

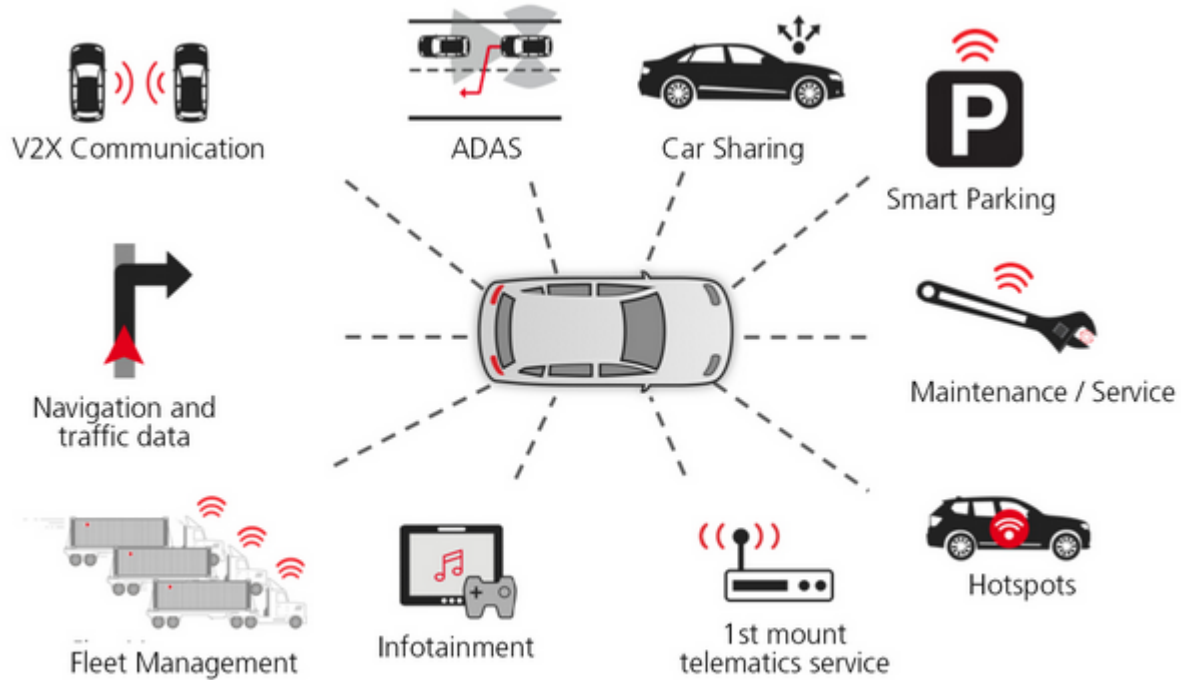
Towards a 5G Satellite Communication Framework for V2X

WueWoWAS'23

Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
Computer Networks and Communication Systems

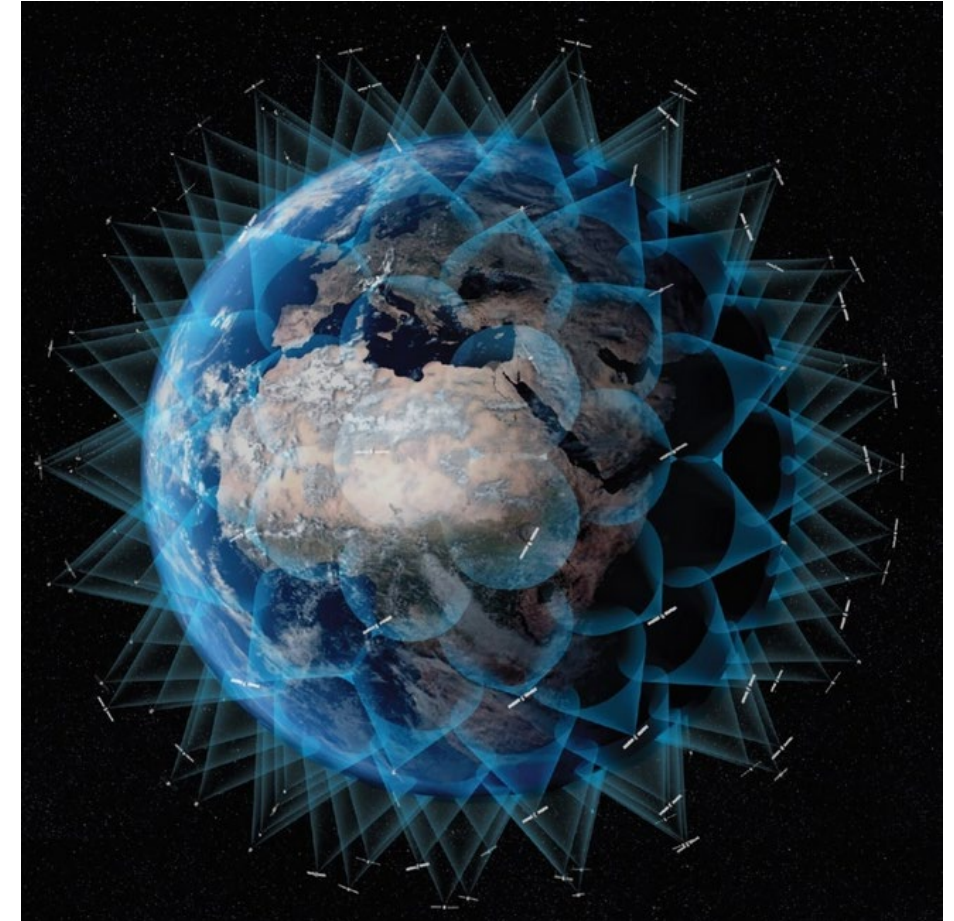
Luigi Martino, Jörg Deutschmann, Kai-Steffen Hielscher, Reinhard German

