

# Examining TCP Fairness in model with Unequal RTT

Kushagra Srivastava

School of Computer Science and Engineering  
Vellore Institute of Technology  
Vellore, India

**Abstract—** Today Transmission Control Protocol(TCP) is most widely used transport layer protocol because of its reliability. One of the major problems of TCP is the unequal sharing of bandwidth for a set of TCP sessions sharing the same bottleneck. This unequal use of bandwidth is can be a result of varying Round Trip Time(RTT) or different segment sizes of different TCP sessions. Since TCP is the de-facto standard protocol for reliable data transfer, it seems we must accept these limitations. Fortunately, that is not the case, and the situation can be improved. This paper analyses the problem TCP faces when multiple TCP session are established each having a different RTT. This paper proposes a theory which would help achieve fairness in TCP. Here the main focus is on controlling the rates of the various TCP sessions. Here we try to drop the rate of the connection with lower RTT and relatively increase the rate of the link with higher RTT to get a better fairness.

**Keywords-**TCP, RTT,Slow Start, Additive Increase,Conjestion Window

## I. INTRODUCTION

TCP is a major connection oriented protocol working on the fourth layer of the OSI model i.e. Transport Layer. It is one of the most robust protocols being used on internet. It is used by popular application which depends on reliable delivery such as peer to peer, FTP, Secure Shell etc.

There are several unresolved issues with TCP .One of such problems is the unequal share of bandwidth among various TCP sessions having different Round Trip Time (RTT).

The fairness problem in TCP is rooted in its congestion avoidance mechanism.We know that TCP increases the congestion window size after every RTT be it Slow Start or Additive Increase. Thus if there are multiple links with varying RTT the congestion window size of the link having relative less RTT will grow faster than the rest. It may so happen that major bandwidth gets consumed by connections having short RTT and the relatively longer RTT suffocate or frequently timeout as they don't get the required bandwidth.

To provide a more detailed explanation we consider three models (In all the models we assume that the segment sizes are same for all the links).

- Connections with equal RTT
- Connections with unequal RTT
- Multiple connections(more than three) with unequal RTT.

## II. MODELLING

To discuss the problem we have come up with three models.We will analyse the fairness of these models and come up with a solution which will help in making these models more fair.

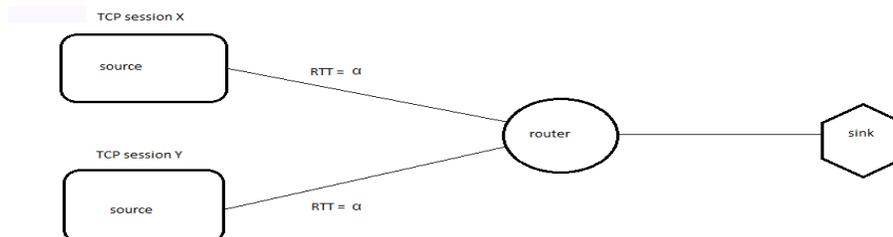


Figure 1. Connections with equal RTT.

