

Monday 14 September · Session 2 · 16:00

STINT 2026

Poster Lightning Madness

Nine posters · one minute each · your poster is on the screen behind you

🕒 15 minutes, hard stop at 16:15

📍 Irish College, Leuven

Session 2 · Protocols & Integration · Chair: Alberto Montilla

How it works

Fifteen minutes at the end of Session 2, then the welcome activity.

Each presenter gets **one minute** at the front. The poster is on the screen behind you: no slides, no laptop swap.

The pitch order follows the wall on the next slide (same order as the website).

Posters go up on **Tuesday morning** and stay on display all day. The PDFs are already online.

9

POSTERS

60

SECONDS EACH

TUE

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PDF

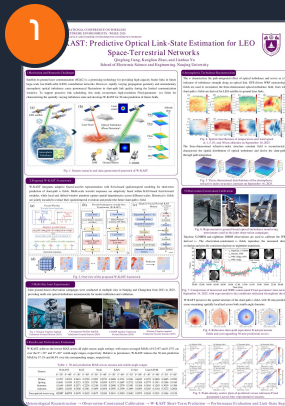
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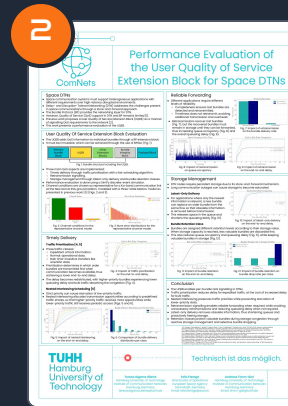
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Nine posters, in pitch order

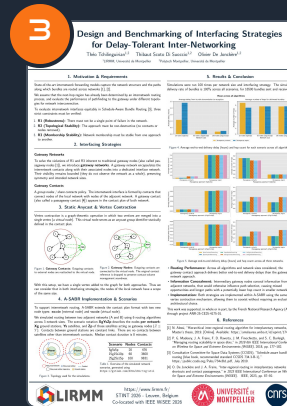
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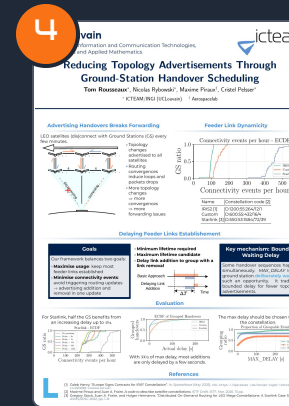
W-KAST
Jiang · Zhao · Yu



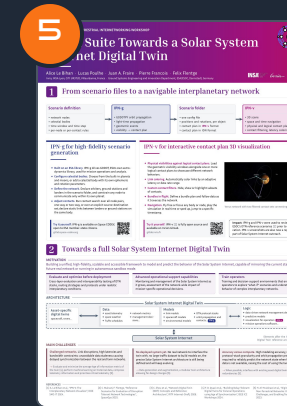
UQEB for space DTNs
Algarra Uliarte et al.



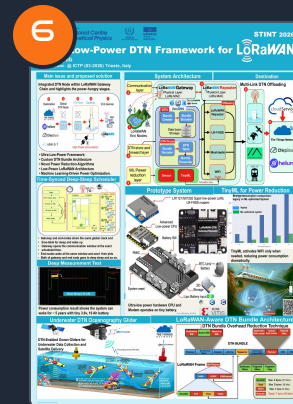
DTN inter-networking
Tchilinguirian et al.



GS handover scheduling
Rousseaux et al.



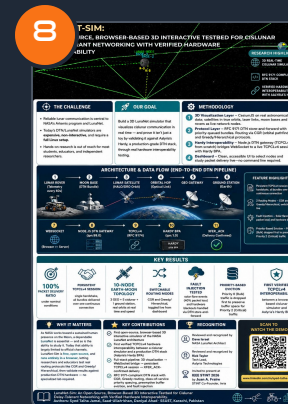
SSI digital twin
Le Bihan et al.



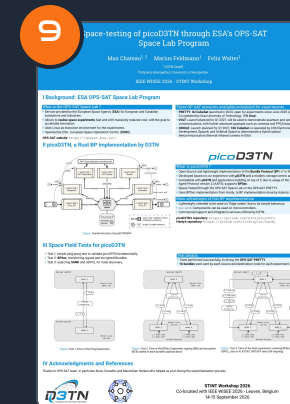
Low-power LoRaWAN
Altayeb



Space-terrestrial IoT
Coeugnet et al.



LunaNet-Sim
Jamal et al.



picoD3TN in space
Chateau et al.

W-KAST: Predictive Optical Link-State Estimation for LEO Space-Terrestrial Networks

Qingfang Jiang, Kanglian Zhao, and Jianhao Yu
School of Electronic Science and Engineering, Nanjing University



1 Motivation and Research Challenges

Satellite-to-ground laser communication (SGLC) is a promising technology for providing high-capacity feeder links in future large-scale low-Earth-orbit (LEO) constellation networks. However, rapidly varying propagation geometry and nonstationary atmospheric optical turbulence cause pronounced fluctuations in slant-path link quality during the limited communication windows. To support proactive link scheduling, this study reconstructs high-resolution Fried-parameter (r_0) fields for characterizing the spatially varying turbulence state and develops W-KAST for 30-min prediction of future fields.

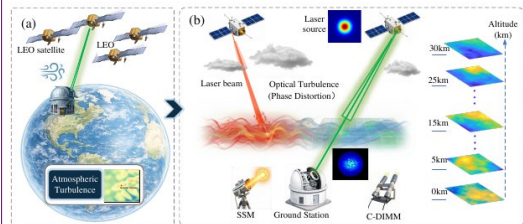


Fig. 1. System scenario and data-generation framework of W-KAST

2 Proposed W-KAST Framework

W-KAST integrates adaptive fractal-wavelet representations with Swin-based spatiotemporal modeling for short-term prediction of slant-path τ_r fields. Multi-scale wavelet responses are adaptively fused within KAN-based feed-forward modules, while local and shifted-window attention capture spatial dependencies across different scales. Historical τ_r fields are jointly encoded to extract their spatiotemporal evolution and predict the future slant-path τ_r field.

