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The Internet Research Centre

NTN developments and contributions: from design principles towards in-field demonstrations

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IETF 123 - 24th July 2025 - Madrid

CERCA Centres de Recerca de Catalunya

tecnio catalonia | ACCIÓ Generalitat de Catalunya

Outline

1. Introduction to Non-Terrestrial Networks (NTN)
2. Contributions to IoT services from NTN
3. In-orbit Demonstrations and Missions
4. In-field use cases
5. Conclusions and key messages

1. Introduction to NTN

3D-network composed of

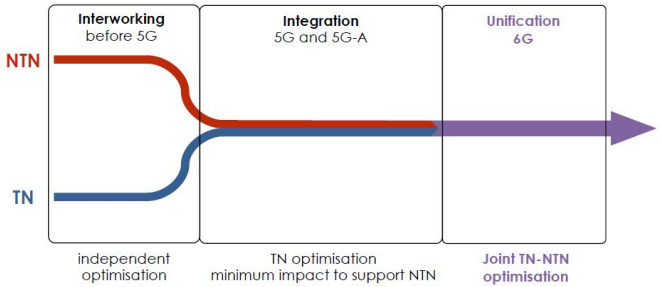
(1) Terrestrial nodes,

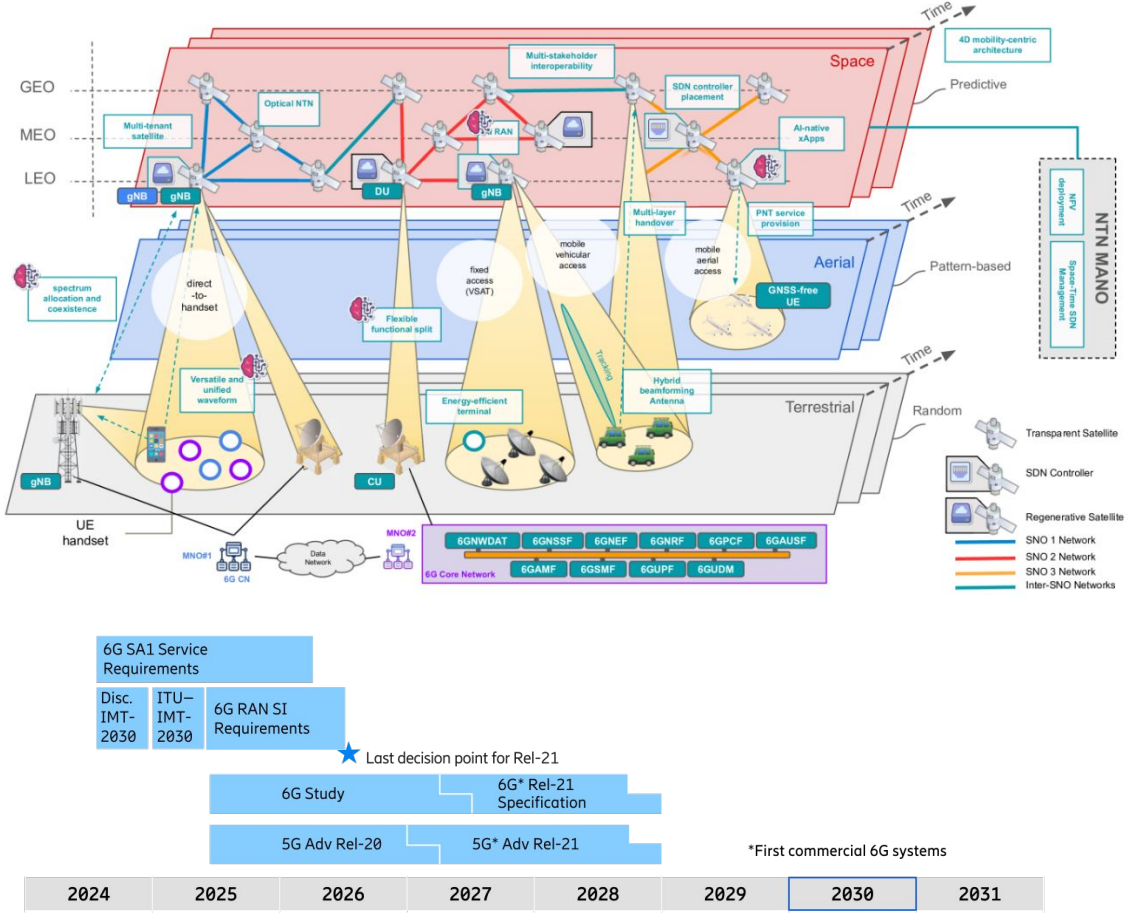
(2) Aerial nodes, and

(3) satellite nodes

Multi-layered and hierarchical structure

Integration of NTN with TN main challenge





1. Introduction to NTN - Commercial Initiatives

Direct-to-Device

Description

Direct connection from phone to satellite

Messaging, voice and data services

Share cellular frequency band

Adapt satellite frequency band

Initiatives

AST SpaceMobile (AST)

SpaceX and T-Mobile (SXTM)

Globalstar-Apple System (GAS)

Fixed Wireless Access

Description

Custom modems to connect satellites

Local network deployed

Voice and data services

Dedicated frequency band

Initiatives

Starlink (SL)

Data Backhauling

Description

Custom high-throughput connection

Satellite to adhoc modem

High-throughput satellites (7.5 Gbps)

Potential usage of Inter-Satellite Links

Initiatives

O3b

OneWeb (OW)

Telesat Lightspeed (TL)

IoT Connectivity

Description

Direct or indirect connection of sensors

Adaptation of traditional satellites

Custom or standard protocols

LEO and GEO solutions

Initiatives

Orbcomm (OMM)

Swarm (SW)

Sateliot (SIOT)

Ligado (LIG)

Wideband / Broadband

Local Area IoT service

Wide Area IoT service

3GPP A GLOBAL INITIATIVE

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1. Introduction to NTN - IoT NTN architectures

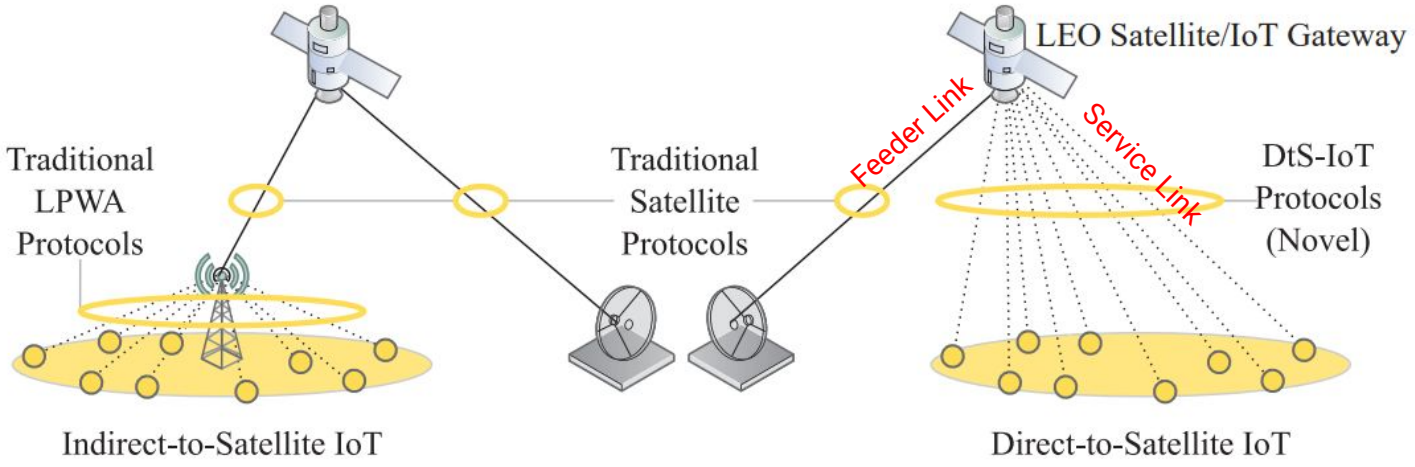


Figure 3. IoT satellite architectures (credits to [Fraire2019])

Local Area IoT service

Wide Area IoT service

[Fraire2019] Fraire, Juan A., Sandra Céspedes, and Nicola Accettura. "Direct-to-satellite IoT-a survey of the state of the art and future research perspectives: Backhauling the IoT through LEO satellites." *International Conference on Ad-Hoc Networks and Wireless*. Cham: Springer International Publishing, 2019.