- Motivation
- Satellite orbits
- Non-Terrestrial Networks Configurations in 5G
- Handovers in Non-Terrestrial Networks (NTNs)
- Framework Description
- Conclusion



Automotive use cases

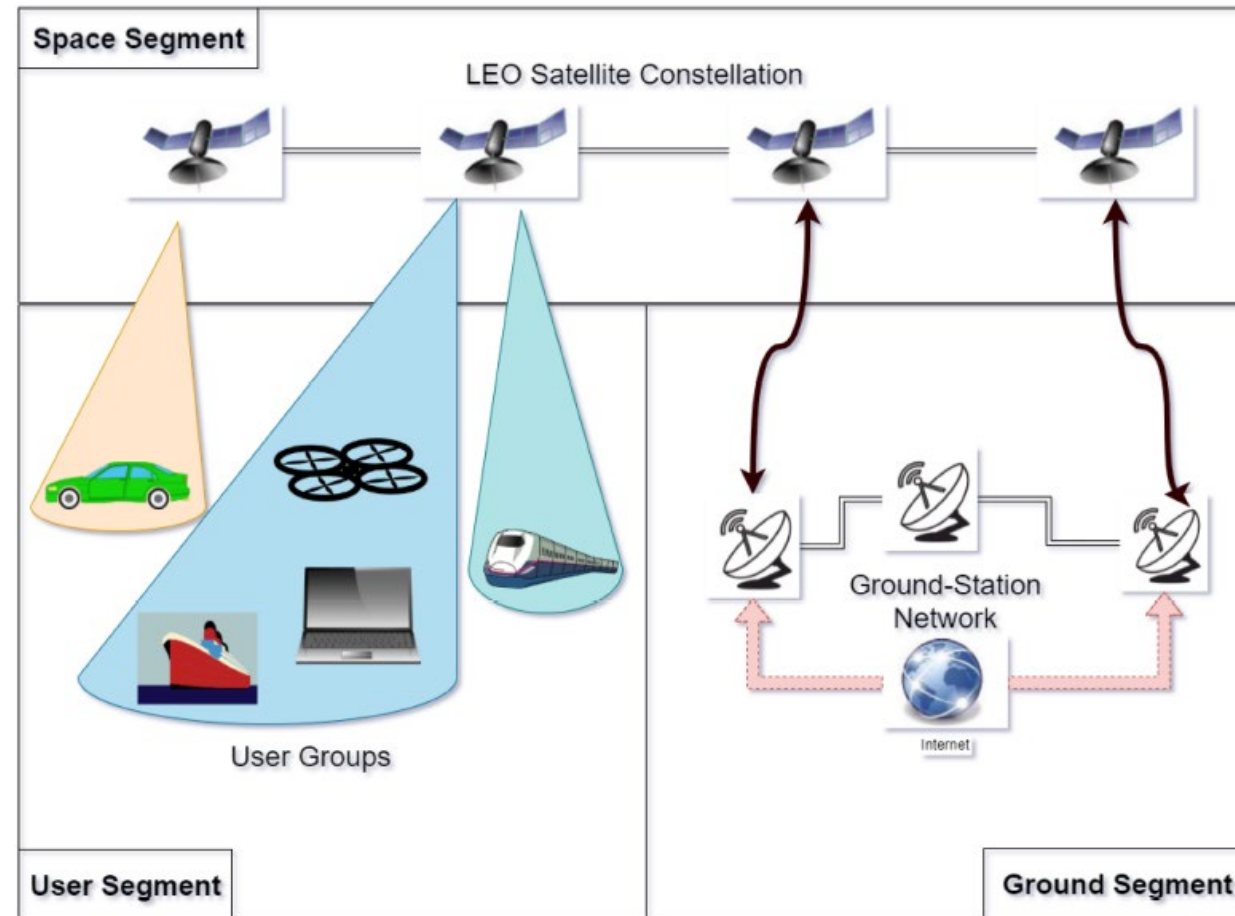
<https://www.u-blox.com/en/blogs/innovation/vehicle-lte-e2%80%93use-cases-and-opportunities-connected-and-autonomous-car>



