Functional Simulation of the Uses of the Onboard Inter-Satellite Network in a Swarm

Developing new network services for swarms | Developing a bench for validating them

Authors

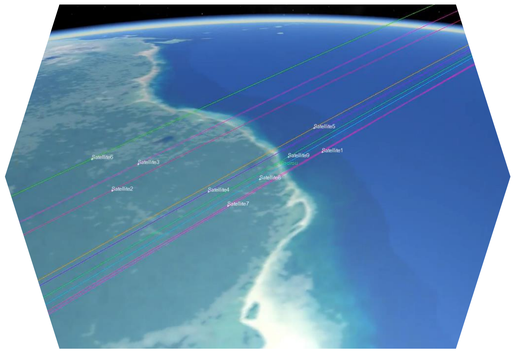
Contact : name.surname@cnes.fr

Pierre Boan, Cécile Dechoz, Julien Galizzi, Patrick Gélard, Yoan Grégoire, Hervé Guillon, Pierre-Baptiste Lambert, Bernard Pontet, Patrice Raveneau, Marie Sauvaud, Irene Valenzuela-Molina, Gavin Walmsley

Context

- Swarms of nanosatellites are useful for future missions, including science missions.
- Data exchanges between the SC of the swarm are needed, thus the use of a radio-frequency Inter Satellite Link (ISL).

→ Our aim is to build an inter-satellite network above these ISL and develop services over this network. This poster aims to present the simulator we are developing for testing these services.



Abstract

There are several network simulators (some on the shelves) that are very useful and helpful for network engineering. Nevertheless, none is efficient enough for simulating an onboard network spread among spacecrafts that are moving in space according to Kepler laws.
Therefore, we tried to fill this gap by building our own tool based on the CNES expertise in space simulator benches.
Our bench simulates the environment and the dynamics of each spacecraft, provides a model of the physical layer of the network layer (i.e. Radio Frequency transmission between moving vehicles) and offers an interface to run actual Flight Software. Embedding flight software allows us to perform functional demonstration of the network use at system level.
As a first step, in order to characterize the network, we have implemented a routing policy based on the "flooding" principle.

Many professions involved

Simulator development, on-board software, avionics, network, flight dynamics, spacecraft control and monitoring, spacecraft operations, radio-frequency transmission, time and frequency measurement and algorithms, etc.

Credit : LOFAR / ASTRON - License : CC BY 3.0

Preliminary study & first use-case : NOIRE

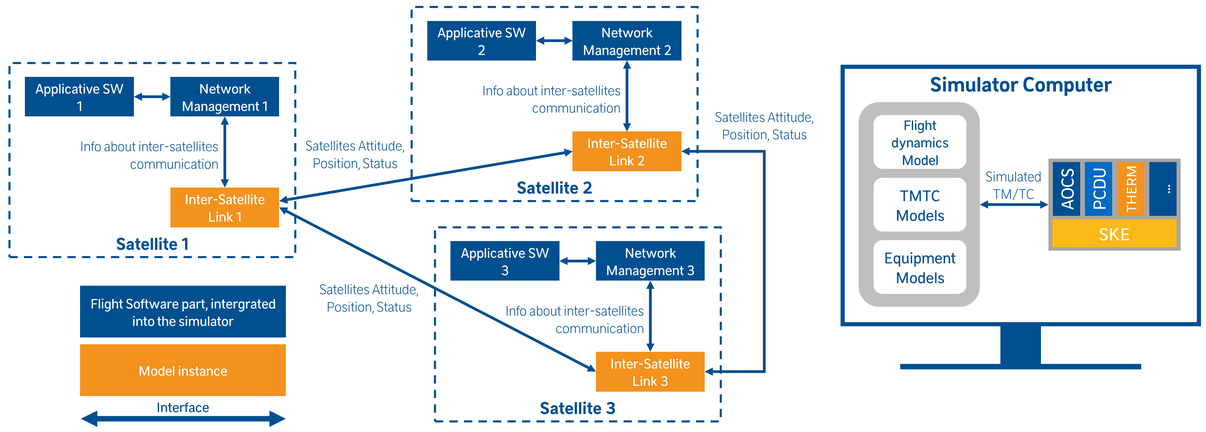
A swarm of 50 nanosatellites spread in cube of 200km

Mission :
Perform interferometric measurements allowing to spatially resolve space objects and access a 2D vision of the radio sky from 1 to 30 MHz, frequency ranges that are today unexplored from earth because of the ionosphere disrupting the measurements.

