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Performance Evaluation of Various TCP Protocol over Broadband Hybrid Satellite Constellation Communication System

Anupon Boriboon and Siriwhaddhanah Pongpadpinit

***Abstract*— This paper presents the evaluation performance of a hybrid satellite constellation network which provides internet access based on various Transport Control Protocol (TCP). Given known constraints on the hybrid satellite constellation resulting from network performance evaluation criteria. The evaluated satellite network uses the COMMStellation^{TM} constellation topology operating on Low Earth Orbit (LEO). The simulation results show the performance evaluation criteria which are Throughput, the percentage of Dropped Packet, Mean End-to-End Delay, and Jitter of traffic each various TCP protocols. All simulations are simulated using the network simulator 2 (NS-2).**

***Index Terms*— COMMStellation^{TM}, Hybrid satellite, NS-2 and TCP**

I. Introduction

SATELLITE communication technology systems have been an important element of telecommunications networks for many years serving, in particular, long distance telephony, data, and television broadcasting. Therefore satellite system to become increasingly competitive commercially to service and grow. To give the service provider a capability to combine the best features of each achieve the most cost effective system. An example is the involvement of satellite in Internet protocol (IP) networks is a direct result of new trends in global telecommunications, where Internet traffic will hold a dominant share in the total network traffic.

Internet has been one the fastest growing technologies within the telecommunications industry in recent years and it is expected to continue as the most important technology for years to come. For the future generations of the Internet, broadband access, and Quality of Services (QoS) are among the most significant issues to be solved.

The economics of the satellite environment has also created opportunities for data communications users. However, the protocols that govern data communications, both for data exchange and for error control, have largely been developed for connections that have different delay. All most application may use the Internet's Transmission Control Protocol (TCP) based that requires a reliable transport service over packet-switched communication network. Matching applications that use TCP with the advantages offered by satellites is, therefore, important. It is natural to think of TCP based applications over satellite networks because the widespread diffusion of TCP application makes difficult to think of another protocol architecture nontransparent to the user, dedicated to the satellite links.

The round-trip delay and the general characteristics (e.g., fading, interference) of the links heavily affect the performance of the protocols at every functional level: physical and data link protocol; IP layer; transport and application protocols. Resource allocation and fading countermeasures are issues of particular importance in this environment. Different from cabled and terrestrial networks for personal communications, satellite channels characteristics vary depending on the weather and the effect of fading that heavily affects the performance of the access system and the whole system [1].

So, the solutions concerning network architectures and each protocol layer which allow the efficient transport of TCP applications through satellite networks, transparently to the final user, should be the goal of Broadband Hybrid Satellite Constellation Communication System (BHSCCS) networks.

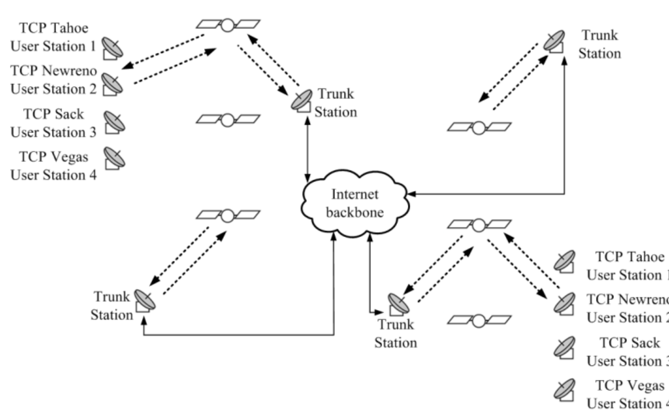

Fig. 1. Network topology in the network simulator

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The analytical study of the performance of data communications protocols and applications in a BHSCCS networks is often made very difficult by the complexity and time-varying nature of the network topology. Therefore, it is helpful to study simulation models of such system. This research is an extended version of the paper that appeared in the previous research work [2] to contribute to previous finding of the development of the COMMStellation™ satellite system model in network simulation tool. We adopt [3] the TCP Tahoe, the TCP New Reno, the TCP Sack, and the TCP Vegas to appraise network performance over BHSCCS by COMMStellation™ satellite model in the NS-2. The rest of this paper is organized as follows: Section II describes the network topology, traffic source load using in simulator, and shows performance evaluation criteria to proof the network performance. Simulation results present in Section III. Whereas our conclusions are drawn in Section IV.

