Transmission Efficiency of Licklider Transmission Protocol (LTP) and Bundle Protocol (BP) in DTN Architecture

Ding Wang\textsuperscript{1,*}, Hongzhi Yu\textsuperscript{2} and Jun Ma\textsuperscript{3}

\textsuperscript{1}Northwest Minzu University, Lanzhou, China
\textsuperscript{2}Northwest Minzu University, Lanzhou, China
\textsuperscript{3}Northwest Minzu University, Lanzhou, China
\textsuperscript{*}Corresponding author and e-mail: wangding212@qq.com

Abstract. From Near-Earth orbit (NEO) to Earth-Sun Lagrangian points will continue to be a majority of Near Earth missions ranging from Near-Earth orbit (NEO) to Earth-Sun Lagrangian points will continue to be a majority of future space missions. A few works have been done with delay/disruption tolerant networking (DTN) technology for Near-Earth orbit (NEO)-space center and deep space communications and provided feasibility for its adoption in NEO- space and deep space missions.\cite{1} However, no much work has been done to fully evaluate the transmission efficiency of DTN in such an environment, especially in the presence of long link disruption, data corruption and lost rate, and link asymmetry. In this paper, we present an experimental performance evaluation of DTN architecture and protocol stack, with Licklider transmission protocol (LTP) serving as a convergence layer adapter (CLA) underneath bundle protocol (BP), in typical NEO-satellite system and deep space communication infrastructures accompanied by a very long link delay, various packet corruption and lost rates, and channel rate symmetry and asymmetry. In addition, we present an experimental research of the transmission efficiency of DTN custody transfer with long link delay. The experiment was conducted by performing realistic file transfers over a virtual server-based test-bed.

1. Introduction

Jet Propulsion Laboratory developed the DTN architecture and Ohio University partially maintained this new infrastructure. The insertion of DTN functionality in to the space transmission research is very impractical. So this new architecture is designed and used in deep space research systems in order to reduce the risks and payment in transmission by simplifying the construction and operation of automated long distance transmission network.

Implementation of The DTN architecture is intended to work successfully in an interplanetary network environment characterized by two major constraints namely the link constraints and processor constraints. The link constraints are mainly characterized by slow and asymmetric bandwidth. Signals are also very weak since the antennas in the spacecraft are relatively small and this also limits the speed at which the data can be transmitted from spacecraft to earth. The processor constraints are characterized by the limited availability of the electric power to operate space computer and they are constantly slower. This leads to the increase in cost for processing data and processors are heavily loaded. Therefore, the processing performed by spacecraft computer should be highly predictable and highly reliable. The core principles of DTN that are intended to overcome the above mentioned constraints is shared memory, zero-copy procedures, highly distributed processing and portability.
2. Related Work on Bundle Protocol (BP) of DTN Network
Bundle protocol is a protocol layer of DTN architecture. It designed to work at the application layer of the DTN architecture. The protocol data unit communicated by this DTN bundle protocol is called Bundles and each bundle consist of two or more blocks of protocol data. The node component that executes the programs of the BP and offers the BP services is known as the bundle protocol agent (BPA). The convergence layer adapter (CLA) utilizes the service of the underlying network protocol layers to send and receive the bundle on behalf of the BPA. The key features supported by BP are the custody based retransmission and the reliable transfer of data during link disruption and long link delay. BP provides all these features through a technique called store-and-forward message-oriented mechanism as shown in Figure 1.

![Figure 1. DTN Protocol Stack (Source: ION Design and Operations Manual)](image)

Each DTN node keeps custody of bundles it forwards to the adjacent node until it receives a positive ACK from the adjacent node is so called store and forward mechanism. If the data is lost or if the node receives negative ACK, it re-forwards the bundle again. The custodian bundle is released when the node receives a notification that some other node or the particular destination node accepted the custody of the same bundle; or the bundle is deleted explicitly due to lifetime expiration. So by this mechanism BP provided reliable transfer of data even in a highly stressed environment. Some of the other services provided by bundle protocol are error-free data delivery, completeness in delivery, fragmentation and extensibility. The service provided by bundle protocol and the location of other protocols in DTN architecture is shown in the Figure 2.

