ETSI Conference on
Non-Terrestrial Networks,
A Native Component of 6G

AI for Satellite Communications - AIComS

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Universität Bremen

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AIComS

Prime
Universität Bremen

DLR
DSI Aerospace
NXP
TESAT
Smart Small Satellite Systems GmbH
ZFT
NOKIA
OHB

Project figures: Two phase project with 6.7 M€ (total cost), 2022/11 (start), and 36 months (duration)
Funding line: ESA ARTES 4.0 Technologies and Products, ”Space for 5G & 6G”

AIComS

Objective

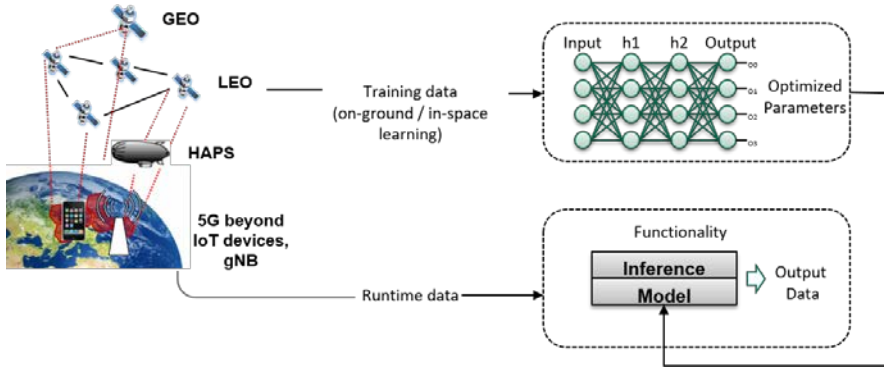
- Development of AI/ML-based SW/HW product platforms of (v)LEO satellites for 3D networks

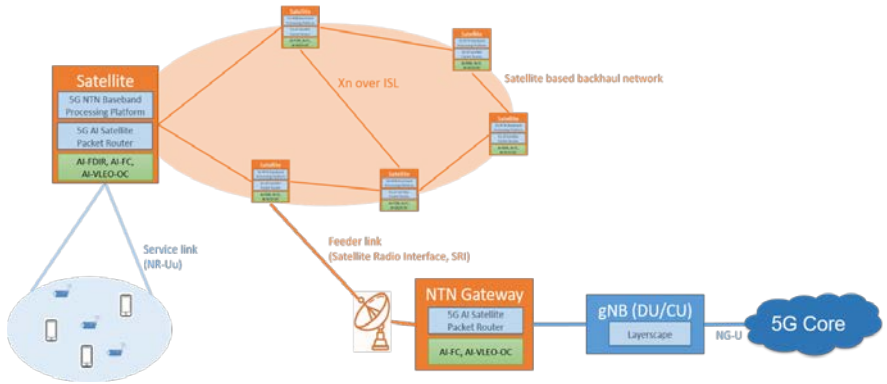
Scenario

- Architecture: Regenerative satellite-based NG-RAN architecture
- Use cases: 5G Services eMBB, mMTC
- UE devices: VSAT, IoT, handhelds

Topics

- ML-based PHY-Layer components of (v)LEO satellites and gNB
- 5G/6G compliant ML-based routing, network slicing, and security components on MAC/network layer
- Functional splits for (v) LEO satellites with ML-based payload
- Antenna tracking by flight attitude control system





Satellites: From 5G to 6G (selected projects)

AIComS supplements these activities with focus on (v)LEO satellites and develops **ML-driven HW/SW product platforms**

AIComS – Structure and Products

WS4 Project Management — Universität Bremen, DSI Aerospace, ZFT, TESAT

WS0 Use Case, Scenario, KPIs, Architecture — Universität Bremen, DLR, DSI Aerospace, NXP, TESAT, ZFT

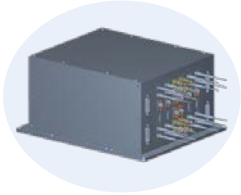
WS1 5G NTN Baseband Processing — DSI Aerospace, NXP, Universität Bremen

