On Delay Variation for Internet Multimedia

Stephen Pena and Lopamudra Roychoudhuri, PhD

Abstract

Internet audio and video, real-time or streaming, are highly sensitive to delay variation. Our research investigates the variation of delay that exists on the Internet today that would adversely affect multimedia communication. To collect real-world data on delay variation, we have run senders and receivers on nodes of PlanetLab, a global research network, for six weeks in the recent past. In this paper we present findings from the datasets that we have gathered so far.

*****

Introduction

Even though it seems a continuous stream, all data over the Internet is sent in the form of a series of individual packets. The Internet is known to be a best effort service, providing no guarantee that the packets will be delivered reliably, in order, or on time. In the face of that TCP (Transmission Control Protocol) (Institute, 1981), one of the main transport protocols on the Internet, provides mechanism for reliability and order. But a majority of highly popular applications, such as games and multimedia, use UDP (User Datagram Protocol) (Postel, 1980) as the underlying transport protocol. Most of these dynamic applications are highly sensitive to delay variation. Unlike TCP, UDP does not provide any guarantee of reliability.

This project investigated the variation of delay that exists on the Internet today and affects the mentioned applications adversely. It will be nothing better if multimedia experiments can be run on the real Internet and real-world trace data can be collected for analysis. The experiments were conducted on machines connected to PlanetLab (PlanetLab), a global research network that consists of 1160 nodes at 547 sites all over the world. These observations were then analyzed using various statistical measures.
We investigated the existence of patterns in the round trip times (RTTs) of Internet packets sent to various geographical locations around the world. We deployed receiver programs to these locations, and used one site, in Texas, as our designated sending location. We then used a sender program to send audio files to the other sites, which then echoed audio files back to the sender. We used scripts to gather the sending and receiving times and then calculated the RTT. We performed various methods of statistical measure and extrapolated the respective delay variations for further analysis. We found that delay variation was overwhelmingly random and unpredictable in nature.

Related Work

There has been research on Internet measurement in this area, such as site-to-site network speeds and packet loss between nodes (Wang, Huang, & Ross, 2009) (Roychoudhuri, Al-Shaer, & Brewster, 2006), but these are far from current. The Internet, on the other hand is a highly dynamic environment with its infrastructure constantly expanding and improving. This makes our work relevant and valuable.

Methodology

Sender and receiver programs were implemented using socket programming in C. The sender program was placed at Rice University in Texas. Table 1 lists the selected sites, as well as their geographic locations.

The sender transmitted data packets from audio clips, with the receivers saving and echoing the data back to the sender. The experiments were run with large packets of size 1280 bytes, as well as small packets of size 128 bytes, which are similar to the packet sizes observed in a Skype packet capture. The data collected include one-way-delay (time between sent and received) and RTT (Round Trip Time - the time between sent and echoed back) for each packet.

United States Sites	International Sites
Princeton, New Jersey	Technische Universitat, Berlin, Germany
Virginia Tech, Virginia	Ecole Polytechnique Federale de Lausanne,
University of South Florida, Florida	Lausanne, Switzerland
University of Massachusetts Lowell, Massachusetts	University of Warsaw, Warsaw, Poland
	Jozef Stefan, Ljubljana, Slovenia
	Chongqing University, Chongqing, China