Mega-constellation coverage

https://www.esa.int/ESA_Multimedia/Images/2019/11/Mega-constellation_coverage

- Provide reliable connectivity for unserved areas
- Connection resilience



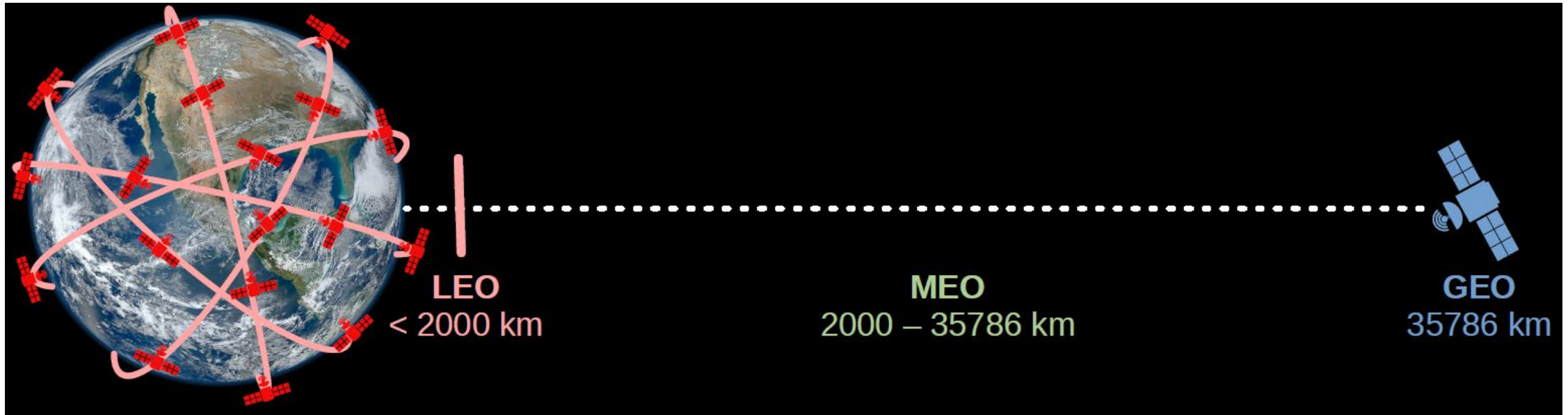
Typical components of a satellite network

[4] K. Çelikbilek, Z. Saleem, R. Morales Ferre, J. Praks, and E. S. Lohan, "Survey on Optimization Methods for LEO Satellite-Based Networks with Applications in Future Autonomous Transportation," *Sensors*, vol. 22, no. 4, p. 1421, feb 2022. [Online]. Available: <https://www.mdpi.com/1424-8220/22/4/1421/html><https://www.mdpi.com/1424-8220/22/4/1421>

Use cases	Datarate	Latency
Remote Driving	High	Very Low
Voice over IP (VoIP)	Low	Medium
Vehicle Monitoring	High	Low
Video Streaming	Low/Medium	Medium
Situational Awareness	High	Low
HD Maps	High	Low



