Die Rolle des Mobilfunks für Sichere und Saubere Mobilität der Gegenwart und Zukunft

Maciej Muehleisen (Ericsson GmbH)
Research Leader &
Technical Coordinator “Enterprise & Mission Critical Solutions“

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Outline

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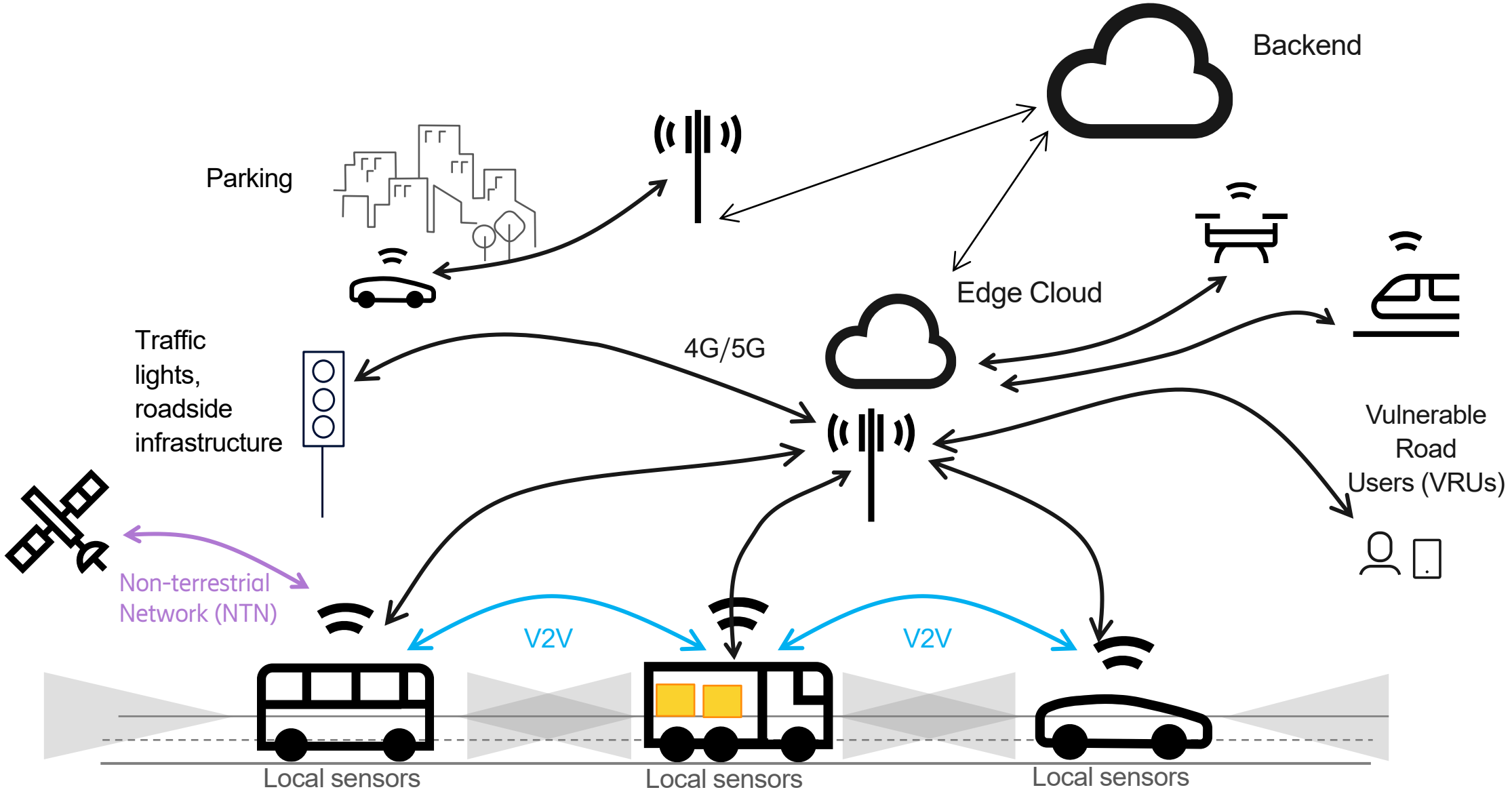
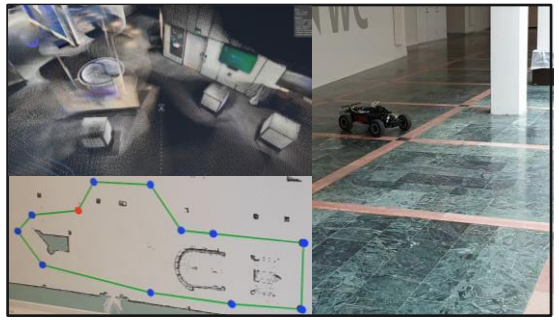
- Autonomous driving and 5G:
  - Opportunity
  - Reality
- Legal vs. business-driven connectivity
- Expectations on 6G
- Summary & outlook

