

Design of Joint Receivers for Satellite IoT

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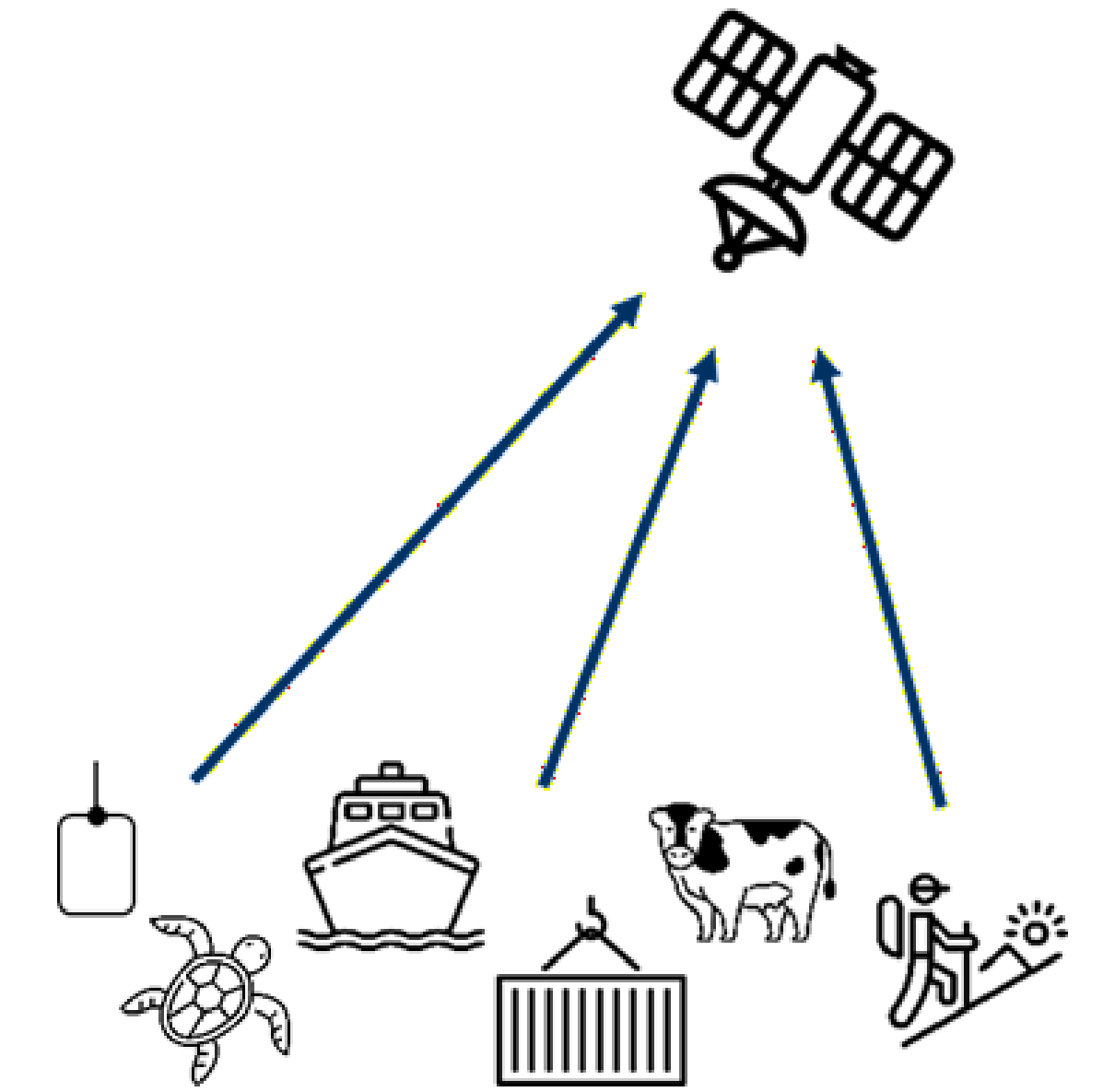
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Context

