



Effects of Link Disruption on Licklider Transmission Protocol for Mars Communications

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Abstract. Some studies on Licklider transmission protocol (LTP) in cislunar and Mars communications have been done. However, little work is currently available in studying how link disruption affects LTP for Mars communications. This study presents a discussion of link disruption on LTP for Mars communications based on experimental data block transfer. The study focuses on how link disruption duration and starting time affect the number of transmission attempts taken, round-trip time (RTT) and goodput performance for Mars communications.

Keywords: Space networks · Network protocols · Wireless networks · DTN

1 Introduction

Delay/disruption tolerant networking (DTN) [1] has been recognized as the primary space networking technology for interplanetary Internet [2]. Since the introduction of DTN technology, different data transport protocols are expected to be operable on the DTN protocol stack under its core protocol, bundle protocol (BP) [3], to provide specific services depending on individual application need [4]. Developed as DTN's main transport protocol, the Licklider transmission protocol (LTP) [5, 6] is developed to operate over unreliable space communication channels for efficient data delivery in space [7].

Link disruption events in interplanetary Internet are generally caused by a lack of limited relay transit capability between a data node on the remote planet and the Earth. They can occur over both the direct planet-Earth link and the broadly adopted indirect, relay-based data links. Taking a typical Mars communications architecture presented in

[7] for discussion, the Mars rover serving as a data source node periodically goes to the opposite side to Earth because of the periodic rotation of the Mars. As a result, the data links connecting the source node on the Mars surface and the destination node at Earth ground station are frequently disrupted. This leads to frequent interruptions to the communication channels. The consequence is that transmission performance and efficiency of data delivery are severely degraded, especially in Mars communications having an extremely long link propagation delay.

Some studies have been done for reliable data transport protocols [8–11] in space, DTN's BP [12–22] and LTP in space [23–35]. Most of these studies focus on design, analysis and implementation of space networking and data transport protocols with emphases on BP and LTP. Little work is currently available in studying how link disruption (either periodic or random) affects LTP for Mars communications. This paper presents a discussion of link disruption on LTP for Mars communications based on experimental data block transfer. The study focuses on how link disruption duration and starting time affect the number of transmission attempts taken, round-trip time (RTT) and goodput performance for Mars communications.

2 System Model

In [30], analytical models are built in estimating the RTT and data block delivery time of LTP in cislunar communication. Although they are built for LTP in Moon communication, they are applicable in Mars communications, and thus are revisited. In [30], the transmission time for a block, T_{Block} , is approximated as

$$T_{Block} = \frac{(L_{Seg} + L_{Frame_Head})}{R_{Data}} \times \frac{N_{Bundle} \times (L_{Bundle} + L_{Bundle_Head})}{L_{Seg}} \quad (1)$$

in which the overhead length L_{Frame_Head} is formulated as

$$L_{Frame_Head} = L_{LTP-Head} + L_{UDP-Head} + L_{IP-Head} + L_{Link-Head} \quad (2)$$

For all the terms in (1) and (2), they are self-explanatory. Refer to [3] for the details. With the data block transmission derived, the RTT can be estimated as

$$\begin{aligned} RTT &= 2 \times T_{OWLT} + T_{Block} + T_{RS} + E(T_{Disrupt}) \\ &= 2 \times T_{OWLT} + \frac{(L_{Seg} + L_{Frame_Head})}{R_{Data}} \\ &\quad \times \left[\frac{N_{Bundle} \times (L_{Bundle} + L_{Bundle_Head})}{L_{Seg}} \right] + \frac{L_{RS}}{R_{RS}} \\ &\quad + E(T_{Disrupt}) \end{aligned} \quad (3)$$

in which the terms are self-explanatory, and $E(T_{Disrupt})$ denotes the time effect to data block delivery caused by the link disruption event.

3 Experimental Setup and Configurations

The same testbed (SCNT) used in [30] was adopted as the infrastructure for the data block delivery experiments in this paper. Refer to [23] for a detailed description of the testbed. The Interplanetary Overlay Network (ION) distribution v3.6.2 [36] was adopted as the LTP protocol implementation.