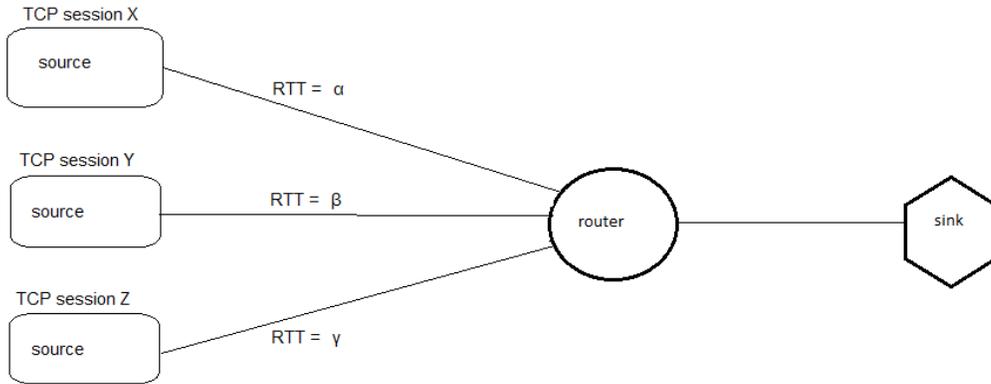


Figure 2. Connections with unequal RTT

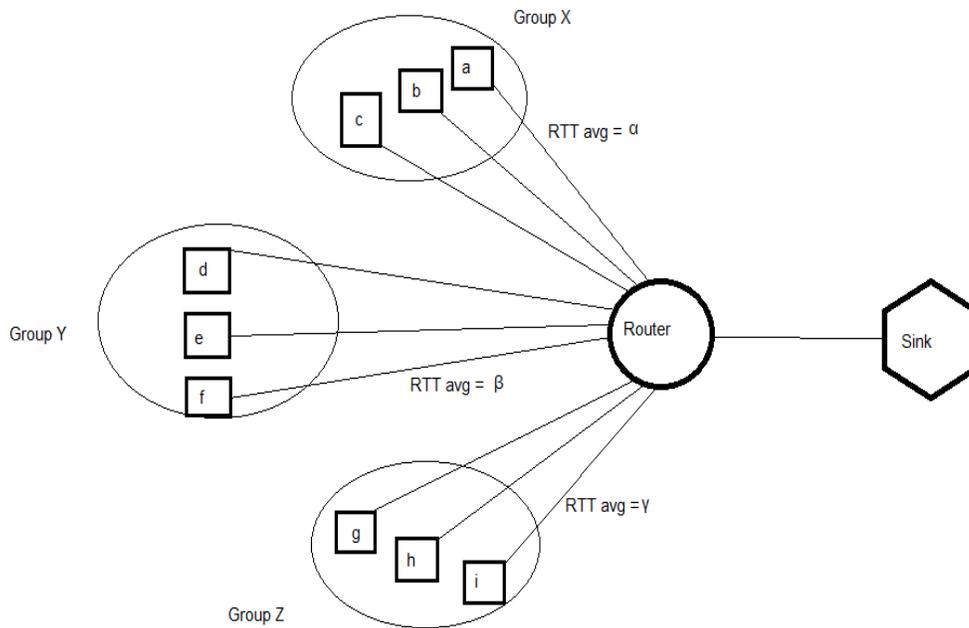


Figure 3. Multiple connections with unequal RTT

A. Connections with equal RTT

This is the most ideal type of model Fig. 1 In this model both the links have equal RTT. If the bottleneck link is of bandwidth 'R' then each TCP session gets to use

$$R/2 \tag{1}$$

of the bandwidth. Similarly if we had established 'N' TCP sessions then each of the links would get an RTT of

$$R/N. \tag{2}$$

We see that when RTT's of different links are equal then TCP seems to be fair. But it is a rare scenario to see such a network with connections of equal RTT. Due to diversity in each layer

and medium this case is rare. Hence now we consider a more realistic scenario of links of unequal RTT.

**B. Connections with unequal RTT**

In the second model we consider three links each connection has a different RTT. In the Fig. 2 we have these three connections marked as X, Y, Z such that their RTT  $\alpha, \beta$  and  $\gamma$  respectively share the relation

$$\alpha < \beta < \gamma \tag{3}$$

Now the session having lower Round trip time will consume more bandwidth compared to the ones having higher Round trip time. The implementation of this model is further discussed in the ‘Working’ section of the paper.

**C. Multiple Connections with unequal RTT**

When we say multiple connections we mean that there are more than three connection share a bottle neck link. This model builds on the second model. When there are several connections at the bottle neck then we bundle the connections in three different groups X, Y and Z. Now the container X will contain all the connections with short RTT. Group Z will contain connections which have very large RTT and Group Y will have connections with average RTT. Hence when we look at these three Groups we get a relation between the average RTT of these groups  $\alpha, \beta$  and  $\gamma$  respectively similar to that of second scenario

$$\alpha < \beta < \gamma \tag{4}$$

**III. WORKING**

In this section we will minutely investigate each of three models and plot out a method for each model so that there in fairness between connections sharing the same bottleneck link.

**A. Connections with equal RTT**

This model Fig. 1 needs no adjustment since all the connections have the same RTT (assuming that the segment size are same for all the connections). In case of a triple acknowledgement the congestion window of each connection gets reduced by a constant. We don't have to worry about fairness in this model. TABLE 1 compares the RTT, old congestion window and new congestion window of both the connection in Fig. 1

TABLE I. COMPARISON OF DIFFERENT CONNECTION FOR FIG. 1

Connection	Comparison metric		
	RTT	Old Congestion Window Size	New Congestion Window Size
X	$\alpha$	A	A/constant
Y	$\alpha$	B	B/constant

**B. Connections with unequal RTT**

We will work on the second model given in Fig. 2 and try to improve its fairness, later we will implement the procedure of second model in the third model.

Initially we do not know the RTT of any of the TCP session. We start with the slow start. In the slow start, the congestion window of all the connections will start to grow exponentially. This exponential function is same for all the links. We come to know the RTT for each of the links.

Suppose at time ‘t’ triple duplicate acknowledgement occurs and congestion window drops to half. As RTT  $\gamma$  is the largest the congestion window of the corresponding RTT grows very insignificantly compared to connection with RTT  $\alpha$ . As a result of this, soon the connection z will be suffocating for its bandwidth. And if  $\gamma \gg \alpha$  (as in this case) Z connection might not be able to hold up its connection and will frequently time out.

We know that the congestion window of connection X is growing faster than that of Z. We try and control the congestion window size of both the connection X and Z.

The TCP works on Additive Increase and Multiplicative Decrease. In a normal TCP the multiplicative decrease is independent of the RTT. The multiplicative decrease is always achieved by dividing the congestion window by a constant.

In this paper we make the multiplicative decrease of congestion window size a function of RTT. We try and reduce the congestion window more for connection ‘x’ which has shorter RTT and less for link ‘z’ which has comparatively larger RTT.