2. Problem Statement - Disruption

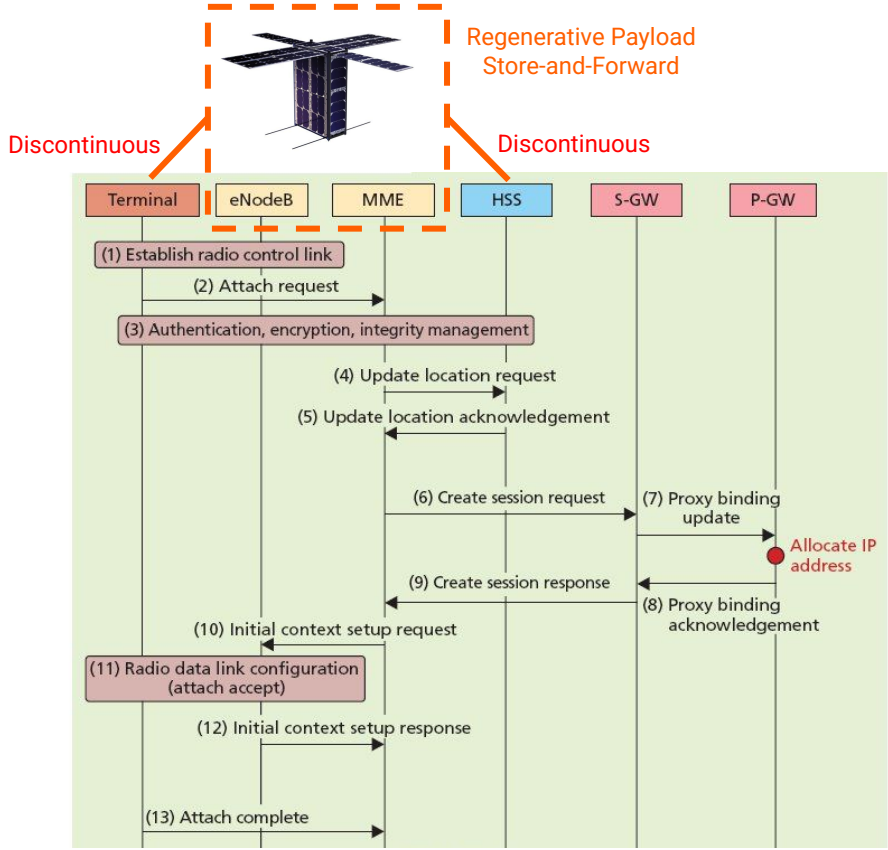
Architecture implications

- Low density LEO satellite constellation
- Limited number of ground stations
- Disruption of service and feeder links

Impact in the 3GPP procedure

- NAS protocol to perform attachment
- NAS protocol to transmit data
- Continuity between Terminal and Core Network is needed

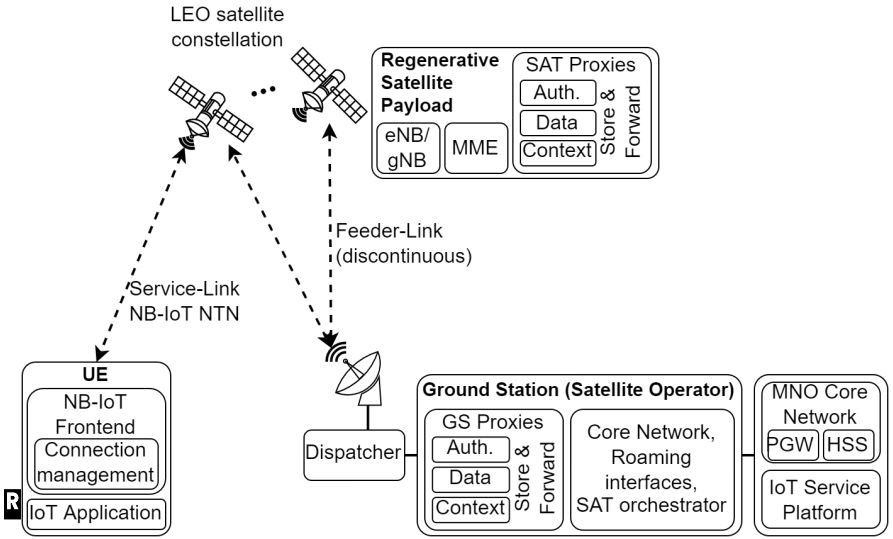
Extension of regenerative payload to support Store-and-Forward capabilities



2. Enabling NB-IoT services from NTN

Store and forward based NB-IoT architecture[1]

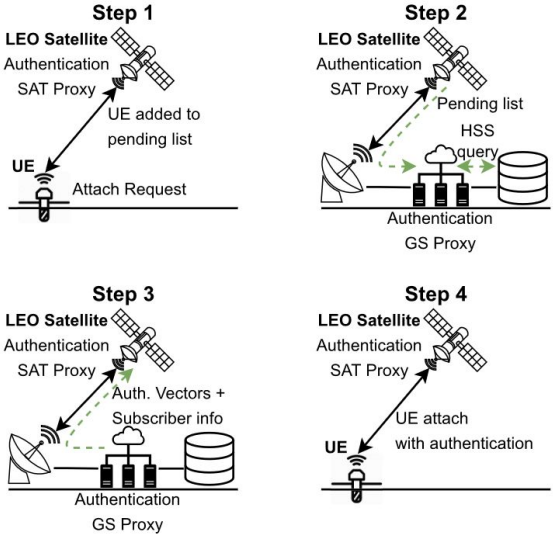
- Network functions in the satellite
- Proxies to manage discontinuity
- S&F capabilities to maintain messages
- **2-step attachment procedure**



Development conducted with **Sateliot**

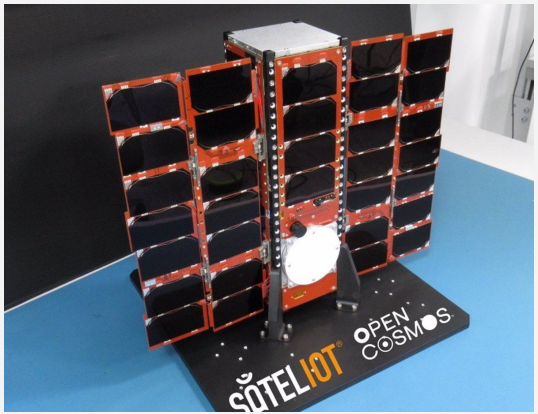
In-laboratory and In-field validation

3GPP standardization – Release 19



[1] Kellermann, Timo, et al. "Novel Architecture for Cellular IoT in Future Non-Terrestrial Networks: Store and Forward Adaptations for Enabling Discontinuous Feeder Link Operation." *IEEE access* 10 (2022): 68922-68936.

3. In-orbit Demonstrations and Missions



Enxaneta Mission

3U CubeSat developed by **Sateliot**

Operative from 2021 to 2023

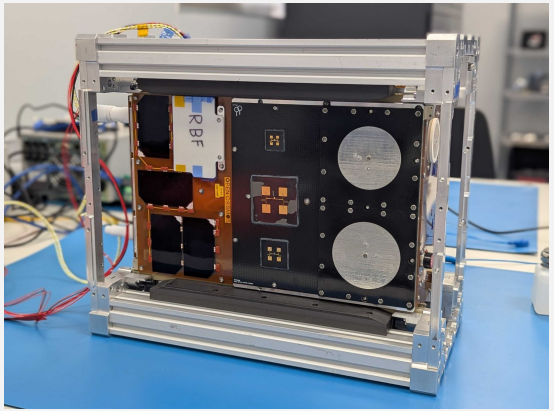
IoT proof-of-concept demonstration

Minairó Mission (Ongoing)

6U CubeSat developed by **Sateliot**

In orbit since April 2023

NB-IoT technology demonstrator



6GStarLab Mission (Ongoing)

6U CubeSat developed by **i2CAT**

In orbit in October 2025

NTN in-orbit laboratory

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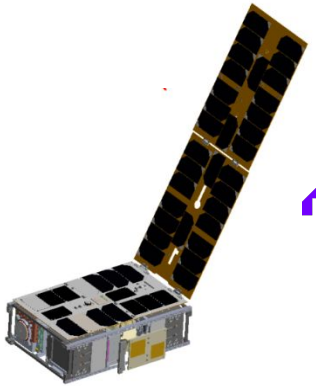
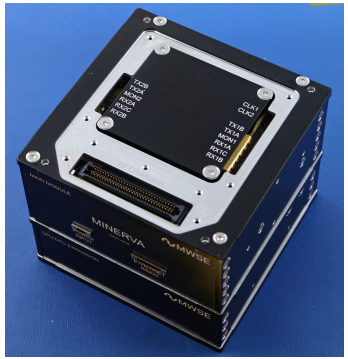
3. 6GStarLab Mission

- Reconfigurable to each experiment
- 2 Software Defined Radio – RF payload
- 1 Optical terminal
- Part of the ESA's 6G OpenLab

Band	Mode	Channel BW	TX power	RX NF	Antenna
UHF 435-438 MHz	TDD	15 kHz	1 W (30 dBm)	< 2 dB	0 dBi monopole
LoRa 869 MHz	TDD	125 kHz for LoRa 15 kHz for QPSK	1 W (30 dBm)	< 2 dB	0 dBi monopole
n256: 1980-2025 MHz UL 2170-2200 MHz DL	FDD	GS: 1 MHz Mobile: 15 kHz	2 W (33 dBm)	< 2 dB	9 dB RHCP patch for both UL and DL
X-band 10.45 GHz	TDD	0.5 MHz	2 W (33 dBm)	< 3 dB	12 dB 2x2 linear array
n512: 19.0-20.0 GHz DL 29.0-30.0 GHz UL	FDD	1 MHz	2 W (33 dBm)	< 3.5 dB	12 dB 2x2 linear array for both





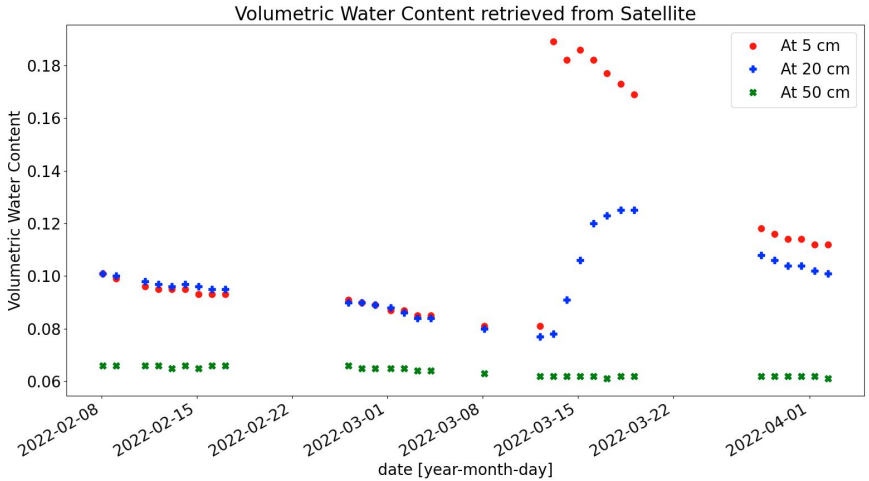
4. In-field Use Cases - Soil Moisture

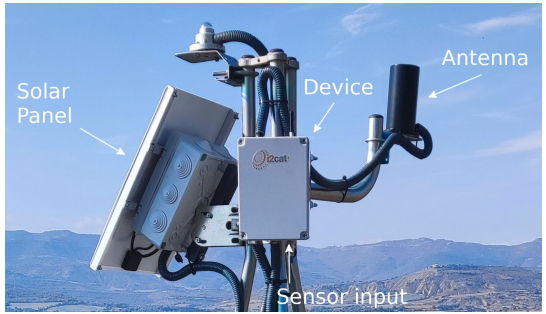
Device that interconnects sensors with satellites [Ruiz-de-Azua2022, Ruiz-de-Azua2023]

VWC retrieved at 5 cm, 20 cm, and 50 cm of depth

Two months of retrieval with three execution phases

Limitations due to channel and location orography





A	Power connector
B	CR800 DataLogger Connector
C	USB Debug Interface Connector

[Ruiz-de Azua2022] J.A. Ruiz-de Azua et al., “Proof-of-concept of direct-to-satellite iot for earth observation applications: Soil moisture experiment,” in IGARSS 2022. IEEE, 2022, pp.7264–7267.

