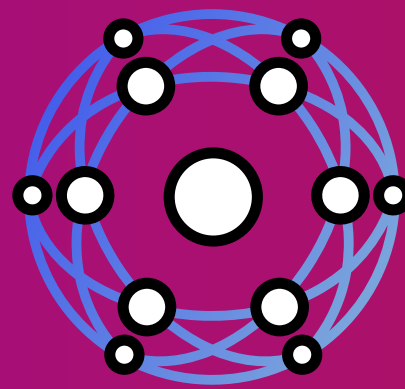


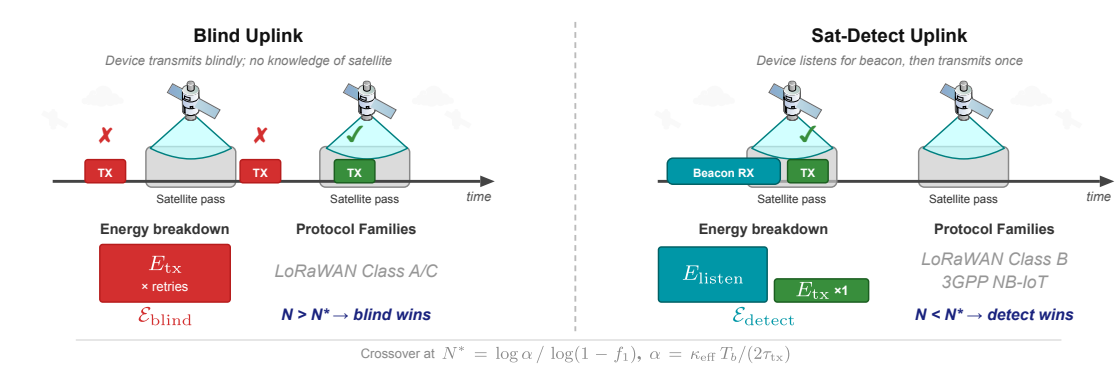


Space-Terrestrial Integrated IoT: Research and Open-Source Tools

Juan A. Fraire · Benoit Coeugnet · Alexander Y. Choquenaira-Florez
Inria, INSA Lyon, CITI UR3720, Villeurbanne · Kinéis, Toulouse