II. Network Model and Performance Evaluation

A. Network Model

We evaluate the performance of the model plan for the COMMStellation™ satellite constellation system was to have 72 satellites on orbit with an altitude range around 1000 km. It consists of microsatellites which are arranged in 6 circular planes (orbits). Planes have a near-circular orbit, with co-rotating planes spaced 30 degree. The minimum elevation angle for an earth station is 10 degree, which maximizes the coverage area of the satellite and improves the link quality when compares with to lower elevation angles. Lower elevations increase multipath fading and have a negative impact on link quality. The ground side of the link consists of two segments: i) Trunk station that is connected to the high-speed Internet backbone similarly with Internet gateway and ii) User Stations is planned to be current or new Internet Service Provider (ISP), which allows individual clients to connect to its satellite link. Thereby, it is adoptive satellite bandwidth is 8.8 Gbps and 1.1 Gbps for link bandwidth (both up/down link) [4], [2]. The orbital parameters are show in Table I summarizes key properties of the COMMStellation™ satellite constellation system.

The simulation tool which has been used in this research was based on Network Simulator (NS) version 2 [5], [3]. NS-2 is an open source software, which is available for public and can be obtained from the Information Sciences Institute (ISI).

Figure 1 illustrates the network topology which uses in this work. All the links between Trunk stations were setup as STM-4 transmission duplex into Internet backbone and STM-1 transmission duplex for Internet backbone communication links with propagation delay of 1 and 5 msec respectively. The DropTail queuing [3] is applied on the queuing system.

Recommended satellite constellation parameters [4], [2] are shown in Table I. In our experiments, four user station links in same areas in Bangkok-Thailand are chosen to observe network traffic. The destination nodes are at Boston-Massachusetts. In this research, efficient of BHSCCS mechanisms are presented over COMMStellation™ system into LEO orbital are handled by NS-2 [2].

B. Traffic Source Parameters

The Transmission Control Protocol (TCP) is the primary transport protocol in the TCP/IP protocol suite. It implements a reliable byte stream over the unreliable datagram service provided by IP. As part of implementing the reliable service, TCP is also responsible for flow and congestion control: ensuring that data is transmitted at a rate consistent with the capacities of both the receiver and the intermediate links in the network path. Since there may be multiple TCP connections active in a link, TCP is also responsible for ensuring that a link's capacity is responsibly shared among the connections using it [6].

TABLE I
SATELLITE CONSTELLATION PARAMETERS

Parameters	Value
Satellite altitude	1000 km
Inclination	90°
Number of orbital plane	6
Number of satellite per orbital plane	12
The cutoff elevation angle	10°
Spacing between orbital plane	30°
Satellite bandwidth	8.8 Gbps
Link bandwidth	1.1 Gbps
Trunk stations	35
User stations	4

Thus, the Transmission Control Protocol (TCP) provides a reliable, end-to-end, streaming data service to applications. A transmitting TCP accepts data from an application in arbitrarily-sized chunks and packages it in variable length segments, each indexed by a sequence number, for transmission in IP datagrams. The TCP receiver responds to the successful reception of data by returning an acknowledgement to the sender, and by delivering the data to the receiving application; the transmitter can use these acknowledgments to determine if any segments require retransmission. If the sending side the connection closes normally, the sending application can be almost certain that the peer receiving application successfully received all of the data [5]. Then the main characteristics of all TCP protocol variants which are analyzed in the simulation are discussed. An overview is provided about their main mechanism of action with the basic discussions. Their major features of their TCP that affect performance.

TCP Tahoe [7], [8] being the first implementation of TCP to involve a few new algorithms in early TCP implementations likes Slow Start, Congestion Avoidance, and Fast Retransmit.

TCP New Reno [7], [8] includes a change to the Reno algorithm at the sender end with a view to eliminate Reno's wait for a retransmit time-out whenever multiple packets are lost from a window. This change modifies the sender's behavior during fast recovery.

TCP Sack [7], [8] is an extension of Reno and New Reno. It intends to detection of multiple packet loss and retransmission of more than one lost packet per round-trip-time.

TCP Vegas [7], [8] extended Reno retransmission strategy, especially in the way the Fast Retransmit is handled and the congestion avoidance algorithm.

In this research, bulk data transfer within hybrid satellite has been an inescapable requirement for the use of scientific data-sets distribution, content replication, remote data backup, etc. Generally, File Transfer Protocol (FTP) [9] is used for handling bulk data transfers.