Introduction



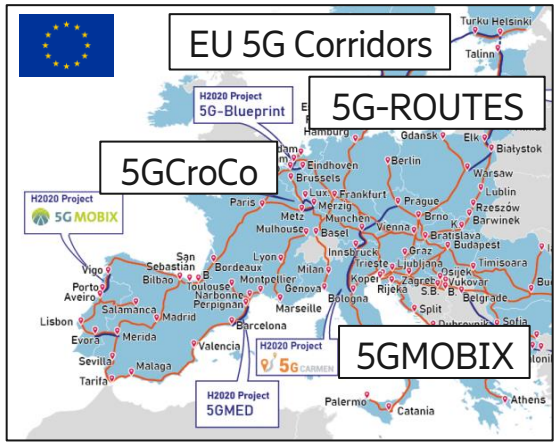
Introduction

Kista 5G Sensor Sharing for Automated Driving



AstaZero

Aldenhoven Testing Center 5G Mobility Lab



Kista 5G for Automotive Trial Site

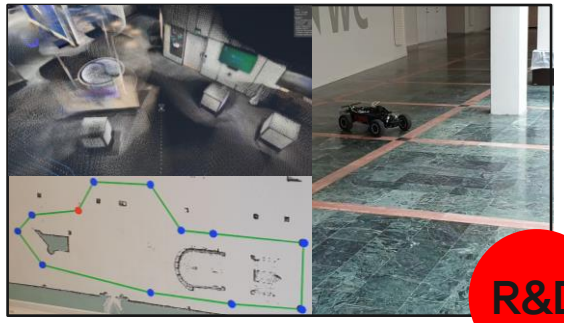
IDIADA

5G-ConnectedMobility Motorway A9 (until 2020)

European 5G Deployment Funding

Introduction

Kista 5G Sensor Sharing for Automated Driving



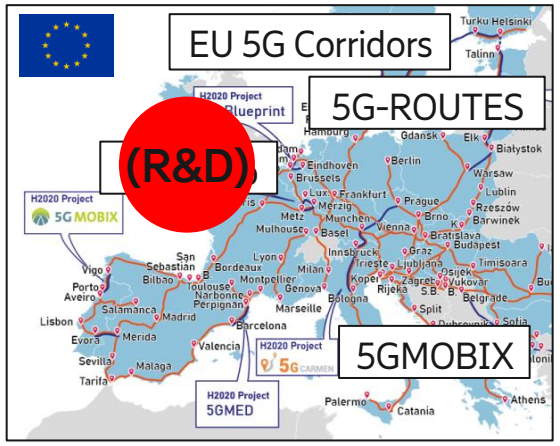
R&D

AstaZero

R&D

Aldenhoven Testing Center 5G Mobility Lab

EU 5G Corridors



Kista 5G for Automotive Trial Site

Pilot

IDIADA

Validate Certify

5G-ConnectedMobility Motorway A9 (until 2020)

European 5G Deployment Funding

Commercial

Introduction

Engagements tend to aim at pushing/determining the limits of 5G:

- **Business and/or societal value often not seriously considered**
- **Network requirements often exaggerated**
  - 3GPP "requirement" 2018: **5 ms one-way network latency** for tele-operation
  - German tele-operation law (StVFernLV) 2025: **200 ms glass-to-glass latency** for tele-operation
- **Traffic volumes exaggerated to challenge network with one or few vehicles**

