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QoS of High Speed Congestion Control Protocols

M. A. Mani, J. B. Abed, S. Laârif and R. Mbarek

***Abstract*— Since many years, computer networks have became more and more extensive; however, this evolution brings with her many problems that we can find among them the congestion phenomenon, which actuates many researchers to propose several solutions for these difficulties, aiming to find some TCP alternative congestion control protocols in order to enhance the performance as well as the link utilization. In this paper, we will be studying the Quality of Service of some congestion control protocols. We will evaluate and compare some of high speed congestion control protocols using a dynamic tool of choice of congestion control protocols.**

***Index Terms*— High-Speed, QoS, TCP Protocols, Congestion Control, Performance and Multiple Flows**

I. Introduction

IN this paper, as we have already said we will focus on the concept of Quality of Service. Obviously, we will talk about the quality of service in details based on the curves drawn after we get the results of simulating with dynamic tool of choice of congestion control protocols.

We always speak in the context of computer networks, according to ISO standards, QOS has several definitions:

- ETSI - QoS: "the collective effect of service performance which determines the degree of satisfaction of a user of the service"
- IETF - QoS: "The ability to separate traffic or differentiate between different types of traffic flows in order to treat some differently from other flows"

This is a set of techniques applied to a network, with the aim of ensuring a well-defined service by generating predictable results.

When we say the quality of service of a network, it says a service offered by the network, and there are several types of this quality: there is that the intrinsic QoS that the network provides to us a direct and which is described in terms of some specific metrics such as flow rate, delay, loss rate, jitter... Subsequently we will focus on this type of QOS.

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There is also the QoS perceived that we can collect from the user by measuring specific standards, and finally there is the QoS estimated that expresses the will of a user to receive a definite service. With the existence of a variety of acts or communications services, there are different qualities of service which they are associated, such as file transfer that describes its quality through reliability data transfer rate... or an example of a video stream with good quality requires the absence of jitter and limited reliability.

Moreover, we should mention that we cannot focus on the concept of the QoS without doing simulations and performance evaluation of high speed congestion control protocols.

II. State Of The Art

Researchers have worked on many network protocols over the years, and particularly those devoted to high speed networks, more exactly about high speed congestion control protocols, seven of them were compared in a previous research work [1] which are High Speed TCP [2], Bic TCP [3], Scalable TCP [4], Cubic TCP [5], Hamilton TCP [6], Illinois TCP [7] and YeAH TCP [8]. In our research we have added another recent congestion control protocol which is Compound TCP [9]. So we have tested three performance criteria for each one of them: efficiency, fairness and performance.

A. Architecture

For simulation of congestion control protocols ;High Speed TCP, Bic TCP, Scalable TCP, Cubic TCP, Hamilton TCP, Illinois TCP, YeAH TCP and Compound TCP, we need a topology on which we perform the simulation, the chosen topology is mainly composed of a receiver and a transmitter with two routers connected by a line whose bandwidth is equal to 1 Gbps, and the period is 1 ms. The line between the two routers is a line having a bandwidth of 200 Mbps, the delay is 98 ms and a queue of a capacity equal to 100 packets, the SSM has a size equal to 1460. We must announce that the differences between bandwidths cause congestion.

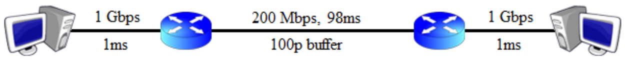

Fig. 1. Basic topology

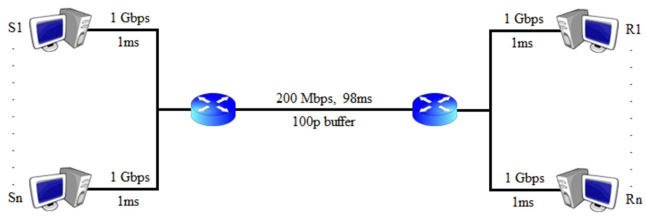

Fig. 2. Topology with multiple flows

B. Efficiency

Efficiency means the use of the available network capacity utilization, so the maximum is the utilization rate, the more this network is efficient. In another term, efficiency is considered as the transmitted packets number for all the resources during a specified period of time.