To evaluate the sole reliable data delivery service of LTP, the BP custody transfer option was disabled so that the effect of BP reliability service on LTP transmission is removed. To achieve reliable transmission service of LTP, the data of entire LTP block is configured red. LTP data block contains 40 bundles with each bundle of 5-Kbytes.

For the setting and parameters of link disruption events, they are presented under each subsection of Sect. 4.

4 Numerical Experimental Results and Discussion

The experiments are divided into two cases:

Case 1—Reliable data block transmission in presence of a single link disruption event with different durations;

Case 2—Reliable data block transmission in presence of more than one link disruption event with different starting times.

Table 1. Settings of link disruption events for two sets of experiments in case 1.

	Link disrupt. starting time (min)	Durations of link disruption event (min)
Experiment-1	7	5, 10, 20, 30, 45, and 60
Experiment-2	13	5, 10, 20, 30, 45, and 60

4.1 Single Link Disruption Event with Different Durations

The setting of the link starting time and various link disruption durations for two sets of experiments in Case 1, named as Experiment-1 and Experiment-2, are listed in Table 1. Experiment-1 and Experiment-2 are different mainly on their link disruption starting time, 7 min and 13 min from the beginning of the transmission, respectively. However, for each set of the experiments, various link durations are configured for the single link break event, ranging from 5 min to 60 min.

Figure 1 presents the extra number of transmission attempts because of the break for successful block delivery for two sets of experiments in Case 1 with a propagation delay of 10 min (600 s). It is observed that for both Experiment-1 and Experiment-2, the extra transmission attempts increase with respect to an increase in the link disruption. This is reasonable. A longer link disruption results in a long waiting time at the sender, leading to an increase of the checkpoint (CP) timer expirations at the sender and thus an increase of the attempts.

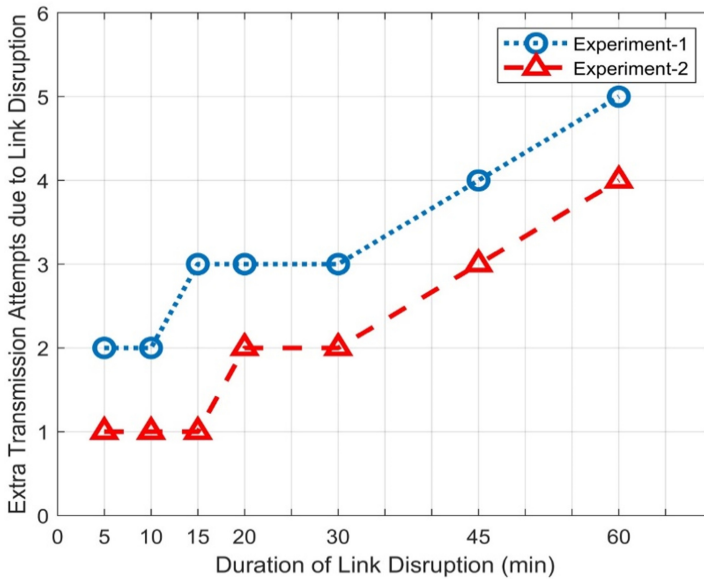


Fig. 1. Extra transmission attempts taken for block delivery for two sets of experiments in Case 1 with respect to various durations of link break.

In comparison, the data delivery runs in Experiment-1 consistently have one extra transmission attempt for all the experimented durations of a link disruption except for 15 min for which Experiment-1 has two extra transmission attempts. The consistent difference of the extra transmission attempt is because of the difference of the starting times. The link disruption in Experiment-2 starts six minutes later than the one in Experiment-1. Regardless of the duration of link disruption, the disruption event in Experiment-1 starts at 7 min from the start of the transmission. This means the disruption event surely causes the CP and a part of the data lost. Therefore, statistically, an extra retransmission attempt is needed.