WS2 5G AI Packet Router — TESAT, DLR, NXP

WS3 Flight Control & Satellite Architecture — ZFT, Universität Bremen

DSI HPDPU

NXP Layerscape®



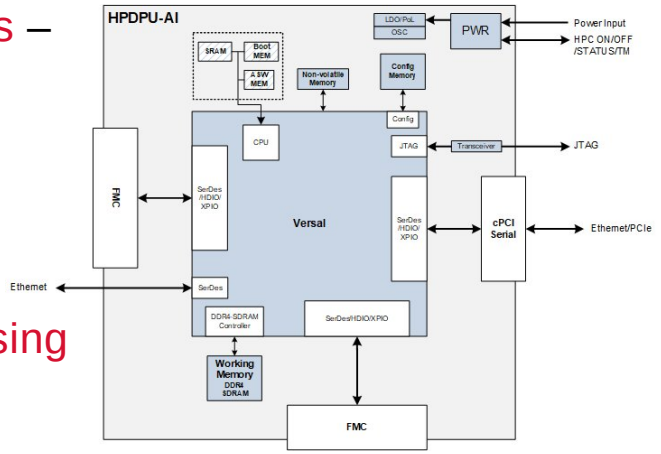
Packet router

Flight Control SW

5G NTN Baseband Processing

- Goals:
  - Development of two platforms:
    - HPDPU (DSI) for on-board processing
    - Layerscape (NXP) for ground station functionality
  - Investigate suitable RU/DU functional split options
  - Investigate ML-based receiver baseband processing

- Achievements (extracts)
  - Functional split (option 7 ?): compromise data rate - platform processing capabilities – performance
    - lower layer gNB NR PHY functionality on-board satellite → HPDPU
    - higher layer gNB NR PHY functionality on ground → Layerscape
    - First results on splitting higher and lower layer PHY differently [RDM23]
  - HPDPU-AI: Requirements defined and system architecture specified for ML processing
  - Layerscape: Identification of Layerscape product line as RU and/or DU

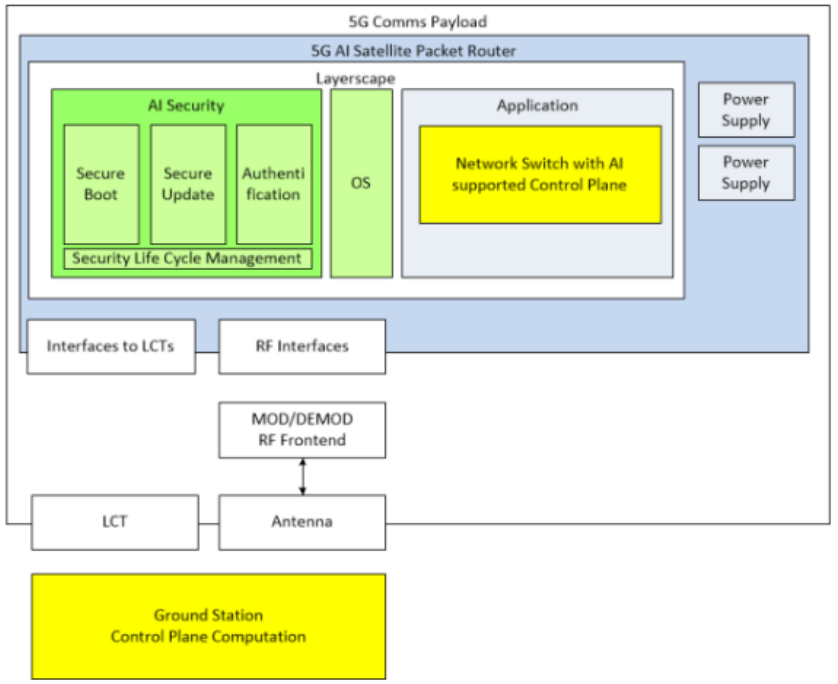


[RDM23] M. Rihan, T. Due, M. Vakilifard, D. Wübben, A. Dekorsy: RAN Functional Split Options for Integrated Terrestrial and Non-Terrestrial 6G Networks, JAC-ECC 2023

5G AI Packet Router

- Goals: Develop a satellite packet router hardware / software with
  - AI based security mechanisms (secure updates & lifecycle management)
  - AI supported control plane mechanisms for QoS aware routing with load balancing, network slicing and orchestration in satellite constellations