Why DtS-IoT is hard

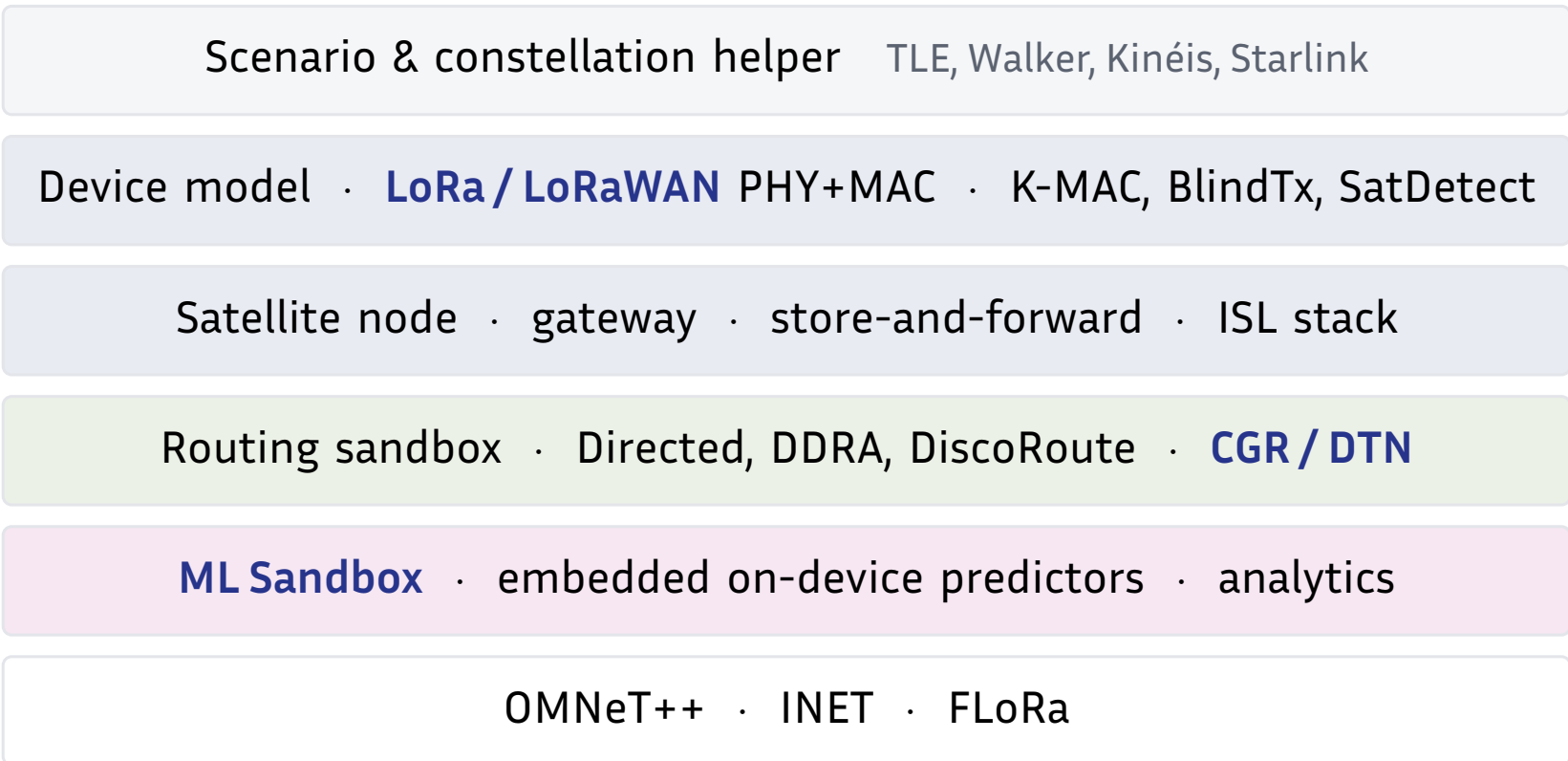


Blind versus satellite-detect uplink.

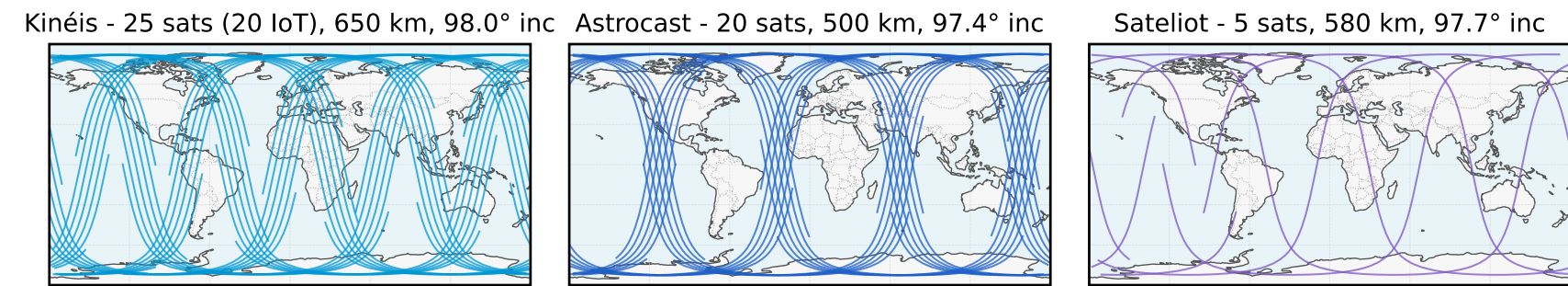
- ◆ DtS-IoT is an architecture where **resource-scarce, battery-powered** IoT terminals **directly communicate with orbiting gateways** during satellite passes.
- ◆ Coverage is intermittent and latitude-dependent. Reliability comes from **repetitions**; repetitions cost energy and spectrum.
- ◆ Access, routing and store-and-forward are **coupled** operations.