In contrast, the disruption event in Experiment-2 starts at 13 min from the beginning of the transmission. At the time the disruption starts, the segments already arrive, and therefore, the link disruption may only affect the transmission of the RS over the opposite ACK link. This leads consistently to one or two fewer retransmission attempts required for successful block delivery than Experiment-1.

The effect of the link break can also be observed from the RTT and goodput performance variation trends. Figure 2 presents a comparison of the corresponding RTT between Experiment-1 and Experiment-2. Obviously, the RTT shows a similar increasing pattern as in Fig. 1. The main reason is that the duration of the link disruption event experienced during block delivery is also counted as a part of the RTT.

In comparison, the measured RTT lengths are the same for all the runs in both sets of the experiments even though their starting times are different. This is because the link disruption is introduced before the block delivery ends and therefore, its duration always contributes to the length of RTT.

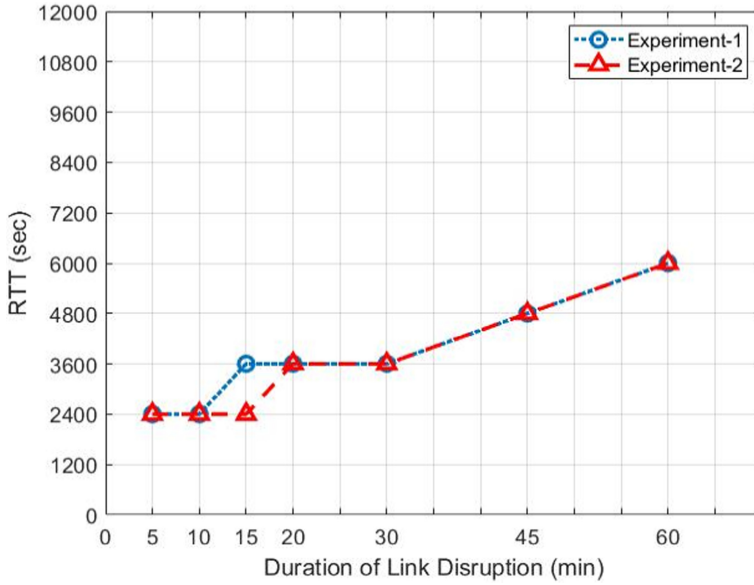


Fig. 2. A comparison of RTT for block delivery between two sets of experiments in Case 1 with respect to various durations of link break.

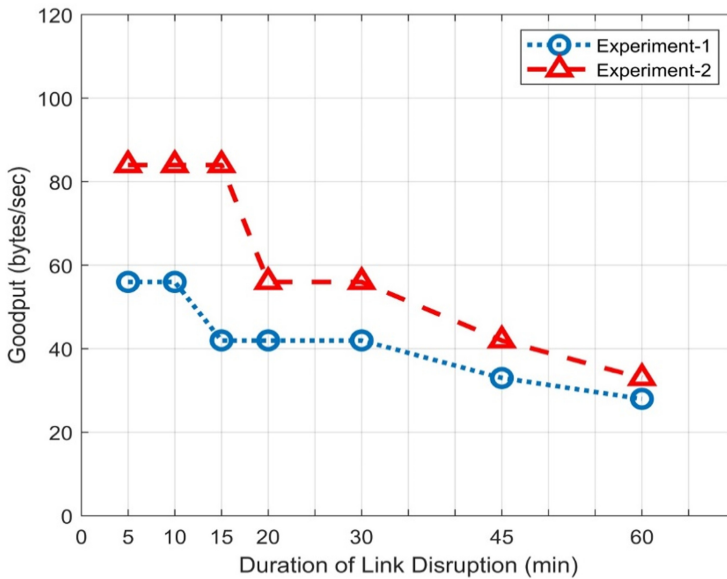


Fig. 3. Goodput performance for block delivery for two sets of experiments in Case 1 with respect to various durations of link break.

Figure 3 presents the corresponding goodput performance. The increase of the RTT in Fig. 2 surely results in a longer block delivery time. As the block size is the same for all the runs, the goodput consistently shows degradation. It is also observed that the difference in goodput between Experiment-1 and Experiment-2 is declining, and it tends to get merged for a very long disruption. This is because the lengthy link disruption has much more significant effect to the block delivery time than their difference in starting time.