<u>But: (Almost) every trial/demo/PoC includes use case "flavors" having short- and mid-term commercial relevance</u>

Autonomous driving (and 5G): Opportunity

Anything reducing emission (e.g. electrification) will also reduce emission from autonomous vehicles

Autonomous driving systems can be (and likely will be) optimized for energy saving

Passengers in autonomous vehicles might accept longer, slower transport that saves energy

Autonomous driving **and 5G**: Opportunity

Best Effort (like our smart phones)

- Infotainment
- Telematics
- Fleet management
- Start heating
- …

Many subscriptions

Price (revenue) per bit low

Better than Best Effort

- Computational offloading (e.g. voice command recognition)
- Safety & efficiency (traffic jam/hazard warning, …)

Extra revenue for extra service

Hard to notice benefit over best effort

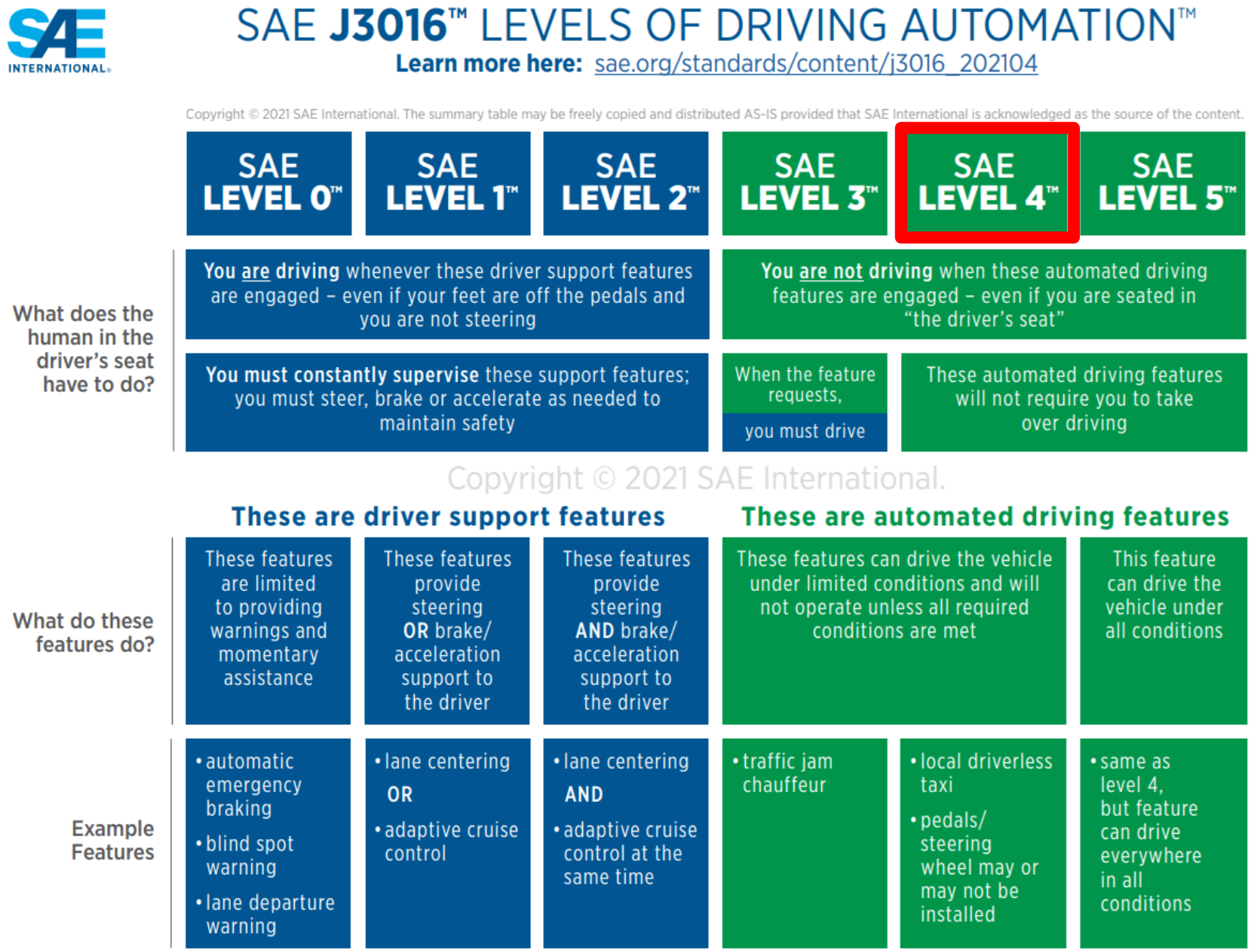
Mission- / Business Critical

- Remote supervision of autonomous vehicles (busses, taxis, trucks)
- Automated Valet Parking

Obvious cost/benefit

What's the benefit over using 2 (or more) best efforts SIMs?

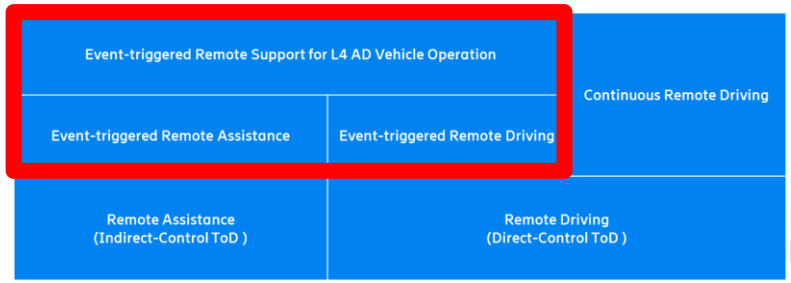
Autonomous driving and 5G: Reality



Autonomous driving and 5G: Reality

	Event-triggered Remote Support for L4 AD Vehicle Operation		Continuous Remote Driving
	Event-triggered Remote Assistance	Event-triggered Remote Driving	
	Remote Assistance (Indirect-Control ToD)	Remote Driving (Direct-Control ToD)	
Role of remote operator	Providing event-driven information and advice to the in-vehicle Automated Driving System (ADS), but not directly control the vehicle maneuver. (The remote operator may need to monitor the environment and execution, and if needed, provide additional inputs to the in-vehicle ADS, e.g., requesting to enter a mitigated risk condition and eventually halt the vehicle.)	Directly taking all or part of the control of vehicle maneuver, like steering, acceleration, and braking.	

