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Low Earth Orbit Satellite Communications for Internet-of-Things Applications

EDITORIAL

Ali Jamoos

Electronic and Communication Engineering Department, Faculty of Engineering, Al-Quds University, Jerusalem, Palestine

A B S T R A C T

Internet of Things (IoT) is a new direction for future internet, where anything embedded with sensors, software, and transceiver can access the Internet. The applications of IoT technology include home automation, smart city, smart grid, smart industry, E-health, environmental monitoring, and geologic disaster forecasting, to name a few. As the demand for high data rate increases due to the huge number of IoT devices, the so-called Low Power Wide Area Networks (LPWAN) have emerged. These LPWAN are designed to cover wide terrestrial areas. Nevertheless, in open areas such deserts, forests and coastal waters of seas, rivers and oceans, there are cost and practical limitation in constructing LPWAN. Therefore, to enable LPWAN in such remote areas, Low Earth Orbit (LEO) satellite communications for IoT have recently attracted considerable interest from researchers. Among the open research issues are interference mitigation, Doppler spread estimation, LEO satellite constellation structure, efficient spectrum allocation, and access and routing protocols. In particular, as the satellite IoT system shares the same frequency band with the existing terrestrial IoT networks and other wireless systems, this results in multiple access interference issue. In addition, the high speed motion of LEO satellites induce a Doppler shift, resulting in inter-carrier interference problem.

Keywords: Satellite, comunication, internet-of-things, low earth orbit

Introduction

Internet of Things (IoT) is a new direction for future internet, where anything embedded with sensors, software, and transceiver can access the Internet (Atzori et al., 2010). The applications of IoT technology include home automation, smart city, smart grid, smart industry, E-health, environmental monitoring, geologic disaster forecasting, to name a few (Asghari et al., 2019). As the demand for high data rate increases due to the huge number of IoT devices, the so-called Low Power Wide Area Networks (LPWAN) have emerged (Mekki et al., 2019). These LPWAN are characterized by low power consumption, wide coverage area, high number of low complexity devices. The main worldwide standardization bodies of LPWAN are the third Generation Partner-ship Project (3GPP) and the Institute of Electrical and Electronic Engineers (IEEE). Therefore, some of these LPWAN are part of 5G mobile cellular networks and include Machine Type Communication (MTC), and Narrowband IoT (NB-IoT) (Rastogi et al., 2020). While the other LPWAN are non-cellular and include Sigfox, Long Range (LoRa) networks, etc. These LPWAN are designed to cover wide terrestrial areas. Nevertheless, in open areas such deserts, forests and coastal waters of seas, rivers and oceans, there are cost and practical limitation in constructing LPWAN. Therefore, to enable LPWAN in such remote areas, satellite communication for IoT has emerged (Chu and Chen., 2021; Kodheli et al., 2021). Indeed, satellite IoT system has covering advantages over terrestrial IoT in the case of extreme topographies such as cliff, valley, and steep slope, where geologic disasters are more easily to happen. In addition, satellite IoT provides a cost-efficient solution with respect to other terrestrial networks in such remote areas. Furthermore, as an extension to the terrestrial IoT network, satellite IoT system is the only approach to achieve global IoT service covering. A Low Earth Orbit (LEO) satellite system consists of a constellation of many satellites in circular orbits at altitudes ranging from 500 km to 2000 km (Kodheli et al., 2021). The satellites can

* Correspondence:
Electronic and Communication Engineering Department, Faculty of Engineering, Al-Quds University, Jerusalem, Palestine. Email: ali.jamoos@staff.alquds.edu

either have inclined, or polar orbits, or a combination of the two. The coverage area and duration depend essentially on the number of satellites in the constellation, their altitudes and their orbit inclinations. Nevertheless, many other parameters must be considered to implement a viable system. Such satellite constellations can achieve either global or regional coverage, either real time or delayed communications.

Flexibility, robustness to failure, true global coverage and capability to reuse frequency more effectively than the Geostationary Earth Orbit (GEO) satellite are key advantages of LEO systems. In addition, due to the lower orbit altitude of LEO satellite constellation, it has lower propagation delay as measured by a round trip time (RTT). Furthermore, the propagation path loss will be smaller, results in lower energy consumption from the energy-constrained remote terminals. The main characteristic of LEO systems lies in the use of a large number of small satellites easily designed and launched. The renewed interest in multi-satellite communication systems is not prompted by a motive of competition with conventional GEO and the highly elliptical orbit system HEO systems, but more by the arising demand for satellite IoT coupled with the advance in LEO satellite technology and low-cost launchers. LEO satellites can provide local, regional or global communications. LEO satellite system can be well adapted to providing real-time local and regional communications but only delayed global communications. Several authors have recently investigated LEO satellite communications for IoT applications. Indeed, in Qu et al., 2017, the authors provide an overview of the architecture of the LEO satellite constellation-based IoT including the following topics: LEO satellite constellation structure, terrestrial-satellite IoT interference analysis, efficient spectrum allocation, heterogeneous networks compatibility, and access and routing protocols. In Cluzel et al., 2018, coverage extension of a LPWAN using a LEO satellite constellation is discussed. The authors in Chu et al., 2021 adopted non-orthogonal multiple access (NOMA) scheme to support massive IoT distributed over a very wide range, where two beamforming algorithms are proposed for minimizing the total power consumption. In Lin et al., 2021, the authors provide a survey on the state of the art in LEO satellite access, including the evolution of LEO satellite constellations and capabilities. The authors in Wei et al., 2021, present a comprehensive survey on hybrid satellite-terrestrial maritime communication networks with focus on enhancing transmission efficiency and extending network coverage. In Kodheli et al., 2022, the authors considered the use of LEO satellites to provide the NB-IoT connectivity to terrestrial user equipment's. They proposed a resource allocation strategy for the uplink data transmission which mitigates differential Doppler shift encountered in a LEO satellite. In Fraire et al., 2022, key open research challenges are pointed-out to achieve a successful space-terrestrial IoT integration.

Among the open research issues in LEO satellite communications for IoT applications are interference mitigation, Doppler spread estimation, LEO satellite constellation structure, efficient spectrum allocation, and access and routing protocols. In particular, as the satellite IoT system shares the same frequency band with the existing terrestrial IoT networks and other wireless systems, this results in multiple access interference issue. In addition, the high speed motion of LEO satellites induce a Doppler shift, resulting in inter-carrier interference problem.

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