Table 1: List of chosen sites and their locations

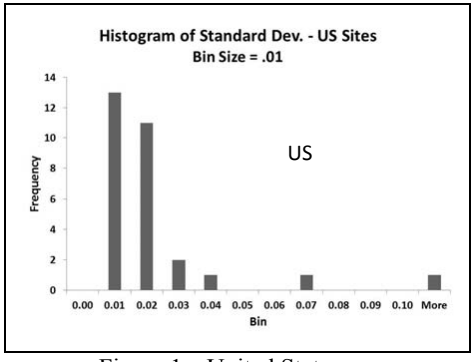

Figure 1a: United States

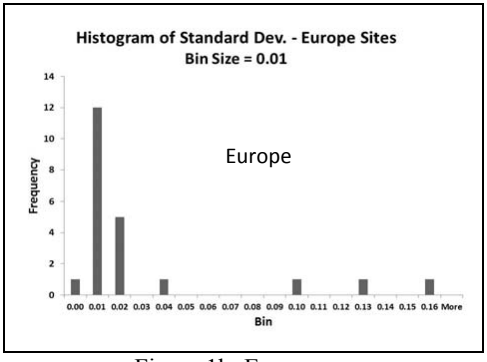

Figure 1b: Europe

Figure 1: US and European Sites: Comparison of Standard Deviation

Results

• Both US sites and Europe sites show similar strong modal right-skewed distributions. We measured mean and standard deviation (stdDev) for each data set. Figure 1 compares the distribution of the RTTs that were recorded for all US and European sites. The histograms of both US and Europe sites show strong modes at low standard deviations. *Geographic distance does not seem to be a distinguishing factor.*

• The distribution of delay variation can be generally identified as uniform, but the degree of outliers has been highly variable. Outliers were identified as data that exceeded *mean + 3*stdDev*. Some sites, US as well as international, have exhibited considerably more outliers than others. Figure 2 shows the outlier percentages for the University of South Florida, Warsaw University, and Chongqing University, respectively. The outlier percentages were strikingly similar, which supports the idea that the number of outliers is governed by randomness, rather than being predicated upon geographic distance.

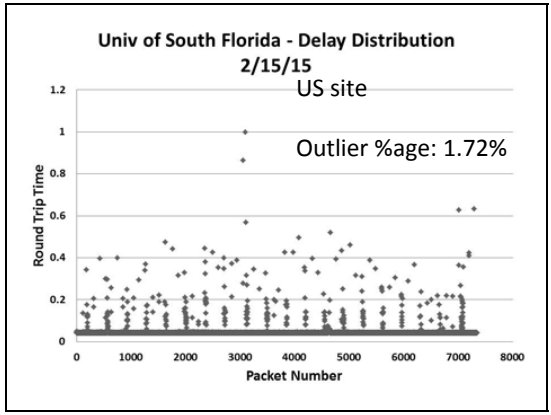

Figure 2a

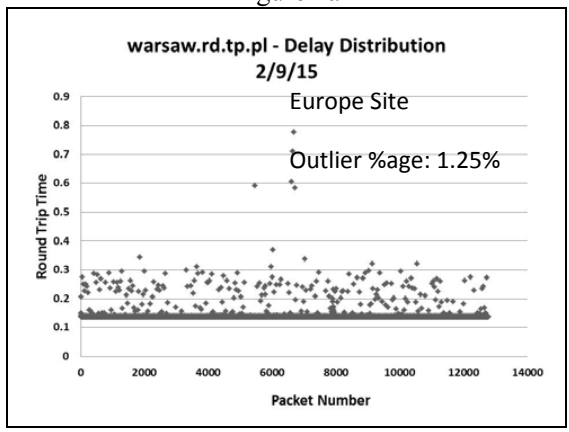

Figure 2b

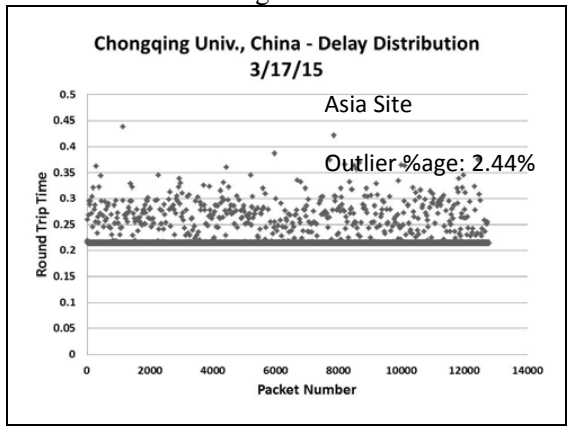

Figure 2c

Figure 2: Comparison of Outlier Percentages for three Sites

Site Group	Outlier %			
	Minimum	Maximum	Mean	StdDev
US	0.024	2.76	0.878	0.795
Europe	0.039	2.44	0.899	0.899

