INTERNET OF THINGS IN SPACE

Connecting “things” with nanosatellite mega-constellations

AARHUS UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

DEIC KONFERENCE 2021
3 NOVEMBER 2021

RUNE HYLSBERG JACOBSEN
ASSOCIATE PROFESSOR

OUTLINE

IoT use cases with satellites

CubeSats and the Delphini-1 mission

Mega-constellations

Challenges for routing and mobility

Future space-air-ground integration

IOT CHARACTERISTICS

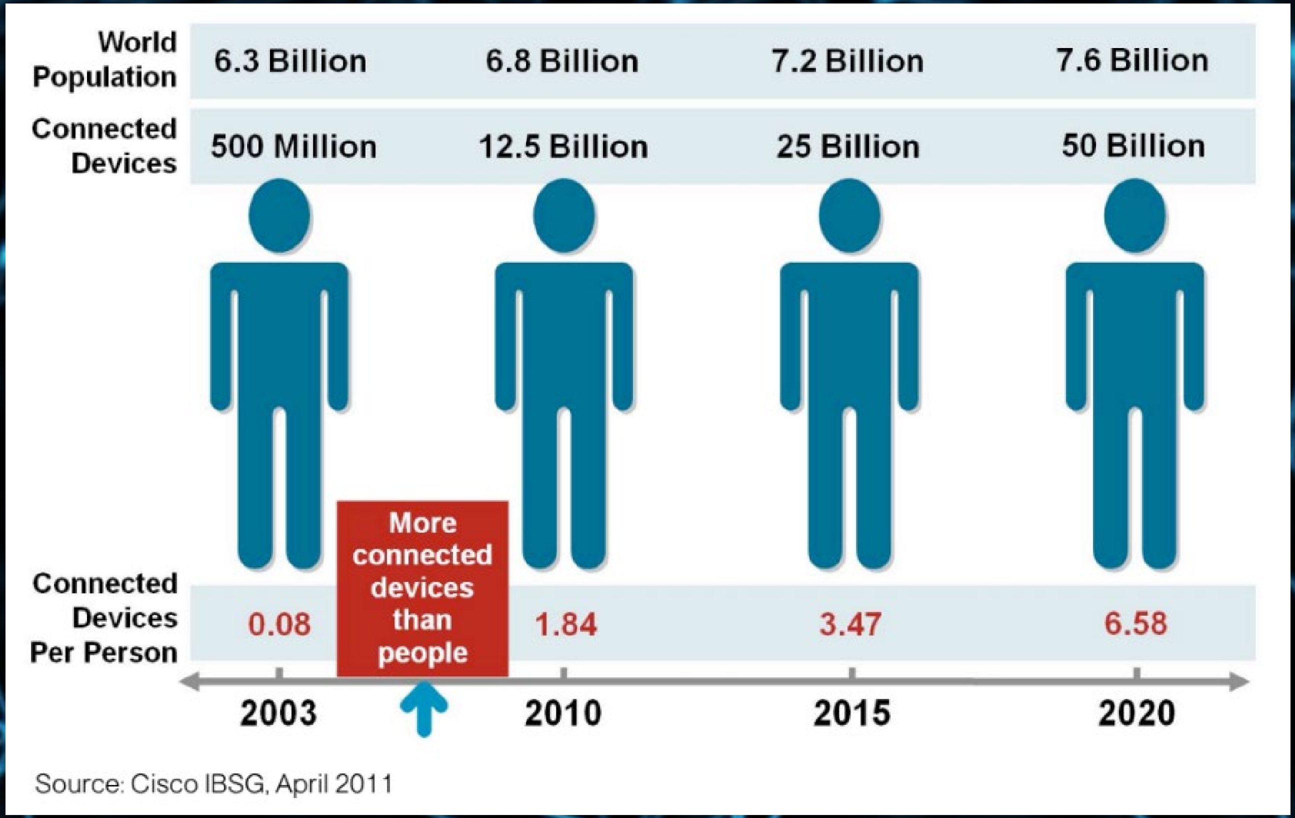
Connectivity
Small devices online

Coverage
Widespread (geographical)

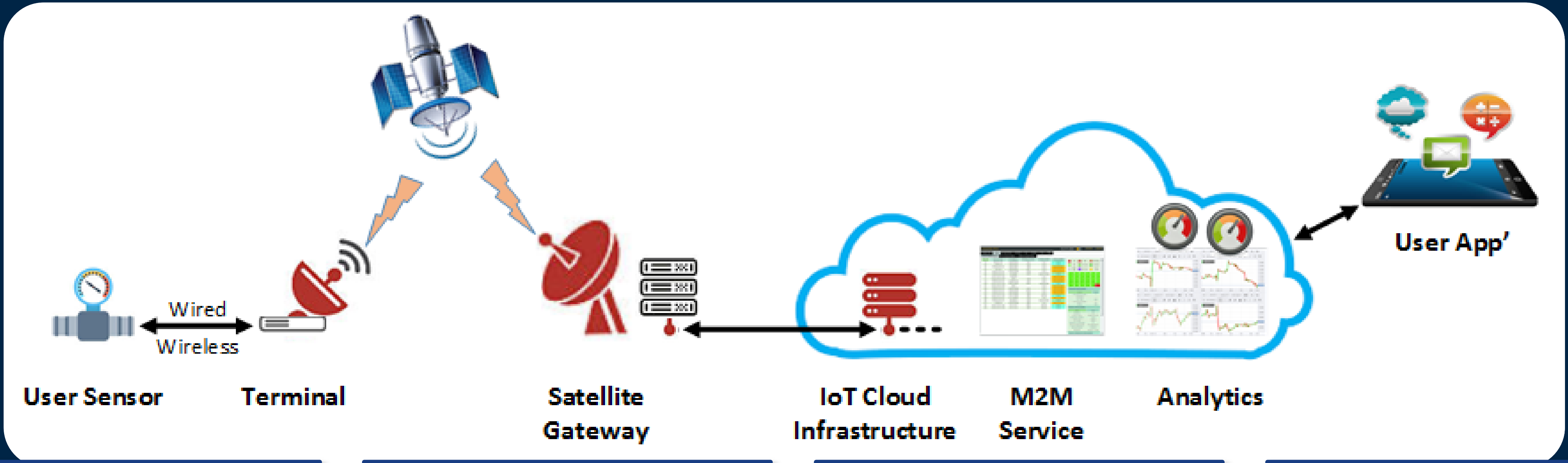
Scale
Large number of units

Resource constraints
Efficient use of energy and radio resources

Cyber Security



IOT USE CASES



Global asset tracking

- Ships/airplane tracking
- Tracking of goods
- Herds tracking

Event detection/alert

- Surveillance
- Natural hazards: volcanic eruptions, tsunami, space weather, etc.