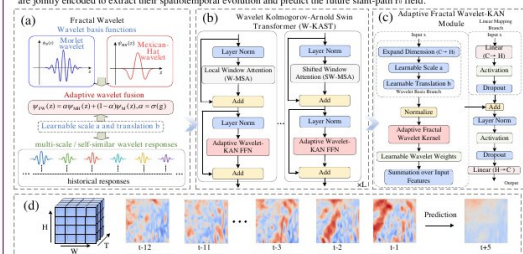


Fig. 2. Overview of the proposed W-KAST framework

3 Multi-Site Joint Experiments

Joint ground-based observation campaigns were conducted at multiple sites in Nanjing and Changchun from 2021 to 2025, providing multi-site optical-turbulence measurements for model calibration and validation.



Fig. 3. Nanjing Yingting Applied Validation Ground Station (2021)

6 Results and Performance Evaluation

W-KAST achieves the lowest MAE across all eight season-angle settings, with macro-averaged MAEs of 0.2197 and 0.1571 cm over the $0^{\circ}\sim 30^{\circ}$ and $0^{\circ}\sim 80^{\circ}$ zenith-angle ranges, respectively. Relative to persistence, W-KAST reduces the 30-min prediction MAE by 57.1% and 66.9% over the corresponding ranges, respectively.

Season	W-Kast		KAT		Swin		KAN		U-Net		ConvLstm2		GWN	
	0°-30°	0°-80°	0°-30°	0°-80°	0°-30°	0°-80°	0°-30°	0°-80°	0°-30°	0°-80°	0°-30°	0°-80°	0°-30°	0°-80°
Winter	0.1707	0.2253	0.2201	0.2307	0.1388	0.3731	0.2541	0.0431	0.1972	0.2885	0.2885	0.2793		
Spring	0.264	0.109	0.621	0.2721	0.2431	0.2039	0.2687	0.272	0.2324	0.2779	0.351	0.3106		
Summer	0.2059	0.2076	0.2077	0.2088	0.2577	0.1981	0.2268	0.2357	0.1981	0.2306	0.3039	0.384		
Autumn	0.2800	0.2036	0.2030	0.3341	0.3499	0.3054	0.3895	0.3389	0.3499	0.4209	0.3269	0.3164	0.3272	0.2824
Four-period macro avg.	0.2197	0.1751	0.2278	0.2632	0.2062	0.2450	0.3401	0.2683	0.2079	0.2458	0.2201	0.3346	0.2134	

Four-period macro avg.	0.2197	0.1571	0.2678	0.2632	0.2672	0.2450	0.3491	0.3099	0.2683	0.2979	0.2458	0.2201	0.3346	0.2134
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4 Atmospheric Turbulence Reconstruction

The r_0 characterizes the path-integrated effect of optical turbulence and serves as a key indicator of turbulence strength along an optical link. GFS-driven WRF meteorological fields are used to reconstruct the three-dimensional optical-turbulence field, from which slant-path r_0 fields are derived for LEO satellite-to-ground laser links.

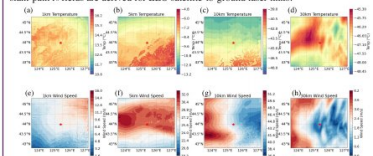


Fig. 4. Spatial distributions of temperature and wind speed at 1, 5, 10, and 30 km altitudes on September 16, 2025.

The three-dimensional refractive-index structure constant field is reconstructed to characterize the spatial distribution of optical turbulence and derive the slant-path r_0 through path integration.

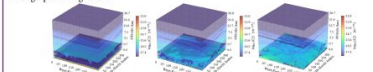


Fig. 5. Three-dimensional distributions of the atmospheric refractive-index structure constant on September 16, 2025

5 Observation-Constrained Calibration



Fig. 6. Representative ground-based optical-turbulence monitoring

Daytime S-DIMM and nighttime DIMM observations are used to calibrate the WRF-derived τ_0 . The observation-constrained τ_0 fields reproduce the measured diurnal evolution and provide consistent daytime-to-nighttime transitions.

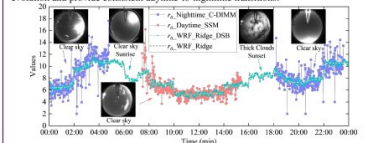


Fig. 7. Comparison of measured and WRF-constrained Fried-parameter time series on September 16, 2025, with representative sky conditions indicated throughout the day.

W-KAST preserves the spatial structure of the slant-path r_0 field, with 30-min prediction errors remaining spatially localized across both zenith-angle domains.

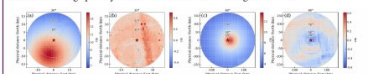


Fig. 8. Reference slant-path equivalent Fried-parameter fields and corresponding 30-min prediction errors.

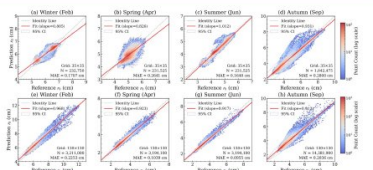


Fig. 9. Point-density scatter plots of predicted versus reference Fried parameters across four representative seasons.

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W-KAST: Predictive Optical Link-State Estimation for LEO Space-Terrestrial Networks

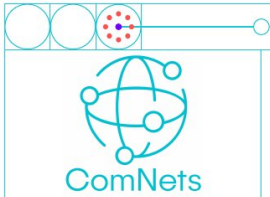
Qingfang Jiang, **Kanglian Zhao**, Jianhao Yu

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Performance Evaluation of the User Quality of Service Extension Block for Space DTNs

POSTER 2 of 9 #64

Performance Evaluation of the User Quality of Service Extension Block for Space DTNs

Teresa de Jesús Algarra Uliarte, Felix Flentge, Andreas Timm-Giel

Hamburg University of Technology · ESA/ESOC

Space DTNs

- Space communication systems must support heterogeneous applications with different requirements over high-latency disrupted environments.
- Delay- and Disruption-Tolerant Networking (DTN) addresses the challenges present in space communication through a store-and-forward approach.
- The Bundle Protocol (BP) provides the networking layer for DTN.
- However, Quality of Service (QoS) support in DTN and BP remains limited [1].
- Previous work proposes a User Quality of Service Extension Block (UQEB) as a manner of signalling QoS requirements to the network [2].
- This work presents a performance evaluation of the UQEB.

