Paper ID: 6746
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SPACE SYSTEMS SYMPOSIUM (D1)
Space Systems Architectures (4)

Author: Ms. Rui Sun
Delft University of Technology (TU Delft), The Netherlands

Dr. Jian Guo
Delft University of Technology (TU Delft), The Netherlands
Prof. Eberhard Gill
Delft University of Technology, The Netherlands

OPPORTUNITIES AND CHALLENGES OF WIRELESS SENSOR NETWORKS IN SPACE

Abstract

A prosperous development of terrestrial wireless sensor networks (WSNs) gives huge impetus to their applications in space. WSNs have been envisioned by many space engineers and researchers as a powerful future technology, as it offers a new paradigm for acquiring data. This paper focuses on space-based WSNs. To this end, we analyze its similarities and differences with terrestrial WSNs, summarize its general properties and relevant technologies, and provide some scenarios for how space-based WSNs might be used in space.

Space-based WSNs share many of the characteristics of terrestrial WSNs. This paper identifies similarities such as source constraints, considerations on network deployment, configuration and organization, as well as the modular property of the node. On the other hand, space-based WSNs also pose new challenges. The communication between two nodes will rely on inter-satellite link or intra-satellite link, whose establishment and stability are impacted by the satellite orbit and attitude, antenna configuration, high mobility, link range, or the layout in satellite. These special space environments will also influence the choice of network protocols. Therefore, a survey is made about the technologies and resources potentially applicable to space-based WSNs, e.g. Ad Hoc routing, internet protocols, IEEE series wireless protocols. It will be addressed how these technologies support space-based WSNs and their consequent challenges.

Several scenarios of space-based WSNs are presented in this paper, including (1) Very-small-satellite cluster/swarm; (2) Distributed spacecraft for earth multipoint sensing and monitoring; (3) Intra-satellite wireless sensors and actuators network; (4) Fractionated spacecraft; (5) Surface vehicles on or around the Moon, Mars and other planets or asteroids. Each point aforementioned is distinctly different from each other. Different scenarios are likely to impose different requirements and demand different networking technologies. To facilitate the analysis, this paper distinguishes these scenarios in terms of the number of nodes, link range, and node mobility, and divides them into coarse-grained subclasses. The detailed characteristics of each subclass are analyzed with the attempt to give suggestions for further design and implementation of technical solutions.

Finally, this paper introduces examples of relevant research and development activities at TU Delft. Autonomous wireless sun sensors on Delfi-C3 proved that it was feasible to incorporate wireless links in a small spacecraft, and inspired continuation of such wireless links for further smart sensor network establishment. A proposed satellite swarm mission OLFAR, consisting of tens or even one hundred of CubeSats, considers sensor networks as one of the largest opportunities and challenges.