The rise of Non-Terrestrial Networks extends IoT connectivity beyond terrestrial infrastructure, enabling large-scale monitoring and communication services in remote or poorly covered areas. Some of the main challenges in this scenario are:

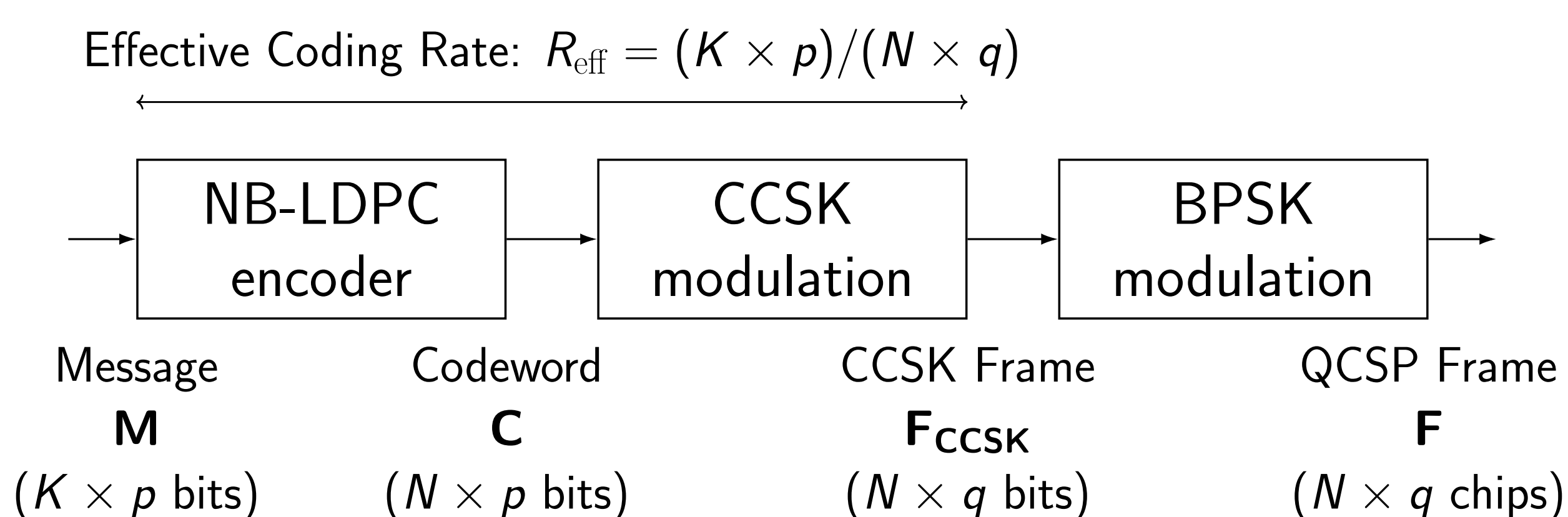
- ▶ **Massive access:** many low-power terminals transmit short and sporadic packets.
- ▶ **Satellite channel:** delay, Doppler, synchronization uncertainty, and limited link budget.
- ▶ **Multi-user interference:** users may overlap in time, frequency, or access resources.
- ▶ **PHY/MAC interaction:** receiver design and access protocols are coupled.

Thesis focus: Receiver design is central to reliable satellite IoT uplinks. This thesis studies joint reception methods that use the structure of multi-user transmissions, rather than treating users separately.



QCSP Frame

A Quasi-Cyclic-Short-Packet is a preamble-less frame that combines non-binary encoding and CCSK modulation.



QCSP reaches a FER of 10^{-4} around $\text{SNR} = -12.5$ dB in theoretical and practical settings [1].