User Quality of Service Extension Block Evaluation

- The UQEB adds QoS information to individual bundles through a BP extension block. It must be immutable, which can be achieved through the use of BPsec (Fig. 1).



Fig. 1: Bundle structure including the UQEB.

- Three main QoS aspects are implemented:
 - Timely delivery through traffic prioritization with a fair scheduling algorithm.
 - Retransmission signalling.
 - Storage management through latest-only delivery and bundle retention classes.
- Performance evaluation is done using a SimPy discrete-event simulator.
- Channel conditions are chosen as representative for a Ka-band communication link at the New Norcia ESA ground station, modelled with a three-state Markov model as presented in previous work [3] (Figs. 2 and 3).

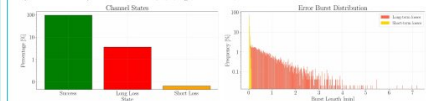


Fig. 2: Channel error distributions for the representative channel model.

Reliable Forwarding

- Different applications require different levels of reliability.
 - Completeness ensures lost bundles are detected and retransmitted.
 - Timeliness does not retransmit, avoiding additional transmission and overhead.
- Retransmissions recover lost bundles (Fig. 7), but the recovered bundles must remain in storage until they can be forwarded, thus increasing queue occupancy (Fig. 8) and the overall queueing delay (Fig. 9).

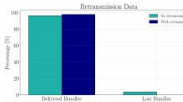


Fig. 7: Impact of retransmission on the bundle delivery rate.

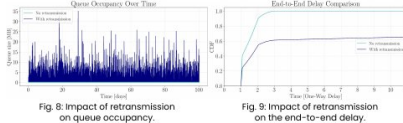


Fig. 8: Impact of retransmission on queue occupancy.

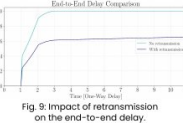


Fig. 9: Impact of retransmission on the end-to-end delay.

Storage Management

- DTN nodes require persistent storage due to its store-and-forward mechanism.
- Long communication outages can cause storage to become saturated.

Latest-Only Delivery

- For applications where only the newest information is relevant, a new bundle can replace an older bundle from the same flow so that obsolete information is removed before transmission.
- This releases space in the queue and shortens the queueing delay (Fig. 10).

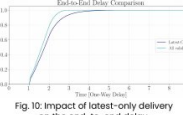


Fig. 10: Impact of latest-only delivery on the end-to-end delay.

Bundle Retention Class

- Bundles are assigned different retention levels according to their storage value. When storage capacity is reached, less valuable bundles are discarded first.
- This also reduces queue occupancy and queueing delay (Fig. 11), while keeping valuable bundles in storage (Fig. 12).

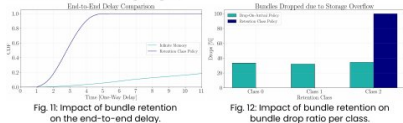


Fig. 11: Impact of bundle retention on the end-to-end delay.

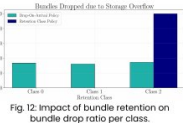


Fig. 12: Impact of bundle retention on bundle drop rate per class.

Timely Delivery

Traffic Prioritization [4, 5]

- Three traffic classes:
 - Expedited: critical information.
 - Normal: operational data.
 - Bulk: time-insensitive transfers like scientific data.
- Prioritization determines in which order bundles are transmitted first when communication becomes available, thus achieving a lower end-to-end delay.
- The delay becomes redistributed, with higher-priority bundles experiencing lower queueing delay and bulk traffic absorbing the congestion (Fig. 4).

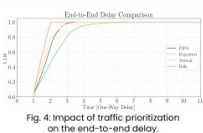


Fig. 4: Impact of traffic prioritization on the end-to-end delay.

Nested Interleaving Scheduling [6]

- Strict priority can cause starvation of low-priority traffic.
- Nested interleaving allocates transmission opportunities according to predefined traffic shares, so that higher-priority traffic receives more opportunities while lower-priority traffic still receives periodic access (Figs. 5 and 6).

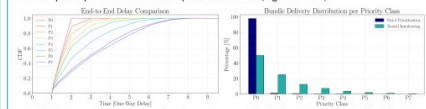


Fig. 5: Impact of nested interleaving on the end-to-end delay.

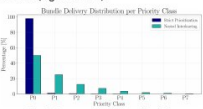


Fig. 6: Comparison of bundle delivery distribution per priority class.

Conclusion

- The UQEB enables per-bundle QoS signalling in DTNs.
- Traffic prioritization reduces delay for expedited traffic, at the cost of increased delay for bulk traffic.
- Nested interleaving preserves traffic priorities while preventing starvation of lower-priority data.
- Retransmission signalling enables reliable forwarding when required, while avoiding unnecessary retransmissions and reducing queueing delay when not required.
- Latest-only delivery removes obsolete information, thus shortening queues and proactively freeing storage.
- Retention classes protect valuable bundles during storage congestion through reactive storage management and selective bundle dropping.

[1] Algarra, U. et al., "A User Quality of Service Extension Block for Space DTNs", in *Proceedings of the 13th European Conference on Satellite Navigation (EUSN)*, 2018, pp. 1-10.

[2] Algarra, U. et al., "A User Quality of Service Extension Block for Space DTNs", in *Proceedings of the 13th European Conference on Satellite Navigation (EUSN)*, 2018, pp. 1-10.

[3] Algarra, U. et al., "A User Quality of Service Extension Block for Space DTNs", in *Proceedings of the 13th European Conference on Satellite Navigation (EUSN)*, 2018, pp. 1-10.

[4] Algarra, U. et al., "A User Quality of Service Extension Block for Space DTNs", in *Proceedings of the 13th European Conference on Satellite Navigation (EUSN)*, 2018, pp. 1-10.

[5] Algarra, U. et al., "A User Quality of Service Extension Block for Space DTNs", in *Proceedings of the 13th European Conference on Satellite Navigation (EUSN)*, 2018, pp. 1-10.

