Connected and Automated Mobility by 5G

Markus Dillinger
Huawei Technologies Duesseldorf GmbH

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Security Level:

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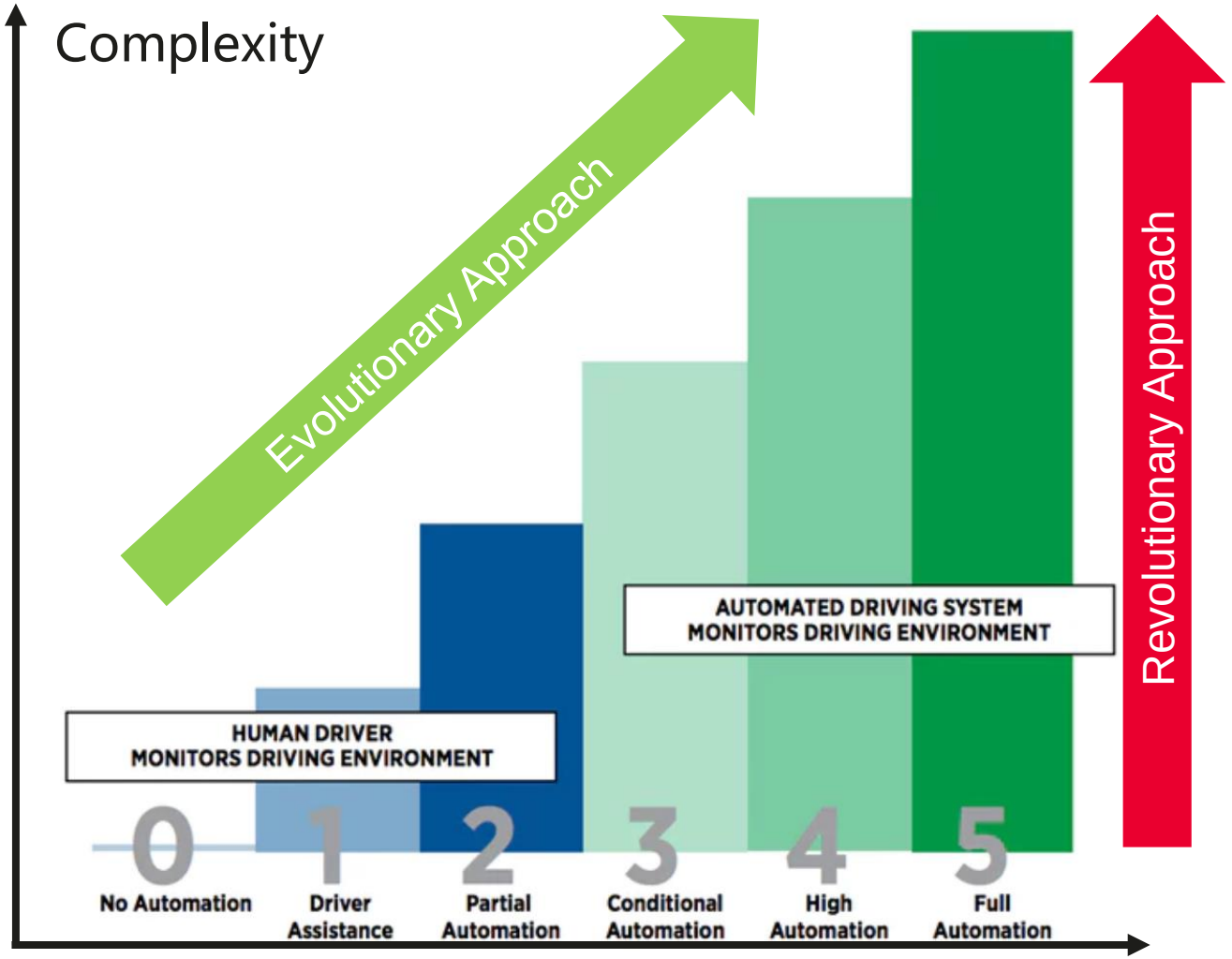
Autonomous Driving is now under development

Something Everywhere

Evolutionary (OEM)

Audi, Volkswagen, VOLVO, GROUPE RENAULT, ...



