechanism to smooth the transmission in case of congestion. so we need a protocol that delivers the data traffic on time and also have congestion control mechanism. Therefore Datagram congestion control mechanism (DCCP) protocol has been developed to overcome the weaknesses with more control on the congestion and the timely delivery of data. This paper provides the details of advanced congestion control techniques of DCCP such as CCID 2 and CCID 3 over different networks through simulations. The proposed simulation networks are configured with highspeed bandwidth and random link failures. The results shows that CCID 3 (TFRC) is better in dealing network congestion in 5 node scenario with and without link failure than CCID 2 and TCP. Whereas on 20 node scenario CCID 2 outperforms the other two.

Keywords: TCP · UDP · DCCP · Congestion · Reliability.

1 Introduction

The research on various real time applications on the Internet, for example, Internet telephony, streaming media, and web based games has put a question on the existing protocols such as TCP. Generally Internet utilize TCP and UDP for sending data for these applications. TCP guarantees ordered data delivery and reliability. It means when a data unit is lost, TCP retransmits it and it has an effect on the processing of new data in queue, data that is already in receiver buffer, which leads to the possibility of the network congestion.

Normally At that point TCP sender decreases its sending rate and unlikely the data rate may not meet the necessities of streaming media or application. Thus TCP needs improvements for streaming media application. Alternatively, if UDP is deployed for those applications, at that point it is challenging to recuperate from congested network because the protocol has no congestion control mechanism.

Therefore IETF has introduced a new Transport layers protocol called DCCP, which provide reliable connection and new congestion control mechanisms. It is suitable for time critical and real time applications. DCCP provides the options of multiple congestion control algorithms, which are differentiated by Congestion control Ids (CCIDs). At the present time, two CCIDs are operational with DCCP. First is CCID 2 (TCP-like Congestion Control) and second is CCID 3 TFRC (TCP-friendly Rate Control). CCID 2 is based on the window stream control and is reasonable for bursty constant applications which essentially need to move a large information in a short period, it is conceivable such as online games and packed encoded recordings. CCID 3 is suitable for real-time application where smooth changes in sending rate are expected, such as web based communication.

The experimental work [1] on the behavior of TCP and DCCP shows that CCID 3 is suitable for those application that need smooth rate. Another experimentation [2] on MPEG4 video over a congested network by using TCP, UDP, CCID2 and CCID3 shows the varients of DCCP gives better throughput, reduced packet loss as compared to UDP but the the delay and jitter of UDP is lesser than DCCP.

Authors in [3] presented the performance of DCCP CCID2 relative to the congestion varients of TCP, that are NewReno, BIC and CUBIC. CCID2 shows good fairness with NewReno under the test conditions, while BIC and CUBIC show unfairness above round-trip times of 25ms.

The work on Mobile adhoc networks [4] for the implementation of DCCP shows that end-to-end delay of TFRC is less than that of UDP and TCP. The end-to-end delay of UDP increases with the increase in the number of nodes. The monitoring of jitter value in the given scenario also recommend TFRC for the mobile adhoc networks.

The researchers in [5] evaluated the congetion control techniques of DCCP in terms of power usage. The study conclude that the DCCP is suitable for multimedia applications.

2 Overview

2.1 TCP

TCP enables two systems to set up a connection and begin correspondence through streams of information. TCP consists of a set of IP headers and port number that identifies the TCP communication.

Using TCP Congestion occurs because of the transmission of large amount of data. During congestion large amount of data are at high risk of to be lost. The delay in data transmission and the overflow are also common consequences of congestion. To overcome from the network congestion four algorithms are used by TCP that includes, fast retransmit, slow start, fast recovery and congestion avoidance.

Fast Recovery: Fast Recovery algorithm has been used widely over the Internet. After the initial congestion is detected the client retransmits few of the packets in order to reduce the congestion. In this algorithm the retransmit delay is not calculated and is based upon the ratio of total number of packets that are lost to total number of packets that are transmitted in an interval of time.

