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Evaluation of Multipath Transmission using the Stream Control Transmission Protocol

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Abstract: Concurrent Multipath Transfer using the Stream Control Transmission Protocol (CMT-SCTP) enables multi-interface devices to send and receive data at the same time over more than one path. However, because of the fair Round robin scheduling, the paths with longer delay (low quality) causes the performance degradation due to gathered outstanding data at receiver. The outstanding data are the data packets sent by the sender for which it is waiting for an acknowledgment. In networks with dissimilar paths, the blockage in the buffer space at the receiver side is also one of the side effects of large outstanding data. This paper presents an evaluation study on the multipath transmission using the SCTP, particularly the techniques that deal with the outstanding data. A simulation scenario is proposed that contains multiple paths from the source to destination, where each path differs with the other path by the propagation delay. The results of evaluation show that the technique that uses the outstanding data in the packet scheduling decision (CMT-OUT) increase the data transmission over multiple paths when it is compared to the CMT-SCTP.

Keywords: CMT-SCTP, outstanding data, round robin scheduling, propagation delay.

1. Introduction

The Internet access these days is one of the keys to access the electronic resources as well as it is a medium of communication. For that, multi-interface devices such as PCs and mobile phones are useful. Nowadays the methods are available to stay connected through multiple ways such as 3/4G, UMTS, 802.11a/b/g and the wired networks. A communication device, which provides this access feature, is called multi-homed device and a reliable transport layer protocol that support multi-homing is known SCTP [1]. In this protocol a multi-homed node can be addressed by multiple IP addresses in one association (connection). SCTP, a reliable protocol enables the data transmission through wired and wireless network at the same time data transfer by achieving CMT (concurrent multipath transfer) [2] [3], by approximately doubling the transmission rate. On the other hand, performance of CMT-SCTP over multipath network with dissimilar paths is always challenging when the size of receiver buffer (RBUF) is small [4, 5]. For example, 3G and WiFi connections are dissimilar to each other in terms of propagation delay, bandwidth, loss rate and many other parameters.

The dissimilar paths are a challenge for multipath transmission because the data assembly at the receiver takes longer time [5]. To a point when one of the path is too slow, then concept of multipath transmission have no benefit. In such cases, some of the packet schedulers perform the retransmission of the actual data sent on the slow path by using the fast path. The slow paths also carry more data in flight then the data received along the corresponding path [3,4]. After some time, the slow paths occupy large space in memory and still wait for some more data. On the other hand the fast paths may not acknowledge [5] and the total data in the buffer may need to be erased if the timers expire.

Few of the reasons for performance degradation are the buffer size and the design of the packet scheduler. In CMT-SCTP, round robin scheduler is used, which uses no intelligence for path quality assessment before the data transmission. Such scheduling follows a circular order for choosing the paths whose congestion window (CWND) is free to carry a packet. Path quality refers to

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how fast or slow a path is delivering the data. For example, a path with longer propagation delay is slow compared to the path with shorter propagation delay.

In order to alleviate the buffer blocking, authors in [4, 6] proposed five retransmission policies. These policies use different parameters such as congestion window and loss rate to decide the path for the transmission of the data. The scheduling of packets and transmission based on path characteristics are given in the literature. Many proposals suggest bandwidth to guess the path quality [7]. The delay is also in consideration for the estimation of path quality [8]. The work [9] on different time values for example the time to enter the queue and time of transmission for the design of packet scheduler also improves the transmission rate. Wallace et al. [10] proposed a technique to decide the path selection by recording the acknowledgement time of a packet. Similar to the acknowledgement time, the work in [11] uses the round trip time (RTT), where it is suggested that the receiver buffer size plays important role in the RTT measurement.

Authors in [12, 13] highlighted the challenges of heterogeneous networks and developed a technique, which divides the buffer space equally into the number of paths. For that, the authors used the amount of outstanding data (CMT-RBS). Authors in [14, 15, 16] proposed a technique (CMT-OUT) to enhance the multipath transmission data rate. CMT-OUT uses a new packet scheduler where the key element is the outstanding data. The technique to maintain a buffer space for each of the path is also proposed in CMT-OUT.