Everything Somewhere

Revolutionary

WAYMO, Uber, ..., SEOUL ROBOTICS A.I. / Self Driving Car Technology Company

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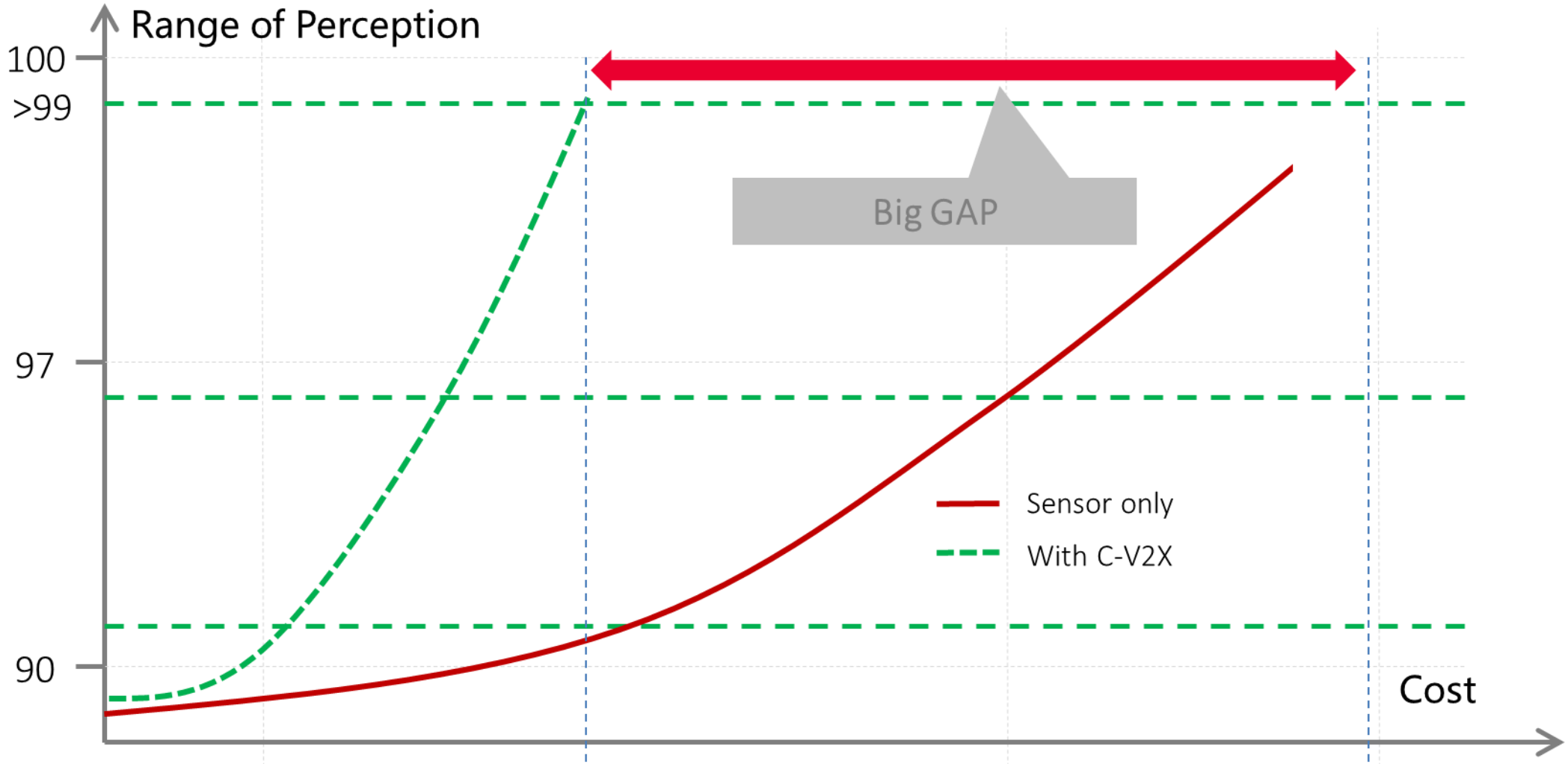
C-V2X improves costs and perception range



