Inter-Satellite Communications for Small Satellite Systems

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ABSTRACT

Small satellite technology has opened a new era in aerospace engineering by decreasing space mission costs, without greatly reducing the performance. The concept of formation flying using small satellites is becoming popular because of their potential to perform coordinated measurements of remote sensing space missions. The current state of art in satellite communications is a one hop link between satellite and ground station. Very little work has been done on inter-satellite communications. This paper aims to design and evaluate feasible MAC and routing layer protocols for distributed small satellite networks. The possibility to implement proposed MAC and routing protocols for two different formation flying patterns are investigated. To validate the authors' proposed system model, they use extensive simulations to evaluate the performance of the system using throughput, access delay and end-to-end delay.

Keywords: Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), Clear-To-Send (CTS) Protocol, Inter-Satellite Communications, Medium Access Control (MAC), Request-To-Send (RTS), Routing Layer Protocols, Small Satellites

INTRODUCTION

Small satellites are artificial satellites with lower weights and smaller sizes. Usually a large satellite has a mass greater than 1000 kg. European Space Agency (ESA) defines small satellites as satellites having a mass of 350-700 kg. At University of Surrey, satellites having a mass of 500-1000 kg are considered as “small”. In the study conducted by Academy of Astronautics, broadly classified small satellites in to different classes based on their mass as shown in Table 1.

Miniaturization of satellites helps to overcome the traditional barriers to space exploration and development. One of the major reasons for miniaturizing satellite is the reduction in cost. It has less mass and thus smaller and lighter launch vehicles can be used. It can be piggy backed on larger vehicles and takes shorter time from development to launch. The small satellites can be launched in various formation flying patterns to collect data from multiple points. It offers attractive features with respect to the design aspect and rapid technology infusion. Because of the agility of sensor mechanisms,
new approaches to observations and calibration are possible using small satellites (Committee on Earth Studies, 2000). With the advances in technology, new missions can be developed and launched that may require a shorter development time. Proba-3 is the ESA’s (presentation by Tallineau. J) first step towards deploying satellites in close formation flying. Proba-3 is currently scheduled to be launched in 2017. Its main mission is to validate the technologies that are required for formation flying of two or more space vehicles. One of the challenges of small satellites are low power compared to large satellites and thus shorter life time because it cannot carry large batteries and the size of the solar panel cannot support high power transmission and reception. The design of various subsystems in small satellite should be done in such a way that each of the subsystem consumes less power and thus ensuring longer life time.

Small and relatively inexpensive satellites have become exclusive domain for scientific and amateur groups. Major advances in microelectronics have made small satellites an effective alternative to large and expensive satellites. There are many organizations and universities (EPFL, STUDSAT) that support small satellite research. Their main research focuses on the design aspect of small satellites. To the best of our knowledge, there are no studies devoted to inter-satellite communications for various formation flying patterns. The authors, Bedon, Negron, Llantoy, Nieto, and Asma (2010) propose the possibility to implement TCP/UDP protocols over satellite links. They have tried to focus on generating and simulating two scenarios of the constellation of satellites based on the QB50 proposed project. The proposed protocol corresponds to the transport layer which is used in Ethernet applications and they have not discussed the protocol they have used for medium access. Hence this remains an open issue. In this paper, we propose and evaluate the Medium Access Control (MAC) layer and routing layer protocols for inter-satellite communications in small satellite systems.

The rest of the paper is organized as follows. Introduction to the various formation flying patterns of small satellite systems are presented in the following section. Afterwards, we briefly describe the system model for the two different formation flying patterns. Then a MAC and routing protocols particularly the CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) with RTS/CTS (Request-to-Send and Clear-to-Send) protocol are described. Followed by the simulation results and discussions for various formation flying patterns. Finally we conclude the paper in the last section.

### FORMATION FLYING PATTERNS

The concept of formation flying pattern is to deploy cost effective cluster of satellites, orbiting in a very precise relative positions. There are a wide range of definitions for formation flying. Formation flying is a subset of a more general category that is classified as Distributed Space Systems (DSS). A brief survey of small satellite systems are discussed by Burlacu and Lorenz (2010). Usually, there are three different formation flying patterns or configurations, namely, Leader-Follower, Cluster, and Constellation.

<table>
<thead>
<tr>
<th>Type of Satellite</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini</td>
<td>&lt;1000 Kg</td>
</tr>
<tr>
<td>Micro</td>
<td>&lt;100 Kg</td>
</tr>
<tr>
<td>Macro</td>
<td>&lt;10 Kg</td>
</tr>
<tr>
<td>Pico</td>
<td>&lt;1 Kg</td>
</tr>
</tbody>
</table>

Table 1. Types of satellites
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