Accelerated simulations are crucial.

FLoRaSat: an open simulator for DtS-IoT



Two layers are new since FLoRaSat 2: the CGR/DTN plug-in and the ML Sandbox.



- ◆ Open source since **2022**, event-driven, end-to-end.
- ◆ The only open simulator evaluating **access and routing jointly** for constellation-grade DtS-IoT.
- ◆ Orbital dynamics from **real TLE sets**; interference, attenuation and capture in the channel model.
- ◆ Calibrated on **Kinéis field measurements**.

Refs [1] ComMag'22 · [2] WoWMoM'22
[3] IJSCN'25 · [4] SMC-IT'24

The scale jump

Constellation-scale, massive-device campaigns are now a routine experiment rather than an overnight job.

100 000

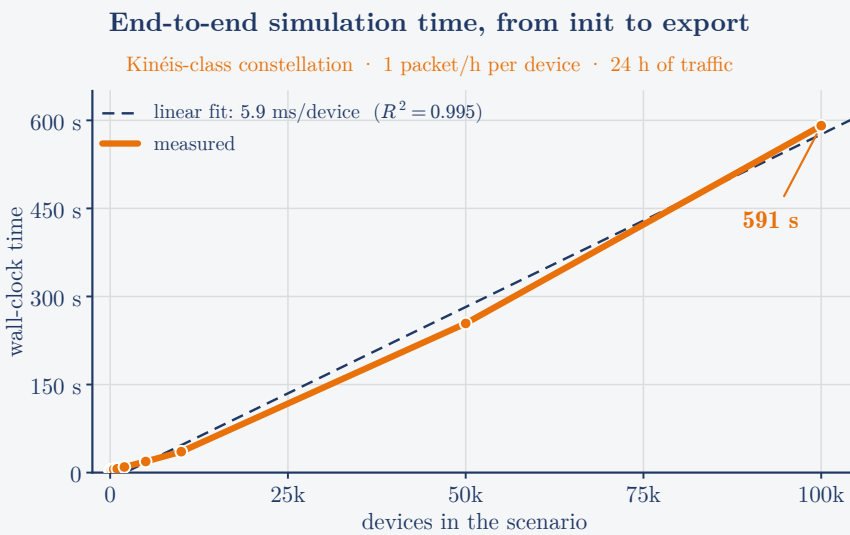
devices, Kinéis-class constellation, **one day** of traffic