Slow start: TCP slow start is an algorithm which balances the speed of a network connection. Slow start gradually increases the amount of data to be transmitted until it finds the networks maximum carrying capacity. Slow start occurs automatically every time a packet arrives. This means a TCP connection is automatically slow starting, unless the user changes the TCP packet header with this option.

Fast retransmission: Quick retransmit is an upgrade to TCP that decreases the time a sender holds up before retransmitting a lost section. A TCP sender normally utilizes a straightforward clock to perceive the lost fragments.

2.2 DCCP

The Datagram Congestion Control Protocol (DCCP) is a Transport Layer protocol based on UDP additionally it is capable to provide reliable connection and congestion control mechanism and feature negotiation. It overcomes the selective functionality problem in TCP and UDP protocols. The main motive is to design this protocol is to support timeliness in data transmission and provide unreliable data transfer with congestion control. The core features of DCCP are the following:

- It provides unreliable flow of datagram
- Reliable handshakes for connection setup and teardown
- Feature negotiation.
- DCCP offers ECN-aware
- Congestion control mechanisms and use additional information
- DCCP provides Path Maximum Transmission Unit (PMTU) discovery.

DCCP is equipped with options to transmit data like TCP congestion mechanism as well as some advanced congestion control techniques. congestion control is mechanism for choosing between several congestion control algorithm in DCCP. It can mainly use two algorithms, that are CCID 2 and CCID 3.

2.3 CCID 2

CCID 2 is a TCP-Like congestion control mechanism which is based on AIMD strategy. CCID 2 take the benefit of available bandwidth which can adopt to the changes of congestion window like TCP. CCID 2 has the following features:

1. Sender maintains a congestion window and send packets until that window is full.
2. One ACK per two packets is used by default.
3. ACK declares exactly which packet are successfully received.
4. Drop packets and ECN are used to predict the congestion.
5. Response to congestion is to half the congestion window (AIMD).
6. Acknowledgments in CCID 2 contain the sequence numbers of all received packets within some window related to a selective acknowledgement [6].

2.4 CCID 3

DCCP can be configured to CCID 3 mechanism, it uses TFRC in order to reduce the network congestion. The sender maintains the sending rate by observing the lost event send by the receiver and goes through a constant sending rate for a duration. one feature of CCID 3 is the use of ECN (explicit congestion notification) which helps in providing end-to-end congestion notification through adjusting ECN in the IP header. TFRC is a receiver based congestion control mechanism that uses throughput equation to estimate the allowable congestion rate and provides a smoother sending rate than TCP. Generally, TFRCs congestion control mechanism works as follows:

1. The receiver measures the loss event rate and notify this information back to the sender.
2. The sender also uses these feedback messages to measure the round-trip time (RTT).
3. The loss event rate and RTT are then used into TFRCs throughput equation, giving the acceptable transmit rate.
4. The sender then adjusts its transmit rate to match the calculated rate [8].

3 Simulation Environment

The tool NS-2.35 is used to configure and simulate the proposed scenarios. Two scenarios are proposed as shown in Fig 1 and Fig 2, to evaluate the performance of TCP and DCCP variants (CCID 2, CCID 3). To analyze the performance throughput is used and it is calculated in Mbps. Throughput is defined as the total number of successfully received packets at the receiver in one second. In the proposed scenarios the simulation parameter Queue type is Droptail, queue size is 20 packets. The overall simulation run time 100 seconds. Three different scenarios are proposed to evaluate the congestion control techniques, TCP, CCID 2 (TCP-Like) and CCID 3 (TFRC).

In Scenario–1 there are 20 nodes in the topology which consist of three senders (S1, S2 and S3) and three receivers (R1, R2 and R3). Scenario–2 consist of five nodes in the proposed topology: two senders (S1 and S2) and one receiver (R1) as shown Fig 2a. In the same 5 nodes topology, link failure is added as shown in Fig 2b.