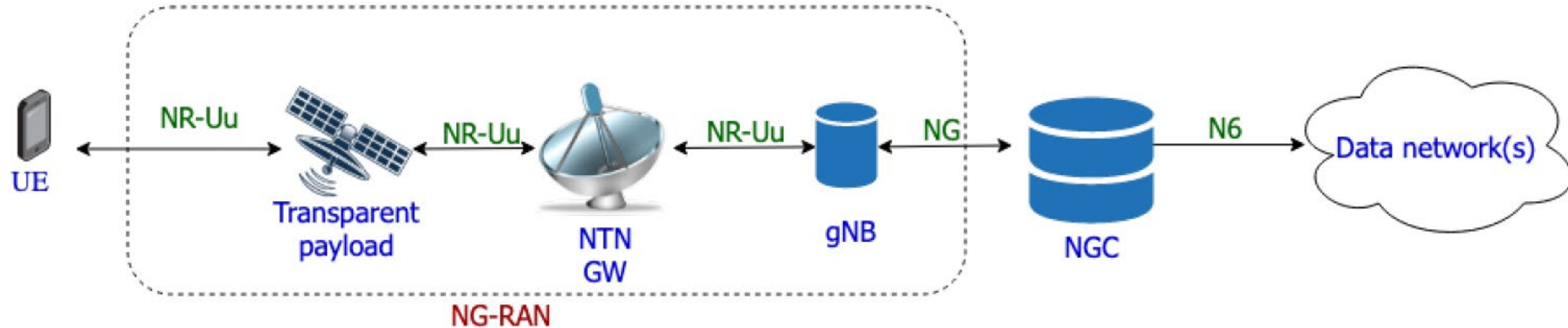
Sources: 5G Automotive Association. 5GAA. 5GAA. Accessed: Jan. 2021. [Online]. Available: <http://5gaa.org/>



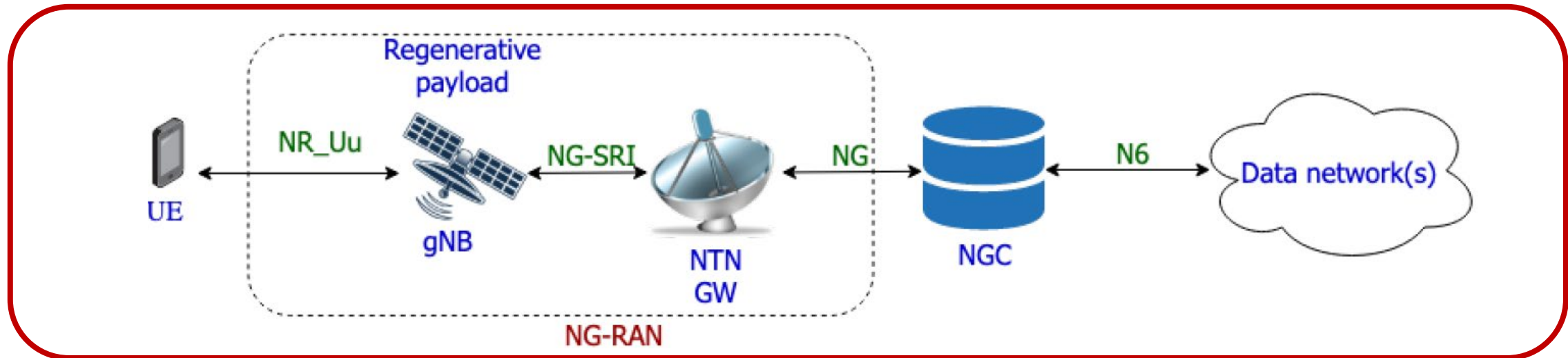
GEO satellites provide larger coverage to the expenses of significantly larger latency times, **LEO** satellites could be applicable where reliability and efficiency are required for real-time applications