Table 2: Comparison of Outlier Percentages between the US and Europe

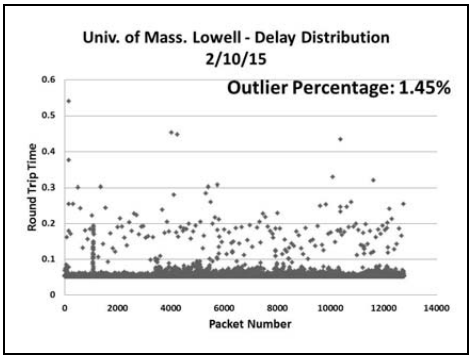

Figure 3a

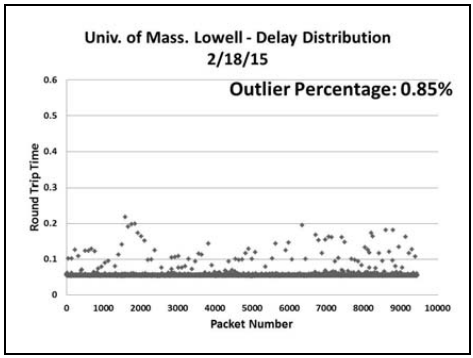

Figure 3b

Figure 3: Comparison between two runs at Univ. of Mass. Lowell

• **Outlier percentages do not appear to be correlated with distance.** Outlier percentage distributions were considerably similar between US sites and Europe sites, with Europe showing slightly higher values. The values used for comparison of outlier percentage between the US and Europe are displayed in Table 2. *Geographic distance does not seem to be a distinguishing factor.*

• **Variations within the same site: different runs at the same receiver site have displayed widely different patterns of variation.** Considerably different patterns of outliers have been observed at the same site, even though the paths shown in traceroute have been more or less the same. In Figure 3, two runs on two different days for Univ. of Mass. Lowell are displayed, showing considerably different outlier percentages. *Thus outlier patterns do not seem to be correlated to site locations or paths.*

• **Packet size makes a difference.** Experiments run with large packets have shown considerably lower percentage of outliers and lower standard deviations. Table 3 shows the average *stdDev* for a US site, a Europe site, and an Asian site. In each instance, the *stdDev* is lower for larger packet sizes than for smaller sizes. These findings suggest that, in general, larger packets have less delay variation than smaller packets. Considering that video data is typically sent with larger packet sizes than its audio counterparts, the data suggest that audio data could be more susceptible to quality degradation due

to delay variation than video data.

Site	Mean *stdDev* -Small Packet Size	Mean *stdDev* – Large Packet Size
Virginia Tech, US	0.015	0.003
Berlin, Europe	0.008	0.003
China, Asia	0.020	0.016

Table 3: Comparison of *stdDev* of delay variation for three sites with large packet

Conclusions and Future Work

Our experiments so far show results that are novel and unintuitive. We will continue running these experiments with existing sites and new sites from other parts of the world. We will also continue to analyze data in order to observe more patterns and reach conclusions regarding the effects of delay variation on multimedia quality.

Biographical Note

Stephen Pena is a mathematics major at Angelo State University. His interests include Statistics, Sabermetrics, and probability theory.

Lopamudra Roychoudhuri, PhD is an assistant professor of Computer Science at Angelo State University. Her research interests include computer networking, multimedia communication, network security and adaptive systems.

Works Cited

Institute, I. S. (1981, September). *Transmission Control Protocol*. Retrieved June 2015, from www.ietf.org: https://www.ietf.org/rfc/rfc793.txt

PlanetLab. (n.d.). (PlanetLab) Retrieved from PlanetLab: https://www.planet-lab.org/

Postel, J. (1980, August 28). *User Datagram Protocol*. Retrieved June 3, 2015, from www.ietf.org: https://www.ietf.org/rfc/rfc768.txt

Roychoudhuri, L., Al-Shaer, E., & Brewster, G. B. (2006). On the Impact of Loss and Delay Variation on Internet Packet Audio Transmission. *Journal of Computer Communication (JComCom), Volume 29*(Issue 10).

Wang, A., Huang, C. L., & Ross, K. (2009). Estimating Packet Loss Rate between Arbitrary Internet Hosts. *Passive and Active Measurement (PAM)*.