# NTN MULTI-CONNECTIVITY FOR 5G-ADVANCED AND BEYOND

**S5LECT Mid Term Event**

*22/10/2025 Donostia-San Sebastian*

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# Project Overview (1/2)

**Project name: 5G-STARDUST** (www.5g-stardust.eu)

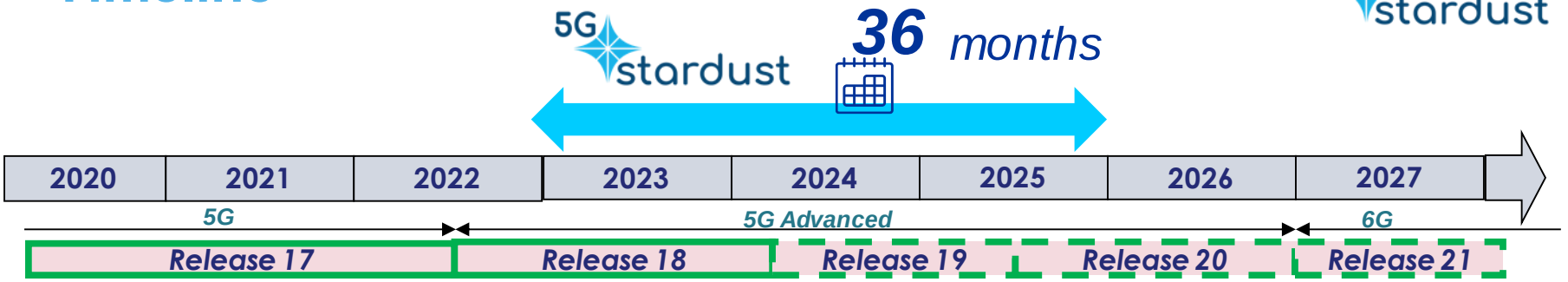
*Satellite and Terrestrial Access for Distributed, Ubiquitous and Smart Telecommunications*

- Co-funded by EU: Smart Networks and Services Joint Undertaking (**SNS JU**) - under the European Union's Horizon Europe research and innovation programme
- **Stream:** *A-01-02 Ubiquitous Radio Access*

**Objective:**

**To design, develop and demonstrate a deeper integration of TN and NTN**: Deliver a fully integrated 5G-NTN autonomous system with novel self-adapting end-to-end connectivity models for enabling ubiquitous radio access

# Timeline




*Assuming 18 months releases*

Satellite backhaul

| | |
|---|---|
| **Transport networks with static bandwidth and latency** | **Transport networks with variable bandwidth and latency** |

Satellite connectivity to smart phones

| | | | |
|---|---|---|---|
| (5G NR): **sub-6GHz, transparent payload** | (5G NR): Coverage & mobility enhancements | *(5G NR): other enhancements (e.g. **regenerative payloads)*** | *5G NR: **further** enhancements ?* |

Satellite connectivity to IoT devices

| | | |
|---|---|---|
| (4G NB-IoT/eMTC): **sub-6GHz, transparent payload** | (4G NB-IoT/eMTC): enhancements (mobility, MAC, discontinuous coverage) | *(4G NB-IoT/eMTC): other enhancements (e.g. **store & forward)*** |

Satellite connectivity to "VSAT"

| | | | |
|---|---|---|---|
| (5G-NR): in **10 GHz bands** | *(5G-NR): other enhancements (e.g. **IAB/VMR)*** | | |
| *6G: Service requirements for NTN* | *6G: Study on the support of NTN component* | *6G: Define features for the support of NTN component* | |