Autonomous driving and 5G: Reality



SAE J3016™ LEVELS OF DRIVING AUTOMATION™

Learn more here: sae.org/standards/content/j3016_202104

	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **OR** brake/ acceleration support to the driver	These features provide steering **AND** brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering **OR** • adaptive cruise control	• lane centering **AND** • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/ steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Legal vs. business-driven connectivity

Legally required

- California:
  - Telematics (vehicle location & status)
  - Bidirectional voice communication
- Germany:
  - Telematics (vehicle location & status)
  - Event-triggered Remote Assistance
    - Approve maneuvers automated driving system is not designed for and/or violating traffic rules
    - Supervise maneuver execution and press "stop" if needed
  - "Watchdog" assuring network availability

"Voluntary", business-motivated

- The legally required services make sense due to
  - Business considerations (prevent having to send people to vehicles that got stuck)
  - Reputation (public and government)
- A network "watchdog" is usually not required
- Legal framework for Event-triggered Remote Assistance/-Driving must be in place
  - Else, only "monitoring" allowed

Most countries are still in a phase of deciding about legal mandates for connectivity for Level 4 automated vehicles

Autonomous driving and 5G: Reality

Link to video

Expectations on 6G

Minimize complexity, Maximize performance

Keep
aspects of 5G that work well

Change
when motivated by significant performance enhancements

Add
selected functionality for new use cases

- The 6G architecture should include selected **open interfaces**
- **6G Spectrum Sharing** shall be supported between 5G and 6G
- 6G RAT shall support **new and evolved use cases**, efficiently & sustainably **with quantifiable benefits**