Satellite config.	RTT (ms)
GEO	≈ 600
LEO	$\sim 45/\sim 47$

NTN Configurations



Networking-RAN architecture with transparent satellite - 3GPP 38.821

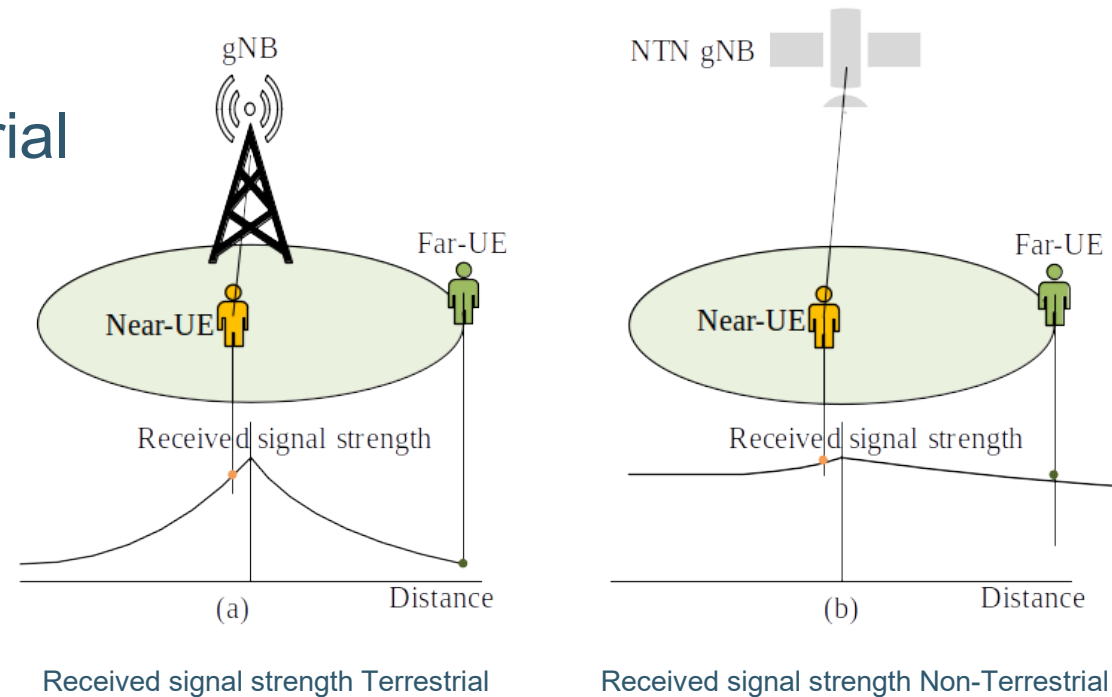


Non Terrestrial Network regenerative payload - 3GPP 38.821

Handover: Terrestrial vs. Non Terrestrial

Received signal level more equally distributed along the cell.

UEs selection of the best cell is more difficult

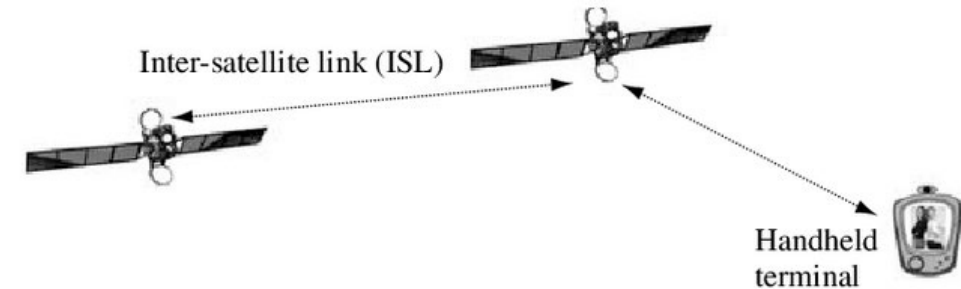


Source: 3GPP Specs. 38.821

Inter-Satellite Handover:

Involves transferring an ongoing communication session from one satellite to another within a constellation or network of satellites

- *Purpose:* Inter-satellite handover is necessary when a user moves beyond the coverage area of one satellite and enters the coverage area of another satellite within the same network
- *Key Considerations:* Inter-satellite handover requires coordination between multiple satellites, including beam handover, resource allocation, and handover decision-making algorithms to ensure uninterrupted service during the transition