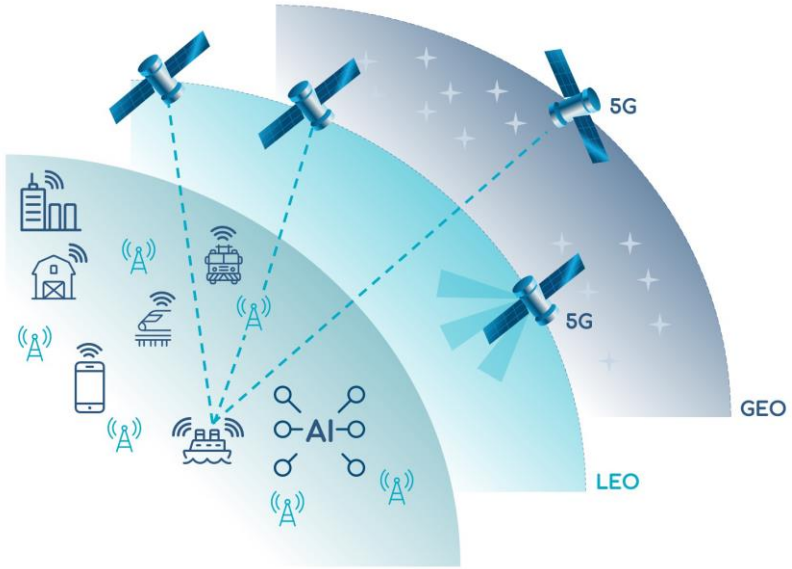
# Multi-Connectivity SoTA

| Anchor layer | Standardized solution | Technical specification | Technical objective | Main limitation |
|---|---|---|---|---|
| PHY | CoMP | TS 36.300 | Improvements in SINR | Requires high level of coordination between BSs |
| | Multi-TRP | TS 38.300 | | |
| MAC | NR-U CA | TS 38.331 | Rapid system adaptation in case of link failures | Complex packet scheduler |
| PDCP | DC | TS 36.300 | Higher data reliability; higher throughput | Requires additional hardware and software capabilities at the UE |
| | MR-DC | TS 37.340 | | |
| | LWA | TS 36.300 | Higher throughput | Aggregation limited to LTE and Wi-Fi controlled by the MNO |
| | NR-U DC | TS 38.331 | Higher throughput | Requires additional hardware and software capabilities at the UE |
| | DAPS | TS 38.300 | Mobility robustness | Currently available between 5G BSs |
| Network | LWIP | TS 36.300 | Deployment affordability | Traffic offload limited to LTE and Wi-Fi |
| Transport (end-to-end) | MPTCP | RFC 6824 | Higher throughput; deployment affordability | MC operations are not in the control of the MNO |
| Transport (core network) | ATSSS | TS 24.193 | Higher throughput; higher data reliability | MC operation limited to TCP-based traffic |

Dual connectivity/multi-connectivity in TS 37.340 at bearer level with one gNB used as master the other as secondary solution

[C. Pupiales, D. Laselva, Q. De Coninck, A. Jain and I. Demirkol, "Multi-Connectivity in Mobile Networks: Challenges and Benefits," IEEE Communications Magazine, November 2021]

# Use Case and Architectures



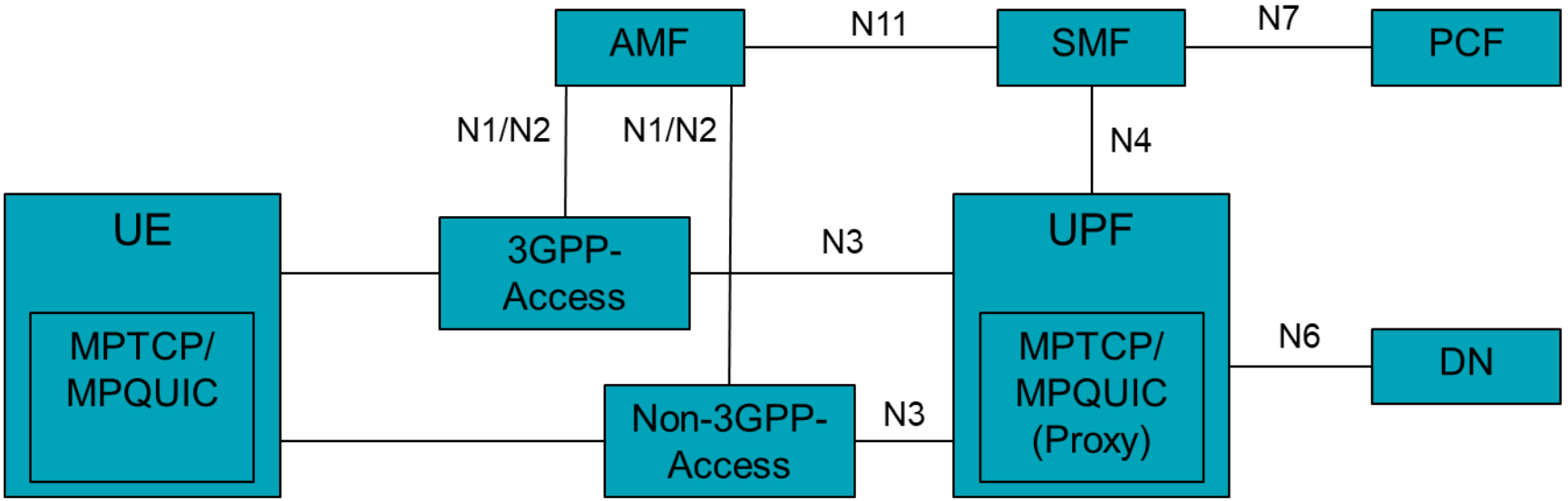

- *Neutral-host cell (Maritime, Railway, Airway)*
- *Residential broadband*
- *Vehicle to network*
- *PPDR*
- *Global private networks*

- *Transparent*
- *Regenerative*
- *Functional Split*
- *Integrated & Wireless Access Backhaul (IAB & WAB)*