![Figure 2. DTN Protocol Stack (Source: ION Design and Operations Manual)](image)
Custody transfer is a good way to improve the reliability of network. Especially, it can help deliver a message to a moving responsibility destination. Protocol will request an acknowledgment to enhance the reliability. A message with custody transfer will not be deleted until it can be received by another node with custody transfer. Node will hold a message and is so called a custodian. Some custodians hold the message and some custodians own a message or message fragment. Protocol requests custody transfer to perform and deliver acknowledgment when host system can move the message to other nodes. Figure 3.4 provides a comparison of Time Line Graphs of BP/LTP with custody transfer and without custody transfer. For a detail discussion of custody transfer see BP reference [5]

3. Related Work on Bundle Protocol (BP) of DTN Network
This experiment research on transmission efficiency assessment of Delay Tolerant Network in the NEO transmission environment. NEO system composition structure already illustrated in previously chapters and operations manual. For the easy peer-to-peer NEO system composition structure also described in related documents. The virtual server of Deep Space Transmission Network (DSTN) was used to simulate the delay-type of NEO system transmission system for the planned testing assessment of Delay Tolerant Network. See [6] for the composition structure of the DSTN and a further examination of its performance. Previous discussion [7] illustrates that the assessment results get files from the DSTN have majority and the system can examination the results of transmission efficiency of BP and Licklider Transmission Protocol (LTP) in all experiments. The network simulation virtual files of Fedora server and some parameters [8], was changed to analogy the status of deep space channel such as transfer outage, unconditional delay, files corruption, and files lost or others.

Table I shows the all experiment parameters about protocol configuration for testbed. These operations were construct by file sender. These virtual servers can send random file of 1.5 Mbyte from the virtual NEO-node in deep space center. Another parts of operations are file receivers, these virtual servers can receive random files from the virtual node on the station of Earth, the parameters of experiments can modify by the transmission progress. Transmission of every data block was deployed many times in each transmission process. When the result of procedures can get from these transmission process. These standard dimensions were used to compared and statistics in the procedure. The experiments for long distance transmissions are done in a similar method as for NEO-satellite transmissions. The experiments for deep space communications are done in a similar method as for NEO-satellite communications. The typical test bed of relay-based deep space communication architecture can construct by Table 1.
In Figure 4, shows a composition structure of the virtual servers in experiment of deep space network transfer experiment and the details of transfer channel.

| Experimental Factors                  | Settings/Values                                      |
|---------------------------------------|------------------------------------------------------|
| DTN Protocol implementations          | Interplanetary Overlay Network (ION) v2.2.1 from JPL, California Institute of Technology, CA |
| DTN protocol layering                 | BP/LTPCL/UDP/IP/Ethernet                             |
| BP custody transfer option            | Enabled                                              |
| LTP red/green settings                | Bundles are set 100% red data                        |
| MTU size                              | 1500 bytes                                           |
| Operating system                      | Fedora Linux 8 (kernel 2.4.18-3)                    |
| Packet corruption rate                | 0%, 10%, and 20%                                     |
| Packet loss rate                      | 0% and 5%                                            |
| Channel ratio (Data rate : ACK rate)  | 1/1 (6.4 Mbit/s : 6.4 Mbit/s, Symmetric channel)    |
|                                       | 800/1 (6.4 Mbit/s : 8 Kbit/s, Asymmetric channel)    |
| One-way link delay                    | 5 ms (A typical LEO-satellite link delay)            |
| Experimental file size                | 5,000,000 bytes                                      |
| Sample size                           | 16 repetitive runs for each configuration             |

Table 1. Experimental Factors and Configuration

In Figure 4, shows a composition structure of the virtual servers in experiment of deep space network transfer experiment and the details of transfer channel.