C. Performance Evaluation Criteria

For the rest of this article we apply the general discussion of network performance evaluation criteria to proof our research.

The performance of the BHSCCS on COMMStellation™ satellite system can be measured in term of throughput, dropped packet, end-to-end (E2E) delay [10], and jitter.

$Throughput$ is described in Eq. (1).

$$Throughput = \frac{N_r \times P_s \times 8}{(T_{stop} - T_{start}) \times 1 \times 10^6}\ Mbps \qquad (1)$$

Where :
N_r is number of packet received at destination.
P_s is packet size (byte).
T_{stop} is stop time of each traffic flow.
T_{start} is start time of each traffic flow.

$Dropped\ Packet$ is described in Eq. (2).

$$Dropped\ Packet\ (\%) = \frac{N_g - N_r}{N_g} \times 100\ \% \qquad (2)$$

Where :
N_g is number of packet generated at source.
N_r is number of packet received at destination.

$End - to - End\ (E2E)\ delay$ is described in Eq. (3).

$$E2E\ delay = \frac{\sum_{i=1}^{N} Di}{N_r} \qquad (3)$$

Where,
D_i is end-to-end delay of packet "i".
i $= Td_i - Ts_i$
Ts_i is time of packet "i" en-queued at source.
Td_i is time of packet "i" received at destination.
N_r is number of packet received at destination.

$Jitter$ is described in Eq. (4).

$$Jitter = \frac{(ET_j - ST_j) - (ET_i - ST_i)}{(j - i)} \qquad (4)$$

Where,
ET is time of packet sequence number en-queued at source.
ST is time of packet sequence number en-queued at received at destination.
j is current packet sequence number.
i is previous sequence number.

III. Simulation Results

In this section, we present our simulation result. For simulation traffic, the source and destination is purely satellite connected network. Each user station has its own FTP service over different TCP. We considered three scenarios in testing our scheme within different packet error rate (PER) 2%, 4%, and 6% respectively. We found that TCP algorithms affect performance over broadband hybrid satellite constellation communication system (BHSCCS) networks.

At first network performance evaluation criteria on simulation, we compare the performance of the hybrid satellite which is computed by throughput criterion. There are four different TCP services with FTP running such as the TCP Tahoe, the TCP New Reno, the TCP Sack, and the TCP Vegas. Figure 1, 2, and 3 illustrate the throughput with PER 0.02, 0.04, and 0.06 respectively. The throughput shows that the TCP Vegas is the highest throughput comparing to other TCP. But when the satellite link has an error, TCP Vegas shows unstable throughput as presented in the Figure 3. This figure has shown the best stable variable length of performance on TCP New Reno. Firstly, the average throughput under limit of PER 2% is 121.30, 157.18, 87.67, and 205.57 Mbps (TCP Tahoe, TCP New Reno, TCP Sack, and TCP Vegas). Secondly, the average throughput under limit of PER 4% is 83.84, 100.81, 56.53, and 113.51 Mbps (TCP Tahoe, TCP New Reno, TCP Sack, and TCP Vegas). Finally, the average throughput under limit of PER 6% is 63.04, 74.85, 45.90, and 89.92 Mbps (TCP Tahoe, TCP New Reno, TCP Sack, and TCP Vegas). The result shows average throughput of various TCP protocol over BHSCCS networks.

Second, we compare the dropped packet in network traffic to show on Table II which is computed by equation (2). Certainly, the dropped packet has some significance to prove mechanism of various TCP modules. For instance, from this Table, we ran simulator with PER 6%. The TCP protocols that had percentage lower than 6% are the TCP Vegas, TCP Sack, and TCP New Reno. The TCP protocol that had the lowest dropped packet network under PER 2% is TCP New Reno. While PER 4% had TCP Vegas the lowest dropped packet network. Therefore, the mechanism of each TCP has effect to dropped packet, that variant to retransmission packet in network traffic.

In third network performance evaluation criteria on this simulation, we proved the measure of end-to-end packet delay which is computed by the previous section. There were four various TCP protocols with different PERs as shown in Figure 4, 5, and 6. The total end-to-end packet delay of TCP Tahoe are 299.1358, 208.9489, and 155.4751 respectively by PER 2%, 4%, and 6%. TCP New Reno are 388.6223, 249.3507, and 186.4953 respectively by PER 2%, 4%, and 6%. TCP Sack are 216.7432, 138.6676, and 114.0383 respectively by PER 2%, 4%, and 6%. The last one is TCP Vegas are 522.5419, 286.4746, and 226.9333 respectively by PER 2%, 4%, and 6%.