[6] Algarra, U. et al., "A User Quality of Service Extension Block for Space DTNs", in *Proceedings of the 13th European Conference on Satellite Navigation (EUSN)*, 2018, pp. 1-10.

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60 s pitch

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On the Design and Benchmarking of Interfacing Strategies for Delay-Tolerant Inter-Networking

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1. Motivation & Requirements

State-of-the-art internetwork forwarding models capture the network structure and the paths along which bundles are routed across networks [1], [2].

We assume that the next-hop region has already been determined by an internetwork routing process, and evaluate the performance of pathfinding to the gateway under different topologies for network interconnection.

To evaluate internetwork interfaces equitably in Schedule-Aware Bundle Routing [3], three strict constraints must be verified:

1. **R1 (Robustness):** There must not be a single point of failure in the network.
2. **R2 (Topological Stability):** The approach must be non-destructive (no contacts or nodes removed).
3. **R3 (Membership Stability):** Network membership must be stable from one approach to another.

2. Interfacing Strategies

Gateway Networks

To solve the violations of R1 and R3 inherent to traditional gateway nodes (also called passageway nodes [1]), we introduce **gateway networks**. A gateway network encapsulates the internetwork contacts along with their associated nodes into a dedicated interface network. Their visibility remains bounded (they do not observe the network as a whole), preserving symmetry and intended network sizes.

Gateway Contacts

A *group nodes / share contacts* policy. The internetwork interface is formed by contacts that connect nodes of the local network with nodes of the adjacent network. A gateway contact (also called a passageway contact [4]) appears in the contact plan of both network.

3. Static Anycast & Vertex Contraction

Vertex contraction is a graph-theoretic operation in which two vertices are merged into a single vertex (a *virtual node*). This virtual node serves as an anycast group identifier statically defined in the contact plan.

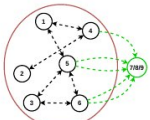


Figure 1. **Gateway Contacts:** Outgoing contacts are connected to the virtual node. The original contact reference is dropped to preserve contact-volume management soundness.

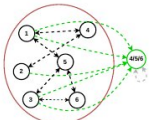


Figure 2. **Gateway Nodes:** Outgoing contacts are connected to the virtual node. The original contact reference is dropped to preserve contact-volume management soundness.

With this setup, we have a single vertex added to the graph for both approaches. Thus we can consider that in both interfacing strategies, the nodes of the local network have a scope of the same size.

4. A-SABR Implementation & Scenarios

To support internetwork routing, A-SABR extends the contact plan format with two new node types: **enode** (external node) and **vnode** (virtual node).

We simulated routing between two adjacent networks (A and B) using 6 routing algorithms across 3 network sizes. The scenario notation **XgYsZp** describes the nodes **per network**: **Xg** ground stations, **Ys** satellites, and **Zp** of those satellites acting as gateway nodes ($Z \leq Y$). Contacts between ground stations are constant links. There are no contacts between satellites other than internetwork contacts. Median contact duration is 8 minutes.

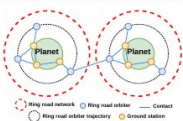


Figure 3. Topology used for the simulations.

Scenario	Nodes	Contacts
5g5s5p	20	476
15g15s10p	60	3600
25g25s15p	100	9831

Table 1. Overview of the simulated network scenarios, generated using <https://gitlab.com/d3tn/dtn-tvg-util>

5. Results & Conclusion

Simulations were run 100 times per network size and interfacing strategy. The simulated delivery rate of bundles is 100% across all scenarios, for 16500 bundles sent and received.

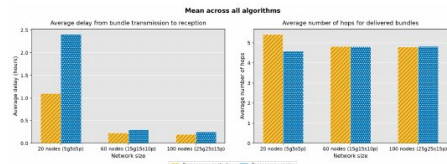


Figure 4. Average end-to-end delivery delay (hours) and hop count for each scenario across all algorithms.

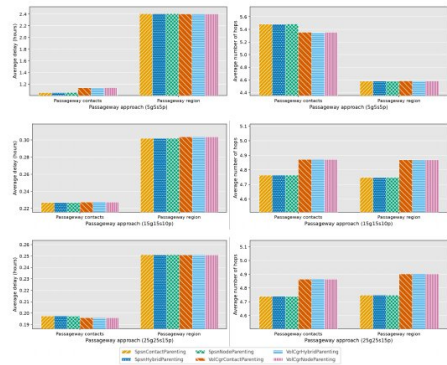


Figure 5. Average end-to-end delivery delay (hours) and hop count across all three networks.

- **Routing Performance:** Across all algorithms and network sizes considered, the gateway contact approach delivers better end-to-end delivery delays than the gateway network approach.
- **Information Concealment:** Intermediary gateway nodes conceal information from adjacent networks, that would otherwise influence path selection, causing missed opportunities and longer paths with a potentially lower hop count in smaller networks.
- **Implementation:** Both strategies are implemented within A-SABR using the same vertex contraction mechanism, allowing them to coexist without requiring an exclusive architectural choice.

This work was supported, in whole or in part, by the French National Research Agency (ANR) through project ANR-25-CE25-4175-01.

6. References

- [1] N. Alessi, "Hierarchical inter-regional routing algorithm for interplanetary networks," Master's thesis, 2019. [Online]. Available: <https://amslaurea.unibo.it/id/eprint/17468/>
- [2] P. G. Madoery, J. A. Fraire, F. D. Raverta, J. M. Finochietto, and S. C. Burleigh, "Managing routing scalability in space dtms," in 2018 6th IEEE International Conference on Wireless for Space and Extreme Environments (WiSEE), 2018, pp. 177–182.
- [3] Consultative Committee for Space Data Systems (CCSDS), "Schedule-aware bundle routing (blue book, recommended standard CCSDS 734.3-B-1)," <https://public.ccsds.org/Pubs/734x3b1.pdf>, July 2019.
- [4] O. De Jonckère and J. A. Fraire, "Inter-regional routing in interplanetary networks with shortcuts and contact passageways," in 2023 IEEE International Conference on Wireless for Space and Extreme Environments (WiSEE). IEEE, 2023, pp. 87–92.