# Task on Multi-Connectivty

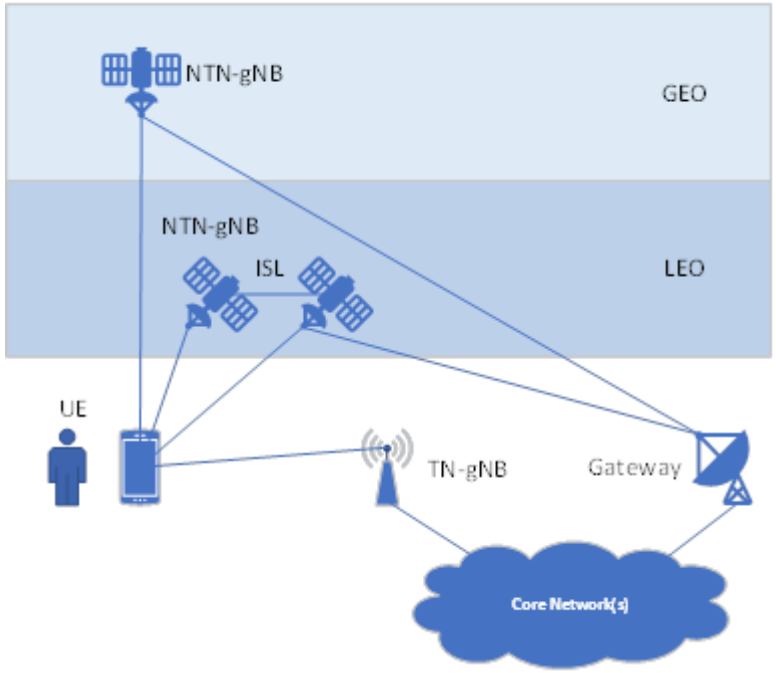
- Architectural Updates
- Adaptation on the control plane
- Transport Protocols
- AI/ML for Multi-Connectivty
  - RL-Based Hot Swapping
  - Predictive Scheduling: system load and satellite handover