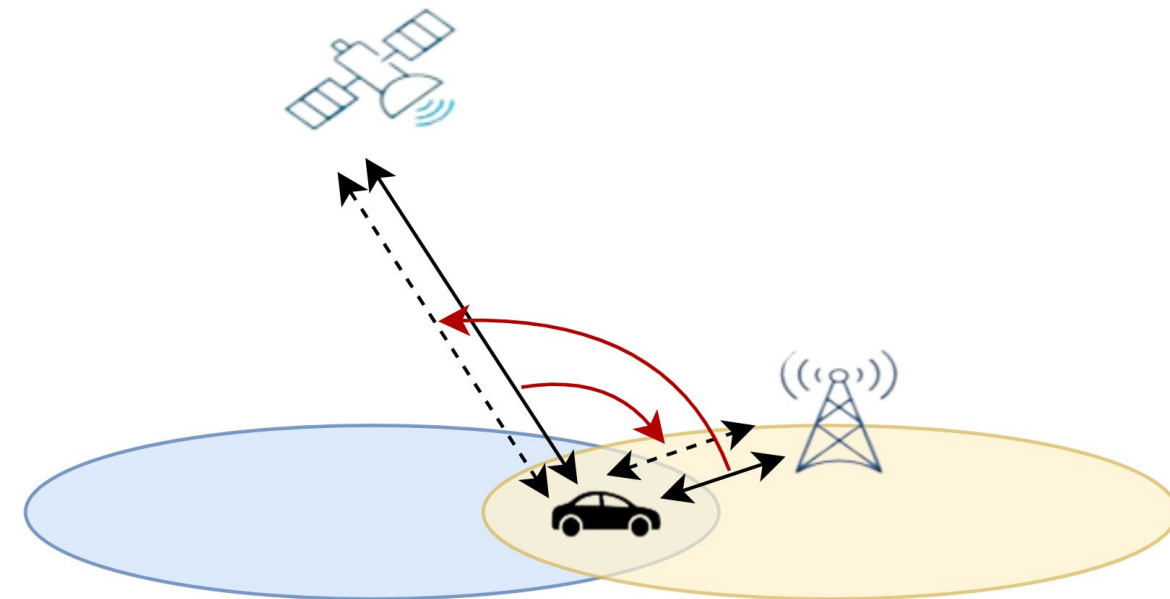


Adapted from:
Sun, Z. (2005). Satellite Networking:
Principles and Protocols.

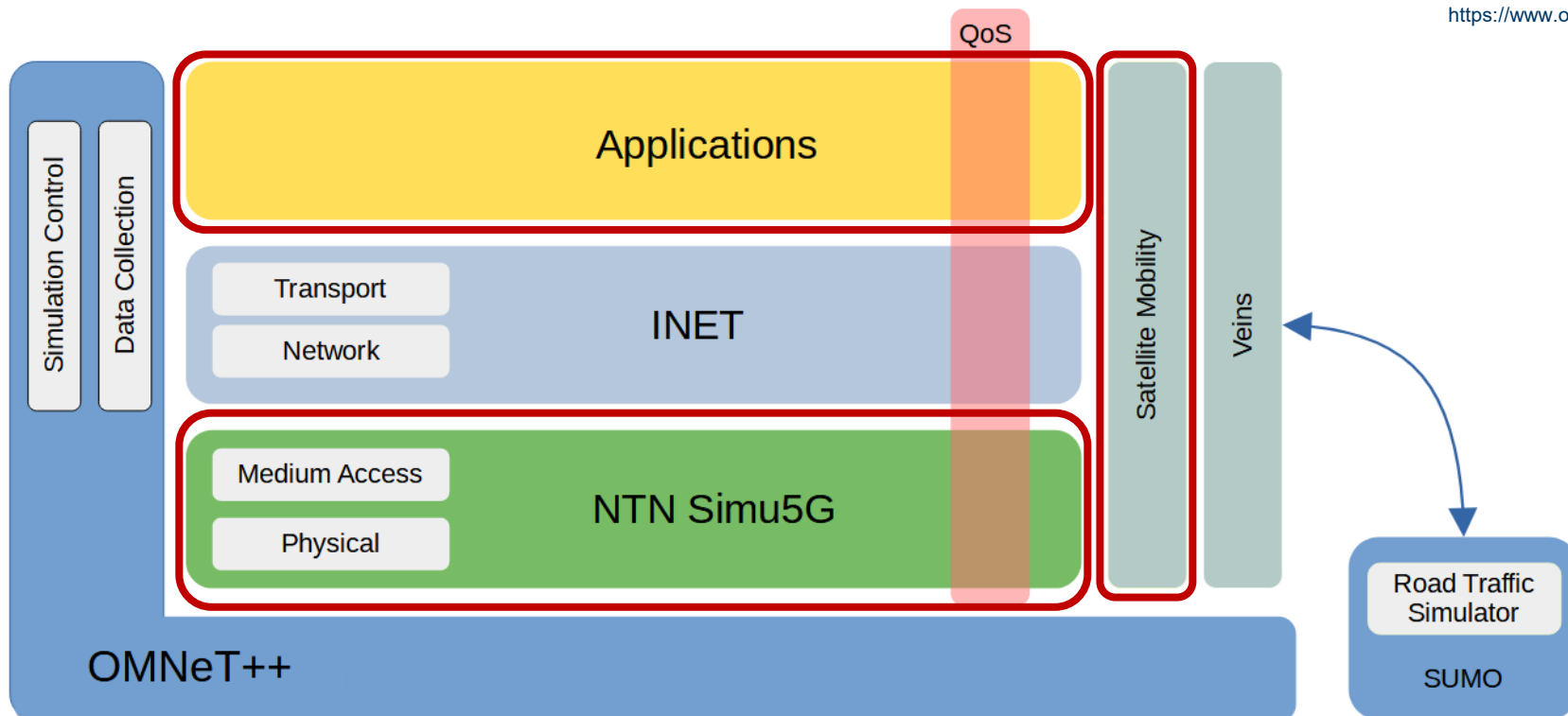
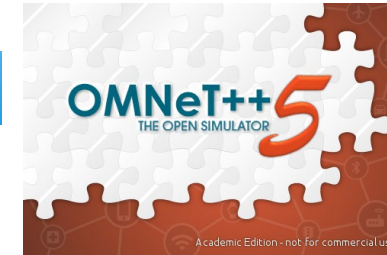
Satellite-to-Terrestrial Handover / Terrestrial-to-Satellite Handover:

