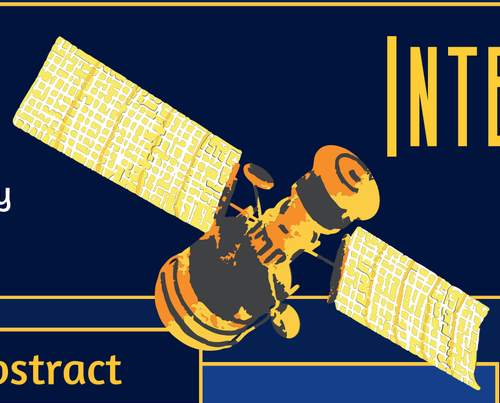
Agathe BOUIS
agathe.bouis@strath.ac.uk
PhD Student
Applied Satellite Technology Laboratory (ApSTL)



INTEGRATED SPACE COMMUNITIES
DO NOT REQUIRE TRUST

University of Strathclyde Glasgow

Abstract

As space becomes increasingly contested, the terrestrial vulnerabilities of GPS will extend into orbit. The resulting inability to rely on GPS for time synchronisation on ground and in space will cause a fundamental shift in the approach to space networks. This project aims to design an autonomous, distributed, robust timing signal in space as an alternative method to GPS time synchronisation. Building upon prior work in consensus algorithms, this project has developed a Disruption-Tolerant Social-Dynamics inspired approach to consensus. This work is being adapted for time synchronisation and space networks which involve dynamic effects, time delays, and relativity effects.

Motivation

GPS signals are used for Earth- and Space-based positioning, and time synchronisation. Many applications rely on these signals to function and coordinate their actions. To be of use, these GPS signals must be time synchronised, with all GPS atomic clocks showing the same time.

However, this reliance faces two issues:

- GPS's centralised approach ("server-client") makes it vulnerable to single point failures (incorrect or spoofed signals), causing all downstream applications to suffer.
- GPS atomic clocks still suffer from drift and error. As such, GPS clocks must still be corrected from ground.

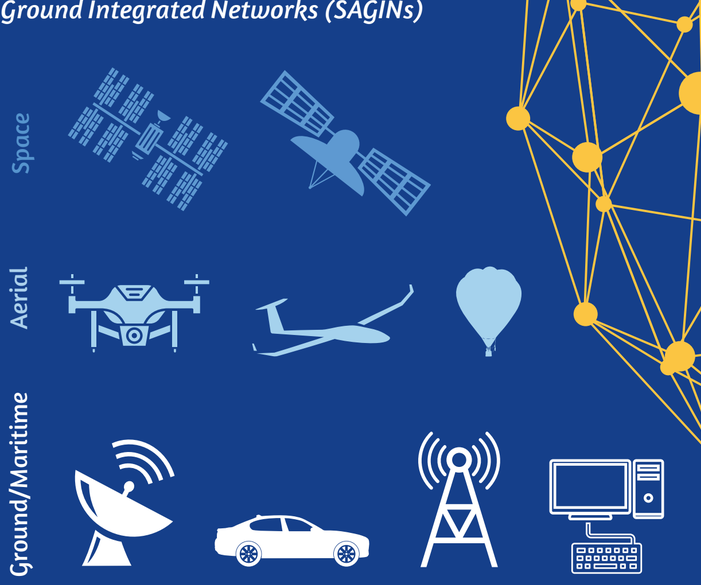
GPS are vulnerable and expensive: an alternative must be proposed.

Space IoTs

This Project will slot itself in the current framework of satellite network communications and offer an alternative to GPS time synchronisation and position.

This will enable a higher level of integration of satellite and constellations, resulting in an augmented architecture allowing for:

- Improved service coverage, reliability, performance, and efficiency.
- A more cohesive use of space resources benefiting ground applications, but also earth- and space-based sustainability efforts.
- An incentive for cooperation and collaboration within the network.
- A unified and harmonised perspective of space networks, promoting regulations and standardisations.



Newer generations of connectivity (5/6G) see increasing levels of integration, with mobile networking technologies realising Space, Air, Ground Integrated Networks (SAGINs)

A Social Dynamics Approach to Consensus

Love, Hate, and Propaganda, or how opinion dynamics can engineer consensus for synchronisation

Opinion dynamics models aim to characterise the outcomes of collective behaviours within social networks as a result of opinion sharing. Notably, models are interested in representing how minority opinions can dominate social groups, and cause polarisation and fragmentation.

The most common Social Dynamics model is the Deffuant Model which defines Agents with a tolerance - a parameter representing agents' willingness to consider other's opinions. Mathematically, tolerance is the maximum allowable difference between two agents' opinions for an agent to account for that of its neighbour when "updating" its own internal state.

(Left) Disagreement - No Opinion Change

(Right) Agreement - New Opinions will Converge

Typically, extremist agents have a low tolerance compared to their more moderate peers, thus swaying them to more extreme opinions (see above).

Based on the similarities in mechanics between Social Dynamics and Consensus Protocols, a **SOCIAL DYNAMICS-INSPIRED PROTOCOL** has been designed, tested, and concluded to be **DISRUPTION-TOLERANT.**

Social Dynamics

Extremists Agents have Low Tolerance

Extremists Agents cause Fragmentation

=

Consensus Protocols

Disruptive Nodes cannot be ignored

Disruptive Nodes cause Fragmentation

→

Social Dynamics Protocols

Exploits and Inverts Tolerance Mechanism

Nodes' Tolerance is now INVERSLY linked to their extremism

ACKNOWLEDGEMENTS:

This project is funded by the Air Force Office of Scientific Research (AFOSR), Contract Award Number: FA8655-22-1-7033

For more information, contact Agathe BOUIS at agathe.bouis@strath.ac.uk

I would like to extend my appreciation and thanks to the entire ApSTL team at Strathclyde, including Joshua Gribben, Dr Astrid Werkmeister, Dr Ruaridh Clark, Dr Chris Lowe, and Professor Malcolm Macdonald.