Research Proposal submitted as part of Research Methods Module for MAI (Masters in Engineering) at Trinity College Dublin

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Emulating Distributed Applications Utilizing Modern CubeSat Technologies and Flight Data

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Objectives

1. Analyse modern CubeSat technology and flight data in order to discern probable network performance characteristics
2. Create an emulation of a network of CubeSats which reflects expected network performance characteristics
3. Examine the performance characteristics of basic command and control network traffic on the emulated network
4. Determine the feasibility of previously researched and proposed distributed network applications on the emulated network

Background

Missions utilizing multiple networked CubeSats are becoming more popular as the already popular and disruptive CubeSat platform becomes more mature and open [1]. Numerous such missions are scheduled for the coming years and two major technology demonstration missions have achieved success in NASA's Nodes [2] and the CNSA's Tianwang-1 [3]. CubeSat constellations and swarms have been discussed and researched, in one form or another, for over a decade [4]. In particular, the proposed research focuses on distributed network applications such as the CubeSat Distributed File System (CDFS) [5]. The first notable flight test of inter-communicating CubeSat technology was during the Nodes mission which was deployed from the International Space Station on the 12th of May 2015. Research into applications such as CDFS that rely on CubeSat inter-satellite links (ISLs) [6] have had to introduce numerous, yet often well informed, assumptions in order to create simulations of CubeSat networking capabilities. Thanks to Nodes, Tianwang-1 and the active development of upcoming missions such as QB50 [7], NASA's CPOD [8], ESA's GomX-4 [9] and AIM-COPINS [10] the availability of high fidelity CubeSat capability data has increased dramatically. This new data creates opportunities for research which examines the capability of modern CubeSat network. This research may then in term inform the development of new technologies, planning of future missions and perhaps most importantly the design of CubeSat scientific payloads.

Methodology

The proposed methodology closely follow the proposed research objectives. Data will be collected to create a model of CubeSat network properties from which a network emulation may be constructed. This emulation can then in turn be used to test the performance of certain applications of interest.

Ephemeris data has already been collected related to the Nodes and Tianwang-1 missions. This data can be used to create a model of how a constellation of CubeSats may move relative to one another. Tianwang-1C (TW1C) is a three unit CubeSat that flew with advanced Microelectromechanical systems (MEMS) for propulsion and ultimately formation flying [11]. This allowed TW1C to stay in range of TW1B for much longer that their unassisted linear formation orbital pattern would have otherwise allowed. In this sense the TW mission gives a clear impression of how CubeSat's may stay within communication range using modern systems. In direct contrast, the Nodes mission and TW1A give an impression as to how long unassisted CubeSat's may stay within range. This is an example of how a model may be built up. This data may then be supplemented with data regarding the radios commonly used to implement ISLs, CubeSat attitude control [12], the commonly used AX.25 protocol [13], available power and so on.

With one or more models of CubeSat network properties have been established an emulation can then be created. The most likely approach is to use create multiple Python agents within a Linux environment and then control their communications using a tool such as Linux traffic control (TC) [14]. TC allows control over the socket layer performance characteristics of each agent. Combining TC with other approaches such as basic packet loss and medium induced error modelling and the fidelity of the emulation can be incrementally increased. This is the approximately the approach taken by Challa et al at the University of Florida in their work relating to the simulation of CubeSat distributed applicaitons1 [15]. Their approach provides a guideline for creating an emulation.

Expected Results

The research is expected to challenge the assumptions made by others as the network properties of CubeSat constellations. Emulations results may be used to inform future work in optimizing applications for such CubeSat network. It is expected that the emulation will show that modern CubeSat constellations would simply be unable to sustain certain applications while other applications may be found to be perfectly

suited. One might expect that "CubeSat Torrent" [16] to be used to drastically improve downlink throughput thus increasing the maximum mission scientific data volume, however the chunking and meta-data overheads may be found to overload the capabilities of the CubeSat constellation.

References

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