The communication changes from a satellite network to a terrestrial network or vice versa

- *Purpose:* This type of handover is necessary when a user moves from an area covered by satellite connectivity to an area covered by a terrestrial network, such as 5G or cellular networks
- *Key Considerations:* Satellite-to-terrestrial handover involves coordination between the satellite network and the terrestrial network



Framework Description



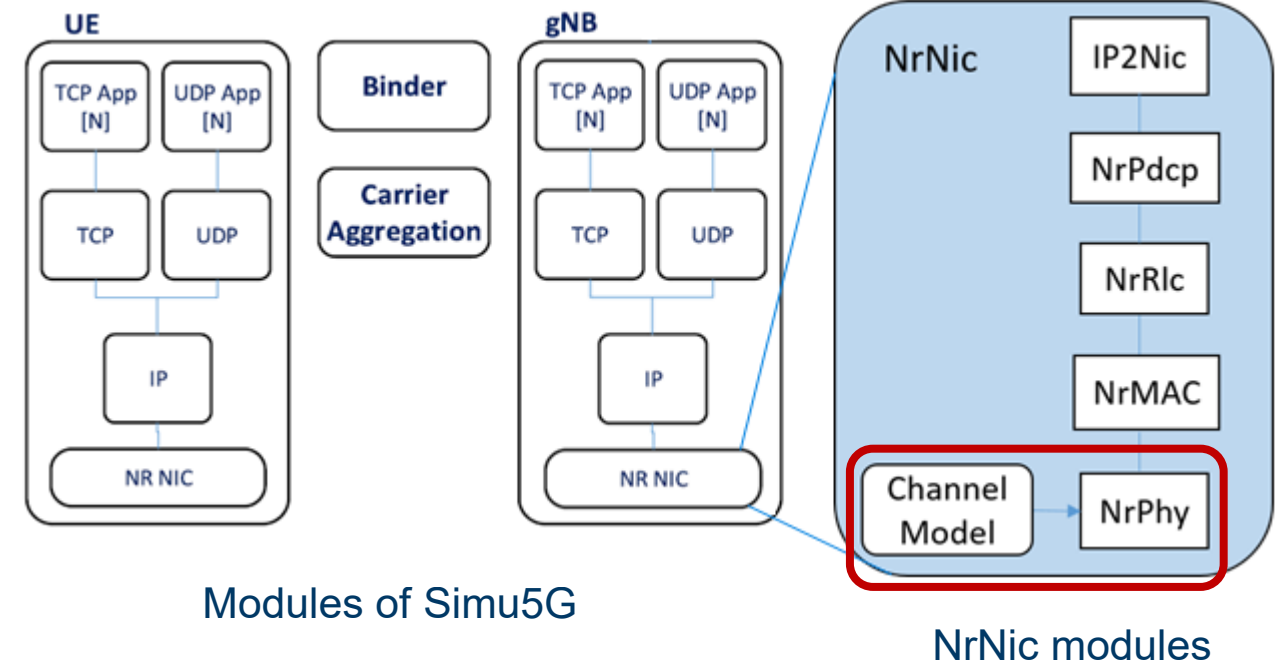
- NTN Simu5G
- Veins
- SUMO
- INET

Simu5G Environment

- NrUe and gNodeB compound modules
- UE and gNB could include all protocol layers, from the physical to the application layer
- The UE's NR functionalities are implemented in its Network Interface Card (NIC), called NrNicUe.