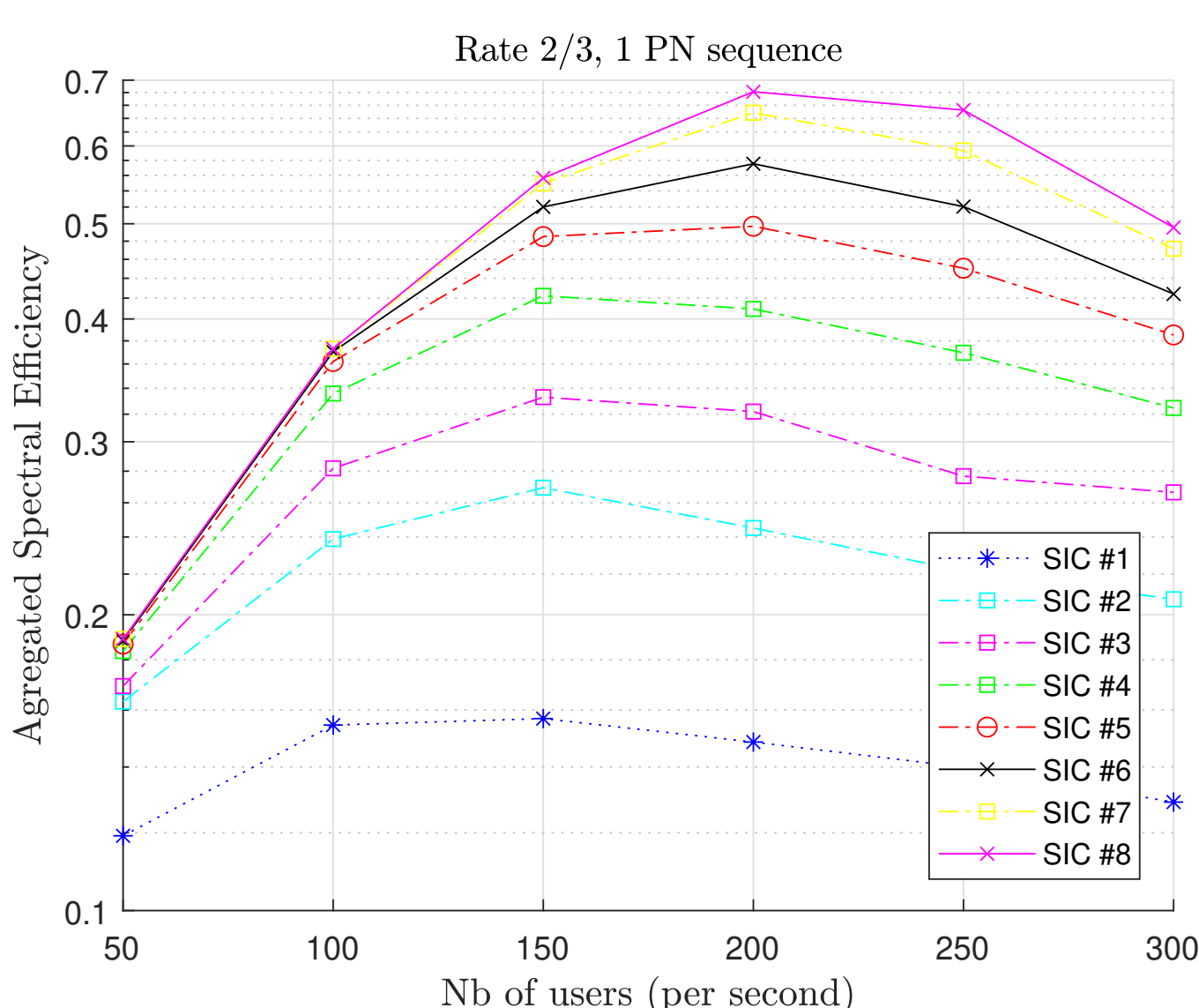
QCSP in LEO Uplink Channel

Earth-to-LEO reception introduces time-varying delay, frequency offset, Doppler shift, and Doppler rate.

$$r(t) = \sum_{k=1}^{K_a} A_k x_k(t - \tau_k) e^{j(\phi_k + 2\pi t(\Delta f_k^c + f_k^d + \alpha_k t/2))}$$

channel gain attenuation, Initial phase offset, Emitter-receiver center frequency mismatch, propagation delay, Doppler shift, Doppler rate

Blind SIC iteratively detects, decodes, and cancels users from the received signal, progressively reducing multi-user interference.