This performance metric is calculated as an average throughput of the totality of circulating flows in the link bandwidth.

As shows the following efficiency formula; it is the average of throughputs, or the average throughput in another term, divided by the optimal one, or what is called the theoretical throughput. Thus an efficient network is a network that uses the maximum of its available capacities.

To calculate the efficiency [10], [11], we should first find the average throughput before:

$$Q = \frac{1}{n} \sum_{i=1}^{n} q_i$$

We calculate the ratio between the average throughput and the optimal one which is the result of an ideal network performance:

$$E = \frac{Q}{Q_{opt}}$$

With
E : the efficiency report
Q_opt : the optimal throughput

For 1 and 2 flows the Compound TCP showed a very high efficiency (96% for a single flow and 95% for 2 flows) as shown in the figure above. Then we find Illinois for 4 and 6 flows with a percentage equal to 93% of the efficiency ratio. The next protocol has shown a good performance ratio equal to 92% with 8 flows is the Cubic TCP. For the remainder of the number of TCP flows Bic showed good efficiencies better than all the others with a percentage that varies between 92% and 95%.

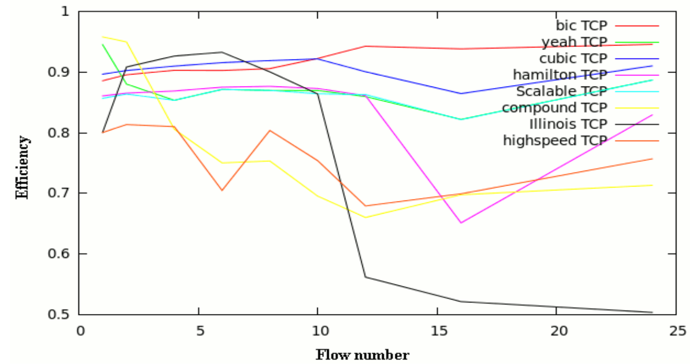

Fig. 3. Efficiency for different flow numbers

Note: Yeah TCP behaves like a Scalable TCP for 4, 6, 8, 10, 12, 16 and 24 flows, but it does not mean that the first congestion control protocol didn't show good efficiency for 1 and 2flows.

Compound TCP is very effective for 1 and 2 flows, but its weakness appears when the flow number gets larger.

The Best congestion control protocol for a large number of flows (greater than 10) is the Bic TCP with an efficiency that varies between [92%, 95%] but it has an efficiency percentage worse than Illinois TCP, TCP Cubic, Compound TCP and TCP yeah for a number of flows less than 10.

C. Fairness

The fairness is the attempt of sharing the network capacities among users in a fair way.

For the purpose of measuring the fairness, one method is used in the networks field which is called the Maximin law proposed by Raj Jain [12]. Here is the procedure that allows us to calculate the fairness of a proposed algorithm:

Having an algorithm that provides the distribution vi = [x1,x2,…,xn] instead of the optimal distribution vopt = [x1,opt,x2,opt,…,xn,opt]. We calculate the standardized distribution for every source as follows:

$$X_i = \frac{x_i}{x_{opt}}$$

Thus, the fairness index F equals the sum of distributions squared and divided by the square of sums:

$$F = \frac{(\sum_{i=1}^{n} X_i)^2}{n \sum_{i=1}^{n} X_i{}^2}$$

We have used these two formulas to simulate the seven protocols for 1, 2, 4, 6, 8, 10, 12, 16 and 24 flows.