Expectations on 6G
Release vs. Generation

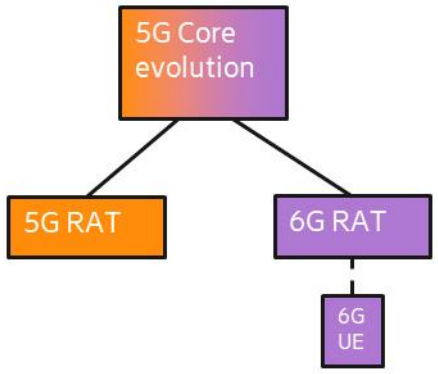
- 3GPP maintains **backwards compatibility across releases and versions of a generation**
  - Allows specifying and implementing new features while supporting legacy end-devices
  - Essential for end-users and the eco-system
  - … but
    - prohibits non-backwards compatible changes
    - makes it increasingly complex and costly to add and improve functionality

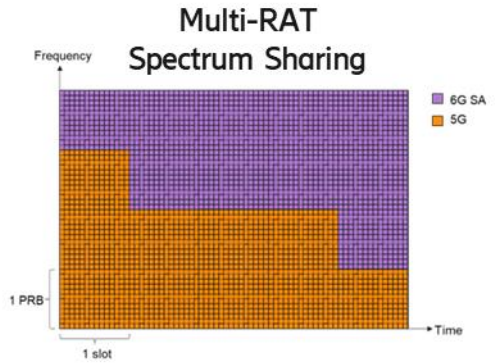
Spectrum sharing:
No need to immediately swap 5G for 6G end devices

- 3GPP allows **non-backwards compatible changes only when starting with a new generation, e.g.:**
  - **Removal of reference signals or messages** that end-devices of the previous generation relied upon
  - **Major changes and restructuring of functionality** to ease introduction of new features

RAT: Radio Access Technology (2G, 3G, …)

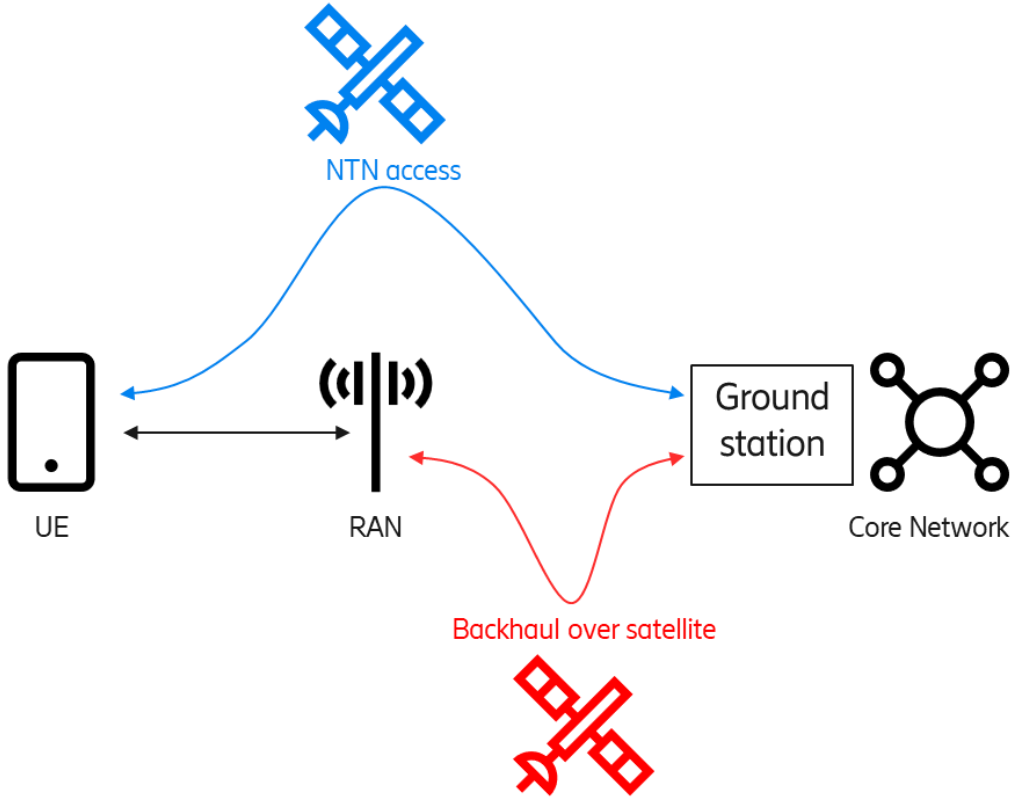
Fast deployment of Standalone 6G
by evolution of 5GC and sharing spectrum with 5G