10 min

end to end on a laptop, init and result export included

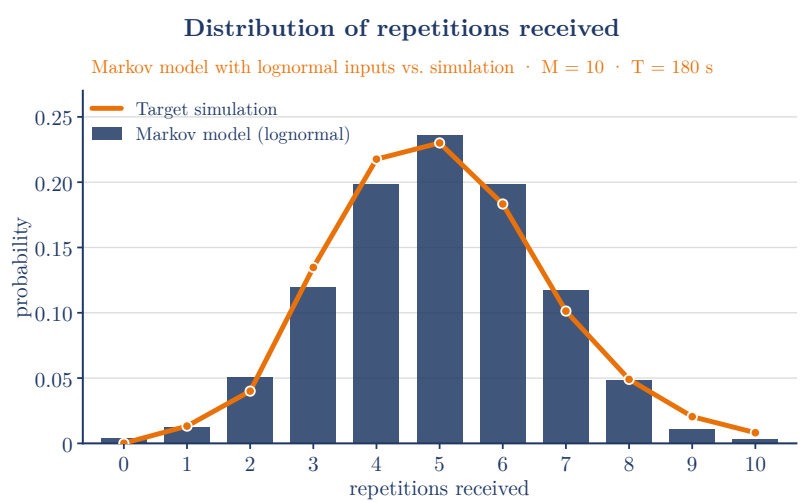
10 000

devices, Starlink-class store-and-forward, in 1 min 40



1 Analytical MAC tuning

Coeugnet, Beylot, Deslandes, Fraire · Kinéis / Inria / IRIT



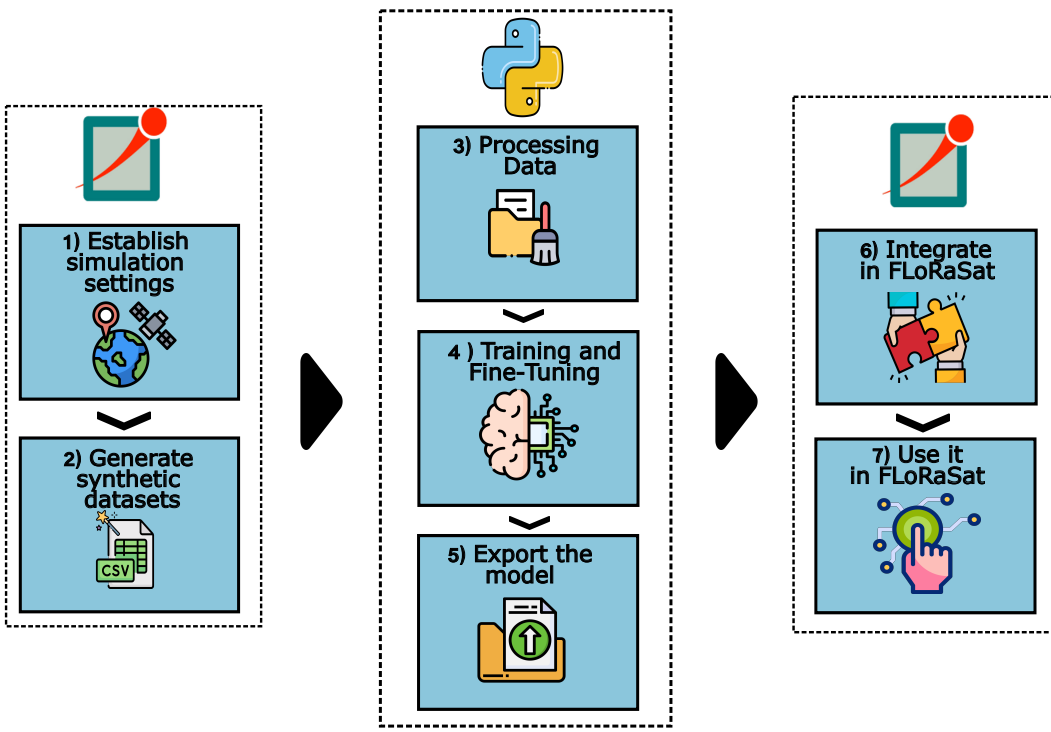
Markov model against FLoRaSat at the Equator: the simulator is the ground truth.

- ◆ Renewal theory and a DTMC over **empirical visibility** taken from real TLEs.
- ◆ Validated against FLoRaSat to **RMSE under 3%**; optimal repetition count and spacing returned in **seconds** against minutes of event-driven simulation.
- ◆ **SatDetect** beats **BlindTx** roughly **4×** better in energy efficiency at low latitudes, at a 95% reception target.

Sustainability lever: **10 of 25** satellites can come out for **24%** more device energy, latency still inside the hour.

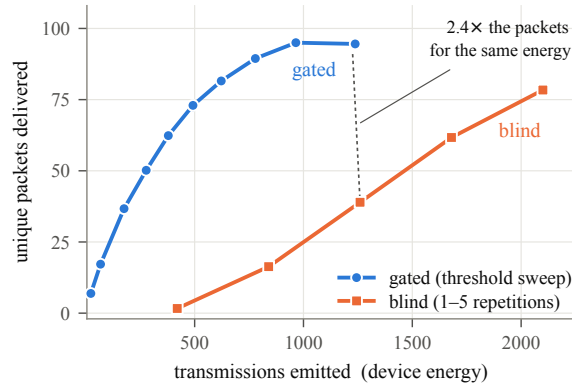
2 Frugal on-device ML

Choquenaira-Florez, Rivano, Fraire · Inria / INSA Lyon



The **ML Sandbox**: FLoRaSat generates the training data that does not exist in the wild, then runs the model inside the simulation.