- NTN Simu5G
 - Implementation of NTN channel model (GEO and LEO configurations) compliant with 3GPP standards



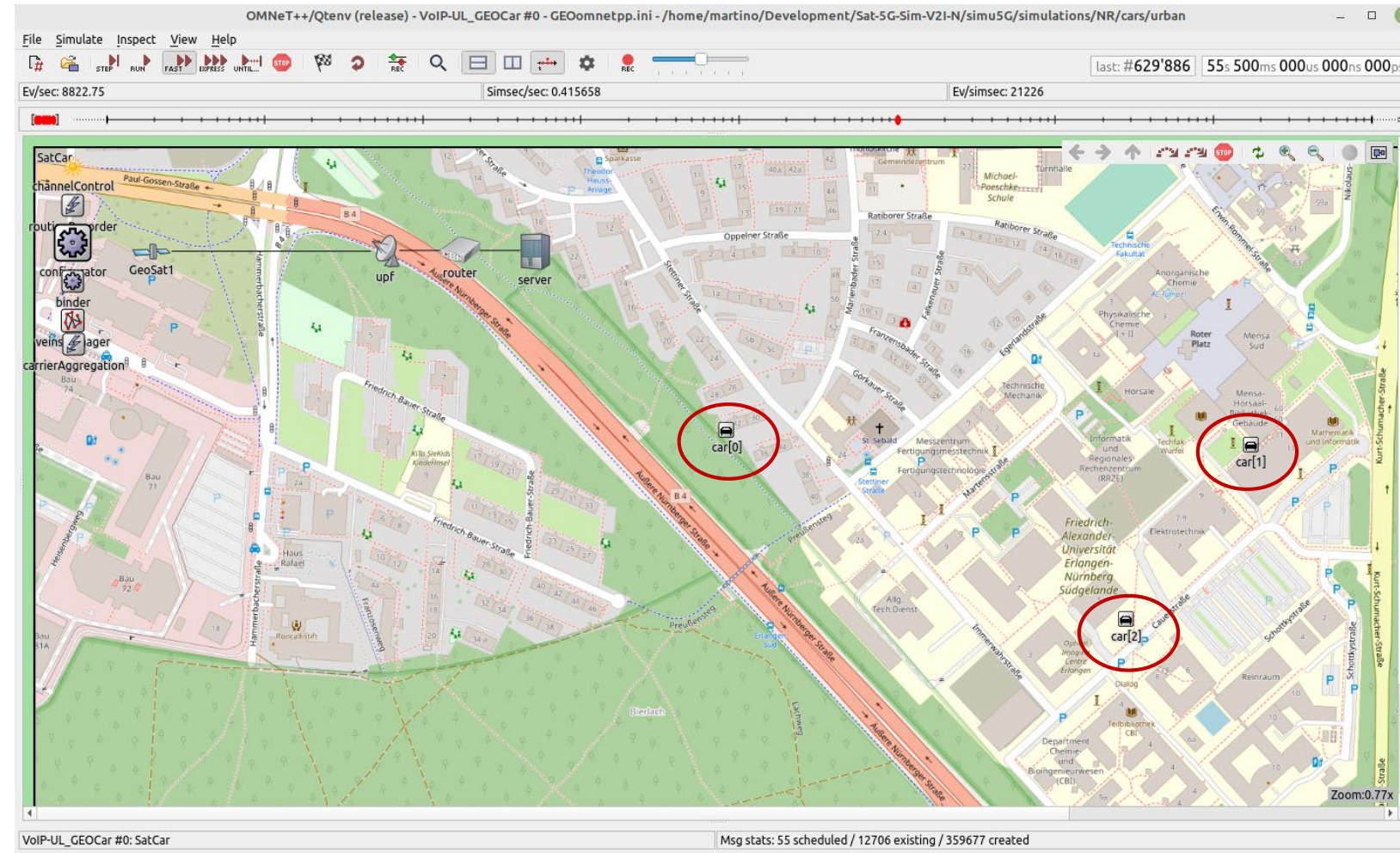
G. Nardini, D. Sabella, G. Stea, P. Thakkar and A. Virdis, "Simu5G—An OMNeT++ Library for End-to-End Performance Evaluation of 5G Networks," in IEEE Access, vol. 8, pp. 181176-181191, 2020, doi: 10.1109/ACCESS.2020.3028550.

Integration with Veins and Sumo

- Example of a VoIP app running in Downlink and Uplink

➤ In the next steps performance evaluation

- Application layer QoS metrics



I. Satellite orbits

- Advantages and limitations of different satellite orbits (Low Earth Orbit, Medium Earth Orbit, Geostationary)

II. 5G NTN (Non-Terrestrial Networks)

- Introduction to 5G NTN and its benefits, key features and advantages of 5G NTN (ubiquitous coverage, low latency, high capacity)

III. Framework for integrating satellite orbits and 5G NTN

- Key components of the integration framework
- Interoperability and protocol harmonization: Ensuring smooth communication across networks, enabling multipath communication

Next steps:

- Mobility model
- Testing different scenarios (urban, dense urban, rural)
- Evaluate several applications
- Test the handover procedure with different configurations

Thank you for your attention!



Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag