Tiny sensors over Geostationary satellites
ESA Telecommunications - what do we do?

We fund research and development in satcom via a program called ARTES (Advanced Research in Telecommunications Systems)

We fund developments or studies in **ground segment, space segment, payload and system** – including in-orbit validation

We issue tenders for **long-term developments** – we fund 100%

**Industry** can always submit a proposal for a development you see a market opportunity for – **we co-fund 80 to 50%, you bring 20 to 50%**

We build partnerships with operators to validate **innovative technology, equipment and services** in-orbit and on-ground

We support European companies with **patents, test facilities**, advice on **regulatory** matters and **technical trade-off’s**.
Question:

Some satellite-specific IoT protocols are have been developed, but can we re-use more from the terrestrial world?
→ This could possibly lead to **very low cost end nodes**.

There are many start-ups looking into new smallsat constellations for IoT, but could we not use existing geostationary satellites for such services?
→ This could possibly lead to **near real-time services**.

Demonstrate performance of terrestrially-inspired protocols **over the air to geostationary satellites**.
Scope of work

- Assess various terrestrial (inspired) protocols
- Initiate small test campaigns
- LoRa over Ku-band and UHF band
- LoRa over GEO in S-band
- UCSS over Ku-, S- and L-band
- TS-UNB over GEO S-band

Satellite capacity

Webcasts with findings
IoT and satellite communications

Geostationary satellite

Non-geostationary satellite
Lora over GEO Ku-band

GeoLoRa
Measurement Campaign (Ku-Band)

EIRP 27 dBm
Min SNR -12

EIRP 24 dBm
Min SNR -15

NOT OK

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Lora over GEO UHF-band

GeoLoRa
Measurement Campaign (UHF)

EIRP 19 dBm
Semtech SX1262
LoRa® Dev Kit

Bitrate 61 bit/s
Bandwidth 7.8 kHz
Spreading Factor 10

Min SNR -16

Bitrate 33 bit/s
Bandwidth 7.8 kHz
Spreading Factor 11

Min SNR -18
Lora over S-band GEO - setup

Echostar XXI (ITU: ECHOSTAR-EML1)

- 2.2 GHz LHCP down
- 2.0 GHz LHCP up

NL beam

Low cost antenna

Lora module

Ka-band feeder link

Griesheim Teleport, D

Beam forming Network

2.2 GHz LHCP down
2.0 GHz LHCP up

Ka-band feeder link

IF frequency 138.5 MHz

-30 dBm

Rx-port

Tx-port

Griesheim Teleport, D

GNU Radio
IQ waveform

"Cloud RAN"

ESTEC, NL, home

GNU Radio
IQ waveform

1 Gbps

10 MHz REF

Raspberry Pi 4
GNU Radio
ZeroMQ
Ubuntu

Public IP

USB 3

10 MHz REF

GNU Radio
IQ waveform

"Cloud RAN"
Lora over S-band GEO – downlink

- 1 kB/minute
- 3 €
Lora over S-band GEO – uplink

LoRa 125kHz/SF11
- EIRP of 8 dBm (linear)
- With a few dB of margin

Absolute minimum
- LoRa 10.4kHz/SF11, LR1110 to LR1110
- EIRP of -5 dBm (linear polarisation)
- 45 bps (excl. error coding)
UCSS over Ku-band

UCSS Multiple Access Demonstration
Ku - Band

User 1
UCSS Transmitter

R&S SMBV
Ku-Band BUC
14 GHz

GEO bent-pipe relay

UCSS Software Receiver
CP-Patch Antenna by ESA

12.5 GHz

SDR Receiver

UniBw Munich Ground Station

UCSS Multiuser Signal
(0-400 users)

R&S SMBV
Ku-Band BUC

User 2, ..., N

Regulatory Limit (Ku-Band):
- 6 dBW in 40 kHz

Minimum Bandwidth:
~ 500 kHz

Link closed:
Bitrate 5.8 bit/s
EIRP 23 dBm
Simultaneous users:
Users 100
Error Rate < 0.01
UCSS over S-band (and L-band)

UCSS Test over Echostar
Setup in S-Band

Multi User Traffic
R&S SMBV → Power Sensor → Power Amplifier → Combiner → Antenna

UCSS packets sent during 2 test days: 3,919,816

GPS receiver → Embedded SDR → Mobile Transmitter

Link closed:
- Bitrate: 12.5 bit/s
- EIRP: -4.5 dBm

Simultaneous users:
- Users: 300
- Error Rate: < 0.001

0.5 mW
50 kHz
60,000 users
768 bytes/day
**TS-UNB over GEO Ku-band**

- **TS-UNB** Telegram Splitting Ultra Narrow Band ETSI Standard: Protocol based on TSMA (TS 103357) - Lightweight, but robust, secure and flexible radio protocol

- **mioty® (Fraunhofer IIS)** Implementation of TS-UNB (nodes and base stations)

- **Native mioty®**: no change of waveform nor decoder required

- **10dBm EIRP** only required to get reasonable low packet error rates

- Even with high system loads (3.5 million telegrams/day, 20 Bytes/200kHz BW) comparable low error rates possible (1% PER)
Plant-powered satellite IoT sensor

Satellite modem *solely* powered by the plant, sending environmental data
Conclusions

- Demonstrated that some terrestrially-inspired, very low data rate, low power IoT protocols work over GEO – often scalable to massive deployments – all with very low cost IoT node costs

- Link budgets and early experiments suggest that scenarios of GEO satcom with individuals/wearables is feasible

- Larger-scale trials with prototype hardware?

- Triggered various requests for other companies for similar testing, claiming “We can do better”!

- New series of tests in February 2022
Areas for future work

1. Novel encapsulations (SCHC RFC 9011) allowing IPv6 over very narrow links
2. Combinations with localisation/RTK
3. Combinations with TinyML/AI – to do smart things at the edge for satcom
4. Combinations with wearables/antennas and energy harvesting
5. Low rate codecs over satellite (M17)
6. Regulatory improvements for Ku-band very-small antennas
Acknowledgements and contacts

1. For GeoLora experiments over Ku-band and UHF, and UCSS over various frequency bands
   - Kai-Uwe Storek storek@neosat.de
   - Christian Hofmann c.hofmann@unibw.de

2. For LoRa over S-band
   - Thomas Telkamp thomas@lacuna.space

3. For TS-UNB over S-band
   - Florian Leschka, Jonas Mrazek florian.leschka@iis.fraunhofer.de, jonas.mrazek@iis.fraunhofer.de

4. General enquiries for future tests/projects
   - Frank.Zeppenfeldt@esa.int