# ATSSS Reference Architecture TS 23.501

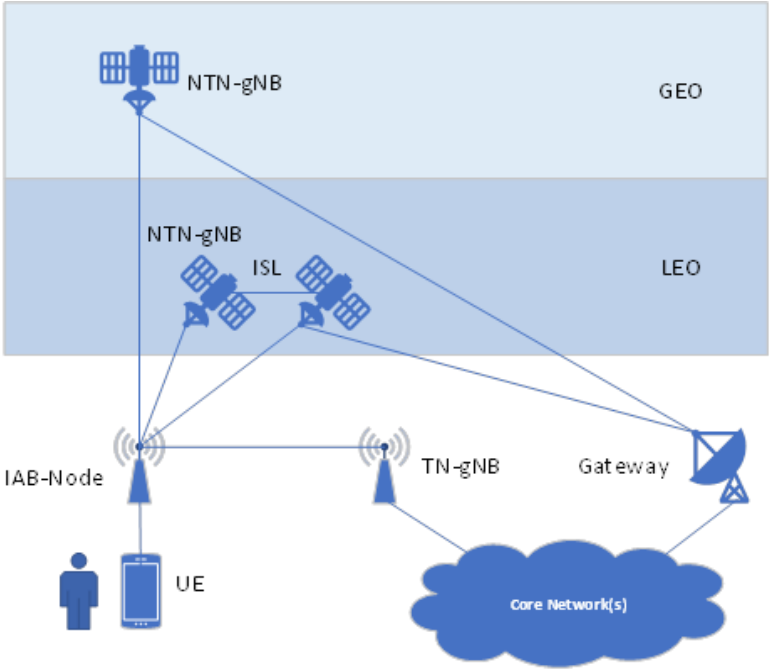


# Multi-Connectivity (MC) Scenarios

Direct connection



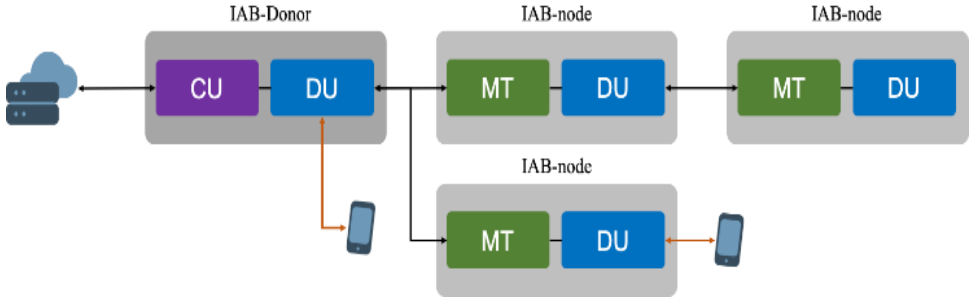

Indirect connection



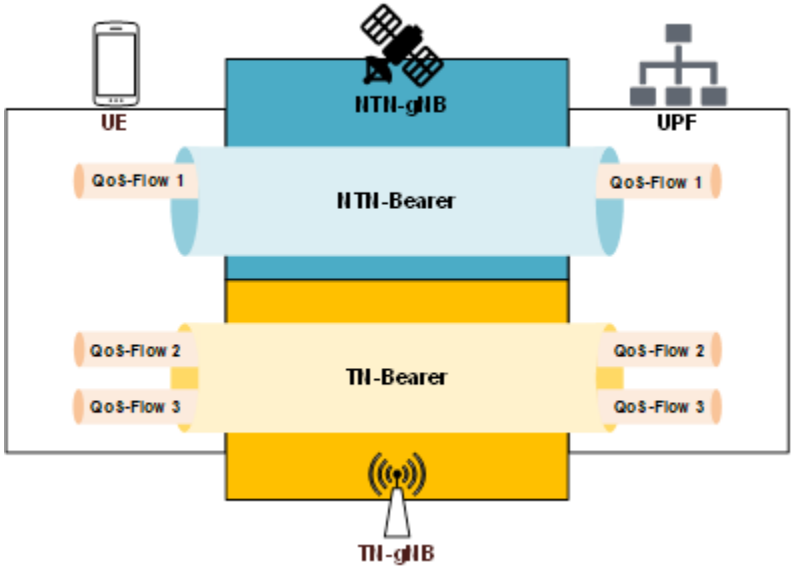
# Architecture: IAB

- Initial idea relay communication, (especially indoor)
- IAB-Donor as payload investigated

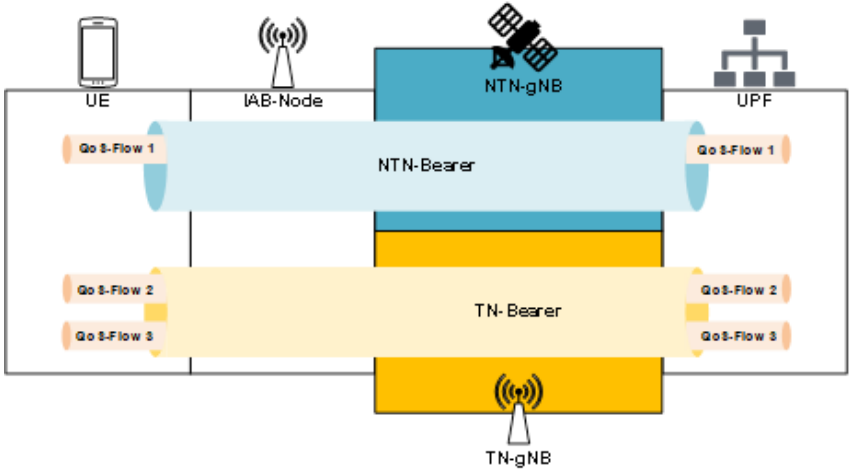
- In the meantime replaced by Wireless Access Backhaul (WAB)
- MT + full gNB
- Allowing Mobile Edge Computing (MEC) on-board and to support Vehicle Mounted Relay (VMR) services
- TR 38.799 user link cannot be NTN, i.e. WAP and NTN only backhauling