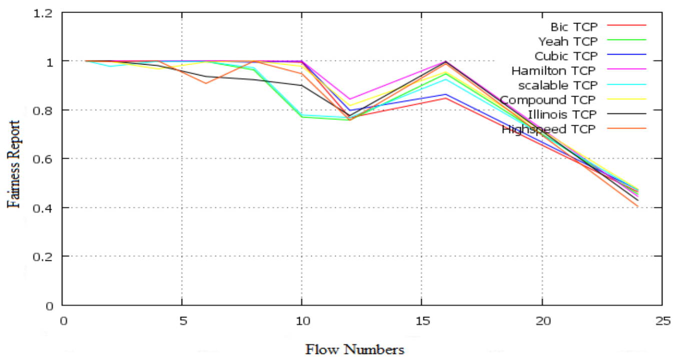

Fig. 4. Fairness for different flow numbers

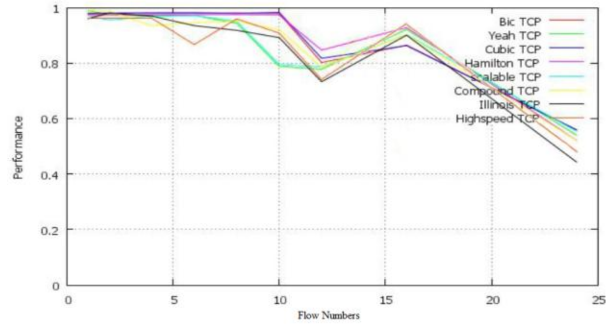

Fig. 7. Performance for different flow numbers (α = 0,2)

For 2 flows, the fairness ratio is 99% for YeAH TCP, Bic TCP, Cubic TCP, High Speed TCP, Illinois TCP and Hamilton TCP. It is equal to 96% for Compound TCP and 97% for the Scalable TCP.

For 16 flows Illinois TCP, Hamilton TCP are fairer with a percentage equal to 99%, then we find the High Speed TCP with a percentage of 98%.

For 12 flows the protocols become unfair, and worst for 24 flows.

D. *Performance*

The performance translates the relation between efficiency and fairness [13]:

$$\text{Performance} = \alpha \times E + (1 - \alpha) \times F$$

With α = [0,1... 0,9], E the efficiency and F the fairness.

For the various algorithms, we calculated performance for: network rather efficient α = 0.8, a network rather fair with α = 0.2 and a balanced α = 0.5. Results for 1, 2, 4, 6, 8, 10, 12, 16 and 24 flows in the following:

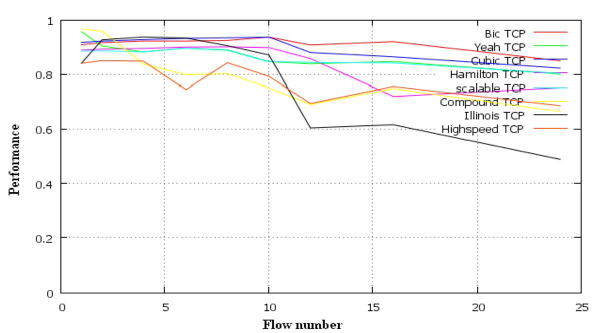

Fig. 5. Performance for different flow numbers (α = 0,8)

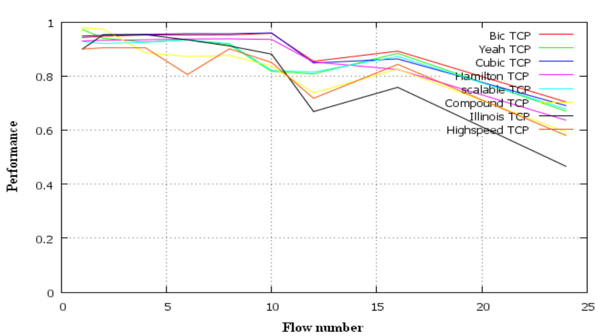

Fig. 6. Performance for different flow numbers (α = 0,5)

We used different values of α in [0.2, 0.5 and 0.8], it is sure that the value of α is chosen according to the needs of the user. If you want an efficient algorithm, α must approaches 1.else if an algorithm rather fair, the value of α must approach 0. Finally, if we seek a balanced algorithm α must be equal to 0.5.

For α = 0.8 calculations showed that Compound TCP is the best performance if we talk about 1 and 2 flows, Illinois TCP for 4 and 6 flows, Cubic TCP for 8 and 10 TCP flows and Bic TCP for 12, 16 and 24 flows.

For α = 0.5 calculations showed that Compound TCP is the best and the most efficient for 1 and 2 flows, for 4 flows; Illinois TCP, Cubic TCP for 6, 8, 10 flows and Bic TCP for 12, 16 and 24 flows.

For α = 0.2 Compound TCP is the most efficient for 1 and 2 flows, Cubic TCP for 4 and 6 flows , and Bic TCP for the rest.

According to the results, we can say that for 1 and 2 flows the best congestion control protocol still is the Compound TCP with a performance percentage that goes approximately to 100%. Illinois TCP also showed a good performance for 4 and 6 flows, however for the multiple flows topologies; Cubic TCP and Bic TCP are the best.

III. CRITERIA OF QOS

A. *Throughput*

It represents the data rate supported by a network connection per unit of time, ie, the number of bits that the network is capable of transmitting or receiving between two points in a latency time. Its unit is in Mbits per second and its formula is that the CIPP has defined to measure the ability to transport (BTC):

BTC = V / T with V the volume of data received (packets) and T is the elapsed time (ms)

According to the comparison part in Chapter 2 we distinguished three types of architecture: efficient, fair and balanced.

- For efficient architecture:

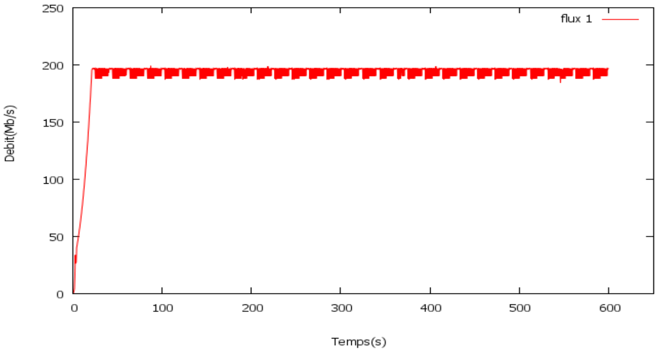

Fig. 8. Compound TCP: Throughput variation for 1 flow

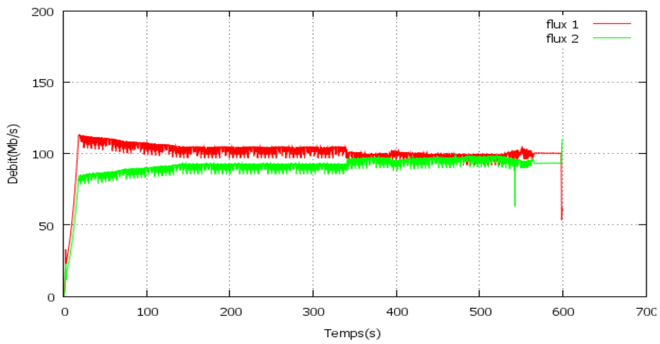

Fig. 9. Compound TCP: Throughput variation for 2 flows

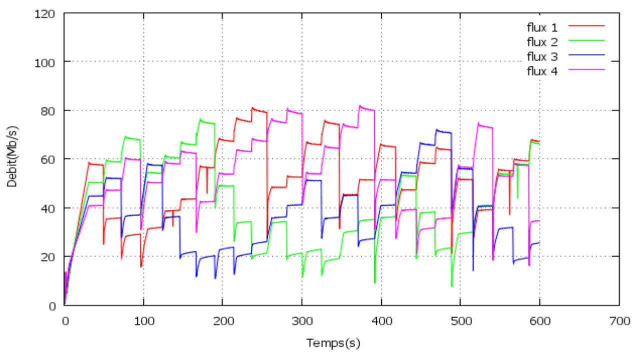

Fig. 10. Illinois TCP: Throughput variation for 4 flows

- For fair and balanced architecture:

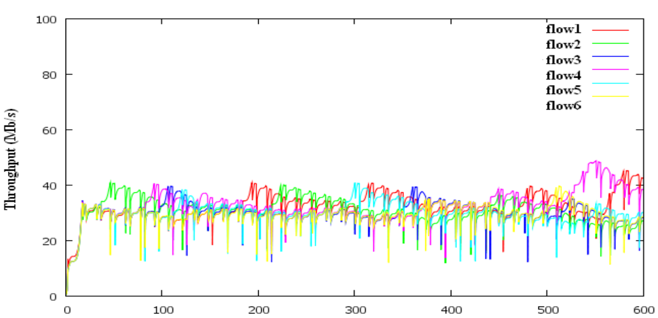

Fig. 11.Cubic TCP: Throughput variation for 6 flows

B. *RTT (Round Trip Time)*

It is also called latency or response time, indeed it is the time for crossing a network starting from a specific source to a specific destination and vice versa, it can be low or high depending the type of application, low if it is a file transfer and high if it is "voice."