This paper evaluates the performance of CMT-SCTP with CMT-RBS and CMT-OUT. In order to simulate the network protocols, a model is proposed in NS2. The network is configured to represent the parameters close to reality, due to which, each of the paths are assigned a different propagation delay value.

In rest of the paper, the details of concurrent data transfer are present in Section II. To evaluate the performance of different protocols a simulation model and related configuration is explained in Section III. Section IV provides a deep discussion on obtained results of the simulation. Section V concludes the paper.

2. Multipath Transmission

A. Stream Control Transmission Protocol

A reliable, young transport layer protocol that provides most of the services provided by the other transport layer protocols. Following is the key comparison of the SCTP with the other protocols:

- One of key feature of SCTP is multihoming. It means SCTP transmits data simultaneously over more than one paths. Such feature is not available in TCP and UDP. However, a new version of TCP called the multipath TCP is able to use multipaths simultaneously.
- SCTP also provides Multistreaming. A stream is a logical division of a path. The data along a path is assigned a stream number. The data transmission by using the parallel stream mitigates the head of line blocking problem of TCP. The multisteraming is not available in both TCP and UDP.
- Before the transmission of the payload data, the SCTP initiates a connection between two end-to-end devices. The connection initiation feature is available in TCP but not in UDP.
- Both of the SCTP and TCP used the similar congestion control and flow control algorithms. These features are not available in UDP.
- Some applications provide built in features for data sequencing and does not require transport layer overhead for the sequencing. In such applications, SCTP could move to the unreliable delivery of message like UDP.

B. Concurrent Transmission through SCTP

The extension of SCTP famous for the load sharing over more than one path is called the CMT-SCTP. As the concurrent transmission is the new idea, therefore many issues in CMT-SCTP needs to be addressed such as congestion control, quality of service, buffer management and security. One of the techniques that improves the performance of CMT-SCTP is the division of buffer into the number of paths (CMT-RBS). However, CMT-RBS still uses the traditional method for the packet scheduling. Another technique that divides the buffer by estimating the path quality is called the CMT-OUT, which mainly focuses on outstanding data. In first phase, CMT-OUT sends packets to the destinations according to a rank based on the path quality and only if the congestion window allows a transmission. In second phase, the technique updates the path quality of different paths after a successful transmission. A path quality is an estimation of desire for the current path to be chosen for data transmission during the upcoming transmission opportunity.

3. Simulation and Topology

Simulation topology consists of two multi-homed (MH) nodes (Sender and Receiver). Considering the popularity of multipath networks each of these MH-nodes contain four interfaces. Interfaces (s_1, s_2, s_3, s_4) and (d_1, d_2, d_3, d_4) are at sender and receiver. The interfaces are connected through four paths (P_1, P_2, P_3, P_4) as shown in Figure-1. Path P_i is along connection between s_i and d_i.

The scenario is setup for paths, which are only asymmetric in terms of propagation delay. Rests of path characteristics of each of four paths are kept same. Propagation delay on paths (P_1, P_2, P_3, P_4) is set to (60, 120, 180, 240) milliseconds. Bandwidth is fixed to 10Mbps across all paths. Maximum transmission unit is set to 1500 bytes. All remaining configuration is set to as of default and simulation runs for 100 seconds. This simplified model is prepared in NS2 simulator [17] and executed to verify algorithm in four experiments each time with different size of RBUF i.e., (64, 128, 192, 256) KB. To investigate the performance, simulations are carried out while executing CMT-OUT against basic CMT-SCTP and CMT-RBS. The implemented of CMT-SCTP is already available in the NS2. The changes are made in the code of CMT-SCTP in order to implement the other two protocols for the evaluation. For the analysis part the individual throughput in Mbps is investigated.