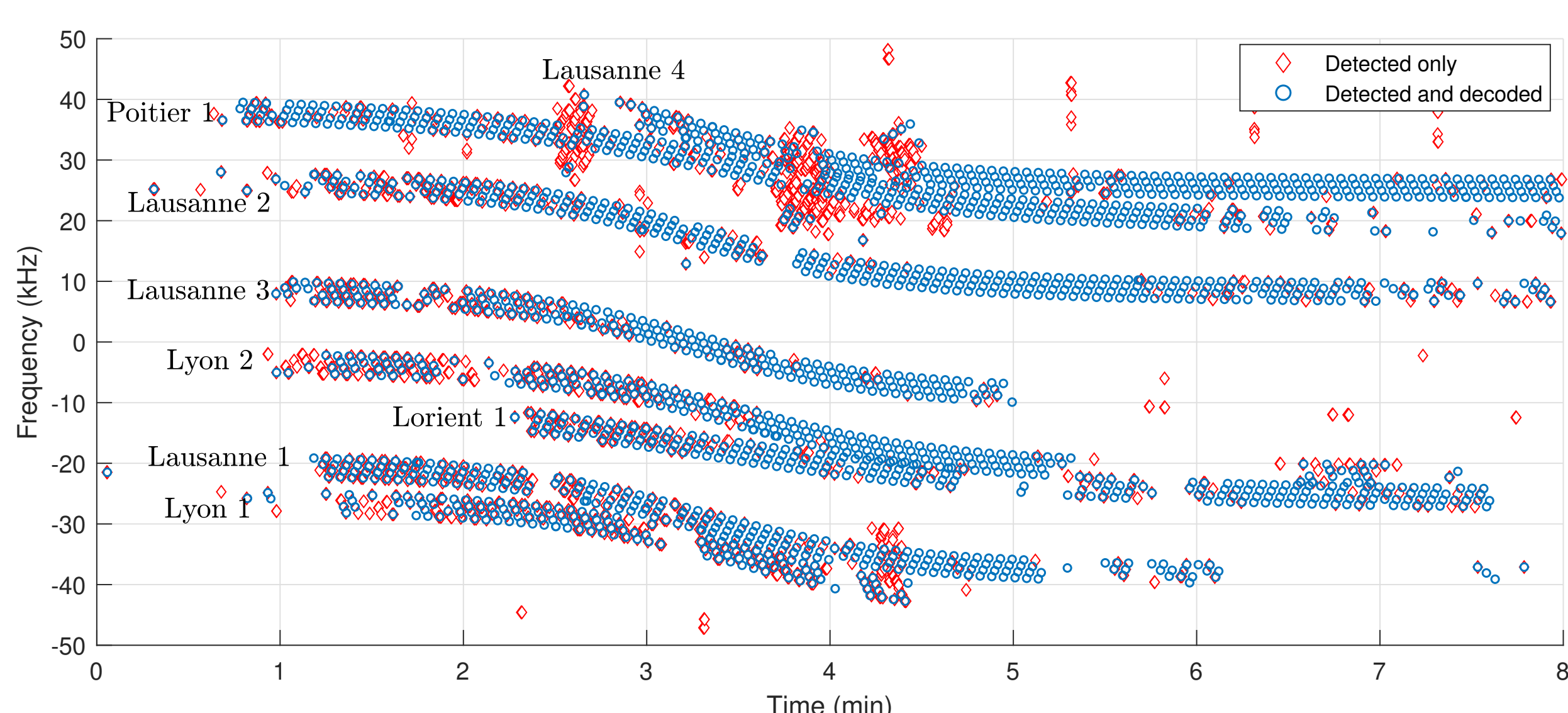
The Aggregated Spectral Efficiency tells how efficiently a system delivers useful information (L_{info}).

$$ASE = \frac{K_a L_{\text{info}}}{B} (1 - FER)$$

Although additional SIC iterations help improve practical ASE, the blind algorithm becomes less efficient at each SIC stage.