IoT aggregation

- Sensor and actuator networks
- Earth observations & environmental monitoring

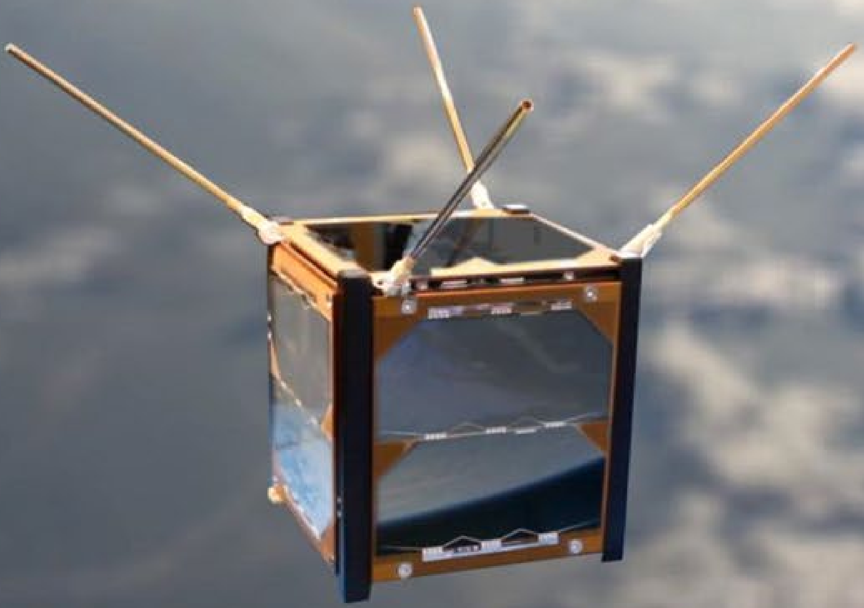
Telecommunications

- Voice and data
- Backup access
- Incident area network
- Relay for other networks

DELPHINI-1 MISSION

5 December 2018 • 31 January 2021 • 14 March 2021

Experience the launch
https://www.facebook.com/UniAarhus/videos/349432732512066/



CUBESAT
THE NEW IOT EDGE DEVICE

Embedded computer; limited processing capability; limited RAM

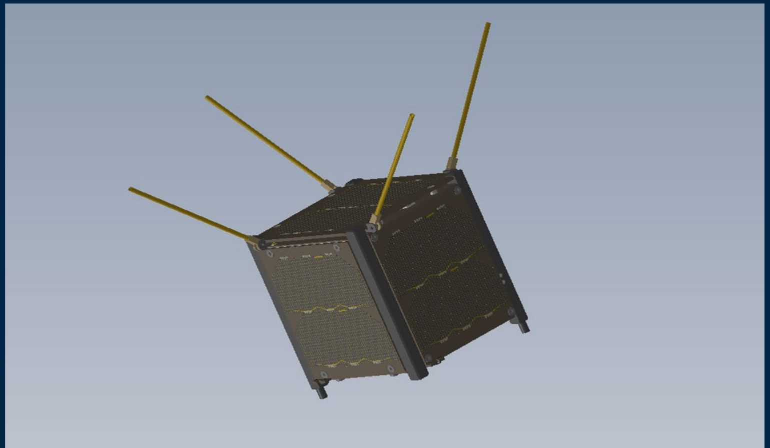
Limited power supply; harvesting & storage

