PhD Position: Machine learning for robust satellite AIS receivers in dense maritime traffic areas

Expected start: Autumn 2022

Partners: Kinéis, CNES, TéSA

Funding: Kinéis (50%) – ARED Bretagne (50%)

Student profile: Engineering school degree / Master 2 degree in signal processing

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Context

AIS (Automatic Identification System) is a vessel tracking system, which provides real-time ship identification as well as other accurate navigation information. Primarily and initially dedicated to reduce collision risks, it gives today access to a quasi-instantaneous picture of the maritime traffic and it enables accurate tracking of ships.
The introduction of low-earth orbit (LEO) satellite constellations offers global coverage. The addition of two new frequencies (dedicated to long-range transmissions) should improve ocean observation and reinforce maritime security, while opening the way to other opportunities such as commercial ones. Thus, the satellite operator Kinéis intends to launch a nanosatellite constellation dedicated to IoT communications, including AIS, to develop new services (https://www.kineis.com/en/).
However, reception of AIS signals by LEO satellites is complex. The interference level is amplified due to a more severe propagation channel (low signal to noise ratio, significant Doppler effect), a widened coverage area (involving several AIS cells) and a denser maritime traffic. On the other hand, on-board processing capabilities are limited by the use of small-size satellites (nanosat and cubesat technologies), whose choice is motivated by necessary launching cost reduction.
The PhD project is incorporated within this context. It focuses on robust detection and decoding of AIS signals. Interfering sources can be grouped into two classes. The first one corresponds to AIS transmitters and the second one to all other transmitters (including VHF). The first could help to detect the AIS signal target contrary to the second ones. The PhD thesis will investigate efficient classification and identification based on preliminary classification step results. Given the standard properties, they could exploit reconstruction of previously detected AIS signals.
All limitations (size, processing capability…) impose that on-board processing are robust to both synchronization and parameter estimation errors. The satellite is equipped with multiple antennas and is part of a constellation. Both features will be taken into account to ensure stable-operating embedded receiver.

Problem statement

In the context of expected maritime traffic densification combined with future LEO satellites-based AIS applications, interference management in the satellite is the bottleneck to ensure robust AIS signal demodulation. The extension of multi-antenna techniques (e.g. beamforming) widely used in usual terrestrial wireless systems (4G and beyond, WiFi) is not straightforward as antennas differ from their type, number or size. The self-organized time-division multiple access technique is only used for AIS, when orthogonal frequency division multiple access is selected in most terrestrial standards. On the other hand, cooperation between base stations (like coordinated multiple point techniques) proved its efficiency to manage interference. Its extension to satellite constellations raises the question of feasible communication links between satellites. The hardware constraints and the number of mutually-interfering signals make the detection complex. Isolation of AIS signals and rejection of the other

signals is the preliminary task. It requires to, first investigate classification techniques compliant with system constraints (hardware, energy, delay) and, then evaluate them in the PhD context. Once the interference rejection is done, the signal of interest must be extracted. The problem is then to cancel the AIS interference with the help of previously demodulated AIS signals.

The breakthrough of machine learning techniques and their application to problems which share similarities with ours (limited a priori knowledge, number and diversity of parameters, complexity constraints) make us think that they could be an interesting candidate, which should be obviously studied.

Expected Contributions of the Thesis

The preliminary step is the study of LEO satellites expected for relaying AIS signals. It will benefit from the expertise of both CNES and Kinéis. It will enable to define the constraints and the simulation model. In parallel, the PhD student will do the state-of-the-art of interference cancellation techniques and will evaluate their compatibility with previously-established system constraints and their limitations (to identify improvement levers). The same approach will be applied to classification and identification techniques with the purpose of AIS signal isolation and interference rejection. The machine learning methods will be studied in a second phase.
From the state-of-the-art, the PhD student will investigate and propose solutions to extract the AIS signal mixture that will be processed in a later phase. It will potentially exploit the conclusions of a first-year Master internship scheduled from April to August 2022.
After the mixture of AIS signals has been extracted, the signal of interest has to be detected. The next step will thus focus on robust demodulation of AIS signals by taking into account the features of the mixture or any relevant a priori knowledge. In particular, the way previously-detected AIS signals can be exploited will be studied to reinforce the demodulation efficiency.
In the end, the proposed receiver will be validated through application on real signals provided by Kinéis.

Organization

The PhD work will be included in a project between CNES, Kinéis, TéSA and IMT Atlantique. The PhD student will be member of the MEE department of IMT Atlantique (Brest) and some long-term stays in Kinéis (Toulouse) will be scheduled.

Application

A detailed application including a cover letter, an up-to-date CV, transcripts of grades (last two years) and reference letters, will be addressed to karine.amis@imt-atlantique.fr and frederic.guilloud@imt-atlantique.fr

References

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[6] K. Nozaki, Y. Takanezawa, Y. Chang, K. Fukawa and D. Hirahara, "Multiuser Detection of Collided AIS Packets with Accurate Estimates of Doppler Frequencies," 2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring), 2021, pp. 1-5.

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[8] M. Zhao, H. Zhao, W. Guo and Y. Tang, "An Interference Suppression Method Based on Space-Eigen Adaptive Processing for Satellite Communications," 2020 IEEE/CIC International Conference on Communications in China (ICCC), 2020, pp. 723-728.