FY25 Strategic University Research Partnership (SURP)

Applying Disruption Tolerant Network (DTN) Standard to Flight Projects

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OBJECTIVES/APPROACH: The primary objective of this project is to enable Delay Tolerant Networking (DTN) as a communication technology for future missions. We leveraged the flight-proven, open-source F Prime Flight Software Product Line and the Interplanetary Overlay Network (ION) software implementation of DTN to demonstrate a reference application for future missions that execute flight-like DTN capabilities.

Our approach to accomplish this objective is to develop and test a reference application that can execute DTN functionalities in a flight-like manner, serving as a pattern for future missions. We leverage prior work at JPL that integrated F Prime and ION software and incorporated that into our testbed environment. Our overall work is decomposed into three objectives:

1. University of Michigan (UM) has conducted a concept study on DTN contact graph management approach for deep space multi-asset missions,
2. Develop a prototype of concept DTN mission utilizing JPL-provided integrated F Prime ION software, and
3. Demonstrate advanced DTN topology management capability for a large-scale network (estimate 5 to 10 nodes).

RESULTS: Towards objectives 1 and 2, UM has developed TrajVis, a high-altitude balloon (HAB) trajectory simulation toolkit, written in Python, to model DTN node positions. TrajVis offers a simulation platform to visualize the flight paths of HABs within a randomly generated windy environment. (Example trajectory shown in Figure 1) TrajVis can also model a balloon network of DTN crosslinks and calculate the achievable data rate for each. Using TrajVis, a topology reconfiguration algorithm was developed to maximize the capacity of network. Using communications link budgets and received power as the metric, a weighted and directed contact graph of node connectivity is computed to maximize the predicted strength of received signal. Simulations were performed to evaluate dynamic reconfiguration for a 5-node network with each node using an XBee Pro SM radio and Molex 900MHz antenna and evaluate the potential data rates improvement through network reconfiguration. We found that within ad-hoc environments, reconfiguration of DTN contact graphs can elevate the overall capacity of network, enabling higher volume of data transfer.

Towards objective 3, we developed embedded flight hardware to conduct these larger-scale network experiments, which is still on-going into 2026. The developed hardware is a 2x3cm printed circuit board (front and back shown in Figure 2) that supports the full avionics capabilities needed for our experiment. It includes an embedded processor, the Raspberry Pi RP2350, running F Prime on top of the Zephyr operating system. An integrated Ublox GPS receiver provides position and time information. An embedded Semtech SX1278 radio provides transmit and receive capabilities. This avionic system is capable of diverse modulation, such as LoRa, FSK, and AFSK, which cover all modulation schemes used in our networked system. The hardware has gone through three revisions during prototyping phase and is currently integrated for flight testing on several high-altitude balloon systems. DTN software is currently being integrated into these nodes to enable DTN networking experiments.

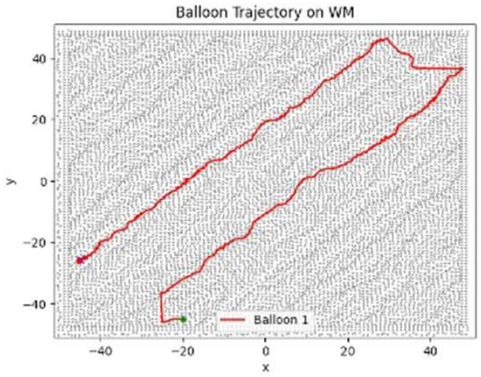

Figure 1 – An example TrajVis balloon trajectory on a randomly generated windmap

Figure 2 – Embedded hardware for running F-Prime and DTN

Benefit to NASA/JPL: Delay Tolerant Networks (DTNs) enable new networking methods for advanced missions, especially those requiring the coordination of multiple assets. DTN-enabled F Prime infuses networking capabilities into a variety of flight missions, including university-based testbeds such what UM has developed and other pilot space missions like the Ingenuity Mars Helicopter and Georgia Tech's GT-1 CubeSat mission. Thus, a DTN-enabled F Prime would allow for a wealth of new mission concepts with varying complexities and sizes for NASA and JPL.

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Publications:

- Ali Mosallaei, Daniil Voloshin, and James W. Cutler, "Demonstrating and Analyzing the Effects of Dynamic Contact Graphs in Improving Wireless Adhoc Delay Tolerant Networks through a Simulated Stratospheric Testbed," AIAA SCITECH 2025 Forum, 6-10 January 2025, Orlando, FL, USA.

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