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On the Design and Benchmarking of Interfacing Strategies for Delay-Tolerant Inter-Networking

Théo Tchilinguirian, Thibaut Scoto Di Suoccio, Olivier De Jonckère

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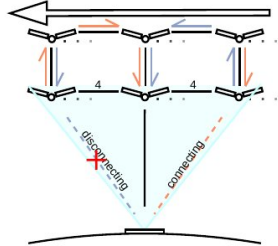
Reducing Topology Advertisements Through Ground-Station Handover Scheduling

Tom Rousseaux*, Nicolas Rybowski*, Maxime Piraux†, Cristel Pelsser*

* ICTEAM/INGI (UCLouvain) † Aerospacelab

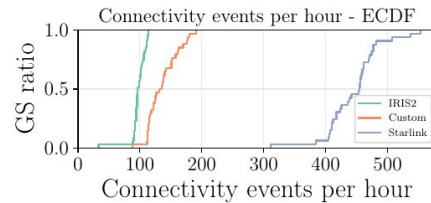
Advertising Handovers Breaks Forwarding

LEO satellites (dis)connect with Ground Stations (GS) every few minutes.



- Topology changes advertised to all satellites
- Routing convergences induce loops and packets drops
- More topology changes
⇒ more convergences
⇒ more forwarding issues

Feeder Link Dynamicity



Name	Constellation code [2]
IRIS2 [1]	D:1200:55:264/12/1
Custom	D:600:55:432/16/4
Starlink [3]	D:550:53:1584/72/39

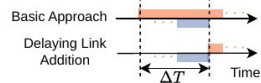
Delaying Feeder Links Establishment

Goals

Our framework balances two goals:

- **Maximise usage:** keep most feeder links established
- **Minimise connectivity events:** avoid triggering routing updates
→ advertising addition and removal in one update

- Minimum lifetime required
- Maximum lifetime candidate
- Delay link addition to group with a link removal

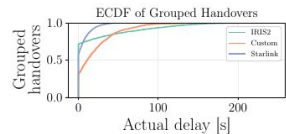
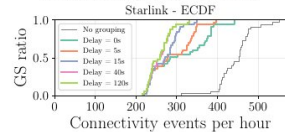


Key mechanism: Bounded Waiting Delay

Some handover sequences happen simultaneously. *MAX_DELAY* lets a ground station *deliberately wait* for such an opportunity. It trades a bounded delay for fewer topology advertisements.

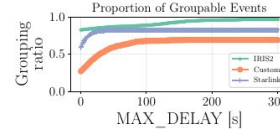
Evaluation

For Starlink, half the GS benefits from an increasing delay up to 40s.



With 300s of max delay, most additions are only delayed by a few seconds.

The max delay should be chosen w.r.t. the constellation.



References

- [1] Caleb Henry, "Europe Signs Contracts for IRIS² Constellation". In: SpaceNews (May 2025). URL: <https://spacenews.com/europe-signs-contracts-for-iris2-constellation/>.
- [2] Maxime Piraux and Juan A. Fraire, A code to describe satellite constellations. IETF Draft. IETF, Mar. 2026. 13 pp.
- [3] Gregory Stock, Juan A. Fraire, and Holger Hermanns, "Distributed On-Demand Routing for LEO Mega-Constellations: A Starlink Case Study", in: *ASNS/SPSC 2022*, pp. 1-6.

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Reducing Topology Advertisements Through Ground-Station Handover Scheduling

Tom Rousseaux, Nicolas Rybowski, Maxime Piraux, Cristel Pelsser

UCLouvain, ICTEAM

60 s pitch

Board goes up Tuesday morning

PDF on stintworkshops.org

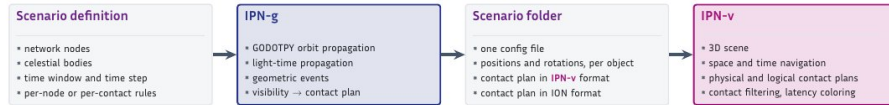


A Tool Suite Towards a Solar System Internet Digital Twin

Alice Le Bihan · Lucas Poulhe · Juan A. Fraire · Pierre Francois · Felix Flentge
Inria, INSA Lyon, CITI UR3720, Villeurbanne, France · Ground Systems Engineering and Innovation Department, ESA/ESOC, Darmstadt, Germany



1 From scenario files to a navigable interplanetary network



IPN-g for high-fidelity scenario generation

- Built on an ESA library. IPN-g drives G0DOTPY, ESA's own astrodynamics library, used for mission operations and analysis.
- Configure celestial bodies. Choose from the built-in planets and moons, or add a celestial body with its own ephemeris and rotation parameters.
- Define the network. Declare orbiters, ground stations and landers in the scenario folder, and constrain any node to communicate only within its own planet.
- Adjust contacts. Run contact search over all node pairs, one-way or two-way, or over an explicit source-destination set; declare static links between landers or ground stations on the same body.

Try it yourself: IPN-g is available on Space CODEV, open to ESA member-state citizens.
gitlab.space-codev.org



IPN-v for interactive contact plan 3D visualization

- Physical visibilities against logical contact plans. Load the geometric visibility windows alongside one or more logical contact plans to showcase different network behaviors.
- Link coloring. Automatically color links by an adaptive latency or data rate range.
- Custom contact filters. Hide, show or highlight subsets of contacts.
- Bundles in flight. Define a bundle plan and follow data as it traverses the network.
- Navigation. Fly free or focus any body or node, play the simulation in real time or sped up, jump to a specific timestamp.



Venus network with two filtered contact sets connecting to Earth.

Try it yourself: IPN-v [1] is fully open source and available on Inria's GitLab.
gitlab.inria.fr



Impact: IPN-g and IPN-v were used to review ESOC's DTN reference scenarios [2] prior to publication. IPN-v screenshots are also now a regular part of Solar System Internet outreach.

2 Towards a full Solar System Internet Digital Twin

MOTIVATION

Building a unified, high-fidelity, scalable and accessible framework to model and predict the behavior of the Solar System Internet, capable of mirroring the current state of the future real network or running in autonomous sandbox mode.