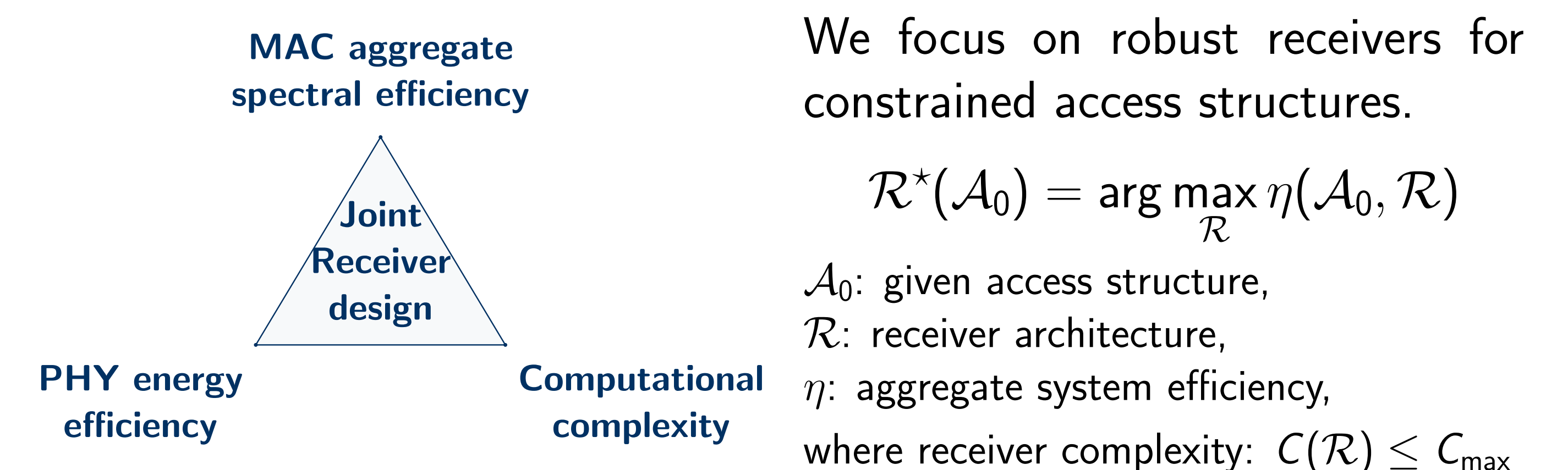
QCSP Earth-to-LEO Satellite Experimentation

In collaboration with UBS and Kinéis, we transmitted QCSP frames to the YAM-5 satellite [2]. A future issue of *IEEE Spectrum* will mention this experiment.