When X receives a duplicate acknowledgment, it will not decrease its congestion by a constant instead the new congestion window will be A1

$$A1 = \frac{1}{2} * \gamma (A) \tag{5}$$

Where A is the old congestion window size of the window. Similarly when for connection Z the the new congestion window size can be given as C1

$$C1 = \frac{1}{2} * \alpha (C) \tag{6}$$

Where C is the old congestion window size of the connection. Hence, the congestion window decreases more for the connection X and less for the link Z.

The rate of flow can be roughly written as

$$\text{Rate} = \text{congestion window size} / \text{RTT} \tag{7}$$

Thus, when there are duplicate acknowledgements received by both the connections X and Z, the rate of X will not reach its

full potential and use less bandwidth. The bandwidth spared by X will be used by connection Z. This way fairness we provide fairness to the connection sharing the same bottleneck link.

The congestion window of connection Y is not disturbed. The rate of Y is such that it will survive the competition but not enough to sacrifice some of it for Z. Hence, it does not decrease its congestion window size dynamically.

TABLE II. COMPARISON OF DIFFERENT CONNECTION FOR FIG. 2

Group	Comparison metric		
	Average RTT	Old Congestion Window Size	New Congestion Window Size
X	$\alpha$	A	$A1 = 1/2 * \gamma (A)$
Y	$\beta$	B	B/constant
Z	$\gamma$	C	$C1 = 1/2 * \alpha (C)$

### C. Multiple Connections with unequal RTT

We have already briefly discussed this model. Fig. 3 shows nine connections. These connections bundled in three groups X, Y and Z.

One can observe that after bundling this model is reduced to the model given in Fig. 2. The connection X, Y and Z are replaced by group X, group Y and group Z. We apply the same method of that we applied for the second model.

The new congestion window for all the connections of group Z will be C1

$$C1 = (1/2 * \alpha)(C) \quad (8)$$

Where C is the old congestion window size of the connection. Similarly, the new congestion window size for group X will be A1

$$A1 = (1/2 * \gamma)(A) \quad (9)$$

Where A is the old congestion window size of the connections in group X.

Hence, the group X will not utilize the bandwidth to its full potential, this will give chance to group Z to utilize the bandwidth spared by group X.

This model can also be applied to any number of connection sharing a bottle neck link. We will have to bundle the connection in three groups according to their RTT and then use the method discussed.

TABLE III. COMPARISON OF DIFFERENT CONNECTION FOR FIG. 3

Connection	Comparison metric		
	RTT	Old Congestion Window Size	New Congestion Window Size
X	$\alpha$	A	$A1 = 1/2 * \gamma (A)$
Y	$\beta$	B	B/constant
Z	$\gamma$	C	$C1 = 1/2 * \alpha (C)$

## IV. CONCLUSION

In this paper we proposed a theory and an approach which will help solve the problem of Fairness in TCP. We have shown that if the reduction of the TCP congestion window is made dependent on the RTT of other connections we will be able to control the rate of the link. The rate control is relative which means that if a link slows down another link will speed up. This ensures that a link with a very short RTT does not suck up the bandwidth.

## REFERENCES

- [1] M. Allman, S. Floyd, and C. Partridge. Increasing TCP's Initial Window. Internet RFC 2414,
- [2] H. Balakrishnan. Challenges to Reliable Data Transport Protocols over Heterogeneous Wireless Networks. Ph.D. Thesis, University of California, Berkeley, 1998
- [3] H. Balakrishnan, V. Padmanabhan, and R. Katz. The Effects of Asymmetry on TCP Performance. Proceedings of Third ACM/IEEE MobiCom Conference, pages 77–89, September 1997
- [4] Issues in Model-Based Flow Control by Sridhar Ramesh and Injong Rhee, Department of Computer Science, North Carolina State University, Raleigh.
- [5] Data Communications and Networking by Behrouz Communications and Networking.
- [6] Computer Networking a Top Down Approach Featuring Internet by Kurose and Kurose.
- [7] A Multi-level TCP Model with Heterogeneous RTTs Pasi Lassila and Michel Mandjes; Helsinki University of Technology, P.O.Box 3000, FIN-02015-HUT, Finland. Pasi.Lassila@hut.fi2 CWI, P.O. Box 94079, 1090 GB, Amsterdam, the Netherlands. Michel.Mandjes@cwi.nl3 University of Twente, P.O. Box 217, 7500 AE Enschede, the Netherlands.
- [8] Bonald, T., Proutiere, A., Régnie, G., Roberts, J.: Insensitivity results in statistical bandwidth sharing. In: Proc. of 17th International Teletraffic Congress, Bahia da Salvador, Brazil (2001) 125–136
- [9] Mathis, M., Semke, J., Mahdavi, J., Ott, T.: The macroscopic behavior of the
- [10] TCP congestion avoidance algorithm. Computer Communication Review 27 (1997) 67–82
- [11] Ayesta, U., Avrachenkov, K., Altman, E., Barakat, C., Dube, P.: Multilevel approach for modeling short TCP sessions. In: Proc. of 18th International Teletraffic Congress, Berlin, Germany (2003) 661–670

## AUTHORS PROFILE

Kushagra Srivastava, is third year student of School of Computer Science and Engineering from Vellore Institute of Technology, Vellore, India.