Evaluate and optimize before deployment

Cross-layer evaluation and interoperability testing of DTN stacks, routing strategies and protocols under realistic interplanetary conditions.

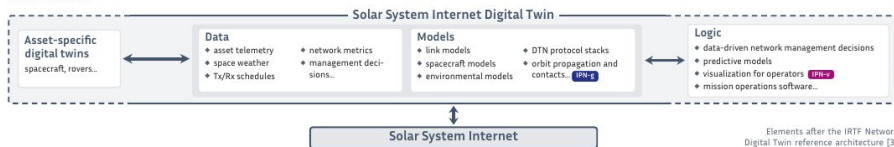
Advanced operational support capabilities

Monitoring and management of the Solar System Internet as it grows, assessment of the network-wide impact of mission-specific operational decisions.

Train operators

Training and decision-support environments that enable operators to explore "what-if" scenarios and understand the behavior of complex interplanetary networks.

ARCHITECTURE



MAIN CHALLENGES

Challenged networks. Link disruptions, high latencies and bandwidth constraints: unavoidable data staleness causing delayed synchronization between the real and twin networks.

→ Evaluate and minimize the average Age of Information metric of the twin [4], perform machine learning on historical data, compress telemetry information and prioritize critical telemetry [5].

No deployed system yet. No real network to interface the twin with, no large traffic dataset to build models on, the precise Solar System Internet architecture is still being defined and will keep evolving.

→ Data generation and augmentation, a modular twin architecture allowing for design changes [5].

Accuracy versus compute. High modeling accuracy, sufficient protocol-stack granularity and orbit propagation precision required to reliably predict the network state when fresh data is not available, raising the cost of using the twin.

→ When possible, interface with existing asset digital twins to avoid redundancies [5].

REFERENCES

- [1] A. Le Bihan et al., "IPN-V: The Interplanetary Network Visualizer", IEEE SMC-IT 2024.
[2] C. Malnati, F. Flentge, "Reference Scenarios for Evaluation of Disruption Tolerant Network Technologies", SpaceOps 2025.
[3] C. Zhou et al., "Network Digital Twin (NDT): Concepts and Reference Architecture", IRTF Internet-Draft, 2026.
[4] F. D. Quazi et al., "Building Delay-Tolerant Digital Twins for Colunar Operations using Age of Synchronization", IEEE ICC Workshops 2024.
[5] H. Al-Hraishawi et al., "Digital Twin for Non-Terrestrial Networks: Vision, Challenges, and Enabling Technologies", 2023.

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A Tool Suite Towards a Solar System Internet Digital Twin

Alice Le Bihan, Lucas Poulhe, Juan A. Fraire, Pierre Francois, Felix Flentge

Inria Lyon · ESA/ESOC

60 s pitch

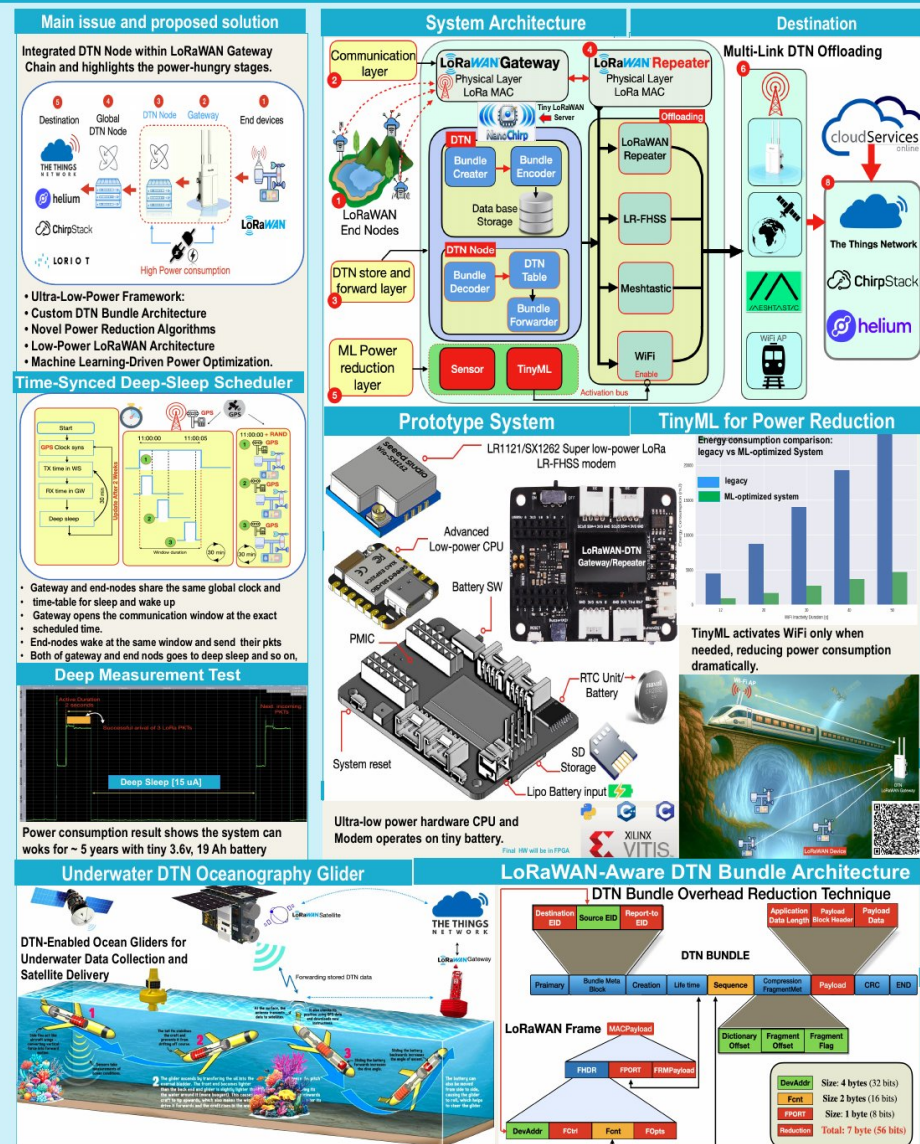
Board goes up Tuesday morning

PDF on stintworkshops.org

Ultra Low-Power DTN Framework for LoRaWAN®

Moez Altayeb

PhD, Postdoc @ ICTP (03-2026) Trieste, Italy



POSTER 6 of 9

Ultra Low-Power DTN Framework for LoRaWAN

Moez Altayeb

The author could not travel to Leuven: no pitch and no board on Tuesday. The poster is online only, on stintworkshops.org.