- ◆ A blind terminal transmits and hopes: fewer than **one frame in five** is received.
- ◆ A tiny failure predictor boosts **+21.2%** unique packets with **-41.1%** transmissions.

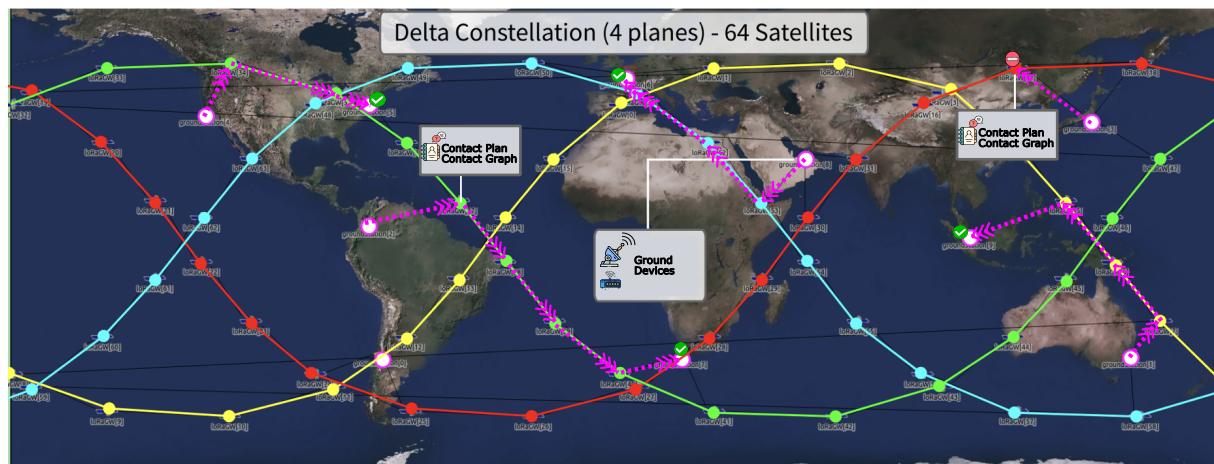


Unique packets delivered vs. transmissions emitted.

Linear models lands similar performance across a 10^5 size span: Accuracy stops discriminating long before cost does.

3 DTN and CGR in FLoRaSat

Montoya, Maldonado, Fraire, Céspedes · PUC Chile / Concordia / Inria



The contact plan is derived from the same orbital propagator that drives the access layer, so access and routing stay consistent.

- ◆ Bundles, custody and **store-and-forward buffers** modelled at the satellite.
- ◆ **CGR** enters the routing sandbox next to Directed, DDRA and DiscoRoute, so schedule-aware routing can be compared head to head with opportunistic schemes.
- ◆ Integration with LoRa/LoRaWAN: the bundle encapsulates the LoRa packet, as it is used in the routing modules in the simulator.

Come argue with us: what should a bundle look like when the payload is 20 bytes and the contact lasts eight minutes?

Adoption **87**

works cite FLoRaSat; 24 name it in the full text

3

independent surveys place it in the NTN simulator landscape

1

external group extended the MAC layer and published

Surveyed by IEEE Access'23 · MDPI JSAN'25 · Sci. Sinica Inf'26.

Built on by Umm Al-Qura (BU-LoRaWAN, IJCN'24) · Concordia · PUC Chile · UTEM · Saarland · LAAS · Kinéis.

Also the experimental backbone of a 2026 INSA Lyon doctoral thesis and of a Frontiers tutorial review on DtS-IoT.

Get it

gitlab.inria.fr/jfraire/florasat

Next up: DTN/CGR release soon.

Bring your MAC or routing scheme and benchmark it against ours.

juan.fraire@inria.fr



Clone the simulator