[Ruiz-de Azua2023] J.A. Ruiz-de Azua et al., “Proof-of-concept of direct-to-satellite iot for earth observation applications: Soil moisture experiment,” in IGARSS 2023. IEEE, 2023.

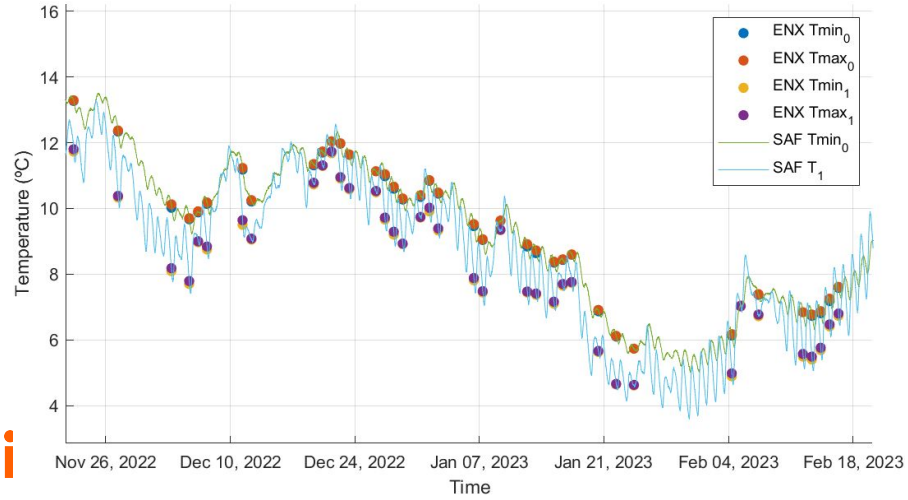
4. In-field Use Cases - Irrigation management

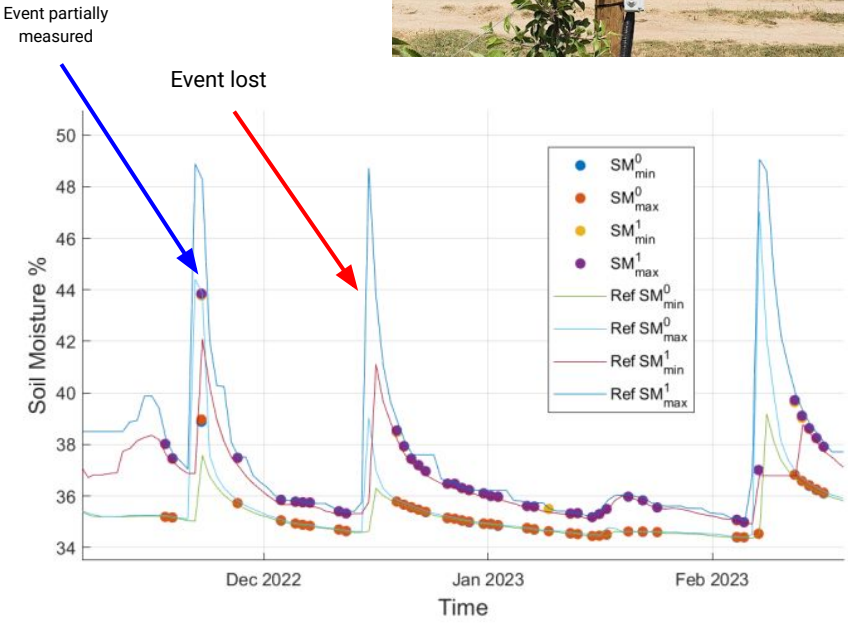
Measurements:

- Soil moisture at 20 (SM^0) and 40 cm (SM^1)
- Atmospheric temperature
- Irrigation water flow