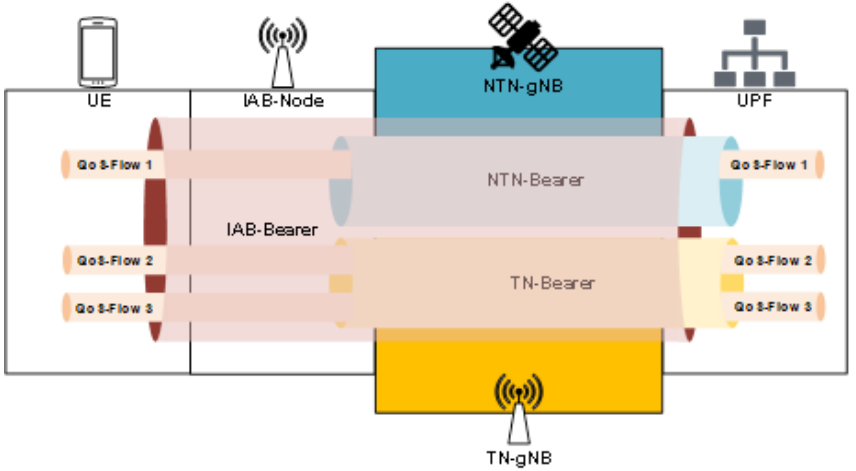


# MC-Bearers Direct Connectivity



# MC-Bearers Indirect Connectivity

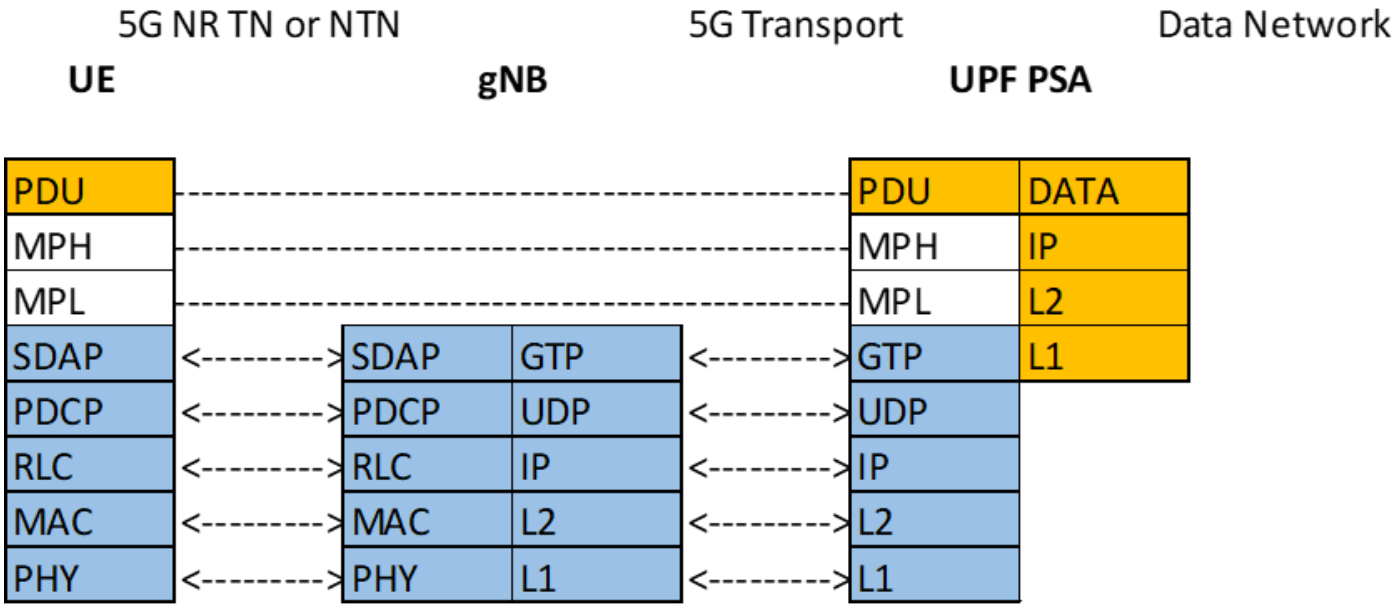


# Architecture Options

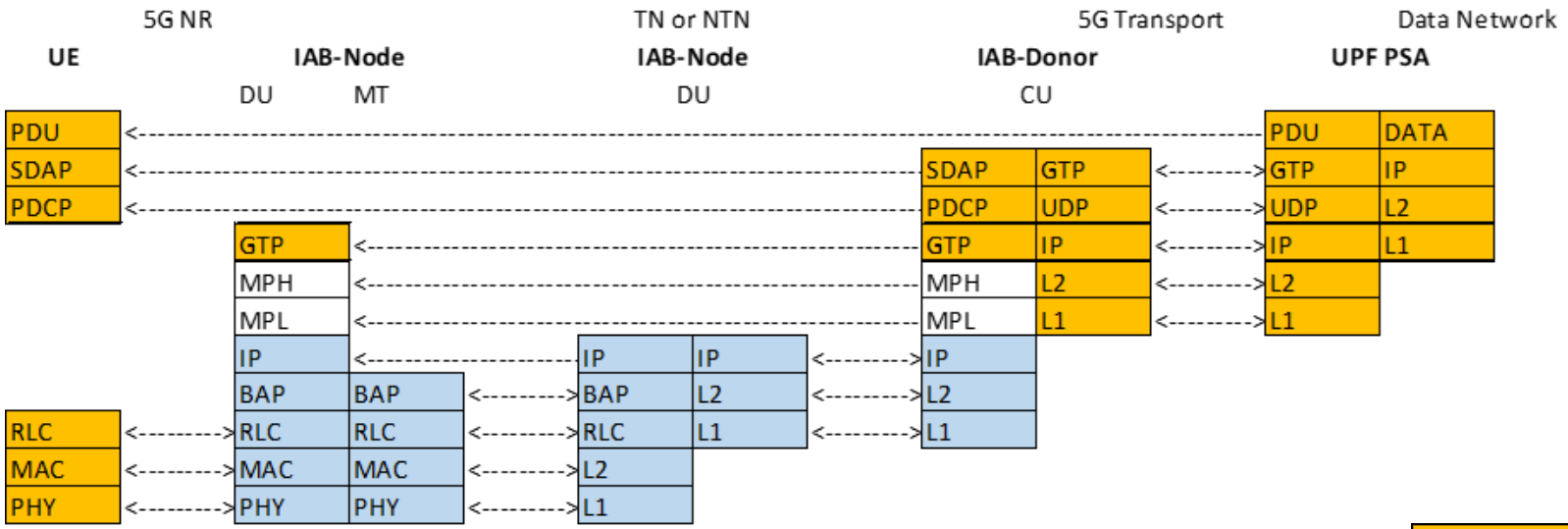
- Direct Connection
  - with MC-layer at UE
  - with MC-layer at UE, MC-termination at UPF in space
- Indirect Connection
  - with MC-layer at UE
  - with MC-layer at UE, MC-termination at UPF in space
  - with MC-layer at IAB-Node
  - with MC-layer at Forwarding UPF function