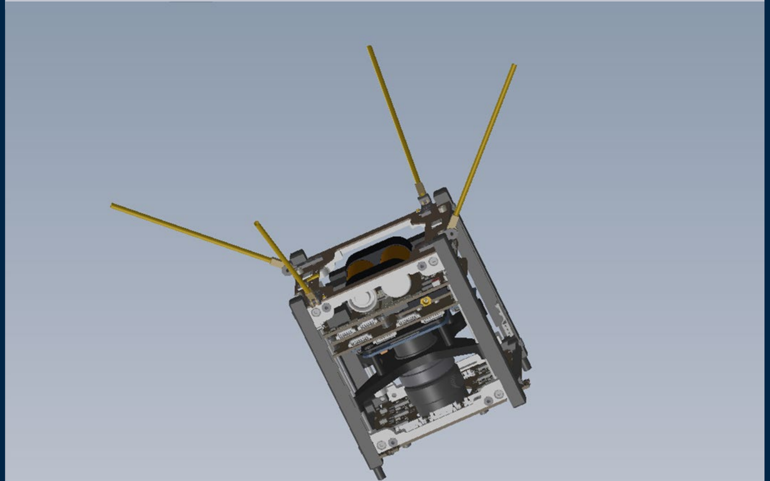
Flash memory

Low-power radios

Typical (minimum) CubeSat sensors setup

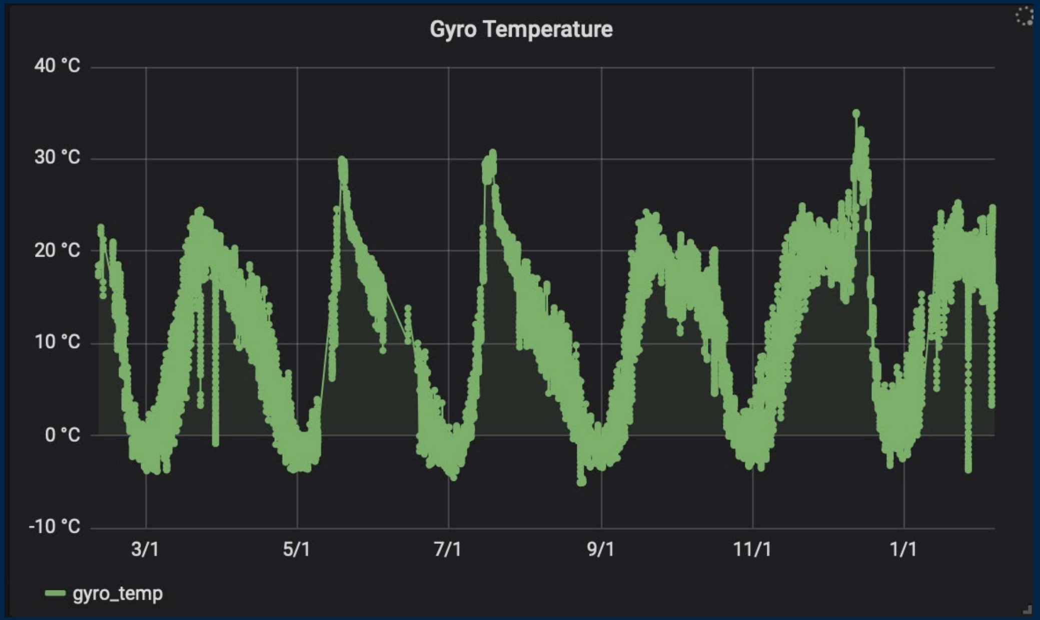
- 6 sun sensors
- 3 axis magnetometer
- 3 axis gyro
- temperature

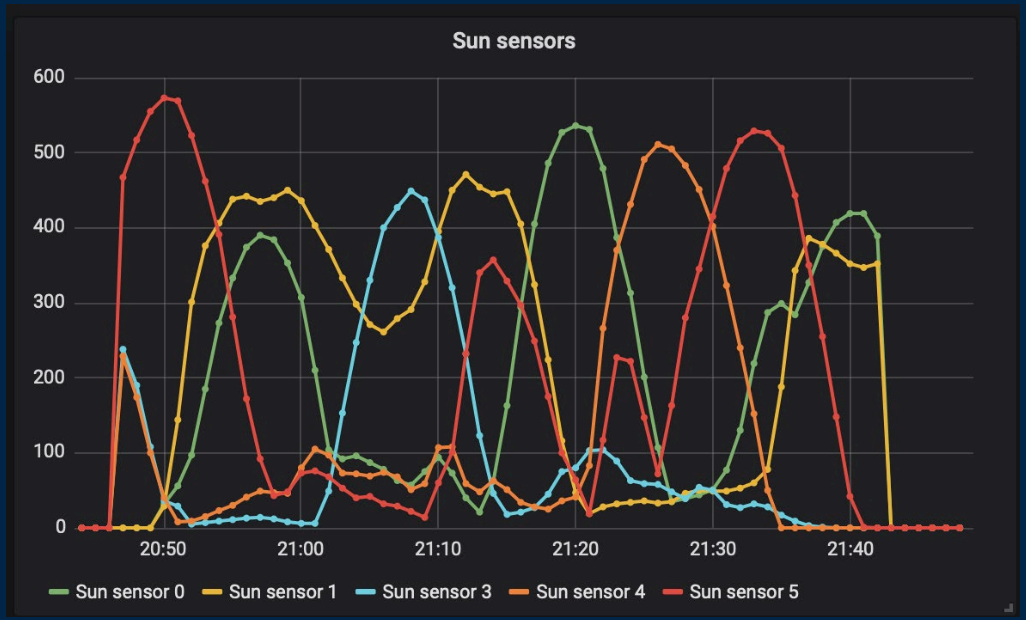

Delphini-1 CAD


Delphini-1 CAD (no fronts)

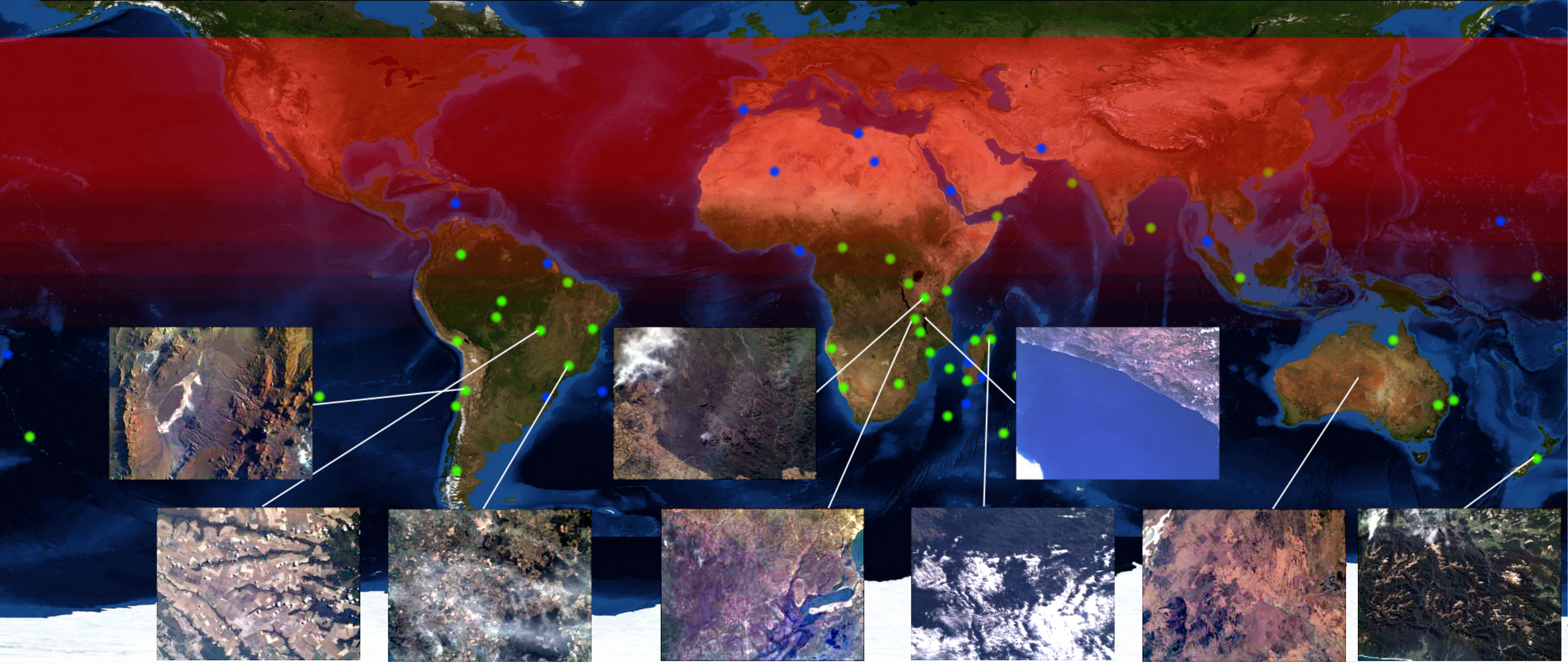
Source: GomSpace (2017)