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Use Cases for 5G and C-V2X from OEM and User Perspective

5G IoV/5G V2X = 5G eMBB+C-V2X

OTA Update

HD map download and Update

Onboard AR (Navi, driver's view sharing)

Onboard HD Video

Remote monitor/drive

5G Smart Cockpit

Traffic Info exchange

V2X fusion sensing,
V2X assist ADAS+

V2X fusion control and value added services
AVP, ToD, greenwave ACC

C-V2X IoV

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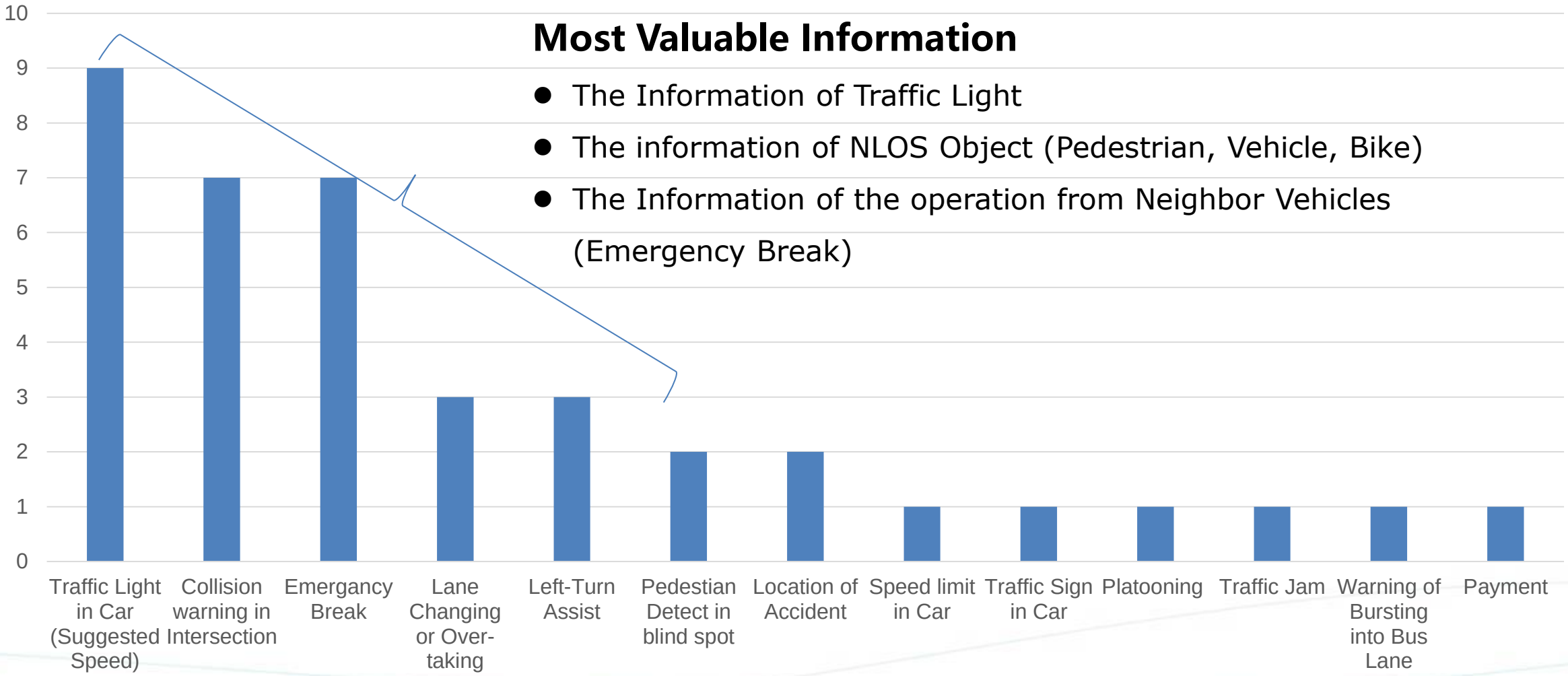
C-V2X industry survey on use cases



Most Valuable Information

- The Information of Traffic Light
- The information of NLOS Object (Pedestrian, Vehicle, Bike)
- The Information of the operation from Neighbor Vehicles (Emergency Break)