# Protocol Stack Direct MC at UE

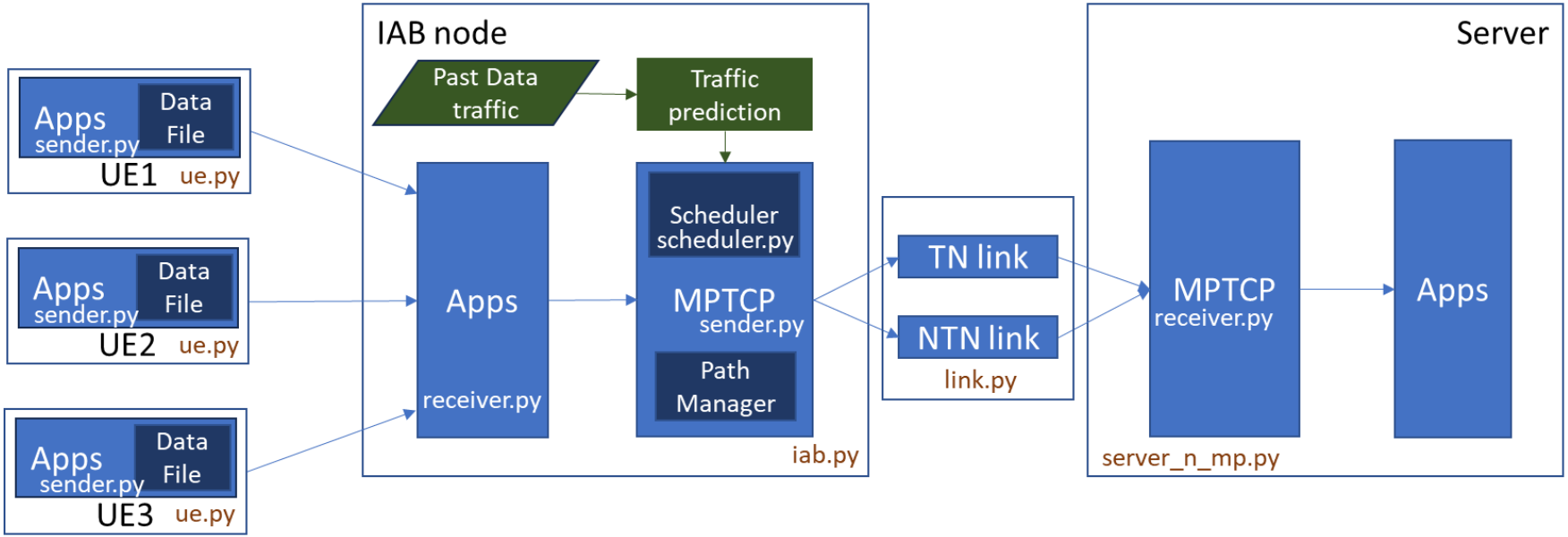



| Single Connection |
|---|
| Multi-Path High |
| Multi-Path Low |
| Multi-Connection |