Data retrieved every day

Located in Catalonia (Spain) at 42°3’15.6”N, °3’42.7”E





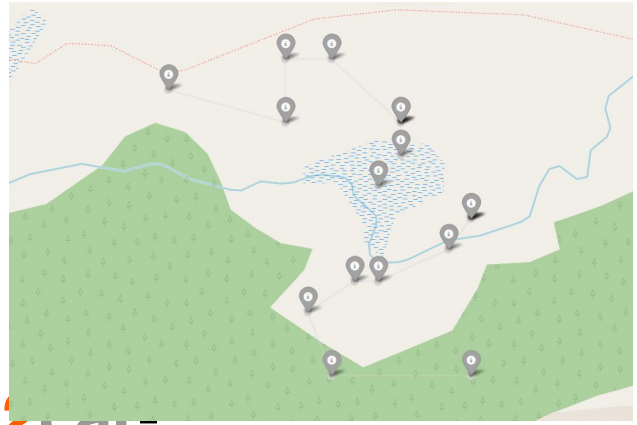
4. In-field Use Cases - Animal Tracking

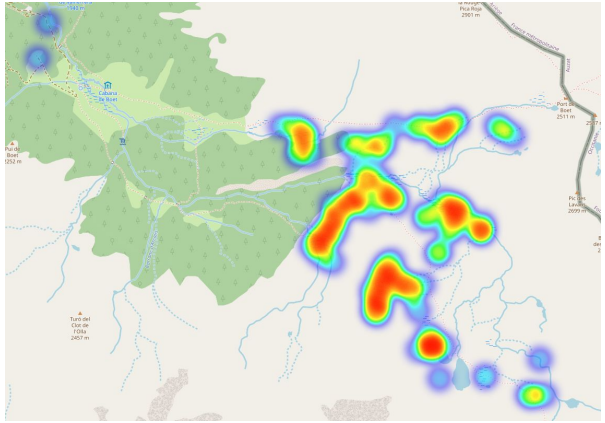
Indirect-to-Satellite architecture

Measurements:
- GPS position
- Time tagged

Data retrieved every 30 minutes

Located in Catalonia (Spain) at
42°35’31.1”N, 1°19’24.4”E





4. In-field Use Cases - Water Reservoir Monitoring

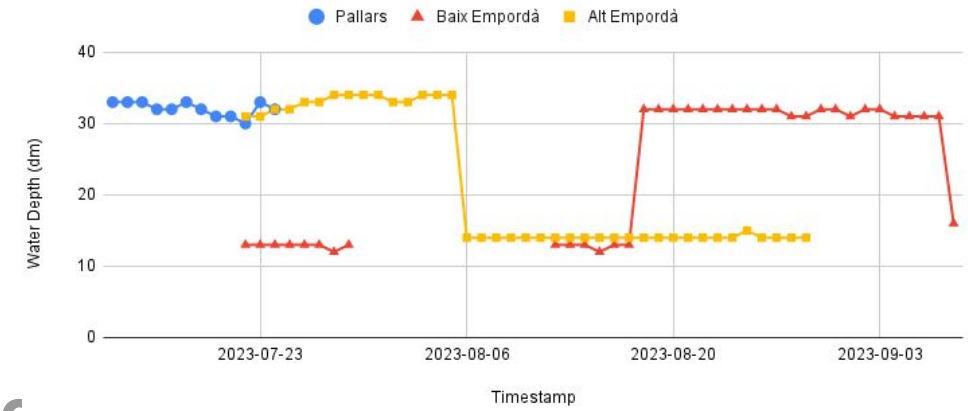
Firefighters need to monitor their remote water reservoirs

Water depth monitored from IoT devices

Deployment of three stations

Decrease of water depth due to usage (yellow line)

Big wildfire emerged in Catalonia



4. In-field Use Cases - Other cases

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5. Conclusions and Key Messages

6G standardization is reaching a crucial phase

Developments conducted for IoT services

Technical challenges still to be addressed to achieve NTN

- RAN, routing, orchestration, core network, transport protocol …

In-orbit infrastructure is needed to contribute to standardization

Use cases demonstrations

- Validate technology developments
- Demonstrate feasibility and benefits to the society

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Thank you

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