The Feedback from 15 OEMs

China: Progress and plan of C-V2X trials

	LTE-V2X Technical Test & Application Demonstration	LTE-V2X Scale Test 5G-NR Technical Test	5G-V2X Technical Test
Test goal	• **Verify the supporting capability of LTE-V2X network for typical services.** • **Carry out application demonstration for typical services in Shanghai, Wuxi and other places.**	• **Test LTE-V2X networking performance; verify the maturity of LTE-V2X products.** • **Verify the supporting capability of 5G NR for IoV services and networking requirements.**	• **Carry out function and performance tests based on 5G-V2X IoV network.** • **Explore network deployment schemes by taking into consideration L4/L5 autonomous driving applications.**
Test result/ Content	**LTE-V2X Communication Performance Verification** ❑ Uu: delay<100ms, reliability ❑ PC5: satisfying the delay requirements of V2I services; network coverage in LOS/N-LOS scenarios. **Application Verification of Services** ❑ Accomplish the consistency verification of standard protocols. ❑ Accomplish the interconnection of verification of multi-manufacturers. ❑ Accomplish the process verification of services.	**LTE-V2X Scale Test** ❑ LTE-V2X air interface coverage, reliability, delay verification and optimization. ❑ V2X Services: Traffic light optimal speed advisory, traffic accident warning, forward collision warning, etc. **5G-NR Technical Test** ❑ Verification of Air interface performance for 5G NR in vehicle scenario. ❑ Verification of service functions and performance in typical applications in closed scenes such as remote driving.	**5G-V2X Technical Test** ❑ Function and performance verification for services such as information sharing of sensors, vehicle platooning, and etc. ❑ Enhancement of 5G NR Uu interface and test of key technology of 5G NR PC5 interface.
	2017-2018	**2019-2020**	**2021~**

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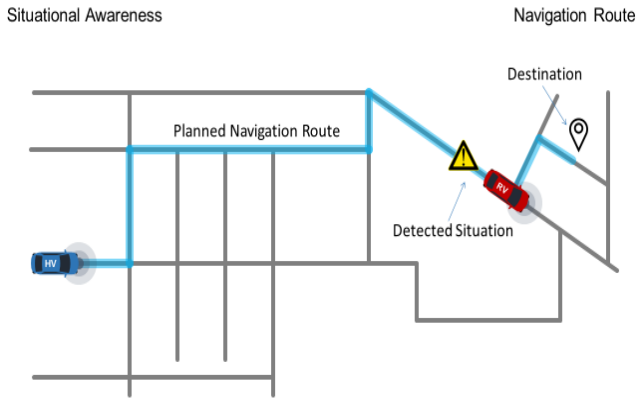
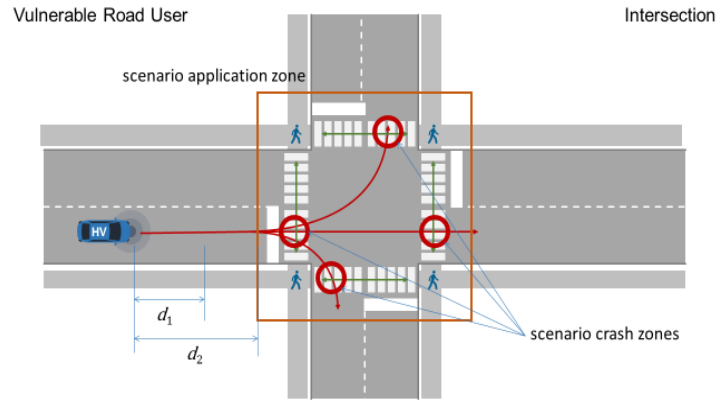
5GAA Prioritised Use Cases Support for R16

5GAA LS on Prioritised Use Cases and Requirements for consideration in Rel-16 NR-V2X