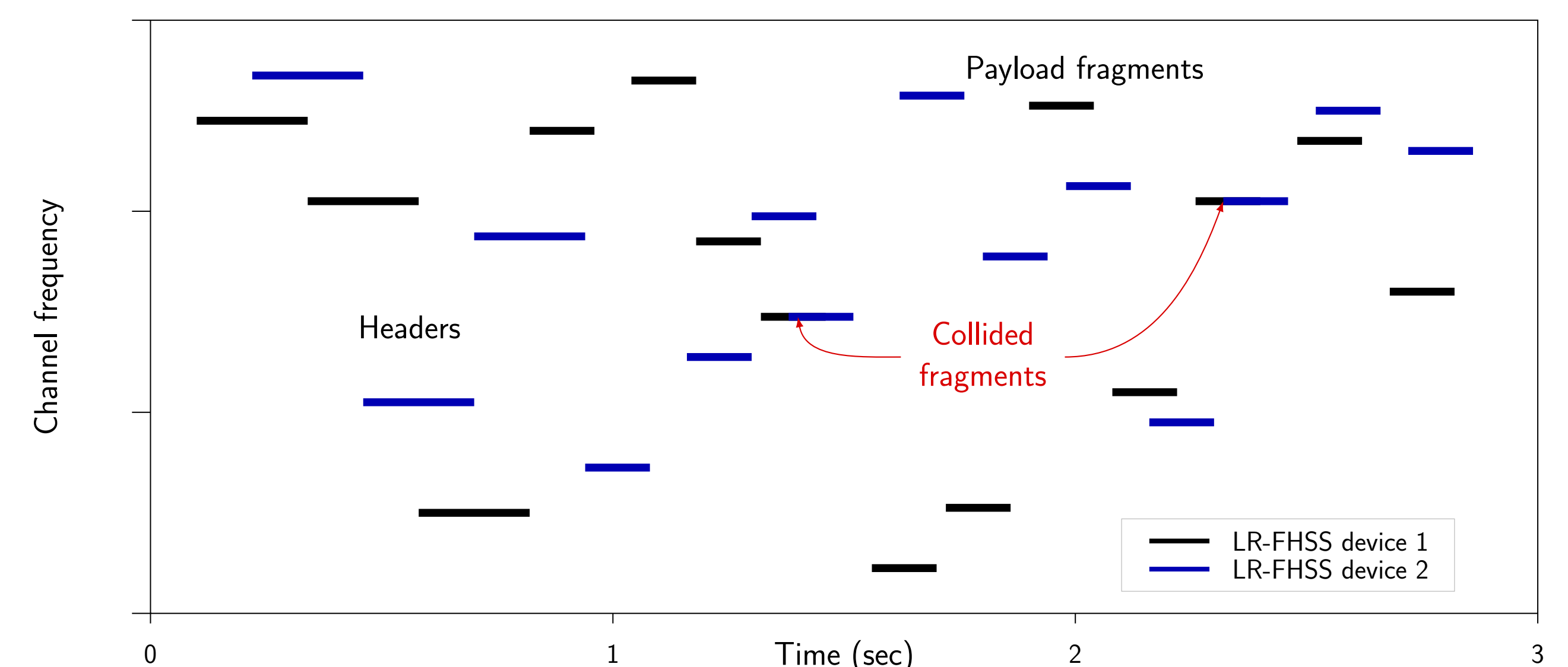
Joint PHY/MAC Reception

Massive random access can be viewed as a coding problem, where channel access, waveform, and receiver design are tightly coupled [3].



LR-FHSS as Starting Point

LR-FHSS provides a representative Sat-IoT waveform/access structure with repeated headers and blockwise narrowband payload fragments. It is used as an initial case to design robust joint receivers for structured IoT uplink signals.



Receiver direction: LR-FHSS is used as a first structured waveform/access case; the final objective is robust joint reception for similar blockwise narrowband Sat-IoT signals.

- ▶ **GMSK memory:** sequence detection using BCJR-type receivers.
- ▶ **Soft information:** exchange of a priori information with decoder and synchronizer.

References

- [1] K. Saied, "Quasi-Cyclic Short Packet (QCSP) Transmission for IoT," Theses, Université Bretagne Sud, Mar. 2022. [Online]. Available: <https://hal.science/te1-03628626>
- [2] L. Montoya Obeso, S. Tannir, et al., "Proof of concept of QCSP frames in earth-to-LEO satellite transmission," in *Proc. IEEE International Conference on Communications (ICC)*, Glasgow, Scotland, United Kingdom, 2026.
- [3] G. Liva and Y. Polyanskiy, "Unsourced multiple access: A coding paradigm for massive random access," *Proceedings of the IEEE*, vol. 112, no. 9, pp. 1214–1229, 2024. DOI: 10.1109/JPROC.2024.3437208

Scientific cooperation

This CIFRE PhD thesis, started in October 2025, is conducted in a collaboration with Kinéis, UBS, IRIT, bridging industrial satellite IoT needs with academic research on communication systems and receiver design.