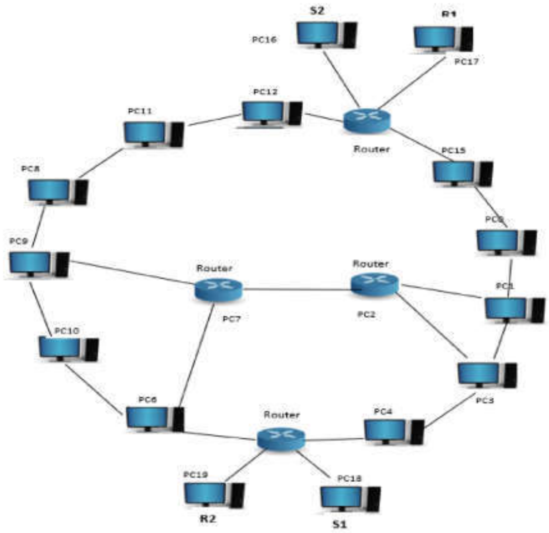
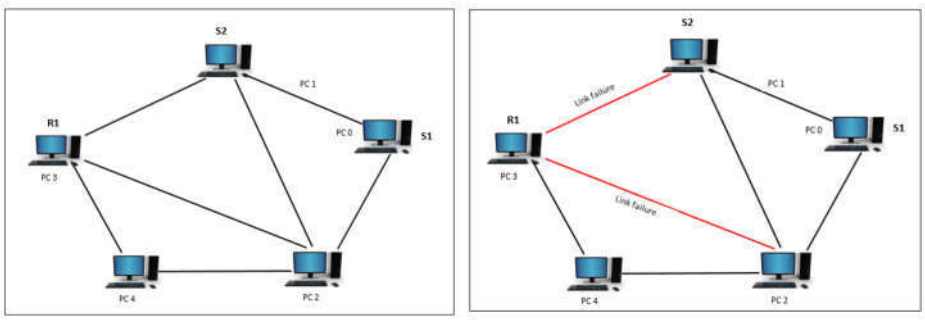
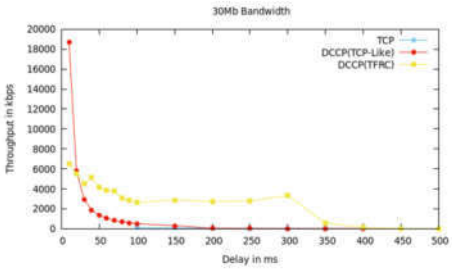


Fig. 1: Scenario 1: 20 node topology

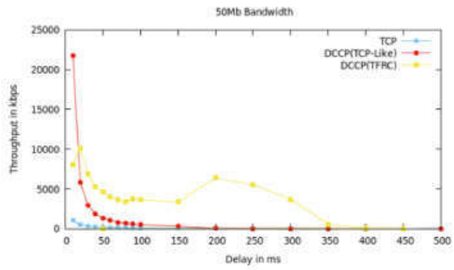


(a) 5 nodes (b) 5 nodes with link failure

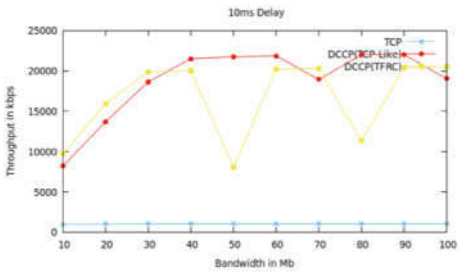
Fig. 2: Scenario 2: 5 nodes



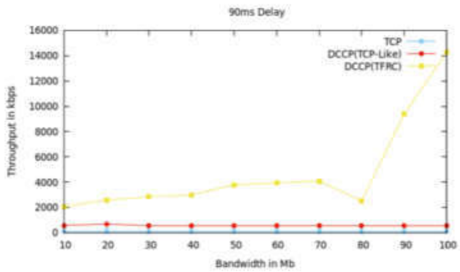
(a) 10ms to 500ms Delay and 30Mbps



(b) 10ms to 500ms Delay and 50Mbps



(c) 10 to 100 Mbps bandwidth and 10ms delay



(d) 10 to 100Mbps bandwidth and 90ms delay

Fig. 3: Throughput (EXPERIMENT 1)

