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NETWORKING WITH DYNAMIC RECONFIGURABILITY AND ROBUSTNESS FOR MODULAR SPACECRAFT

Abstract

Modular and dynamically reconfigurable space hardware systems are a high priority for research and development as they can significantly decrease development costs, facilitate multiple payloads, and enable indefinite lifetime extension for orbital assets through on-orbit servicing operations. However, dynamically reconfigurable space hardware systems have many fundamentally different design and implementation requirements from monolithic single-mission systems that are currently in use. Most critically, the communications between modular and reconfigurable components must be decentralized, robust to changes in physical organization, common to all components at the physical, electrical, and protocol levels, and able to accommodate new elements beyond the original mission specification.

This paper describes adaptable and robust networking technologies that are currently under development to support novel modular satellite and space robot systems that implement dynamic reconfiguration and autonomy. While it is desirable to adapt existing communications technologies to the use of modular spacecraft, a review of these technologies indicates a clear capability gap between current technologies and the needs imposed by autonomous reconfigurability.

To fill this gap, we describe a novel communications protocol that can be used over existing Ethernet hardware and CAN bus for wired communications that provides the reconfigurability and robustness needed for data and power networking of changing physical configurations of hardware. We also describe the extension of this protocol to wireless systems that could be deployed safely on space hardware and allow spacecraft modules to communicate between each other and with ground stations when not physically connected.

For robust fault tolerance and connectivity with ground stations, it is necessary to have the capability to recover from network degradation due to both internal system faults and external factors such as atmospheric conditions and cloud cover. We have created a Machine Learning (ML) application capable of interfacing with switch nodes in an emulated network to record traffic, predict link health using ML, and then re-route traffic to a more optimal path.

Decentralized adaptive routing and ML-based routing test results from network emulators have showed improvements in throughput from re-routing following fault injection. Improvements were also seen in robustness to network changes and latency of fault response compared to traditional networking solutions, and the nodes successfully used local autonomy to recover from dynamic reconfiguration faults. Future development will include implementing these protocols and ML technology in a fully representative space hardware network, with distant and autonomous modular satellite nodes.