- Achievements (extracts)
  - Hardware:
    - Assessment and trade-off hardware architectures
    - First iteration of requirements and test concepts
  - Security updates:
    - Identified threats and attack vectors in the context of NTNs
    - Implemented ML architecture for anomaly detection based on autoencoder models
  - Routing, Network Slicing & Orchestration
    - Identification and critical assessment of different AI-based approaches
    - Trade-Off analysis and selection of most promising candidates



Satellite Flight Control

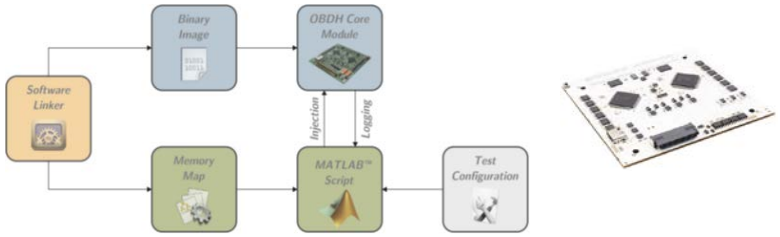
- Goals: Develop concepts and SW for
  - Reliable operations for COTS HW using Fault-Detection-/Isolation and Recovery (FDIR) techniques
  - Self-organizing formation control
  - Adaptive flight control in high disturbance VLEO environment

- Achievements (extracts)
  - Advanced FDIR simulation environment
  - Advanced simulator for formation and spacecraft control
  - Robust beamforming exploiting statistics of phase error [RMW23] and by using ML approaches [GSR24, SGR24]

    → Less control accuracy needed

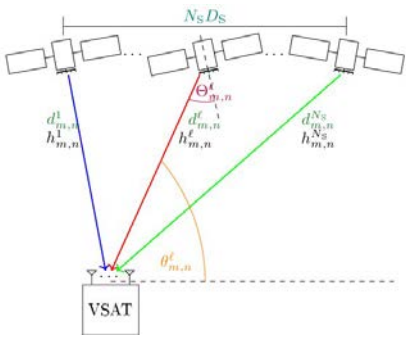
    → Timing requirement on split option can be relaxed (RU in sat, DU on ground)

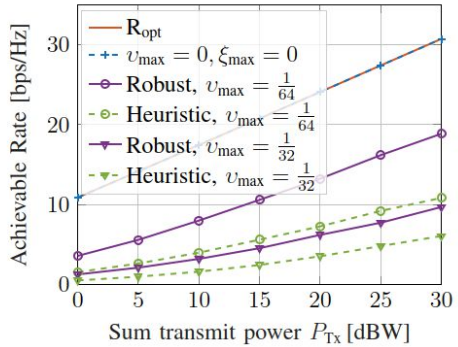
FDIR simulation environment



Simulator for formation control

Robust beamforming





[RMW23] M. Röper, B. Matthiesen, D. Wübben, P. Popovski, A. Dekorsy: Robust Precoding via Characteristic Functions for VSAT to Multi-Satellite Uplink Transmission, ICC 2023
[GSR23] S. Gracla, A. Schröder, M. Röper, C. Bockelmann, D. Wübben, A. Dekorsy: Learning Model-Free Robust Precoding for Cooperative Multibeam Satellite Communications, ICASSP 2023
[SGR24] A. Schröder, S. Gracla, M. Röper, C. Bockelmann, D. Wübben, A. Dekorsy: Flexible Robust Beamforming for Multibeam Satellite Downlink using Reinforcement Learning, ICC 2024

AIComS - TakeAways

- Technical approaches
  - Functional splits for (v)LEOS, but also subject to product specific capabilities
  - ML-replacement of functionalities, but also subject to product capabilities

- Project embedding
  - Close bi-directional knowledge and idea transfer to 3GPP by Nokia, NxP, DLR
  - Close alignment ensured to other NTN projects (e.g. 6G-TakeOff, 6G-NTN) by almost all partners

- Benefits for industrial partners
  - AIComS focuses on their pre-products
  - AIComS implements innovation-driven development for their products
  - AIComS closely links academia with industry within a single project (direct transfer)

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