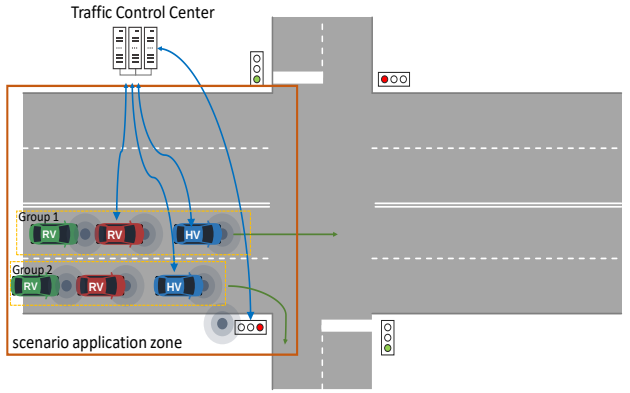
1. Software Update (including vehicle-to-vehicle)
2. Real-Time Situational Awareness & High-Definition Map
3. Vulnerable Road User (VRU)
4. Group Start in Cities (variant of Platooning Use Case)
5. Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations
6. Remote Automated Driving Cancellation (RADC)
7. Automated Intersection Crossing
8. Autonomous vehicles parking by remote driving



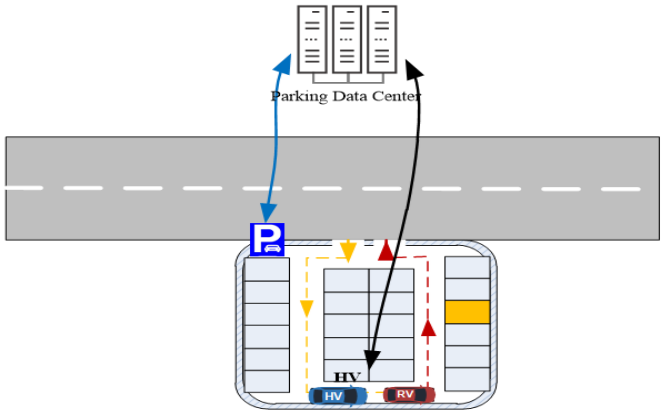
Real-Time Situational Awareness & High-Definition Map



Vulnerable Road User (VRU)