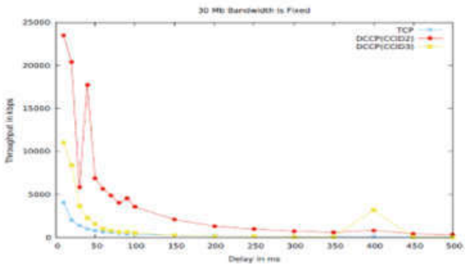
4 Simulation Results

In this section, we will analyze the outcomes achieved from our simulations in different scenarios. We compared TCP with CCID2 (TCPLike) and CCID3(TFRC) in terms of throughput. We increased delay from 10ms to 500ms for all scenarios and retained bandwidth of 10Mbps to 100Mbps. Then in the next simulation we Kept delay of 10ms, 30ms, 90ms and raised bandwidth from 10Mbps to 100Mbps.

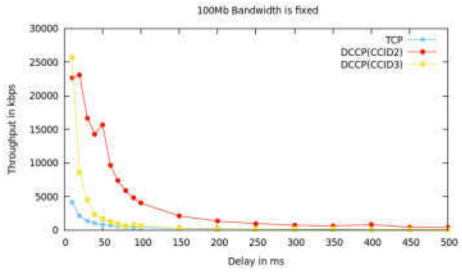
4.1 Experiment 1: 20 Nodes Scenario

The experimental graphs of 20 node scenario are shown in Fig 3 x-axis shows delay or bandwidth y-axis represents throughput in kbps.

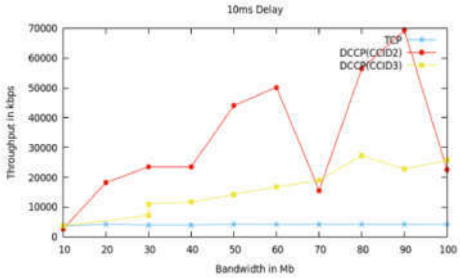
In Fig 3 our graph shows that at low delay throughput of CCID 2(TCP-like) is greater than CCID 2 (TFRC) but as delay increases TFRC's throughput is higher than TCP-like and TCP. Similarly in graphs as seen in Fig 3c bandwidth increases from 10Mbps to 100Mbps at 10ms delay, it is noticed that at 50Mbps and 80Mbps bandwidth, TFRC's throughput decrease abruptly. The overall it is analyzed that throughput of TCP-like and TCP is less than TFRC as shown in Fig 3.



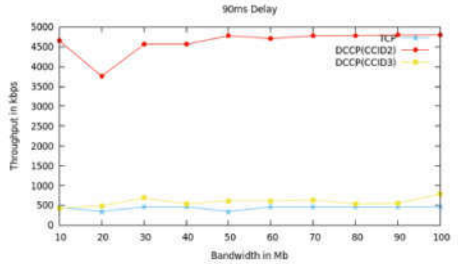
(a) 10ms to 500ms delay and 30Mbps bandwidth



(b) 10ms to 500ms delay and 100Mbps bandwidth



(c) 10Mbps to 100Mbps bandwidth and 10ms Delay



(d) 10Mbps to 100Mbps bandwidth and 90ms Delay

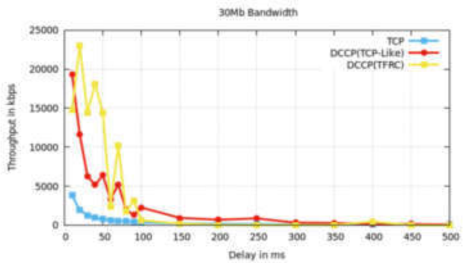
Fig. 4: Throughput (EXPERIMENT 2)

Our results shows that in this scenario TFRC's performance is better than TCP-like and TCP.