CUBESAT
THE NEW IOT EDGE DEVICE





DELPHINI-1 IMAGES FROM SOUTHERN HEMISPHERE



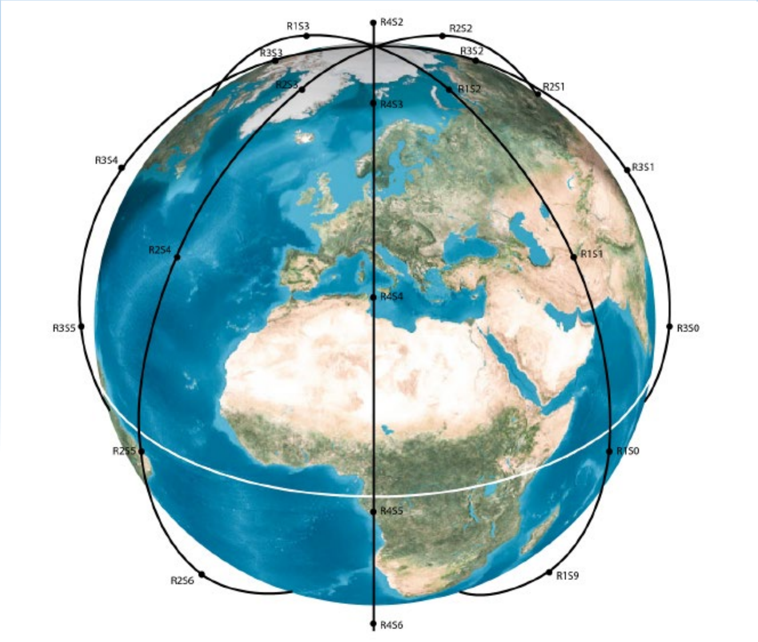
AARHUS
UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

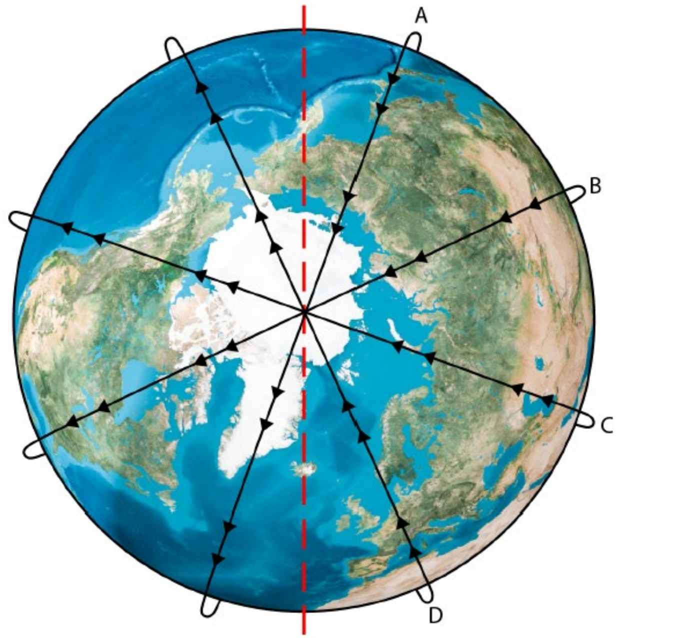
RUNE HYLSBERG JACOBSEN
ASSOCIATE PROFESSOR

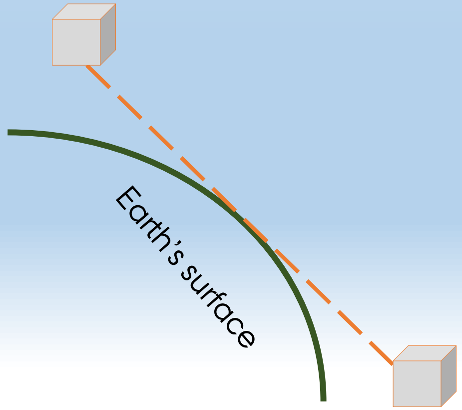
MEGA-CONSTELLATION DESIGN

- LEO orbit: 300 km – 1000 km
- Network design 10/4/0°
- Static/dynamic topology

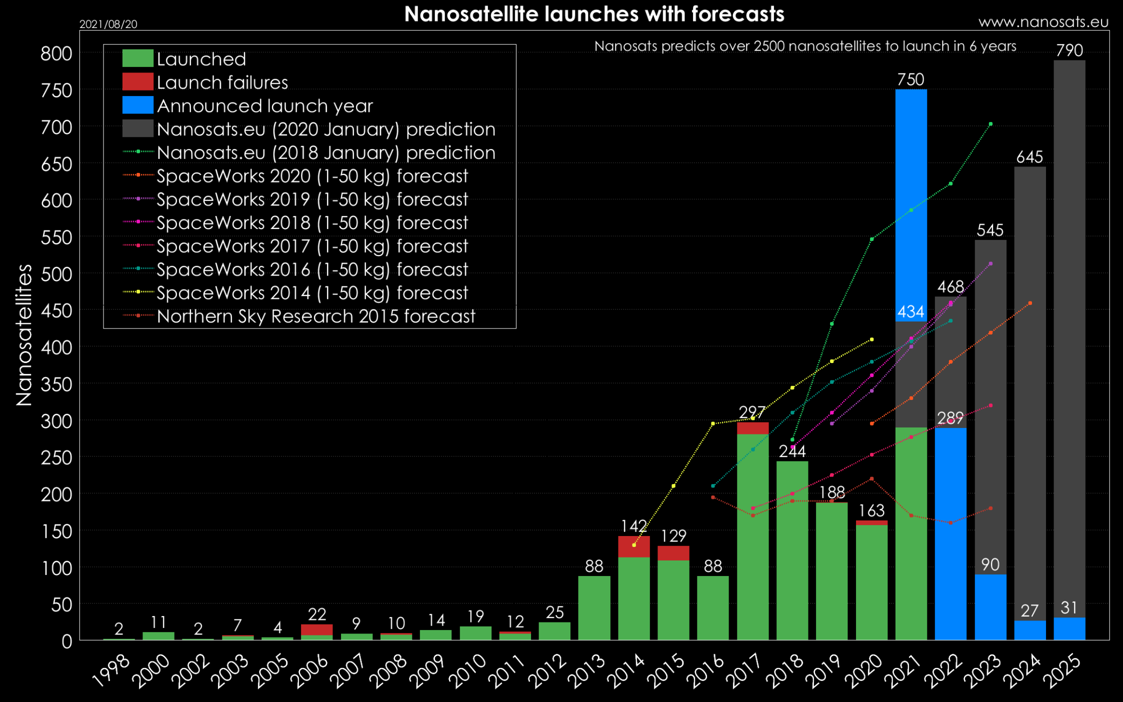
- Resource-constrained devices
- Varying link-stability and link distance
- Large relative motion between some orbits