Group Start in Cities



Autonomous vehicles parking by remote driving

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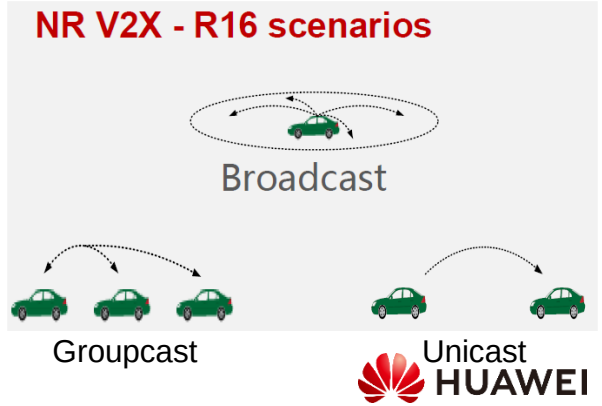
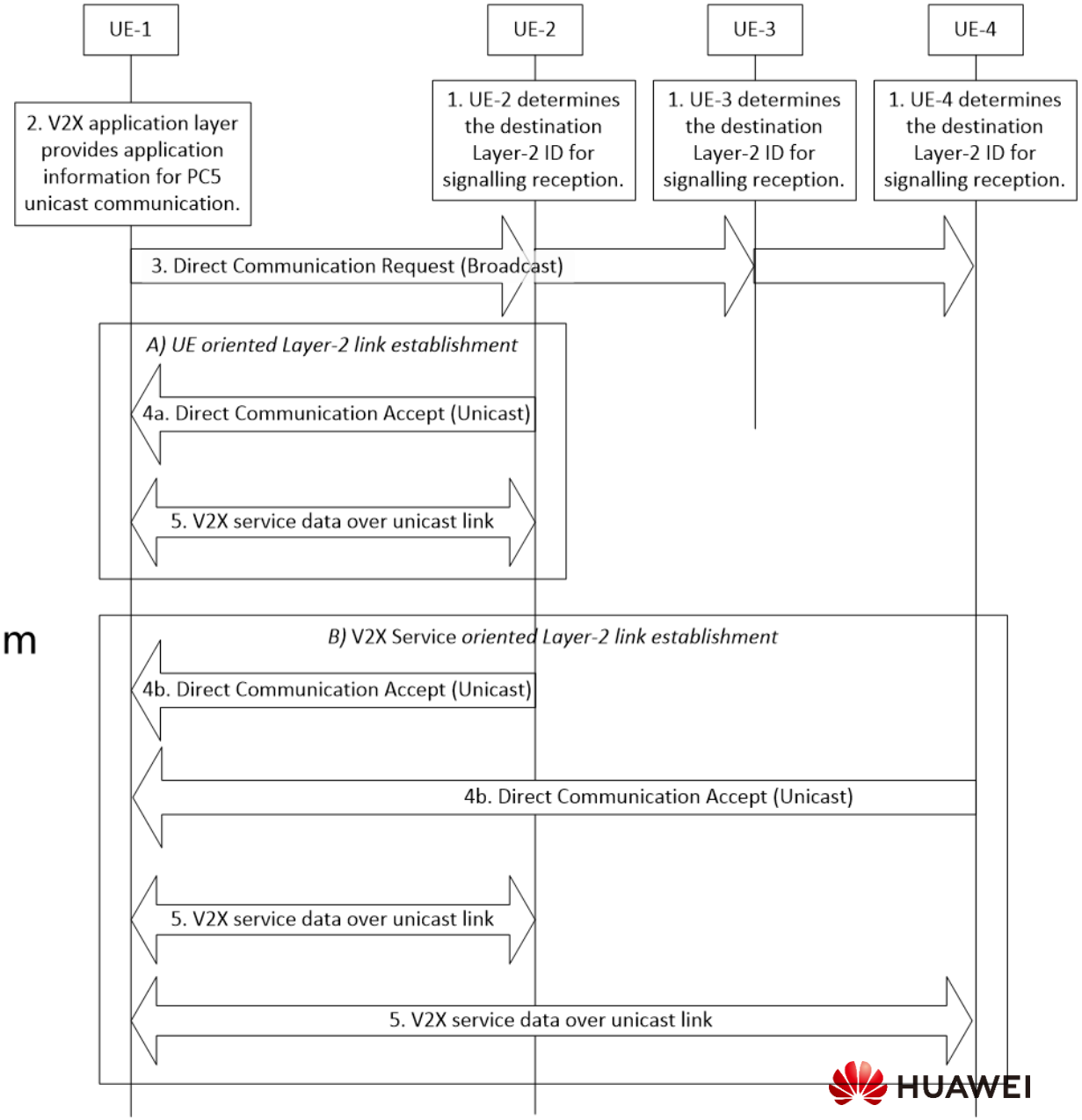
5G V2X with NR Sidelink (SL)

- Radio solutions that are necessary for NR to support advanced V2X services based on the study outcome captured in TR 38.885
  - Support broadcast – support LTE-V like service, such as basic safety message broadcast
  - Support unicast – support advanced driving service, such as sensor sharing, see through and ETC-like service
  - Support groupcast – support platooning use case
- Considering in-network coverage, out-of-network coverage, and partial network coverage
- Support of sidelink structure/ synchronization /procedure aligned with NR Uu
- Support Resource allocation
  - Mode 1 – NR sidelink scheduling by NR Uu and LTE Uu - enable licenced spectrum
  - Mode 2 – enable OOC and ITS spectrum
- Sidelink L2/L3 protocols and signalling – whole NR V2X protocol support
- Unique QoS with Uu – enable QoS comparison with NR Uu
- UE Tx and Rx RF requirement/RRM core requirement – RAN4 spec support



Sidelink Unicast

- **Support low latency/high reliability SL communication in link level**
  - 3ms E2E latency/99.999% reliability
  - High data rate support
- **Unicast support in NR V2X**
  - PHY source/destination ID
  - HARQ including sidelink HARQ ACK/NACK report from transmitter UE to gNB
  - CQI, RI (up to 2 layers) measurement and feedback
  - Link adaptation/Multi-antennas
  - RLM/RLF
  - 64QAM