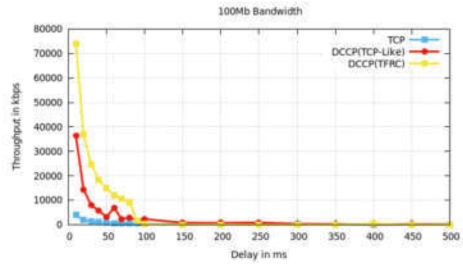
4.2 Experiment 2: 5 Nodes Scenario

The experimental results in terms of throughput of DCCP variants(CCID2 and CCID3) and TCP are shown in Fig 4. The throughput of DCCP varients is greater. Because TCP retransmits the loss packet and reduces the congestion window to one-half of current value after occurrence of packet loss. On the other hand less number of lost packets are not retransmitted by CCID2 and CCID3 congestion control mechanisms. Hence CCID2 and CCID3 achieved greater throughput than TCP.

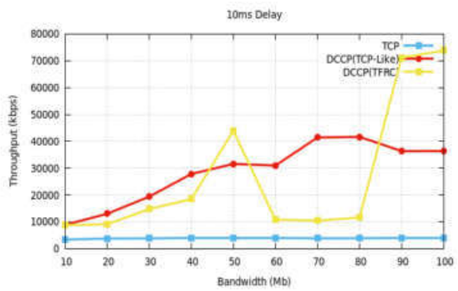
It is also noticed that the performance of CCID 3is better than CCID 2. Because the congestion control mechanisms acts differently in congestion scenario. CCID 3 uses TFRC mechanism in which sender maintain its sending rate by information that is advertised by the receiver. CCID 3 uses TCP based congestion mechanism in which it simply reduces the congestion window.



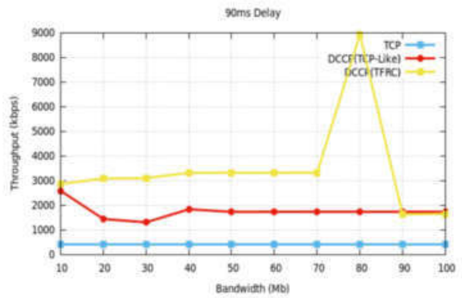
(a) 10ms to 500ms Delay and 30Mb Bandwidth



(b) 10ms to 500ms Delay and 100Mb Bandwidth



(c) 10Mb to 500Mb Bandwidth and 10ms Delay



(d) 10Mb to 500Mb Bandwidth and 90ms Delay

Fig. 5: Throughput (EXPERIMENT 3)

4.3 Experiment 3: 5 Nodes with Added Link Failure

In this experiment the link failure is added in terms of packet loss in scenario of 5 nodes. The packet loss is randomly assigned to two links. The packet loss is random, for example in case of 10% packet loss the simulator randomly discards 10% of the data on the given link by assuming that the link is in failure state. In the topology the link failure is applied on two links. One on between R1 and S2 and second on between R1 and PC2. The evaluation results of link failure scenario while changing bandwidth and delay are presented in Fig 5.

In link failure situation it is investigated that, TFRCs performance is better than TCP-Like and TCP because in TFRC mechanism as packets are dropped sender regulate their transmission rate according to its receiver rate.

5 Conclusion

DCCP is a new protocol and is still in the research phase due to its high-speed data transfer, efficient congestion control and bandwidth usage. Due to the DCCP functionality, it is very appropriate for applications such as online games, video streaming, uploading large amounts of data and selecting the best links from multiple links. A number of scenarios are developed in this project to configure DCCP and TCP. Most of the developed scenarios are multipath scenarios. DCCP produces higher performance than TCP in the specified scenarios. We evaluated the performance of transport layer protocols: TCP, CCID2 (TCP-like) and CCID3 (TFRC) in different scenarios. We conclude that TFRCs performance is better than TCP and TCP-like in link failure. From our experiments we also analyze higher performance of TCP-Like congestion mechanism in terms of throughput as compared with TCP and TFRC in 20 node scenario. Because of reliable and retransmission of loss packets TCP is not suited for todays real-time applications. Therefore, it is concluded that the performance of DCCP (CCID2 and CCID3) is much better than TCP in all scenarios.

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