National Aeronautics and Space Administration

FY24 Strategic University Research Partnership (SURP)

Applying Disruption Tolerant Network (DTN) Standard to Flight Projects

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OBJECTIVES/APPROACH: The primary objective is to enable Delay Tolerant Networking (DTN) as a communication protocol 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 multi-year phased effort begins with a concept study, followed by a 2-node prototype, and a multi-hop end-to-end DTN networking demonstration.

RESULTS IN FY24: Our objectives will be accomplished by developing and testing a reference application that executes DTN in a flight-like manner, serving as a pattern for future missions. We will leverage prior work to integrate F’ and ION by JPL as the core operating system for the testbed. Our overall work has the following three tasks:

1. UM will conduct a concept study on DTN contact graph management approach for deep space multi-asset missions.
2. Develop a demonstration prototype of the DTN mission concept study utilizing JPL-provided integrated F’-ION software.
3. Demonstrate advanced DTN topology management capability for a large-scale network (estimate 5 to 10 nodes).

Towards 1 and 2, we developed TrajVis, a high-altitude balloon (HAB) trajectory simulation toolkit to model DTN nodes in such missions. Written in Python, TrajVis offers a simulation platform to visualize the flight path of HABs within a randomly generated windy environment (see Fig 1). Nodes in TrajVis contain a communication system that models balloon DTN crosslinks and calculates data rates.

Using TrajVis, a reconfiguration algorithm was developed. The algorithm forms a network that maximizes node connections. Using a communications link budgets and receive power as the measurement metric, a weighted and directed contact graph node connectivity and how strong the received signal would be. Throughout distinct time intervals in flights, this algorithm can be executed, set as the network’s current cg, and evaluated to see whether there is a possible link between a provided start and end node, or if data should be stored at the start node for later retransmission.

Experiments were performed to evaluate dynamic reconfiguration against similar systems that used static contact graphs for various network sizes. An example result, from a 5 node network with each node using an XBee Pro SM radio and Molex 900Mhz antenna, resulted in the graph shown in Fig. 2. It shows the reconfigured path resulted in a higher total receive power from an arbitrary start to end node, which means that a higher data rate could be achieved with a reconfigured contact graph.

Similar results were observed with other communication systems with varying operating frequencies, antenna polarizations, and more. We conclude that networks of systems in ad hoc environments benefit from DTNs with reconfigured contact graphs, as the overall connectivity time to any node is lengthened enabling greater data transfer.

JPL F’ developers M. Starch and T. Boyer-Chammard presented an F Prime Software Workshop to 30 UM students who participated out of the 100+ who applied. The University of Michigan and Western Michigan University students integrated F Prime into a class stratospheric balloon flight, launched on the 13th of April 2024, to an altitude of 98K feet, using F Prime collected data and was commanded from a ground station. This F’ system is now deployed in an educational laboratory environment to provide hands-on experience and train 20-40 students each semester.