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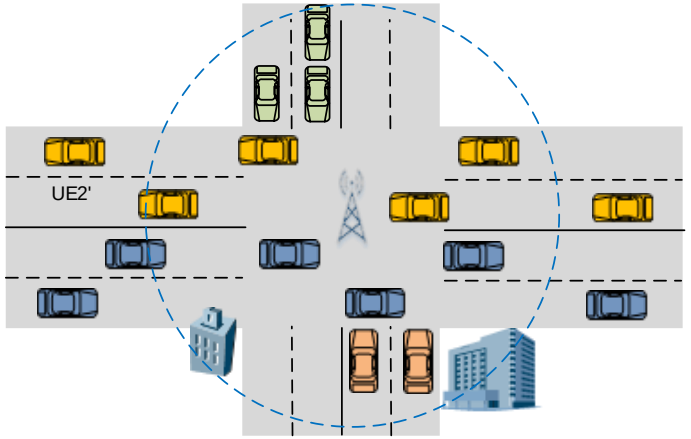
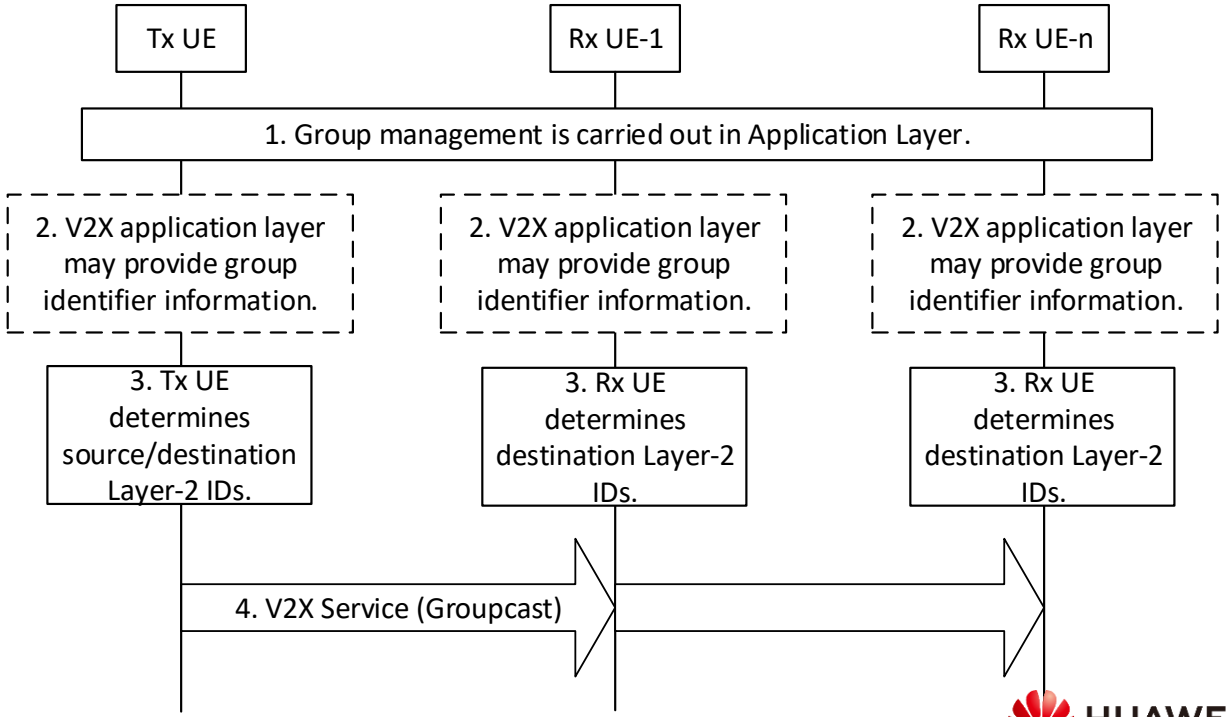
Sidelink Groupcast Transmission

- **Motivation**
  - High efficiency for Platooning
  - High reliability
  - Distance based sensor sharing
- **Groupcast support in NR V2X**
  - When HARQ feedback is enabled for groupcast, support
    - ➢ Option 1: Receiver UE transmits only HARQ NACK
      - For at least option 1 based TX-RX distance-based HARQ feedback for groupcast
    - ➢ Option 2: Receiver UE transmits HARQ ACK/NACK
      - Higher transmission reliability
      - Lower interference to other UE reception
      - No DTX problem
      - Feasibility to identity the failure receiver UEs