Online only

PDF on stintworkshops.org



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

Inria

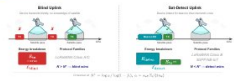
POSTER 7 of 9

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

Benoît Coeugnet, Alexander Choquenaira Florez, Juan A. Fraire

Inria Lyon

Why DTS-IoT is hard



Blind versus satellite-detect uplink.

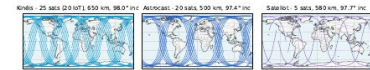
- DTS-IoT is an architecture where resource-scarce, battery-powered IoT terminals directly communicate with orbiting gateways during satellite passes.
- Coverage is intermittent and latitude-dependent. Reliability comes from repetitions; repetitions cost energy and spectrum.
- Access, routing and store-and-forward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

Accelerated simulations are crucial.

FLoRaSat: an open simulator for Dts-IoT

Scenario & constellation helper	TLE, Walker, Kinéis, Starlink
Device model	LoRa / LoRaWAN PHY+MAC · K-MAC, BlindTx, SatDetect
Satellite node	gateway · store-and-forward · ISL stack
Routing sandbox	Directed, DDRA, DiscoRoute · CGR / DTN
ML Sandbox	embedded on-device predictors · analytics
OMNet++	INET · FLoRa

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] ComMag22 · [2] WoWMoM22
[3] USCNS25 · [4] SMC-IT24

The scale jump

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

100 000

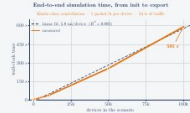
devices, Kinéis-class constellation, one day of traffic

10 min

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

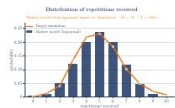
10 000

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



1 Analytical MAC tuning

Coeugnet, Beyer, Deslandes, Fraire · Kinéis / Inria / IRIIT



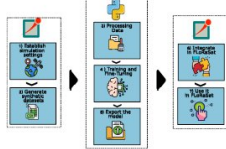
Markov model against FLoRaSat at the Equator: the simulator is the ground truth.

- 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 4x 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.

Linear models lands similar performance across a 10³ 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, JUCNC24) · 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

github.inria.fr/fraire/floresat

Next up: DTN/CGR release soon. Bring your MAC or routing scheme and benchmark it against ours.

juan.fraire@inria.fr



Clone the simulator

60 s pitch

Board goes up Tuesday morning

PDF on stintworkshops.org

LUNANET-SIM:

AN OPEN-SOURCE, BROWSER-BASED 3D INTERACTIVE TESTBED FOR CISLUNAR
DELAY-TOLERANT NETWORKING WITH VERIFIED HARDWARE
INTEROPERABILITY

RESEARCH HIGHLIGHT

3D REAL-TIME
CISLUNAR SIMULATION

RFC 9171 COMPLIANT
DTN STACK

VERIFIED HARDWARE
INTEROPERABILITY
WITH AALYRIA'S HARDY

THE CHALLENGE

- Reliable lunar communication is central to NASA's Artemis program and LunaNet.
- Today's DTN/LunaNet simulators are expensive, non-interactive, and require a full Linux setup.
- Hands-on research is out of reach for most students, educators, and independent researchers.

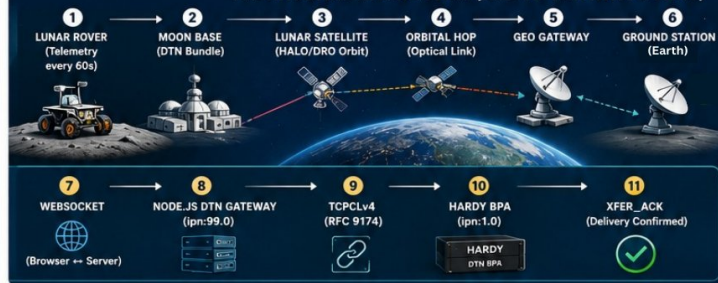
OUR GOAL

Build a 3D LunaNet simulator that visualizes cislunar communication in real time — and prove it isn't just a toy by validating it against Aalyria's Hardy, a production-grade DTN stack, through real hardware interoperability testing.

METHODOLOGY

- 3D Visualization Layer** — CesiumJS on real astronomical data; satellites in true orbits, laser links, moon bases and rovers as live network nodes.
- Protocol Layer** — RFC 9171 DTN store-and-forward with priority-queued bundles. Routing via CGR (orbital pathfinding) and Greedy/Hierarchical protocols.
- Hardy Interoperability** — Node.js DTN gateway (TCPCLv4 from scratch) bridges WebSocket to a live TCPCLv4 session with Hardy BPA.
- Dashboard** — Clean, accessible UI to select nodes and study packet delivery live—no command line required.

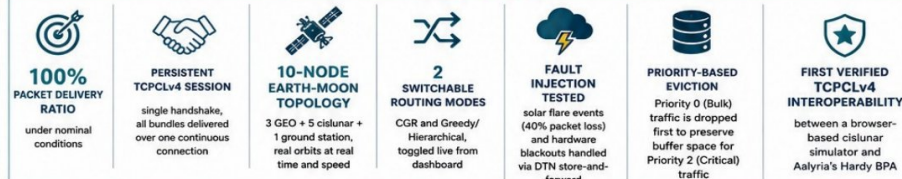
ARCHITECTURE & DATA FLOW (END-TO-END DTN PIPELINE)



FEATURE HIGHLIGHTS

- Persistent TCPCLv4 session — single handshake, all bundles over one continuous connection
- 2 Routing Modes — CGR and Greedy/Hierarchical, switchable live
- Fault Injection — Solar flares (40% packet loss) and hardware blackouts
- Priority-Based Eviction — Priority 0 (Bulk) dropped first to preserve Priority 2 (Critical) traffic

KEY RESULTS



WHY IT MATTERS

As NASA works toward a sustained human presence on the Moon, a dependable LunaNet is essential — and so is the ability to study it. Today that ability is largely limited to official channels. LunaNet-Sim is free, open-source, and runs entirely in a browser, letting researchers and educators test real routing protocols like CGR and Greedy/Hierarchical, then validate results against production DTN hardware — no specialized lab required.

