SIGMA for Space Sensor Web Networks

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Abstract— **A constellation of spacecrafts, carrying sensing equipment for collection of scientific data, can be connected using communication links to form a space sensor web. Data collected by the sensors are downloaded to Earth through ground stations through the sensor web. The relative motion of the spacecrafts require a mobility management scheme to maintain continuous connectivity between the sensors and computers on Earth. This paper outlines the use of Seamless IP-diversity based Generalized Mobility Architecture (SIGMA) for managing managing handovers in space sensor networks.**

I. Introduction

Spacecrafts with sensing elements, such microwave imager, visible and infrared radiometer, Earth radiation budget sensor, lightning imaging sensor, etc. are used for observing the Earth, surveillance, and monitoring. Data are periodically downloaded from the spacecrafts using dedicated links with ground stations. The spacecrafts work autonomously, downloading data to Earth whenever they come in contact with a ground station. Buffering of data in a spacecraft until it comes in contact with a ground station results in delay of transmission of real time data to Earth.

Connecting the spacecrafts (having on-board sensors) using inter-spacecraft communication links, and thus forming a space sensor web, can reduce the data transmission delay to Earth. Future space networks will consist of sensor constellations of numerous semi-autonomous spacecrafts (for example, JPL Sensor Web project [1] and EO-1 satellites [2], [3]), each generating and relaying enormous amount of data to scientists on the Earth [4], [5]. Other scenarios include space sensor webs relaying information from human missions to Moon and Mars through the Interplanetary Internet.

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When a spacecraft is in contact with a ground station, other spacecrafts that are not in contact with the ground station can transmit their data to the one which is in contact and thus get the data to the Earth faster than waiting for a direct connection to a ground station. Communication among the sensors which are spread over multiple spacecrafts can also enable coordination among sensors to improve data collection by exploiting shared knowledge among the sensors. The continuous movement of the spacecrafts relative to each other requires mobility management for managing the handoff of connections between the sensors and the scientists on Earth. The objective of this project is to demonstrate the use of Seamless IP Diversity based Generalized Mobility Architecture (SIGMA), a mobility management scheme for terrestrial and space networks, for managing handoffs in space sensor webs.

II. Mobility Management in Space Sensor Web

Use of Internet protocols, for transmitting large volume of data to Earth, is attractive because it allows easy interconnection with the terrestrial Internet, reduces the development/design time of spacecraft communication systems, increase networking capabilities and help secure remote access to cost effective unmanned ground stations, and improve spacecraft's ability to interoperate with ground stations by making on-board equipment active nodes on the Internet [6]. As a result, there is significant interest in deploying the Internet protocol in space, which will mirror the terrestrial Internet in its capabilities and flexibility [7].

NASA has been investigating the use of Internet protocols for space communications [6], [8] and handover management [4], [9]–[11] for quite some time. A number of projects studied the possible use of Internet technologies and protocols to support all aspects of data communication with spacecrafts [12]–[16].

A moving spacecraft (such as LEO satellites) carrying scientific sensing instruments, stays in contact with a ground station for only a short period (8-15 minutes) of time [12]. Similar situation arises when a sensor network on the surface of the Moon or Mars will handoff between the three antennas of the Deep Space Network. A constellation of spacecrafts (such as Sensor Webs) form an ad hoc network where the spacecrafts can communicate among themselves, and also switch data between other spacecrafts and ground stations [16]. A *handover management* protocol is required to maintain continuous connectivity between nodes on Earth and moving spacecrafts or sensor networks as they orbit in space.

NASA has been experimenting with Mobile IP for managing handovers in space [6], [9], [15]. Base Mobile IP suffers from a number of *performance problems*, the most important ones being high handover latency, high packet loss rate, and low throughput. To develop an alternative to Mobile IP, researchers at the University of Oklahoma and NASA Glenn Research Center have developed a transport layer based end to end handover management scheme, called Seamless IP-diversity based Generalized Mobility Architecture (SIGMA) [17]. SIGMA can be used for both space and terrestrial networks [18], [19], thereby allowing easy integration between the two types of networks. SIGMA is an end to end handover management scheme and hence does not require any change in the Internet infrastructure.

The main idea of SIGMA is to decouple location management from data transfer, and achieve seamless handover by exploiting IP diversity to keep the old path alive during the process of setting up the new path during handover (Fig. 1). SIGMA is based on an end to end transport layer handoff [20], which allows developing a handoff solution without requiring any change in the Internet infrastructure. Stream Control Transmission Protocol (SCTP) [21], a new industry-standard transport protocol from the Internet Engineering Task Force (IETF), supports IP diversity and has been found to work well in a space environment [22]; SCTP has therefore been used in prototyping SIGMA for simulation and experimental evaluation.

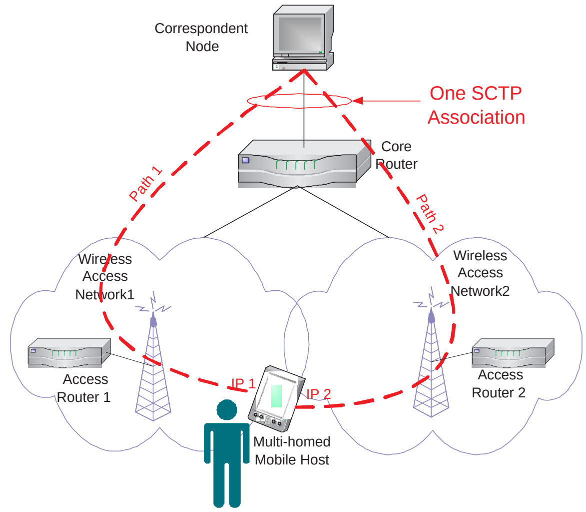

Fig. 1. Architecture of SIGMA.

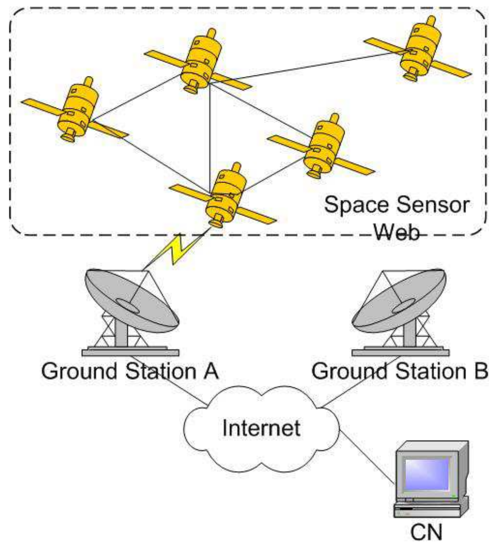

Fig. 2. Spacecrafts forming a space sensor web.

A typical SIGMA handover in terrestrial networks is shown in Fig. 1, where Mobile Host (MH) is a multi-homed mobile node connected to two wireless access networks, and Correspondent node (CN) is a node sending traffic to MH, representing services like file download or web browsing by mobile users. In the case of space networks (Fig. 2), CN represents a scientist on Earth, a spacecraft is analogous to MH, and ground stations through which spacecrafts communicate with the terrestrial network are similar to Access Routers. The topology represents data being downloaded to a computer Earth from a spacecraft which is moving in orbit and is being handed over between ground stations.

III. Conclusions

Spacecrafts containing on board sensing equipment can be connected using inter-spacecraft links to form a space sensor web network. The paper outlined the use of SIGMA, a mobility management scheme for space networks, for handoff management of space sensor web networks.

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