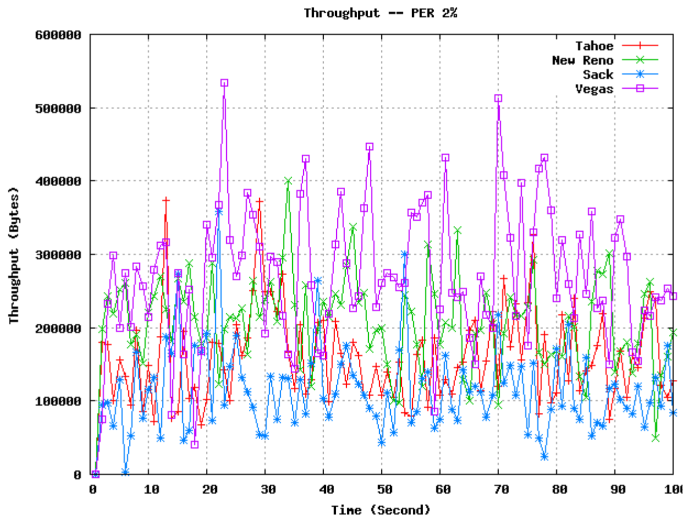

Fig. 1. Throughput with PER 2%

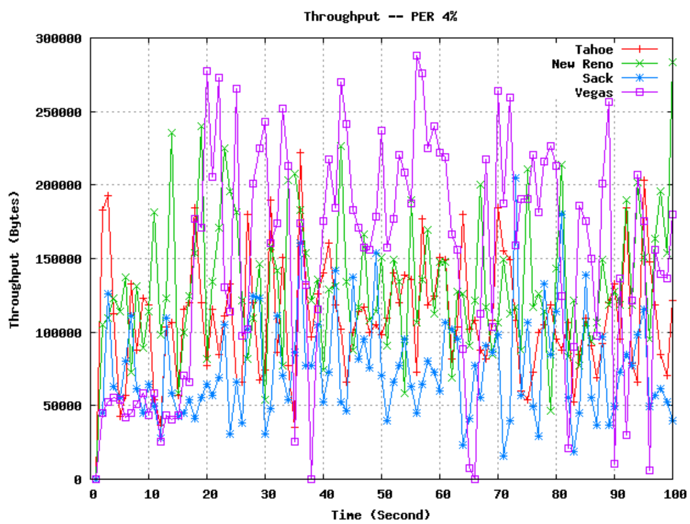

Fig. 2. Throughput with PER 4%

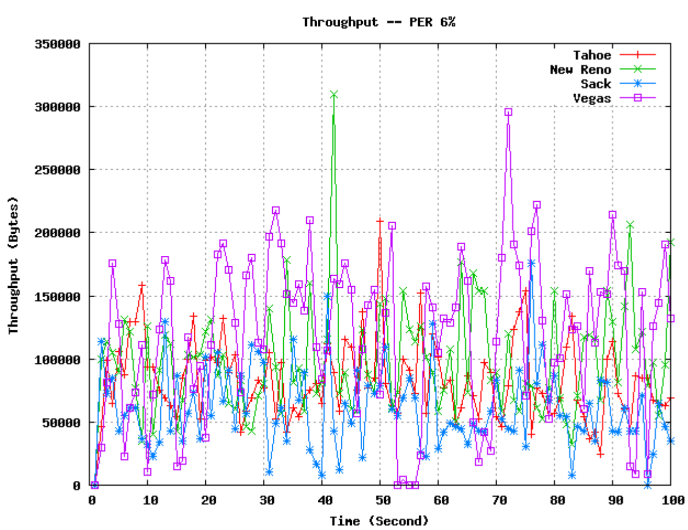

Fig. 3. Throughput with PER 6%

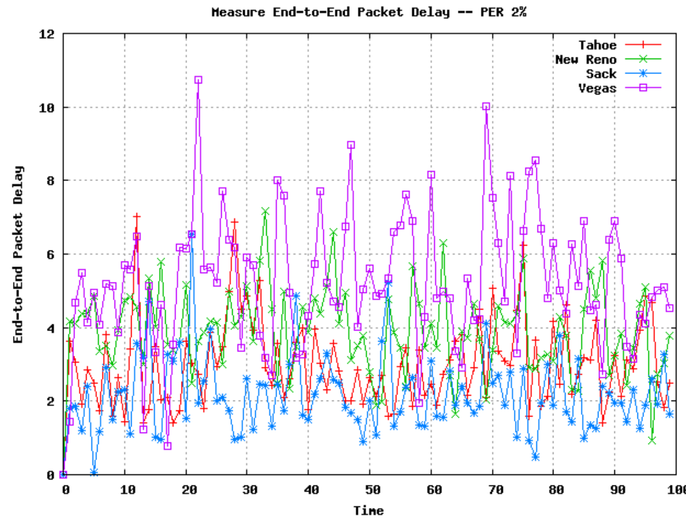

Fig. 4. Measure End-to-End packet delay with PER 2%

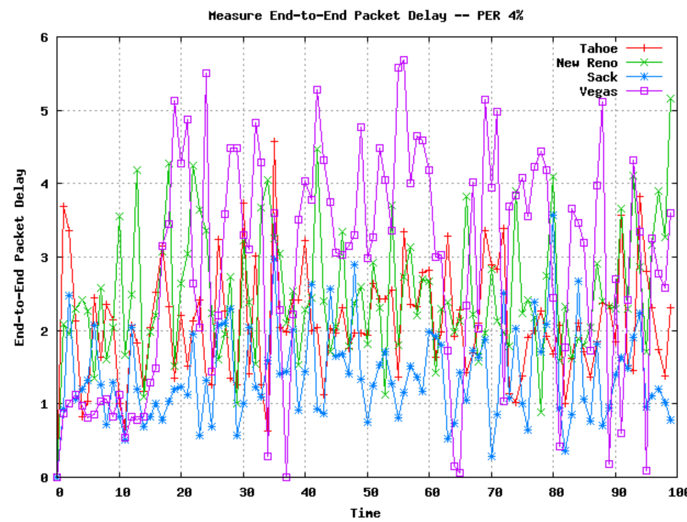

Fig. 5. Measure End-to-End packet delay with PER 4%

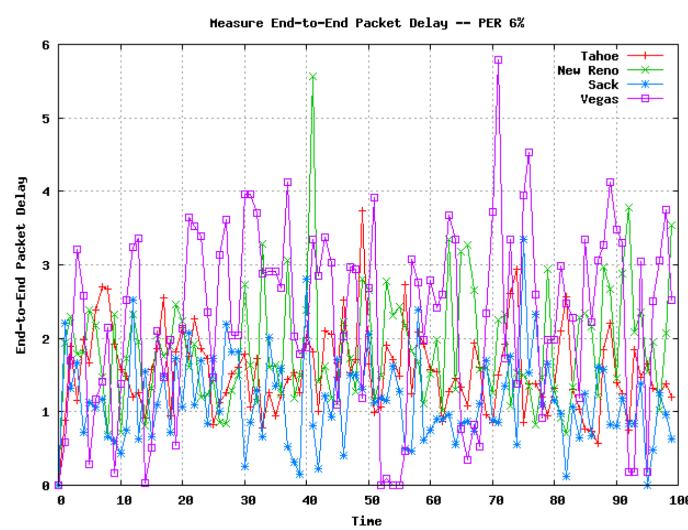

Fig. 6. Measure End-to-End packet delay with PER 6%

TABLE II
DROPPED PACKET IN NETWORK TRAFFIC

TCP Module	PER 2%	PER 4%	PER 6%
Tahoe	2.234	4.238	6.465
New Reno	1.913	4.004	5.905
Sack	2.060	4.104	5.581
Vegas	2.002	3.689	5.574

TABLE III
JITTER IN NETWORK TRANSMISSION

TCP Module	PER 2%	PER 4%	PER 6%
Tahoe	0.47523	0.46333	0.41204
New Reno	0.38954	0.38195	0.37466
Sack	0.36531	0.33497	0.30275
Vegas	0.32836	0.33610	0.29915

At last, we compare the jitter which has been represented previously. The computed jitter equation is shown in the previous section in equation (4). The jitter is apparent in Table III including different PERs and four TCP protocols.

Jitter time is shown under each PER as shown in Table III. The first jitter with PER 2% of TCP Tahoe is standard calculate a rule of three in arithmetic. The TCP New Reno has decreased jitter to 18.03%. The TCP Sack has decreased jitter to 23.13% and the TCP Vegas has the most decreased jitter to 30.90%. Thus the TCP Vegas is less variance of packet delay in network traffic.