Concept :
Imitate terrestrial radio telescopes like LOFAR, based on spread antenna networks forming a global radio interferometer.

Stakes :
- Access a new part of the electromagnetic specter
- Develop the concept of nanosatellites swarms

Simulator Bench Architecture



Test Results

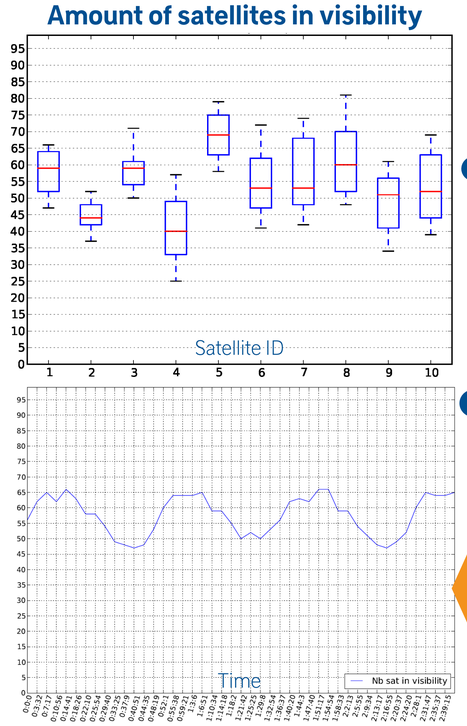
Simulation config

50 satellites
2 days

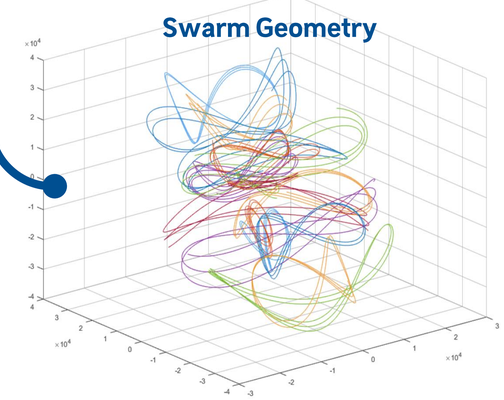
Simulation Results

- Swarm geometry
- Evolution of distances during simulation
- Inter-satellite visibility
- Message routing

Amount of satellites in visibility



Swarm Geometry



Synthesis

- Each message can reach almost all the spacecrafts in a few steps
- Sending a message with flooding generates a huge number of messages, wasting too much throughput → flooding cannot be used as an operational routing method for our swarm.

Chronology

Jan 2022
Kick-Off +Bench Architecture Definition

Sep 2022
1st bench release with flooding version

Dec 2022
1st results from flooding simulation

May 2023
1st Bench release Integrating FSW

Sep 2023
Ranging release for next simulations

Jan 2024
Development & Validation of flight dynamics algorithms

June 2024
Development & Validation of new concepts

Following & Perspectives

- **Short term**:
  - Replacing the "flooding" by an efficient routing function
  - Testing a "ranging" function based on RF pseudo-distances measurements
  - Integrating flight dynamic algorithms sharing positions between spacecrafts
  - Hybrid simulation (SW+HW integrated at simulator level)
- **Long term**: development and testing of new concepts
  - "Smart TM" and data reduction, Smart routing (based on orbit position forecast)
  - Monitoring functions and FDIR (Failure Detection Isolation and Recovery)
  - Autonomous orbit control and collision avoidance
  - Cloud computing & FOTA (Firmware Over The Air)