It is the time that a signal needs to travel quite a closed circuit (the transmission of the packet to its acknowledgment of receipt) which has as TCP formula:

The RTT value is usually between 0 and 300ms for land cover (Land-line) and for networks orbits until it reaches 800 ms, although safe for our work we will focus on the first category which RTT is the maximum value of 300ms.

- For efficient architecture:

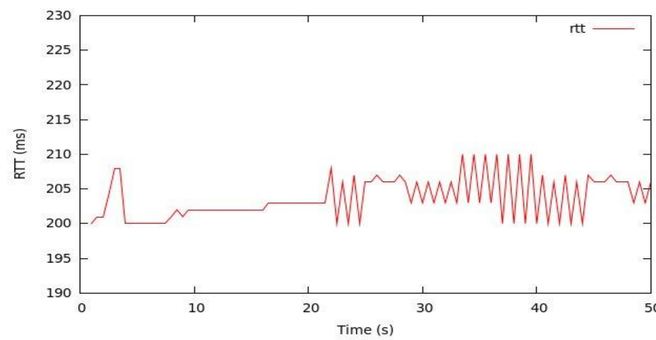

Fig. 12. Compound TCP: RTT variation for 1 flow

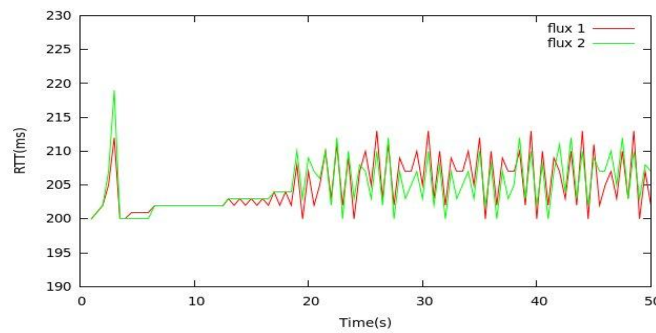

Fig. 13. Compound TCP: RTT variation for 2 flows

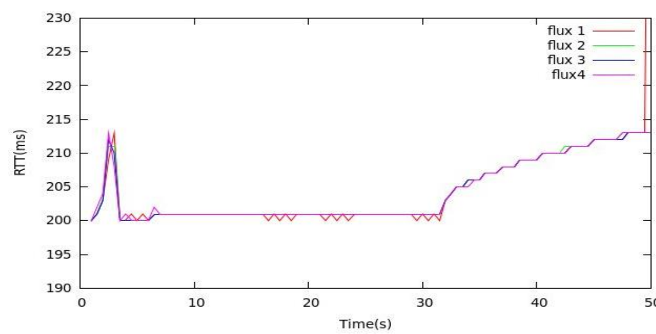

Fig. 14. Illinois TCP: RTT variation for 4 flows

- For fair and balanced architecture:

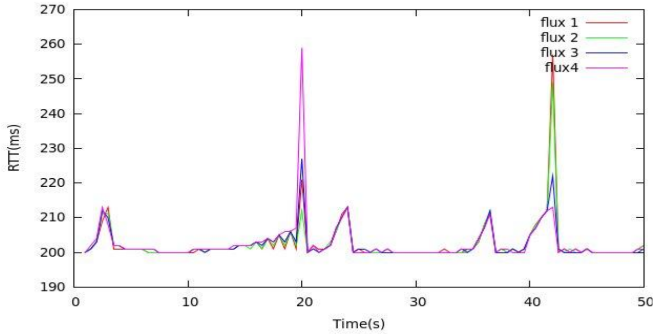

Fig. 15. Cubic TCP: RTT variation for 4 flows

C. *Loss Rate*

For packets, it can be low, medium or high.