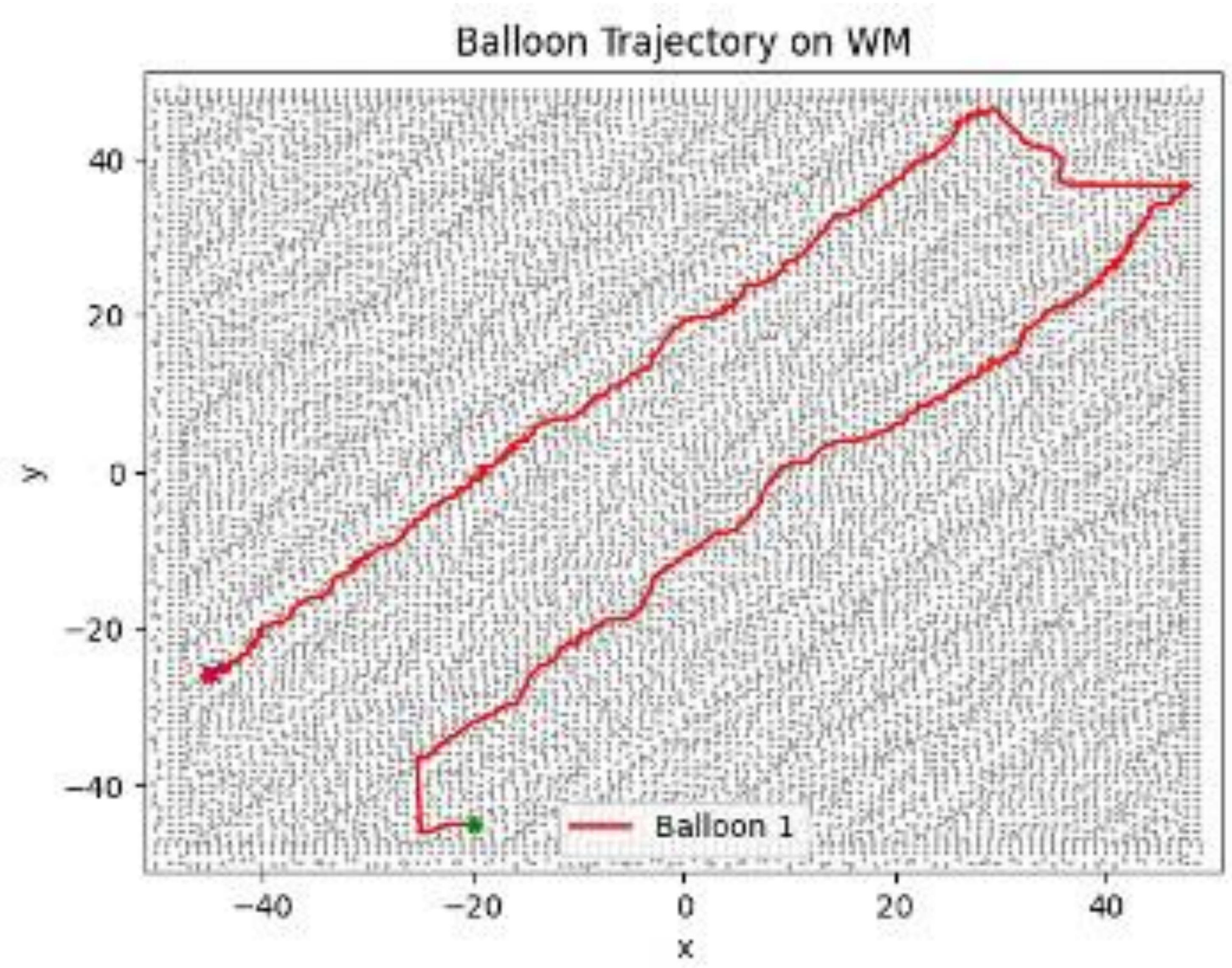

Fig. 1: An example TrajVis balloon trajectory on a randomly generated windmap.

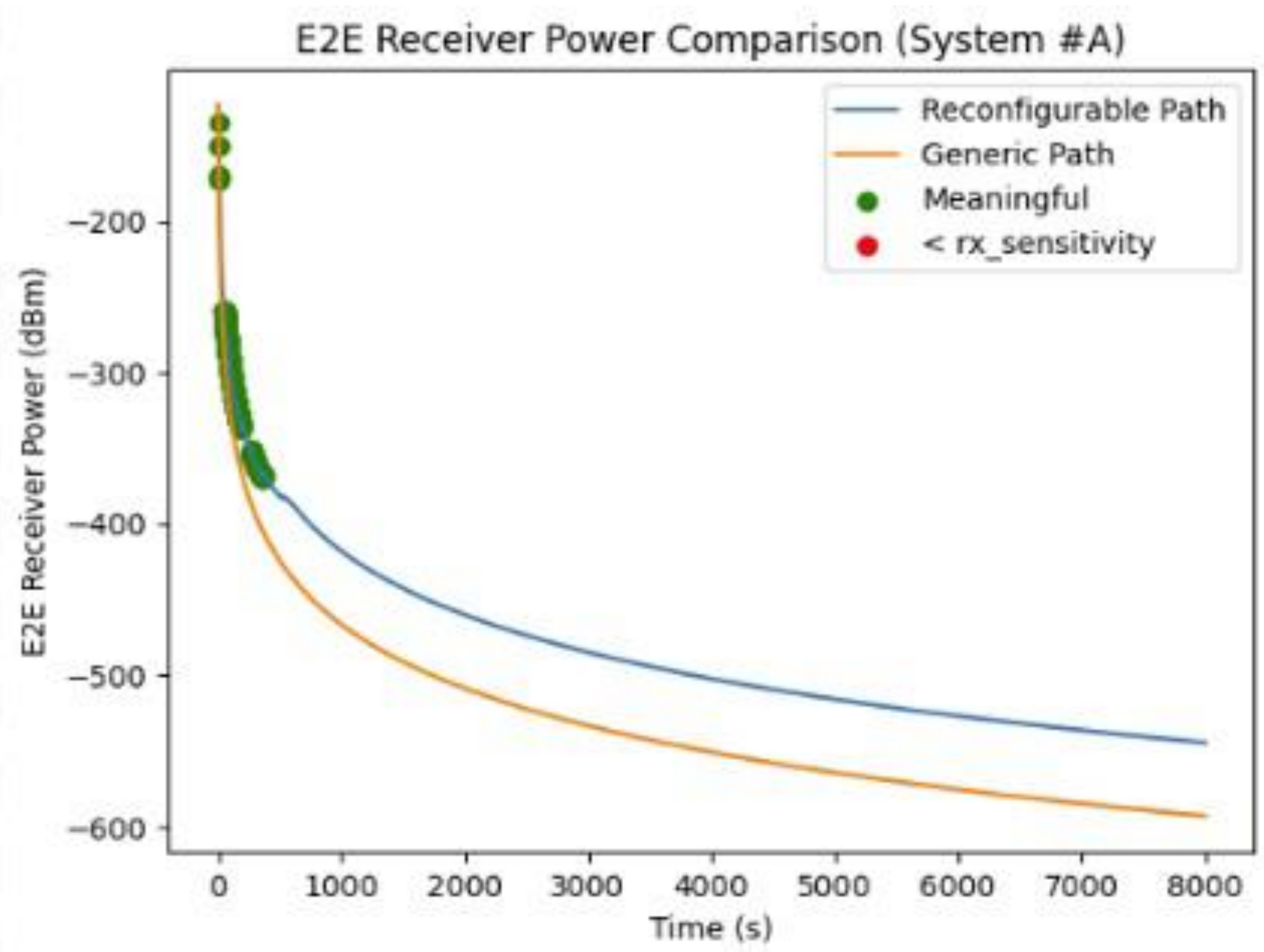

Fig. 2: Total receive power comparison between network with and without reconfigured contact graphs. The blue and orange lines are the total receive power graphs for reconfigured and generic paths respectively. The green dots signify a meaningful reconfiguration.

Benefit to NASA/JPL: Delay Tolerant Networks (DTN) enable new networking methods for advanced missions, especially those managing multiple assets. DTN-enabled F Prime will enhance DTN capabilities in additional flight missions that are capable of using F Prime. This includes university-based testbeds we are developing and novel small 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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