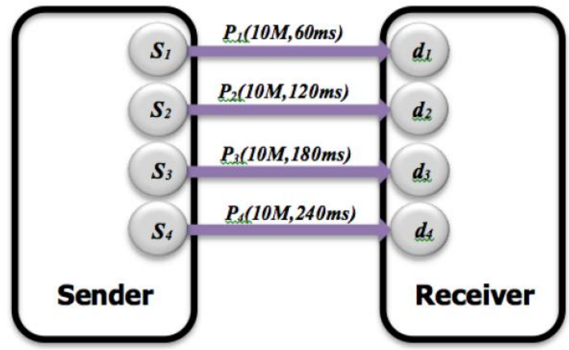

Figure 1: A four-path simulation setup

4. Results and Discussion

Investigations show that the throughput increases as RBUF size increases from 64KB to 256KB. Obtained results of evaluation shot that the CMT-OUT clearly achieve higher aggregated throughput compared to CMTSCTP/CMT-RBS in each of different RBUF size of 64, 128, 192 and 256 (KB) as shown in Figure 2.

During simulation there are many places where two destinations have CWND and RBUF (at same time). Despite path quality CMT-SCTP and CMT-RBS give the opportunity to transmit to all of the destinations in order. However, CMT-OUT does the same but in precedence of their path quality. So a good path avails opportunity to transmit data first over the rest of competitor paths. For example at time 1.781475 secs when RBUF = 64KB, CMT-SCTP/CMT-RBS transmits data chucks to d_1 and d_2 (delay along d_1 is shorter than d_2) such that d_2 transmits first and d_1 later. Contrary, CMT-OUT transmits to d_1 first and d_2 later. There are situations such as at time 2.023955 secs where for example d_3 and d_4 have no cwnd or very low path quality, only destination d_1 and d_2 are in position to receive packets. CMT-SCTP/CMT-RMS checks for assigning opportunity in sequence {d_3, d_4, d_1, d_2} and sends to only available {d_1, d_2}. While, CMT-OUT checks out sequence in order {d_1,

d_2, d_3, d_4} and sends to {d_1, d_2} and then checks for d_3 and d_4. In both of above qoted examples CMT-OUT takes intelligent actions by choosing right destination and at right time.

Firstly, one of the reasons a common buffer is inapproriate in dissimilar paths is because of the slow path, it could accommodate more outstanding data. Splitting a RBUF has lessen the quantity of outstanding data on most of slow paths in CMT-RBS as shown in Figure 2 (P_3 and P_4 when RBUF = 64KB to 256KB). Secondly, alone buffer splitting is not enough solution to the given chellage. One should also incorporate some proper decision making in selection of path when several of them are competing. Otherwise with smaller share (splitted-buffer) the slow path would occupy its own sub-buffer quick compared to when RBUF is unshared and halts untill release. CMT-OUT takes both of advantages. First, it divides rbuff as in [13]. Second, it makes intelligent decision in choosing destination such that to impede the quantity of data chunks on slow paths as shown in Figure 2 (P_3 and P_4 when RBUF = 64KB to 256KB). In CMT-OUT, outstanding over the fast path are more because the scheduler targets the fast paths.

A. Dealing the slow paths

The difference in throughput of fast and slow path (i.e., P_1 and P_4 in Figure 2) of CMT-OUT is clearly more than CMT-SCTP/CMT-RBS. It is mainly becuause of sending less data to the slow path (P_4). CMT-OUT restrict slow paths as follows. Out of the available paths the estinations along which acknowledgment is received are at higher chances of getting selected for transmission.