KEY CONTRIBUTIONS

- First open-source, browser-based 3D interactive simulator of the NASA LunaNet architecture
- First verified TCPCLv4 hardware interoperability between a cislunar simulator and a production DTN stack (Aalyria's Hardy BPA)
- Full-stack pipeline: 3D visualization → WebSocket bridge → persistent TCPCLv4 session → XFER_ACK-confirmed delivery
- RFC 9171-compliant DTN stack with CGR, Greedy routing, class-of-service priority queuing, preemptive buffer eviction, and fault injection

RECOGNITION

- Reviewed and recognized by **Dave Israel**, NASA LunaNet Architect
- Reviewed and recognized by **Rick Taylor**, Tech Lead, Aalyria Technologies
- Invited to present at **IEEE STINT 2026** by **Juan A. Fraire**, STINT Co-Founder, Inria

SCAN TO WATCH THE DEMO



www.linkedin.com/in/syed-talha-jamal

LunaNet-Sim: An Open-Source, Browser-Based 3D Interactive Testbed for Cislunar Delay-Tolerant Networking with Verified Hardware Interoperability.
Authors: Syed Talha Jamal, Saad-Ullah-khan, Daniyal Ahad · SSUET, Karachi, Pakistan

POSTER 8 of 9

LunaNet-Sim: An Open-Source, Browser-Based 3D Interactive Testbed for Cislunar Delay-Tolerant Networking with Verified Hardware Interoperability

Syed Talha Jamal, Saad-Ullah-khan, Daniyal Ahad

Sir Syed University of Engineering and Technology, Karachi

The authors could not travel to Leuven: no pitch and no board on Tuesday. The poster is online only, on stintworkshops.org.

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Space-testing of picoD3TN through ESA's OPS-SAT Space Lab Program

Max Chateau^{1, 2} Marius Feldmann¹ Felix Walter¹² Polytech Montpellier, University of Montpellier

IEEE WISEE 2026 - STINT Workshop

I Background: ESA OPS-SAT Space Lab Program

What is the OPS-SAT Space Lab ?

- Service provided by the European Space Agency (**ESA**) for European and Canadian institutions and industries.
- Allows to **realise space experiments** fast and with massively reduced cost, with the goal to accelerate innovation.
- Uses Linux as execution environment for the experiments.
- Operated by ESA - European Space Operations Centre. (**ESOC**)

OPS-SAT website: <https://opssat.esa.int/>

II picoD3TN, a Rust BP implementation by D3TN

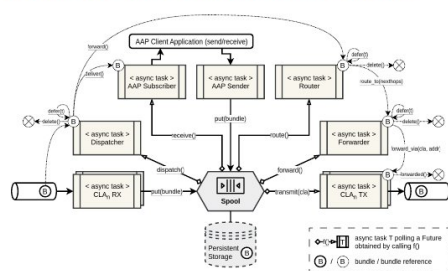


Figure: Overall structure of picoD3TN BPA

III Space Field Tests for picoD3TN

- Test 1: simple ping-pong test to validate picoD3TN fundamentally.
- Test 2: **BPSec**, transferring signed and encrypted Bundles.
- Test 3: exploring **SAND** and UDPCL for node discovery.

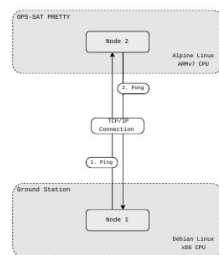


Figure: Test 1: Flow of the Ping Experiment

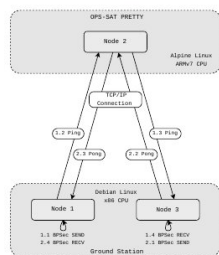


Figure: Test 2: Flow of the BPsec Experiment, signing (BIB) and encryption (BCR) added to each bundle's payload block

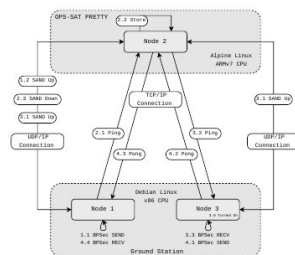


Figure: Test 3: Flow of the final experiment, involving BPsec, SAND and UDPCL (ran on FLAT-SAT. OPS-SAT tests still ongoing)

IV Acknowledgments and References

Thanks to OPS-SAT team, in particular Nuno Carvalho and Maximilian Henkel who helped us a lot during the experimentation process.



STINT Workshop 2026

Co-located with IEEE WISEE 2026 - Leuven, Belgium
14-15 September 2026

POSTER 9 of 9

Space-Testing of picoD3TN Through ESA's OPS-SAT Space Lab Program

Max Chateau, Marius Feldmann, Felix Walter

D3TN GmbH · Polytech Montpellier

picoD3TN

What is picoD3TN ?

- Open-Source and lightweight implementation of the **Bundle Protocol (BP)** v7 in Rust.
- Developed based on our experience with **µB3TN** and a modern, storage-centric architecture.
- Compatible with **µB3TN** and applications building on top of it, due to usage of the Application Agent Protocol version 2 (AAP2); supports **BPsec**.
- Space-Tested through the OPS-SAT Space Lab on the OPS-SAT PRETTY.
- Uses BPsec implementation from Hardy. (a BP implementation done by Aalyria)

Main advantages of this BP implementation

- Lightweight, intended to be used on "Edge nodes" due to its simple behaviour.
- no-std: Components can be used on microcontrollers.
- Commercial support and integration services offered by D3TN.

picoD3TN's repository: <https://gitlab.com/d3tn/picod3tn>

Hardy's repository: <https://github.com/ricktaylor/hardy>

Thank you, poster presenters

STINT 2026

See you at the boards on Tuesday

Posters go up on Tuesday morning and stay on display all day · PDFs at stintworkshops.org

Up next · Welcome activity, 18:00 · Leuven Botanical Garden