4. Experiment Results and Discussions
In this part, we begin to a tough comparison for the throughput capability contains with or without a long link delay. According to these principles, we investigate the capability of the BP/LTP without a long link delay, after that, we research the capability contains a long link delay.

4.1 Comparison of Performance with and Without Link Outage Confused
In Figure 4, as the statistic result, there is the graphic of goodput capability for these two protocol based on DTN to transfer a 1.5 Mbyte file over NEO-system is presented about three package corruption rates with respect to no link delay and long link delay of 1, 4, 8 and 16 hours confused.

4.2 BP/LTP with Custody Transfer vs BP/LTP Without Custody Transfer with 1.5MB File Size
In Figure 5, there is also a graphic of throughput capability for these two protocol based on DTN with and without custody transfer to transfer a 1.5 Mbyte file on long distance communication system. It is described at three BERs with respect to no link delay and long link delay ranging from 10 minutes to 8 hours.
Figure 5. Throughput comparisons for the LTP-based DTN protocol to transmit a 1.5 Mbyte file over NEO-system windows with respect to no link delay and long link delay confused. (a) SYM with Lost Rate=0%. (b) SYM with Lost Rate=5%. (c) ASYM with Lost Rate=0%. (d) ASYM with Lost Rate=5%.

Figure 6. Throughput comparisons for the LTP-based DTN protocol to transmit a 1.5 Mbyte files over deep space communication with different links disruption and BER. (a) BER=0 (b) BER=10^{-6} (c) BER=10^{-5}

From the above discussions, custody transfer absolutely is not good at in the retransmission architecture on NACK system. In fact, the only question is that causes retransmission by a bundle custodian is expiration of a countdown timer. In general, custody transfer is not good at the full-featured reliability system at all. The specification imposes very few solid requirements on the implementer.

5. Conclusion
If files who transfer over NEO-system transfer without a transfer outage experienced, the effect of transfer-rate asymmetry, the transmission ratio is about 800/1, in experiment. On the throughput capability of protocols-based Delay Tolerant Network reduced along with the improve of package corruption rate. The corruption rate is about 0% to 20%. The effect reduced more meaningfully when package lost 5% or even are happen in this progress. The effect of package corruption, the corruption
rate is about 10%~20% on the throughput capability of the BP and LTP improve when the transfer rate becomes asymmetric, and it improve more meaningfully over a lost transfer.

As Deep space communication, Licklider Transmission Protocol(LTP) and Bundle Protocol (BP) is the significant effect to transfer files in existence of an exceptionally long transfer delay of 5 minutes. Depend on the transfer situation, the results of comparison are different. Licklider Transmission Protocol(LTP) and Bundle Protocol (BP) without custody transfer has so many benefits over with custody transfer when no break or very short break contain for transfer progress of the regular files. The different between with custody transfer and without custody transfer illustrate very similar transmission efficiency for the long delay situation and/or small transmission blocks. Licklider Transmission Protocol(LTP) and Bundle Protocol (BP) without custody transfer to transfer huge block files with long delay has good performance. For these research results, custody transfer is not good to use in the retransmission architecture on NACK system. And these results do not illustrate many benefits in long distance transmission.

6. Future Work

Delay Tolerant Network architecture has very good performance for transmission file of deep space communications in the experiment. However, Delay Tolerant Network has not yet to be test in very long distance file transmission. When assessment of Bundle Protocol and other assistant routing protocols is acknowledged as analytical for Delay Tolerant Network establishment, comprehensive assessment and optimization of Licklider Transmission Protocol is similarly analytical before Delay Tolerant Network is used in deep space communication. Another side, the effect of the Licklider Transmission Protocol flood switch “opening dimension” on the transmission efficiency of Delay Tolerant Network should also be research and verify to find out the best maximum goodput of Licklider Transmission Protocol.

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