Before ending this section, we compare the latency time of TCPs and PERs to reflect the main feature mechanism of performance of the various TCPs.

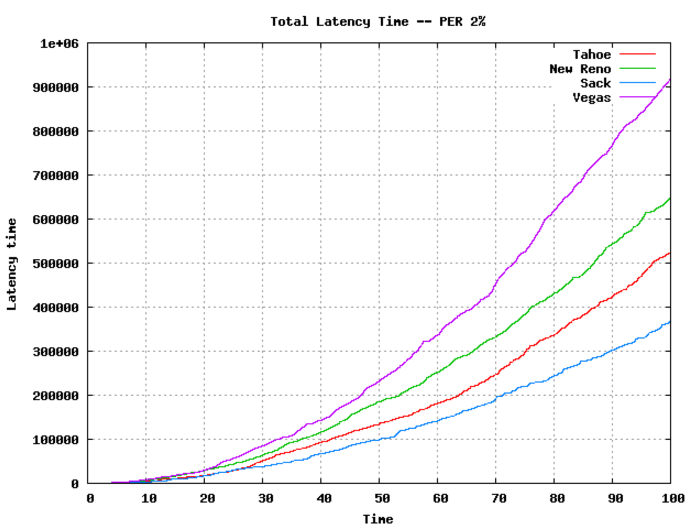

Fig. 7. Total latency time with PER 2%

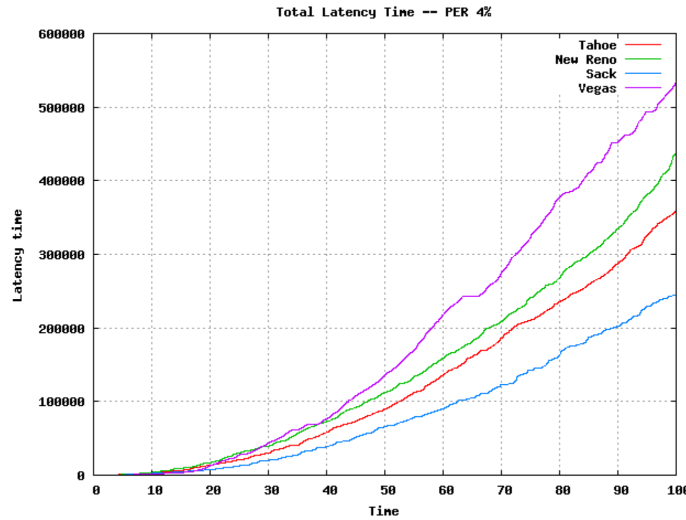

Fig. 8. Total latency time with PER 4%

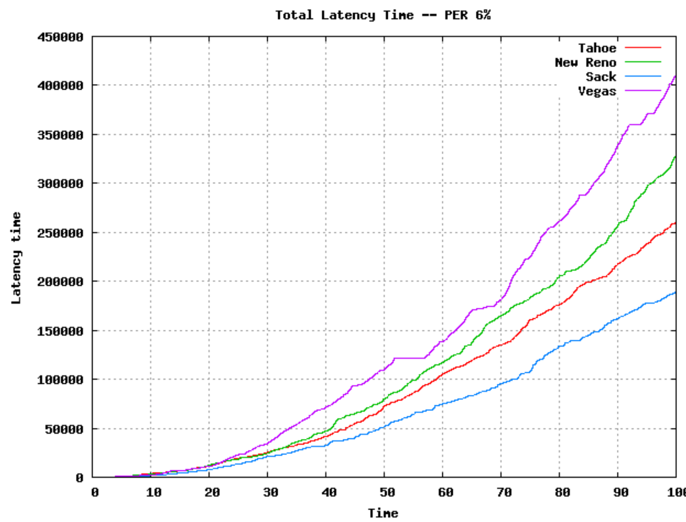

Fig. 9. Total latency time with PER 6%

IV. CONCLUSION

In this research, we study to compare the various TCP protocols over broadband hybrid satellite constellation communication system (BHSCCS) networks by using network simulation tool (NS-2). We use throughput, dropped packet, mean end-to-end (E2E) delay, jitter, and latency for different type of traffic sources as evaluation criteria.

The paper presented the evaluation performance of BHSCCS network on COMMStellation™ model in NS-2, with recent TCP protocol modules in NS-2. Finally, we have evaluated the network performance of the TCPs with PERs. Our simulation results give an expression of the most view point of the TCP protocol on BHSCCS networks.

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