- For efficient architecture:

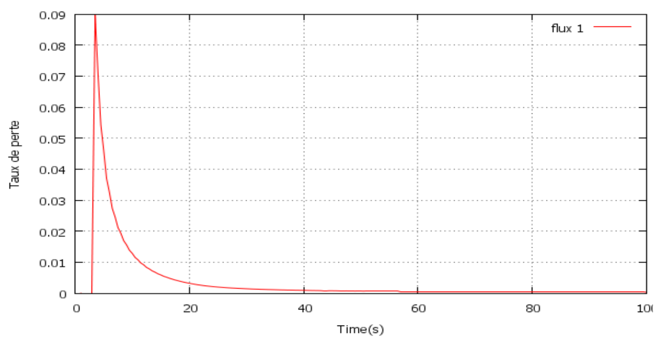

Fig.16. Compound TCP Loss rate variation for 1 flow

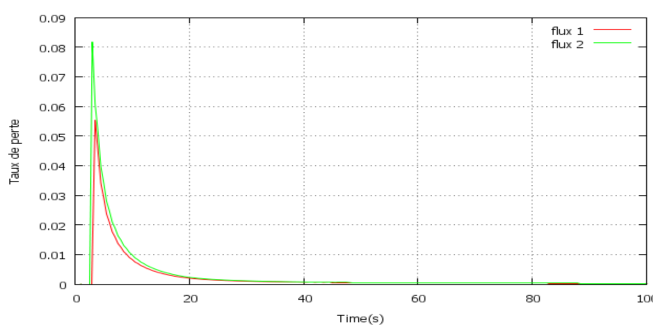

Fig.17. Compound TCP Loss rate variation for 2 Flows

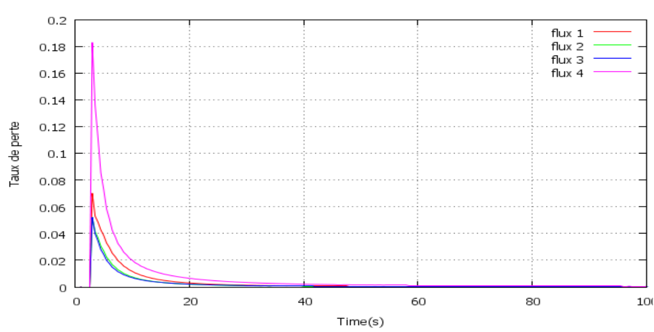

Fig.18. Illinois TCP: loss rate variation for 4 flux

- For fair and balanced architecture:

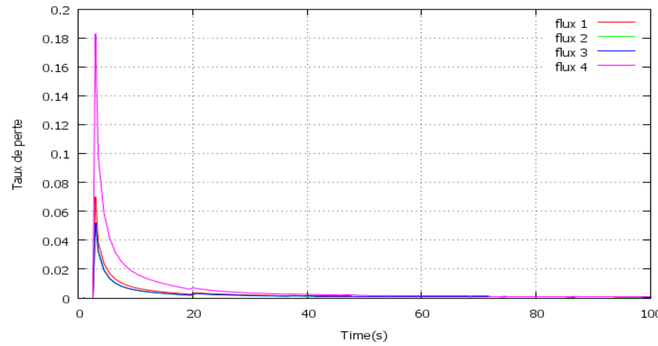

Fig.19. Cubic TCP: Loss rate variation for 4 flows

IV. CONCLUSION

In this paper we have study the QoS criteria's of High Speed Congestion Control Protocols. The first criteria is Throughput, in the efficient architecture, flow curves depend on the number of flows and according to the protocol, for one single flow (Fig.8) Compound TCP shows the aggressiveness and after 20 seconds, it stabilizes at a rate very close to optimal throughput (200Mb / s) with slight variations, the existence of a single flow explains the approximate theoretical throughput achieved since there is no flow to share the bandwidth with. According to figure 9, we interpret that the bandwidth is divided equally to meet the needs of the two competing flows such a way we can say that Compound TCP is a TCP friendly since the band split equally, and yet we find that the first flow is greedier, but between 340s and 530s the two flows undergo overlap to return after 530s to its original condition. For 4 and 6 stream, the protocol used is TCP Illinois, according to the curves, we see that each flow high throughput when an event of congestion, gives way to another stream, which confirms that Illinois is not TCP friendly. Knowing that in all cases, the optimal flow rate is the sum of the flow rates practices. For the fair and balanced architecture for 1 and 2 flows, the behavior of Compound TCP is the same as with an efficient architecture. It is considered a TCP friendly protocol, as it uses the link capacity in an equitable manner despite the slight differences at specific times, but it keeps TCP fairness.