4.2 More than One Link Disruption Event with Different Starting Times

The experiments in Case 2 are configured to run with two link disruption events that start at different times. Table 2 lists the settings of the link disruption starting times for the first and the second link disruption and the durations of both events for Experiment-1 and Experiment-2. For each set of Experiment-1 and Experiment-2, while the starting time for the first link disruption event is fixed, various starting times are configured for the second disruption event. Both disruption events have the same duration, 10-min. Figure 4 and Fig. 5 present the extra transmission attempts and the RTT with respect to the time interval between two link disruption events for successful block delivery, respectively, between Experiment-1 and Experiment-2. For the comparison of the extra transmission attempts, the runs in Experiment-1 consistently have three extra transmission attempts for the link disruption durations of 5–20 min and increase to four starting from 25 min. In comparison, the runs in Experiment-2 show opposite variation trend for which they consistently have two extra transmission attempts for the link disruption durations of 5–15 min and drop to one starting from 25 min.

Table 2. Settings of link disruption events for two sets of experiments in case 2.

	1st link disrupt. starting time (min)	2nd link disrupt. starting time (min)	Durations of link disruption event (min)
Experiment-1	7	22, 27, 32, 37, 42 and 47	10
Experiment-2	13	28, 33, 38, 43, 48, and 53	10

Experiment-1 and Experiment-2 have a difference of one extra transmission attempt for the link disruption durations of 5–15 min. It is reasonable because the link disruption event in Experiment-2 starts much later while the duration of the disruption is equal. This is discussed in in Sect. 4.1. The significant difference in the extra transmission attempts between Experiment-1 and Experiment-2 is on their variation trend. Their significant difference is related to the time at which the second disruption starts. For the runs in Experiment-1, the effect of the second link disruption still exists after the transmission starts for twenty-three (23) minutes, which continue to affect the subsequent data transmission. In comparison, for the runs in Experiment-2, there is no data flow existing after the transmission starts for seventeen (17) minutes. This means

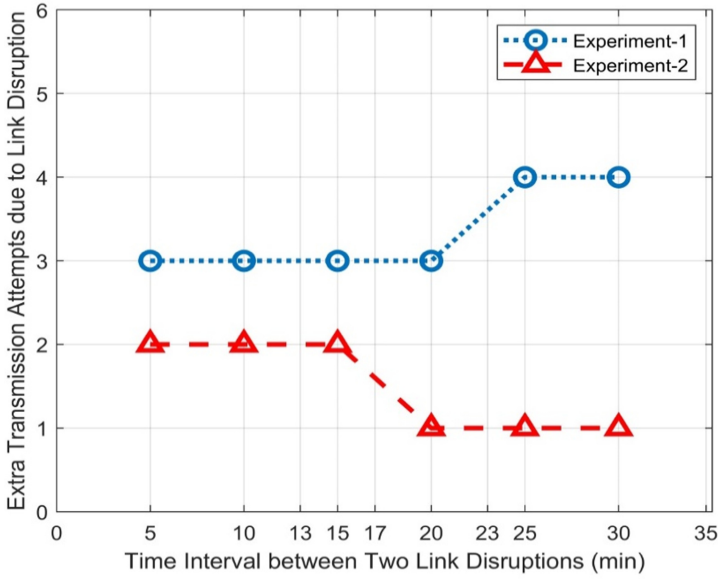


Fig. 4. A comparison of extra transmission attempts taken for block delivery between two sets of experiments in Case 2.

