Network Configuration Analysis For Formation Flying Satellites[1]

Eric J. Knoblock
Department of Electrical and Computer Engineering
Cleveland State University
Cleveland, Ohio 44115
kno3179@csvax.egr.csuohio.edu

Vijay K. Konangi
Department of Electrical and Computer Engineering
Cleveland State University
Cleveland, Ohio 44115
konangi@csvax.egr.csuohio.edu

Thomas M. Wallett
Satellite Networks and Architectures Branch
NASA Glenn Research Center
Cleveland, Ohio 44135
wallett@grc.nasa.gov

Kul B. Bhasin
Space Communications Office
NASA Glenn Research Center
Cleveland, Ohio 44135
kbhasin@grc.nasa.gov

Abstract—The performance of two networks to support autonomous multi-spacecraft formation flying systems is presented. Both systems are comprised of a ten-satellite formation, with one of the satellites designated as the central or "mother ship." All data is routed through the mother ship to the terrestrial network. The first system uses a TCP/IP over ATM protocol architecture within the formation, and the second system uses the IEEE 802.11 protocol architecture within the formation. The simulations consist of file transfers using either the File Transfer Protocol (FTP) or the Simple Automatic File Exchange (SAFE) Protocol. The results compare the IP queuing delay, IP queue size and IP processing delay at the mother ship as well as end-to-end delay for both systems. In all cases, using IEEE 802.11 within the formation yields less delay. Also, the throughput exhibited by SAFE is better than FTP.

TABLE OF CONTENTS

1. INTRODUCTION

Multi-spacecraft formation flying systems enable an improvement in mission performance while reducing operating costs [1]. These systems are comprised of multi-satellite fleets and their associated ground stations, which together achieve the following objectives. First, satellites in the same formation can provide redundancy in the event of a node failure. Second, multiple satellites in a formation can be used to increase the overall system capacity and throughput, and finally, multiple satellites in a formation enable larger spatial coverage as well as prolonged temporal availability. It is anticipated that the use of autonomous multi-satellite formation flying systems will be cost-effective to implement and more reliable than single-satellite counterparts [2][3].

Several papers have been published in the literature concerning the precise control of the spacecraft within a multi-satellite formation. The literature indicates that the distances between the satellites in a formation should be controlled to within a centimeter in the near-term, i.e., the next five years, and to within a fraction of a centimeter for missions in the next ten years. The Autonomous Formation Flyer (AFF) Sensor, for example, borrows technology from the Global Positioning System (GPS) to maintain the precise control of the spacecraft within the Deep Space 3 (DS3) mission [4]. Similarly, a Collective Intelligence (COIN) has been devised to control the constellations of communications satellites [5]. From reviewing the literature, it is clear that the precise control of the spacecraft within a formation flying system is very important for several planned missions, and the degree of precision is a function of the intended mission.

This paper presents the simulated performance analysis of two networks to support the communication needs for autonomous distributed multi-spacecraft formation flying systems. An important objective of this research is to investigate the concept of "Internet node in the sky" as it applies to formation flying satellite systems. Therefore, from a networking perspective, the formation flying system has to be interoperable with the terrestrial Internet. The basic simulated protocol architecture is TCP/IP over ATM. The first system uses a TCP/IP over ATM protocol architecture within the formation, and the second system uses the IEEE 802.11 protocol for communication within

[1] 0-7803-6599-2/01/$10.00 © 2001 IEEE