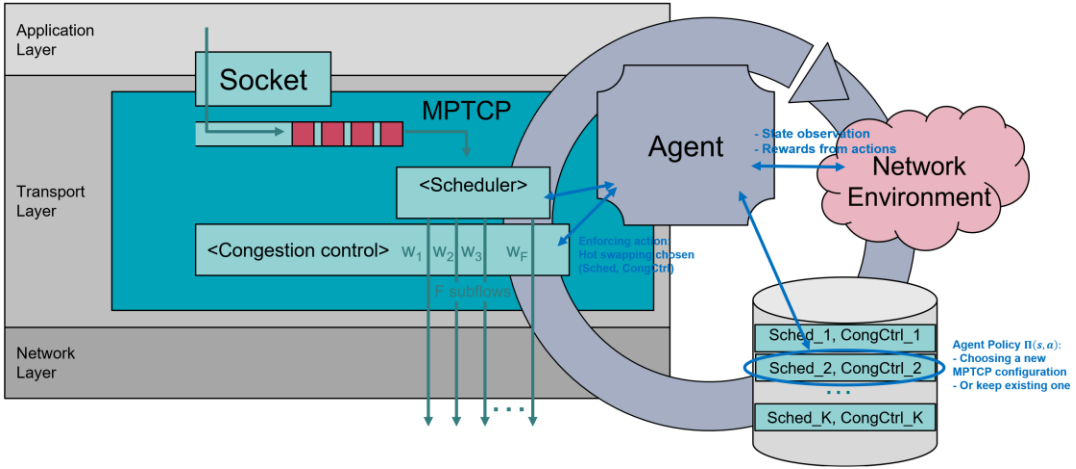
# Protocol Stack Indirect MC at IAB

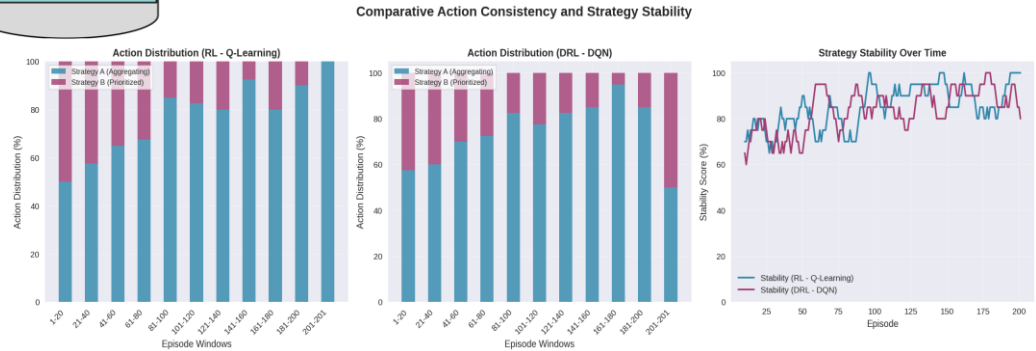


# Mininet Testbed

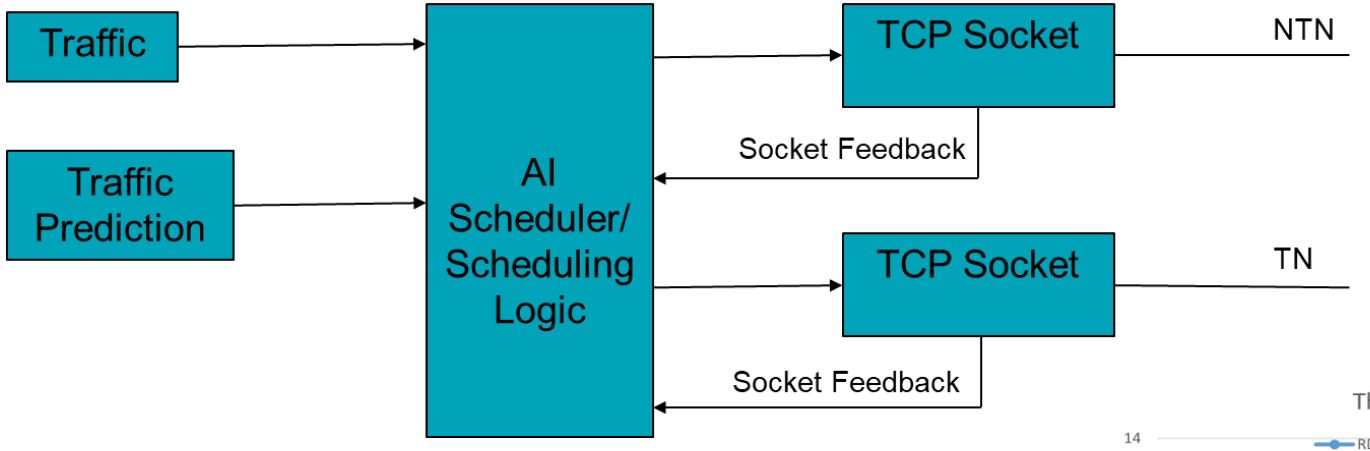


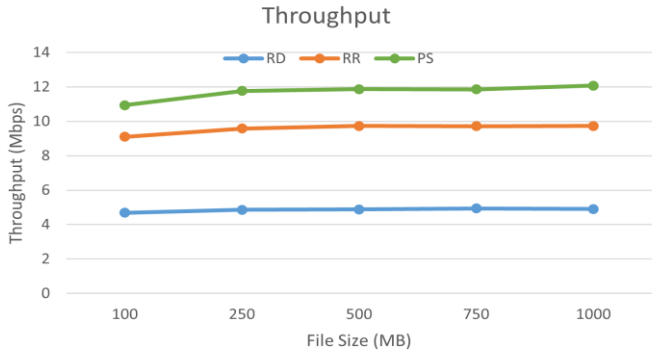
# Hot Swapping



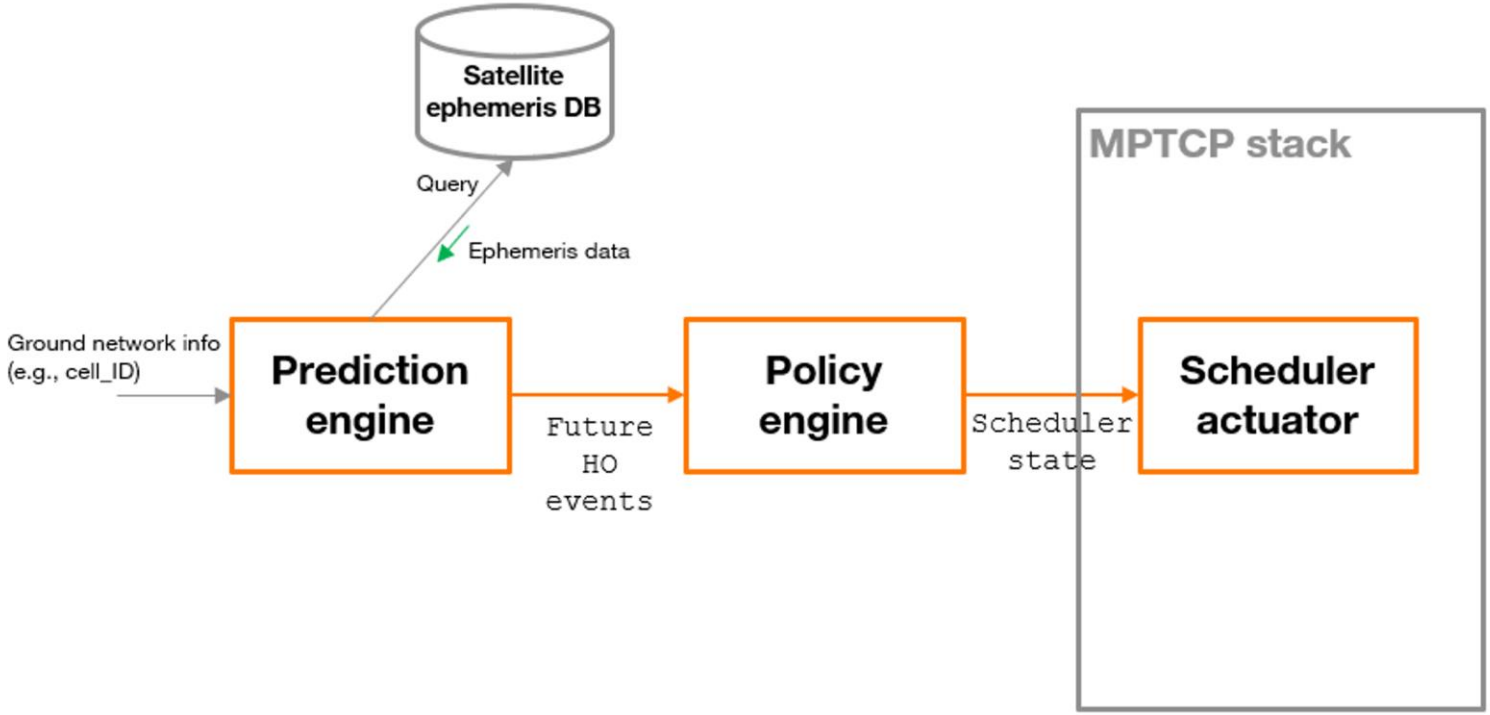



# Predictive Scheduler: Load



# Prediction: Handover



# Findings and Next Steps

- Turning connectionless link into a connection-oriented
- Terminating MC at UPF in space for NTN/NTN connections would offload the feeder
  - Only option affected by regenerative payloads
- Encrypting can break UPF chaining, order in the stack must be observed
- ATSSS needs to be adapted for parallel 3GPP connections: exteneding UE identity
- Conituing AI Integration and Optimisation

# References


- C. Pupiales, D. Laselva, Q. De Coninck, A. Jain and I. Demirkol, "Multi-Connectivity in Mobile Networks: Challenges and Benefits," IEEE Communications Magazine, November 2021
- 5G-STARDUST D5.4 “Final Report on Multi-Connectivity and Software Defined Network Control”, 09/2025
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- Accepted: Roshith Sebasitan, Benjamin Barth, Tomaso de Cola, Cristian J. Vaca-Rubio, Luis Blanco, Marius Caus, Engin Zeydan, “A Predictive Approach for Transport Protocol Multi-Connectivity Scheduling”, FNWF 2025, Bangalore
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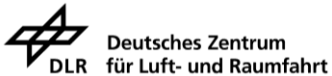
# The Consortium









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