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Author: Mr. Emil Ares
Cranfield University, United Kingdom

Mr. Daniel Codina
Cranfield University, UK, United Kingdom
Ms. Emma Faillat
Cranfield University, United Kingdom
Mr. Dorian Guijarro
Cranfield University, Cranfield UK, United Kingdom
Dr. Nicola Garzaniti
Cranfield University, United Kingdom

A LOW-EARTH ORBIT NARROWBAND COMMUNICATIONS AND NAVIGATION CONSTELLATION STUDY

Abstract

This paper presents a system-level study of a Low Earth Orbit (LEO) satellite constellation designed to provide Narrowband-IoT (NB-IoT) connectivity and complementary navigation Positioning, Navigation, and Timing (PNT) services.

NB-IoT technology is drawing significant interest in satellite communications as it has the potential to support reliable, wide-area, and low-power connectivity for applications like telemetry, command and control, and safety messaging. This makes NB-IoT particularly useful for use cases such as traditional aviation and the growing Unmanned Aerial Vehicle (UAV) sector. This paper takes these use cases to formulate requirements that drive the mission design.

A trade space exploration approach is adopted to navigate the engineering trade-offs derived from stakeholder needs and user requirements. The key figures of merit (FoMs) include constellation geometry and coverage, communication performance, navigational accuracy, risk and trade-off metrics, and compliance with relevant standards (3GPP, ITU regulation, and ECSS guidelines).

The resultant system architecture features a total of 1144 satellites spread across 26 planes at an operational altitude of 600 km, arranged in two shells to ensure pole coverage. Each satellite carries an NB-IoT payload acting as a 3GPP-compliant base station, and an inter-satellite link is included to complete the space segment. Software-Defined Radio (SDR) technology is leveraged for operational flexibility, addressing spectrum allocation, RF interference, and Doppler shift challenges. The design also makes use of the communication signal for PNT purposes. The analysis confirms the robustness of this approach, and business projections indicate a suitable return on investment by servicing tens of millions of devices globally.

The proposed constellation is a technology enabler that integrates space and terrestrial networks to provide ubiquitous narrowband connectivity and navigational services. Systems engineering rigour ensures the proposed design meets technical objectives and is resilient to risks in orbit and the marketplace. This work highlights that by leveraging relevant standards and careful economic planning, LEO NB-IoT constellations can be both technologically feasible and commercially viable.