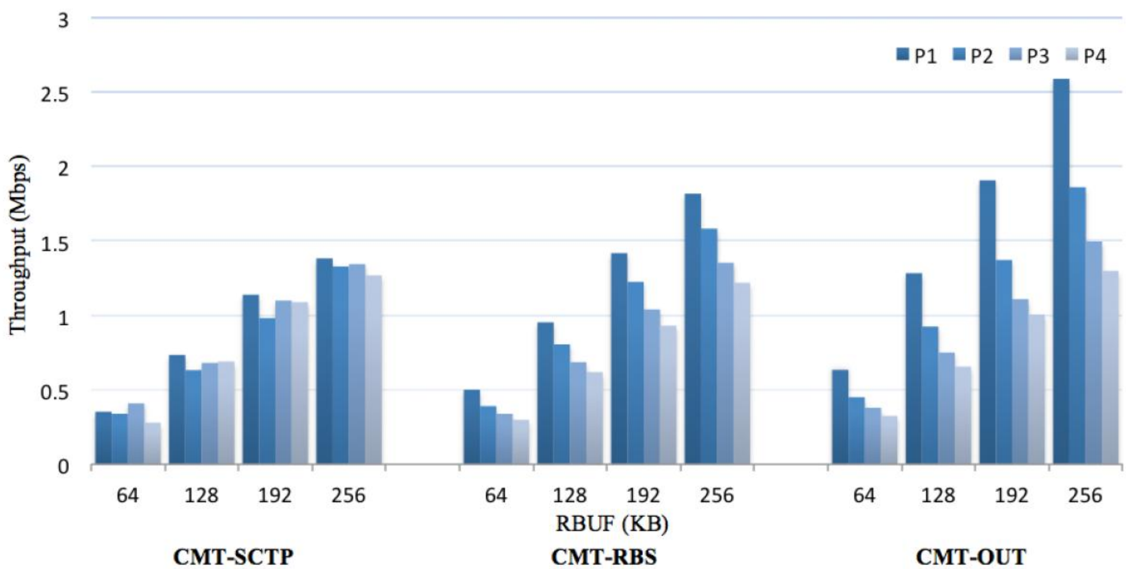

Figure 2: Throughput of individual paths

B. When receiver buffer is small

When RBUF=64KB CMT-OUT improves overall throughput of CMT-SCTP by 29% and CMT-RBS by 17% approximately. However CMT-SCTP achieves good throughput on slower path (P_4), a consequence of dominance of the outstanding data over receiver buffer. CMT-OUT accumulatively outperforms CMT-SCTP because with small buffer space the destinations in CMT-OUT along shorter delay fill up their respective RBUF by availing the opportunity frequently. As a result, longer delay destinations are granted the opportunities to transmit only when shorter delay paths have no CWND. CMT-RBS performs well compared to CMT-SCTP by reducing the dominance, an advantage of the buffer splitting.

C. When receiver buffer is large

If we increase RBUF size as a consequence the slower paths in CMT-SCTP/CMT-RBS start to degrade transmission throughput by availing the opportunity most of the times during their turn. In the simulation, longer delay paths gather more outstanding data. Even though longer delay paths in CMT-OUT could do the same, but PQU plays role to restrict them. Longer delay paths most of the time are labeled as PQU_L as low quality by DSV. The same applies to CMT-RBS compared to CMT-SCTP. CMT-OUT decreases the frequency of sending data to slower paths like P_3 and P_4. When buffer is 256KB CMT-OUT improve throughput approximately by 36% and 21% compared to CMT-SCTP and CMT-RBS.

D. Path-wise performance

In our simulation model CMT-SCTP performs worst in all experiments in aggregating throughput. Despite of CMT-SCTP not performing well, the longer delay path (P_4) of CMT-SCTP performs well better than P_4 of both of CMT-RBS and CMT-OUT in most of experiment, among all CMT-RBS performs the worst. It is a straight benefit of fairness of CMT-SCTP. CMT sends more outstanding on longer delay paths i.e., P_3 and P_4, therefore shorter delay paths cannot improve aggregated throughput. In CMT-RBS short delay paths receive around equal outstanding data as longer delay paths, so fast paths are bounded by slow path. Once slow paths fill up entire small sub-buffer it pauses transmission, affecting fast paths (P_1 and P_2). CMT-OUT considers longer delay paths as low quality and restrict sender to transmit outstanding along these paths. That's the reason longer delay paths in CMT-OUT surpass CMT-RBS when it comes to throughput. In all different buffers from 64KB to 256KB fast paths in CMT-OUT enhance throughput notably as shown in Figure 2.

5. Conclusion

The concept of multipath transmission using the transport layer protocols is beneficial for higher transmission date rate as well as redundancy. One the key protocols that provide multipath transmission is the CMT-SCTP. Performance of CMT-SCTP in networks with dissimilar paths is challenging and to tackle the issue packet scheduling of the transmission opportunity to send data to destinations is important. This paper evaluates CMT-SCTP, CMT-RBS and CMT-OUT over a four path scenario. The results suggest that the CMT-OUT is preferable protocol for multipath transmission.

Future work on multipath transmission should focus on the design of buffer assignment techniques based on the path quality.

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