For the case of 4, 6, 8 and 10 Flows, we have Cubic TCP, we note that there is always a flow more greedy but in an event of congestion, it gives way to another stream, as shown in (fig. 10) when the two streams had the highest rate at time 20s but when he falls congestion, flow 4 takes its place, and so on.

Of this principle all other curves undergo variations, even for 12, 16 and 24 flows (Bic TCP), so we can say that the Cubic and BIC are not TCP-friendly, since they do not share bandwidth between the different flows in an equitable manner.

For 4, 6 and 10 flows, the behavior of Cubic TCP does not provide fairness between flows, since each time a stream with a high flow undergoes a congestion problem, its throughput falls and another stream takes its place, so we have always a greedy flow compared to others.

The second criteria is the RTT in which we were able to have RTT curves in function of time for three architectures (efficient, fair and balanced).The curves are taken in a time interval between 0 and 50 ms. In efficient architecture, the first curve tells us the RTT of the Congestion control Protocol “Compound TCP”.

If we divide the time interval of the curve in subintervals, from 0ms to 4ms, we note that the RTT for this protocol increases very quickly from 200 ms to 208 ms and then remains stable by taking the value of 200 ms for 4 ms time. then from 8 ms to 22 ms of time, the RTT is almost stable with small increases until it reaches the value of 203 ms. then there is a period of behavior that brings together saw teeth up to 50 ms.

For 2 streams, the graph is a plot of RTT of Compound TCP, the first flow increases from 200 ms to 212 ms after it returns to 200 ms, the second stream has the same behavior but the value of the RTT is higher the fact that increases to 218 ms. From 6 ms to 18 ms of time, the two flows have RTT values between 200 ms and 203 ms. In the following, the two curves have behaviors that bring together generally saw teeth with RTT values between 200 and 213 ms maximum.

for 4 flows, we note that there are 4 spikes reaching 214 ms, then the 4 flows remain almost stable from 6 to 32 ms by taking the value of 202 ms, then these four flows gradually increase up to 214 ms again. The shape of this curve is the appearance of the congestion control protocol “TCP Illinois”.

The other two architectures, architecture fair and balanced architecture, we note that the first two flows curves for 1 and 2 are the same flows curves in the architecture effective are those curves Compound TCP.

For the stream 4 in the two previous architectures, the graph shows that there are 5 spades clear. The first value reaches the spades 213 ms, 20 ms in the second spade time reaches the value of 260 ms for the above fourth flows, the third flows to 228 ms, the second reaches the value of 220 ms and the last does not exceed not 215 ms. The 3rd and 4th pic does not exceed 215 ms. In the last pic we can see that the first stream reaches 258 ms, the second flows reached 250 ms, 222 ms reached the third and finally the fourth stream reaches 212 ms.

Third criteria is the Loss Rate, which we can see that for one single stream, the curve representing the loss rate has two phases: the first phase is the phase where the loss rate increases vertically just after a few moments until a maximum loss rate which is equal to 0.09. Then the curve decreases exponentially until the end of time, the same thing happens for 2 streams for the other two architectures fair and balanced the fact that for 1 and 2 flows the congestion control protocol is Compound TCP.

It is needed to announce that for the first figure.17, the first stream reaches 0.08 and then decreases exponentially and the second flow does not exceed 0.06 and then decreases exponentially. For 4 flows and more, we see that the curves keep the same form, i.e., they reach a maximum and then decrease exponentially. We should mention also that always the last stream that do not get sufficient flow from the first flow will have a higher error rate than the other, which is due to a packet loss of low flows.

Further work is required to evaluate the performances of these protocols by using Relentless TCP which will be the topic for a multitude of research works in the near future.

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