Effects of Networking Configurations on Space Channel Throughput

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Abstract. The throughput results for file transfers using file sizes ranging from 1 Kbyte through 1 Mbyte using both the standard TCP/IP and SCPS protocol stacks are reported here. The file transfers are performed at a range of balanced and unbalanced link speeds and channel error rates. The host computers used in the simulations are using standard Linux operating system configurations on PC platforms. The PPP is used as a framing protocol to support communications between the computers. The file-transfer throughput results will show the effects of link configuration and channel error rate on the necessary time to transfer a file. Because the operating system can be configured with different options for the protocols, for example enabling packet header compression, these options need to be factored into the comparison. As part of the throughput reporting, we will show the effects of header compression and selection of congestion algorithm upon the results. The TCP/IP ftp and SCPS-FP using VJ congestion control algorithm results give similar results and better results than SCPS-FP with the Vegas congestion control algorithm in these experiments. No noticeable delay effects were noted with links delays corresponding to GEO orbits with file transfers of 1 Mbyte.

Introduction

The use of Internet-type protocols for space communications is no longer considered a "new" topic of investigation. Research on the subject has been conducted at NASA, DoD, contractor, and university facilities for several years now. At New Mexico State University (NMSU), we have been concentrating on the performance of two protocols suites: the file transfer protocol (`ftp`) that is part of the Transmission Control Protocol/Internet Protocol (TCP/IP) stack and the file protocol (`fp`) that is part of the Space Communications Protocol Standard (SCPS) [1] developed under the Consultative Committee for Space Data Systems (CCSDS) standards process. In the NMSU studies, we have been concentrating on the performance of the protocols in a small satellite environment. By that, we mean that the anticipated user would be interested in the following characteristics and capabilities:

- Forward and return data rates from 2400 bps through 100 kbps, selectable in each direction,
- Bit Error Rate (BER) selection from 0 through 0.0001, selectable in each direction,
- Data file sizes from 1 Kbyte through 1 Mbyte,
- Short transfer opportunities, e.g., typical 5-minute ground station passes,
- User-selectable delay times for the forward and return link up to 5 seconds.

We have developed a Space-to-Ground Link Simulator (SGLS) to provide the simulation capabilities to test both protocol suites ([2], [3], and [4]). During the testing, we discovered that the protocol suites have a number of options that affect the overall protocol performance more greatly than others. This report discusses the experiments performed to map out how the options affect the overall performance from the user's point of view. When possible, option performance on both suites of protocols will be compared in a fair a manner as possible.

This investigation is intended to look at the performance of the TCP/IP and SCPS protocol suites in a simulated space channel environment. In particular, we are interested in investigating the similarities and differences caused by congestion control algorithms, compression options, and time stamp options on the protocol performance. We will be running these investigations with channel BER, link delay, and file size as variables that can be controlled to simulate various user needs.

The range of investigations is limited to the following parameter space:

- Data file transfers from 1 Kbyte through 1 Mbyte
- Return link speeds of 115200 bps and forward links speeds of 115200 bps for symmetric links and 2400 bps for unsymmetric links
- PPP as the data link layer framing protocol
- Channel bit error rates of 0, 10^{-6} and 10^{-5} due to Additive White Gaussian noise on the channel
- Channel delays of 0, 3 ms, 120 ms, and 1280 ms
- `ftp` header compression enabled or disabled
- `fp` time stamps enabled or disabled
- `fp` VJ or Vegas congestion control algorithm
- Single-hop point-to-point data links

In particular, these results may not be applicable to networks with significantly different bandwidth-delay products. The simulator models links that are composed of a single ground station and a single satellite. There are no relay satellites or external control centers modeled in this configuration. Because we have an emphasis on short-term file transfers, the interactions that may occur in long file transfer processes are not covered here.

Methods and Procedures

The SGLS channel simulator is used to perform the error generation and link delay used to test the protocol suite performance. In this section, we describe the simulator and the standard tools for gathering data to measure the performance.

The Space-to-Ground Link Simulator (SGLS) has been developed at NMSU to model space channel characteristics experienced in transmitting data. The simulator is described fully in [2], [3], and [4]. Basically, the SGLS configuration allows the user to configure the simulated channel to

- Allow for simultaneous bi-directional data flow (forward and return channels),
- Allow user-selectable error rates and statistical descriptions of the channel,

Allow different data rates on the forward and return links as would be found in satellite links, e.g. 2400 baud forward, 115200 baud return, and

Provide for a simulated delay up to 5 seconds on each link.

The SGLS utilizes the LabVIEW programming language to control data throughput through the simulator, mix the baseband data stream with the user-selected error vector, and provide for the user-selectable link delay value. The hardware configuration is illustrated in Figure 1. The LabVIEW software is run as an application on each of the SGLS computers. Typically, the LabVIEW modules are the only applications software running on the computers. This configuration was developed to model point-to-point satellite links in its current configuration. The bandwidth-delay product for the system under a 115200 bps symmetric link with no imposed channel delay is 671 bytes. As a comparison, a T-1 line crossing the United States has an estimated band-width delay product of 11,580 bytes [5]. Therefore, this simulator corresponds to a relatively low capacity system.