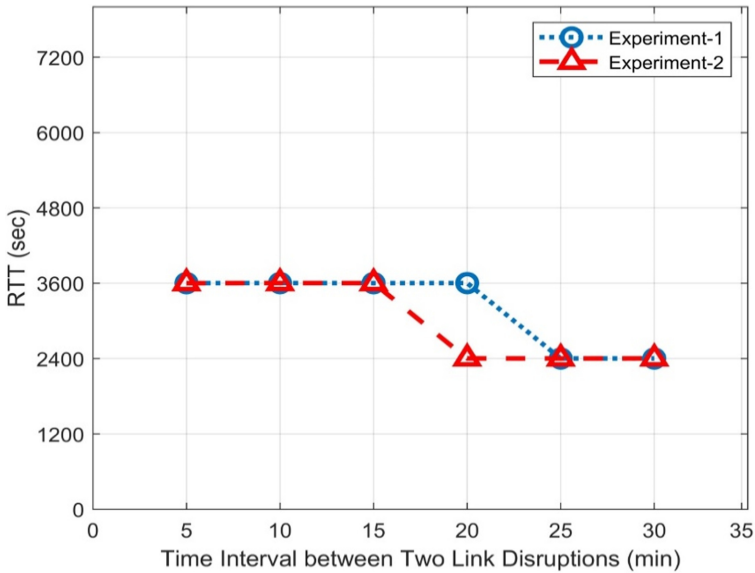


Fig. 5. RTT for block delivery for two sets of experiments in Case 2 with respect to time interval between two link disruption events.

that the second disruption is actually ineffective to the data delivery and therefore, the extra transmission attempts drops by one. This also explains the declining trend of RTT and why the numerical values of the RTT are either 3600 s or 2400 s.

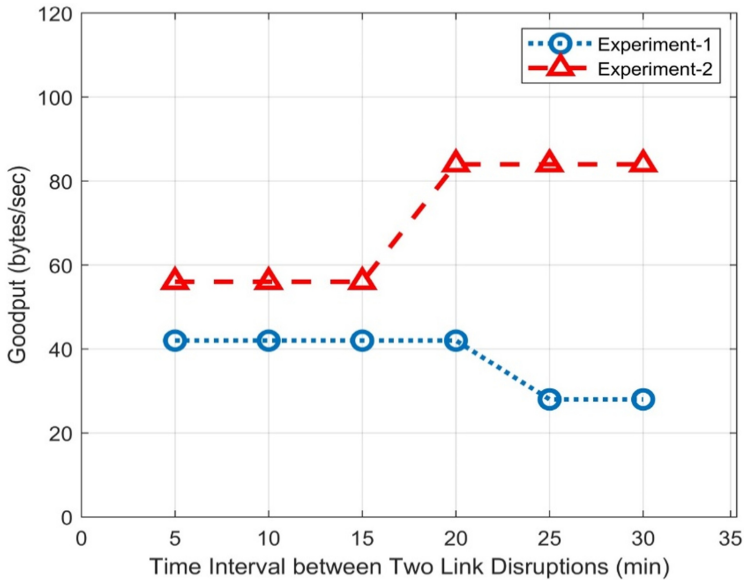


Fig. 6. A comparison of goodput for successful block delivery between two sets of experiments in Case 2 with respect to time interval between two link disruption events.

Figure 6 illustrates the corresponding goodput between two sets. While the data block size is consistently the same, the block delivery time is mainly contributed by the transmission attempts. In other words, more extra transmission attempts are taken, the longer the block delivery time is. This implies that the goodput performance in Experiment-1 and Experiment-2 is expected to be inversely proportional to the transmission attempts in Fig. 4. This is exactly what the goodput performance comparison in Fig. 6 illustrates for with respect to the goodput for each of Experiment-1 and Experiment-2 and their relationship.

5 Conclusions

It is found that the link disruption leads to extra data attempts and thus total number of transmission attempts. The experiment results shows that the extra transmission attempts and thus total attempts increase with respect to an increment of the duration of link disruption. As a result, the RTT and data block delivery time also increase, leading to goodput performance degradation.

For a given link disruption event, earlier it starts, more likely the number of transmission attempts increases and thus longer data block delivery time and lower the goodput performance are. For a transmission involving more than one link disruption event, their effect to all three aspects of transmission performance can't be linearly added. It is related to the connections among the link disruption events.

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