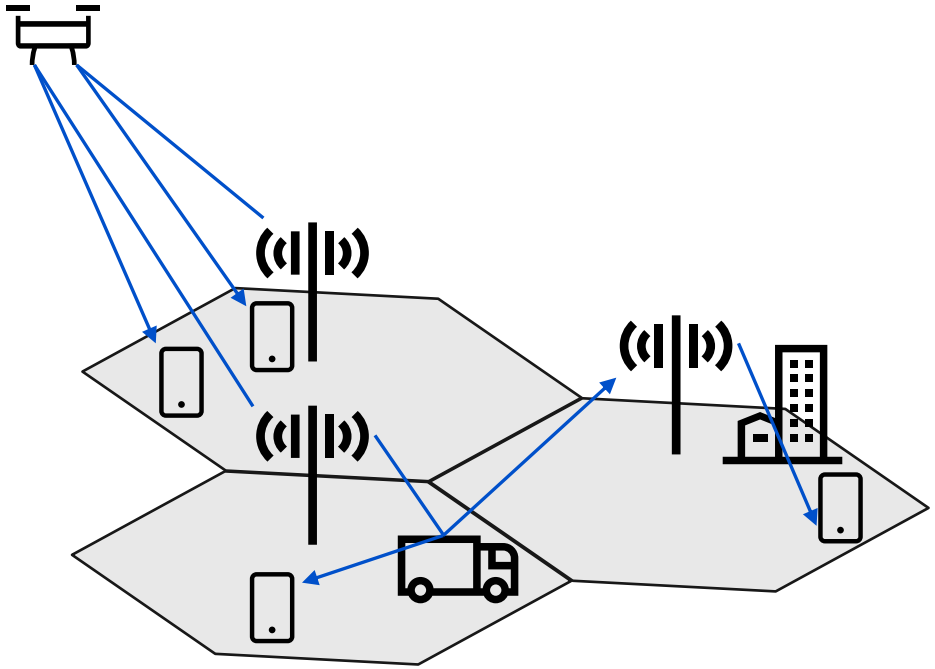


Expectations on 6G

Non-Terrestrial Networks (NTNs)



Integrated Communication and Sensing (ISAC)



Summary & outlook

- Autonomous driving is safer and more energy efficient, with or without communication,
- 4G/5G/6G/… communication is evolving, not revolutionizing autonomous driving
- It is mandated in many, but not all jurisdictions; many regulations still evolving
  – Essential for smooth operation **& reputation** where not mandated
- Mobile Network Operators stuck in Chicken-Egg situation: build highly reliable Mission- / Business critical networks for pilots with few vehicles
- 6G expected to be a gradual evolution of 5G, but it will also allow a clean slate approach

Requirements

Availability (ratio of time connectivity is delivered within requirements)	One-way Uplink Video Latency	Overall Throughput
99.9x% (legally mandated) 99.x% (business motivated)	**50 ms – 100 ms**	**Uplink: 50 Mbit/s (10 Mbit/s minimum)**
• Per vehicle (total network failure affects all vehicles) • When legally mandated, there is usually a network watchdog stopping the vehicle when network not available • When "business motivated" a failure will usually not trigger a vehicle stop, it might not even be noticed because no real-time connectivity service used during failure	• Uplink video is the most demanding service for Remote Assistance / Remote Driving • If you can support this, you can support all other services • German tele-operation law (StVFernLV Straßenverkehr-Fernlenk-Verordnung) requires 200 ms glass-to-glass latency at 80 km/h (incl. application delays like en-/decoders)	• Uplink video is most demanding, rest is neglectable (kBit/s to few Mbit/s) • HD (1080p) video at 60 FPS requires 10 Mbit/s throughput, maximum • 6 cams: E.g. 3 front cameras, 1 back camera and 1 inside camera • Not streaming all cameras and/or reducing stream quality can reduce it to 10 Mbit/s • Usually, only needed on-demand during Remote Assistance / Remote Driving