NANOSATELLITE DEPLOYMENTS



Source: http://www.nanosats.eu/

COMMUNICATION CHALLENGES

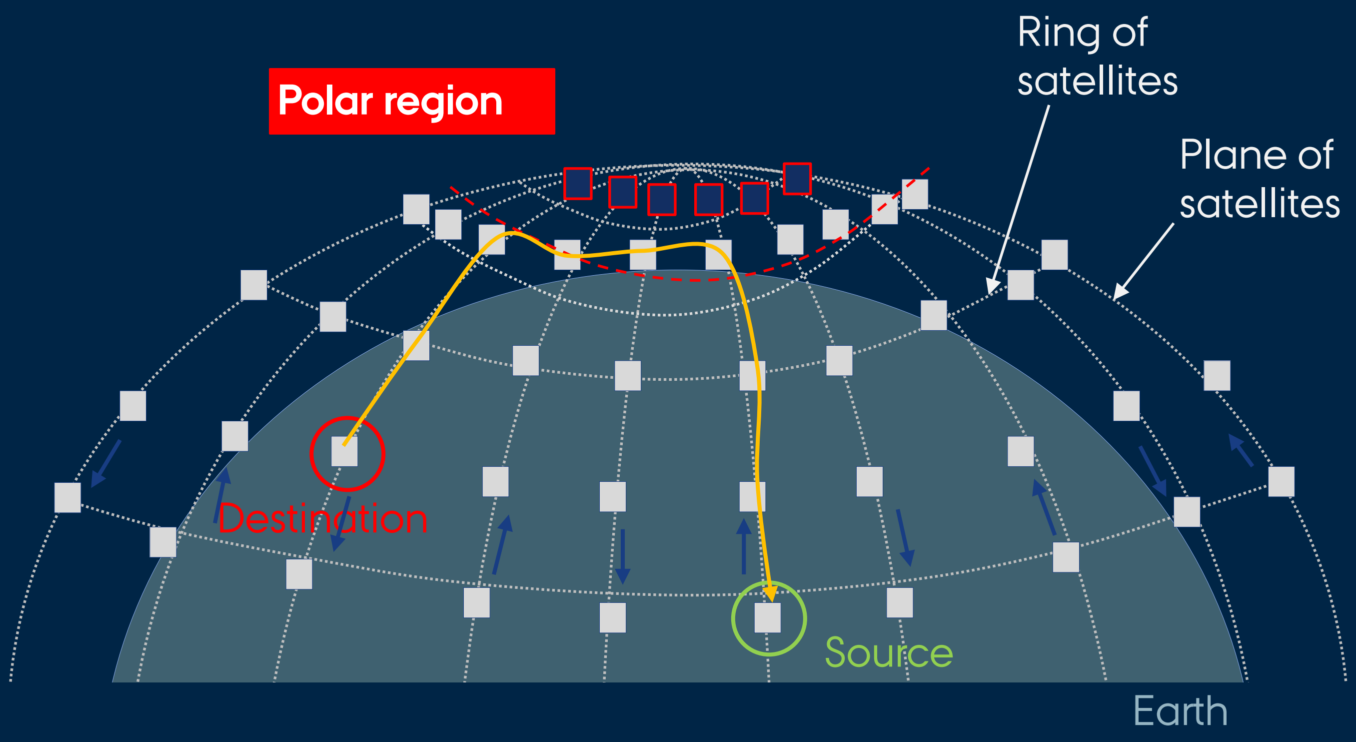
Intersatellite links (LOS/NLOS)

Up/downlink data throughput

Medium access control

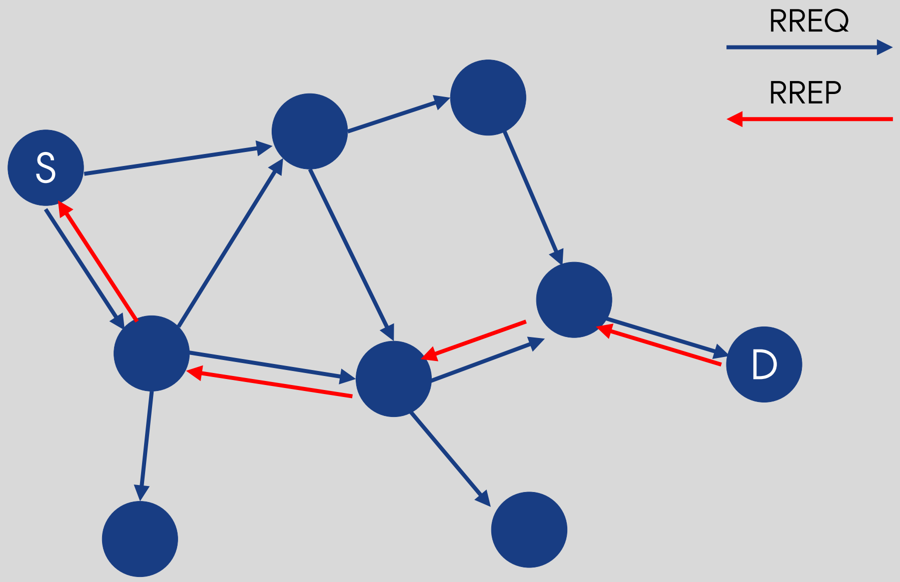
Routing

Mobility management



AD HOC DISTANCE VECTOR (AODV) ROUTING

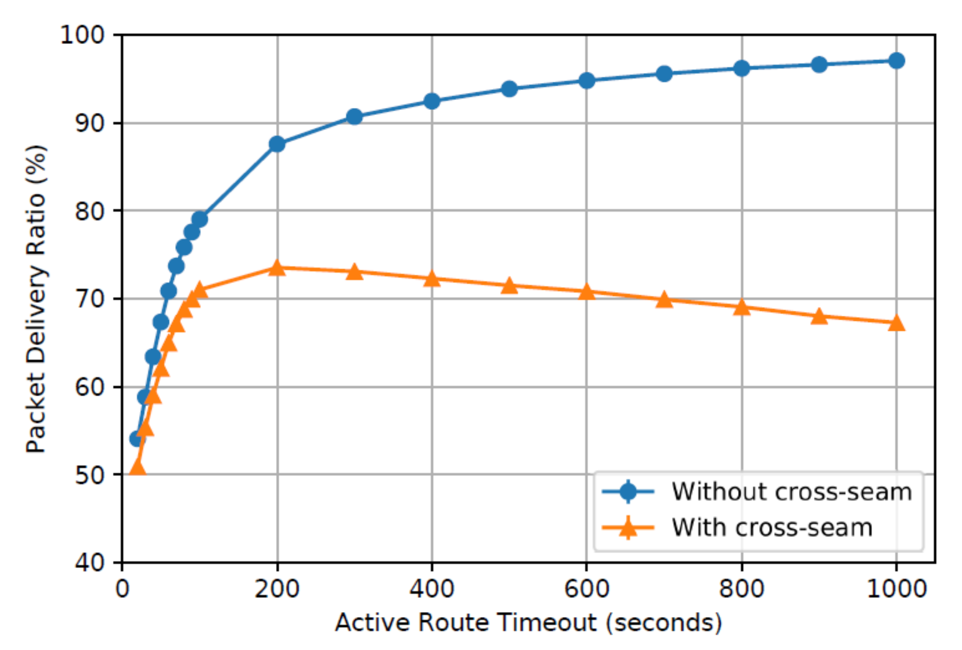
- Designed to handle a relatively high topological dynamics.
- Key protocol messages:
  - Route Request (RREQ)
  - Route Reply (RREP)
  - Route Reply Acknowledgment
  - Route Error
- Depth of route search follows the expanding ring mechanism controlled by TTL
- Links “freshness” is controlled by an Active Route Time out



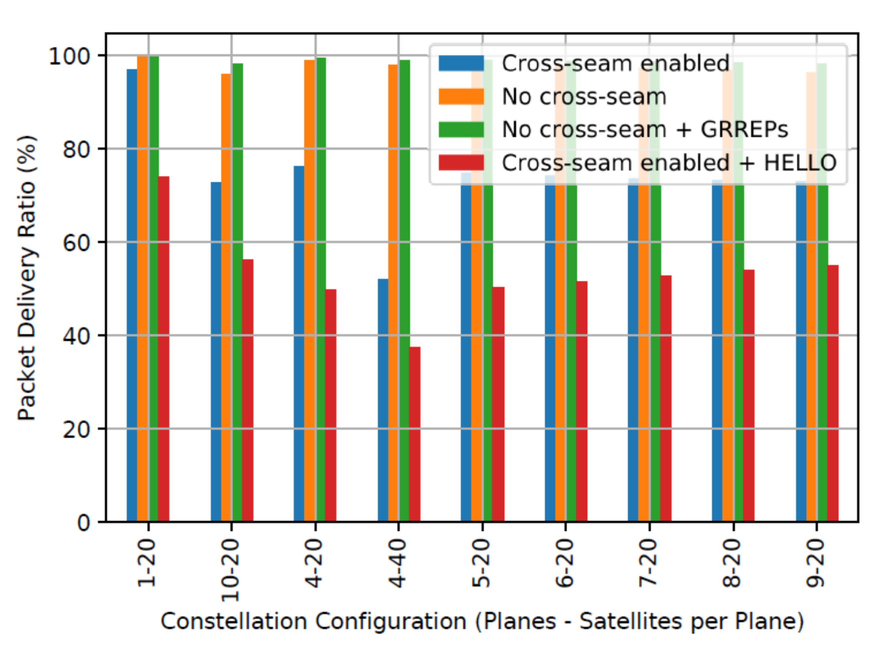
AODV SIMULATION

Packet Delivery Rate (PDR) as function of Active Route Timeout.

- PDR is given by the % of total number of received packets in the network with respect to total number transmitted.



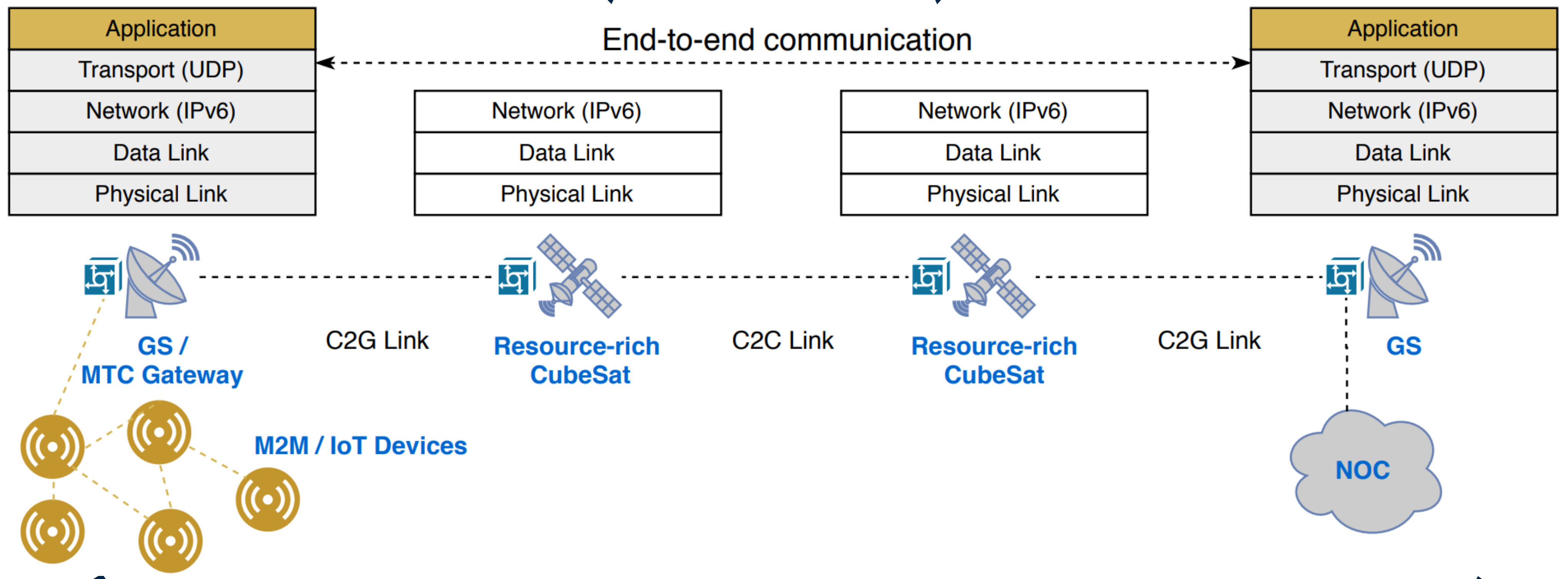
8-20 constellation



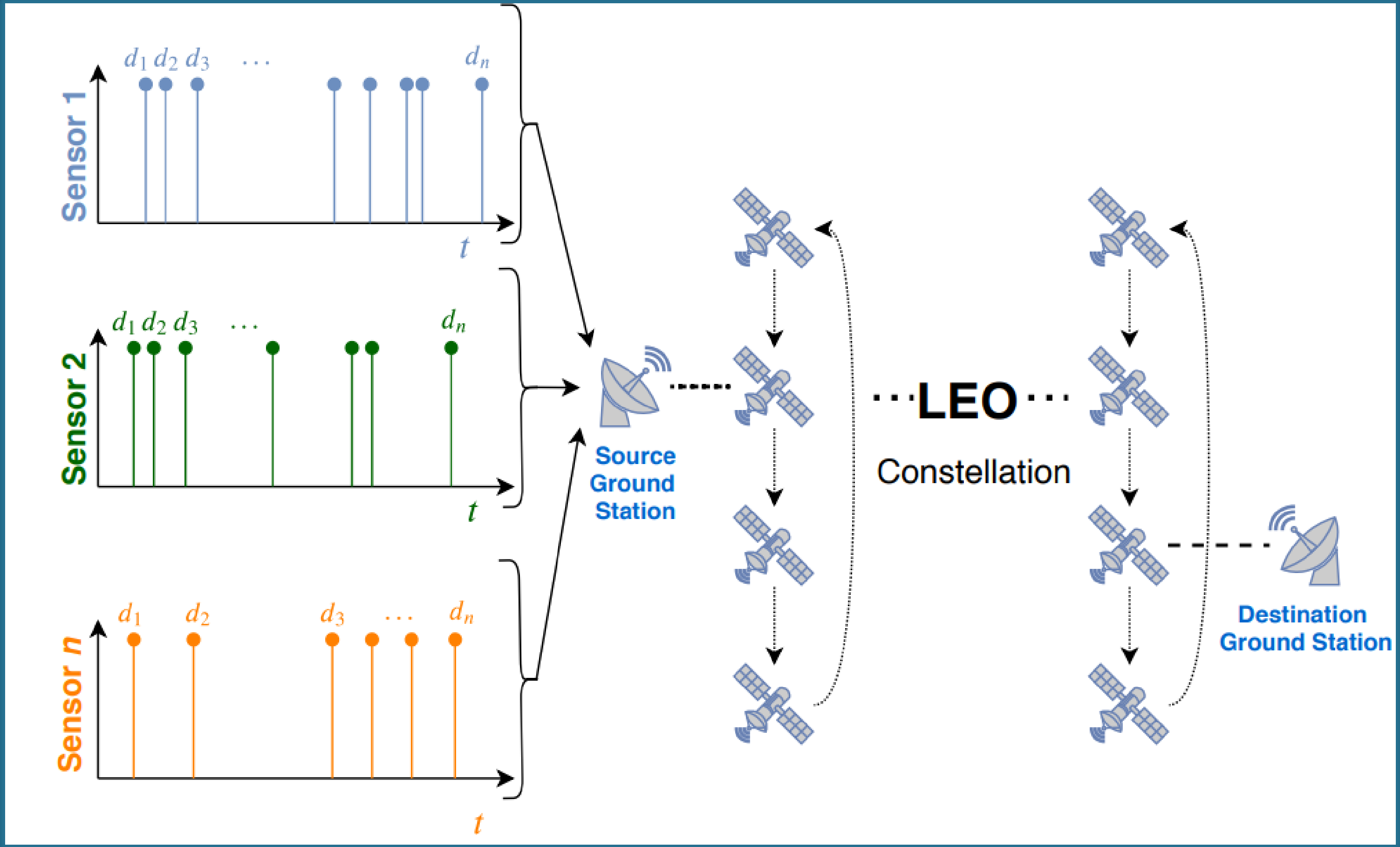
Active Route Timeout fixed at 200 s

Marcano et al. On Ad hoc On-Demand Distance Vector Routing in Low Earth Orbit Nanosatellite Constellations, VTC2020-Spring, 2020

THE MOBILITY CHALLENGE



THE MOBILITY CHALLENGE



"Double mobility problem"

- Both the mobile and the corresponding nodes are mobile

Frequent hand-over

- Relative short access times

Service characteristics

- Latency
- E2E link robustness

THE MOBILITY CHALLENGE

Routing breaks when a mobile IP node changes attachment to the Internet

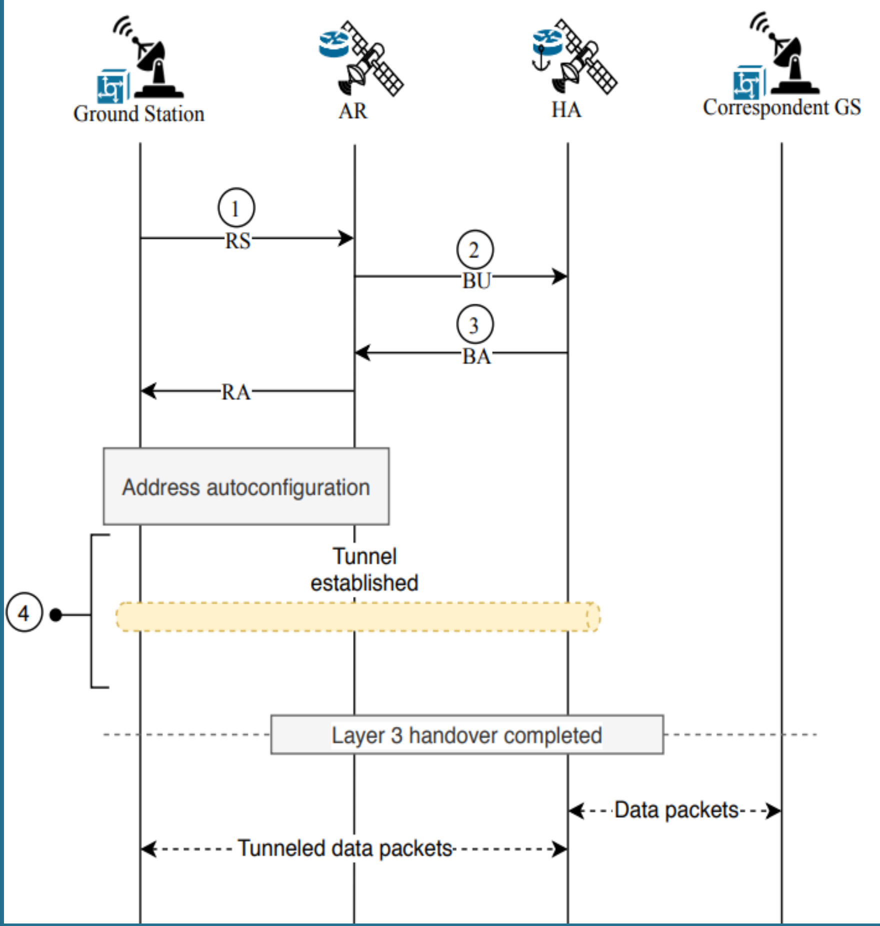
Care-off-address (CoA)

Home agent & binding updates (control)

Route optimization

Currently investigating suitability of the different IP mobility protocols (IETF) for IP networks in space.

- MIP – Mobile IP
- PMIP – Proxy mobile IP
- DMM – Distributed Mobility Management



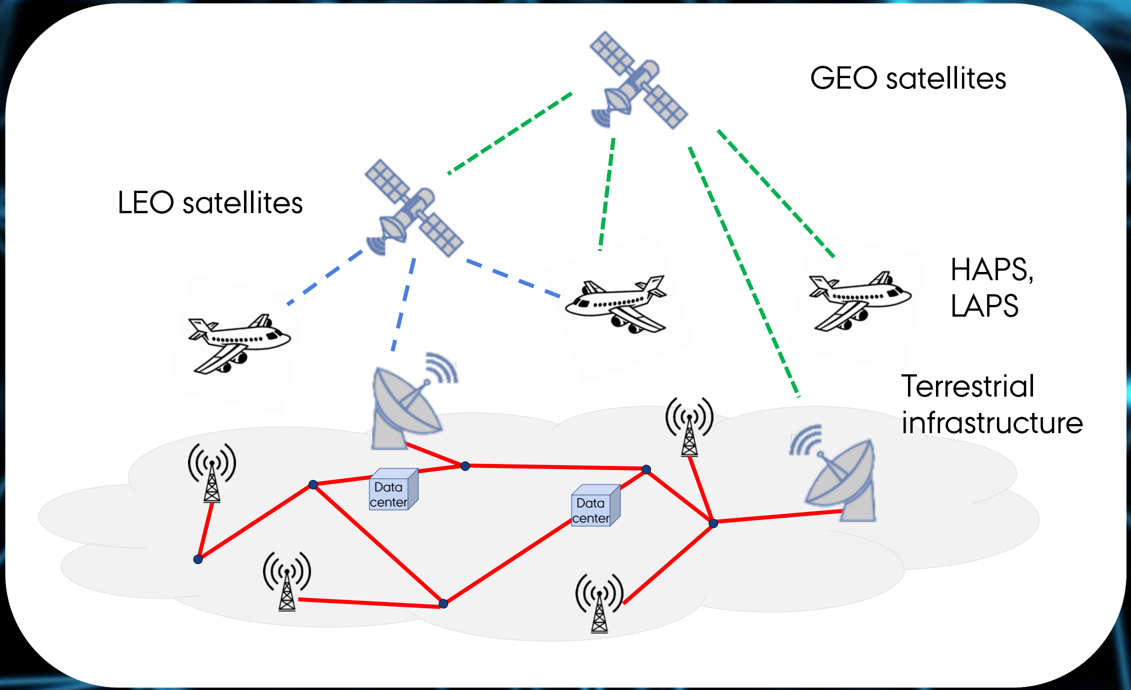
SPACE-AIR-GROUND INTEGRATED NETWORKS

GEO, MEO, LEO satellite constellations

High- and Low Altitude Platforms (HAPS and LAPS)

Mobile infrastructure integration

Backhaul network for IoT devices



SUMMARY

Mega-constellations based on nanosatellites have become an option for connecting IoT devices potentially covering remote areas.

Building, launching and **operating nanosatellites** can be done by "ordinary folks" → Delphini-1.

Research and Innovation in **new network technologies and services** are needed → Examples: routing and mobility.

A view on future **space-air-ground integrated networks**.

DISCO-2: The next student-led CubeSat from Aarhus University with partners

Crowd sourcing campaign just launched!

Visit: discosat2.dk

AARHUS UNIVERSITY

AARHUS UNIVERSITETS FORSKNINGSFOND

Innovation Fund Denmark

RESEARCH, TECHNOLOGY & GROWTH