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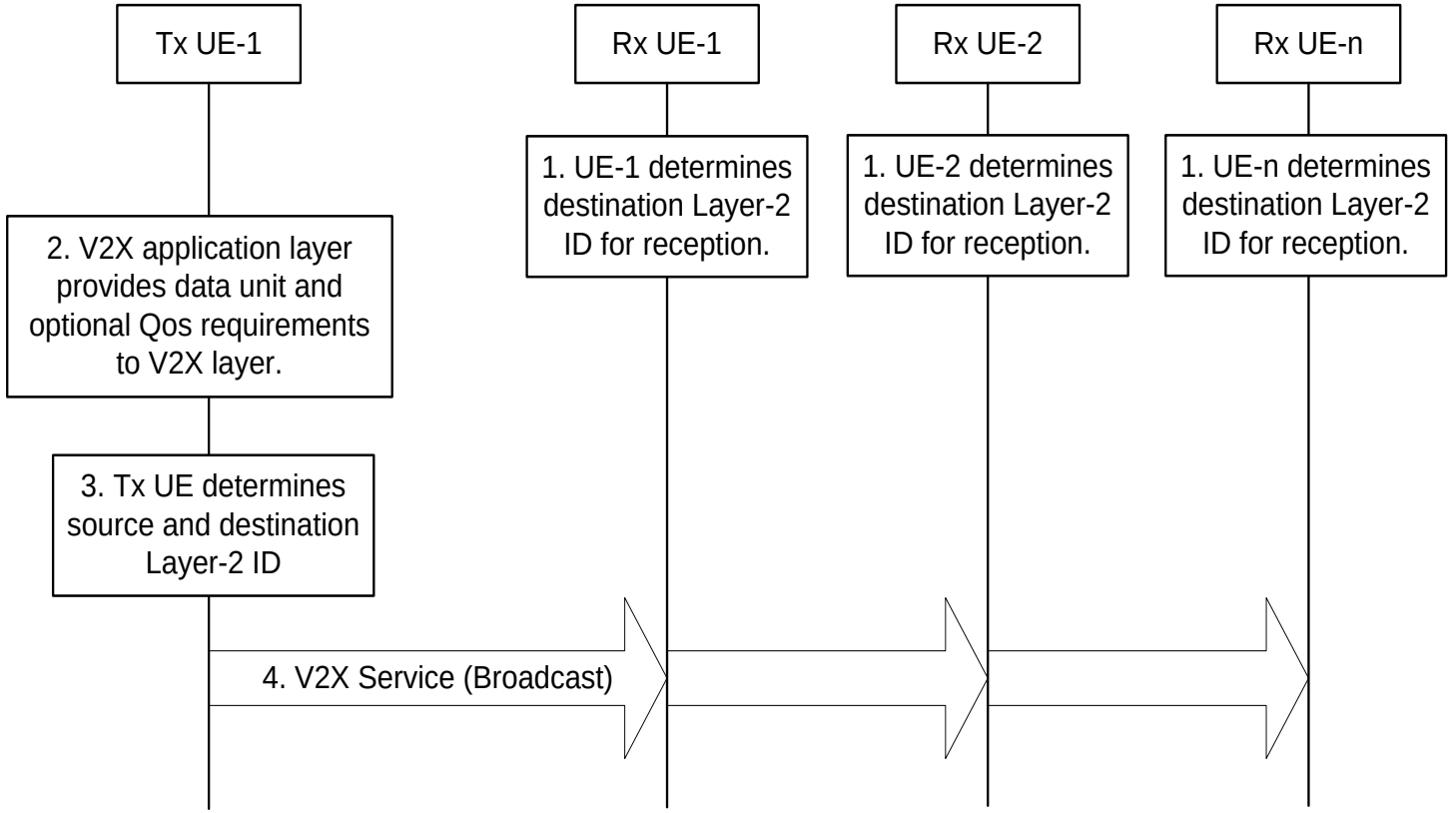
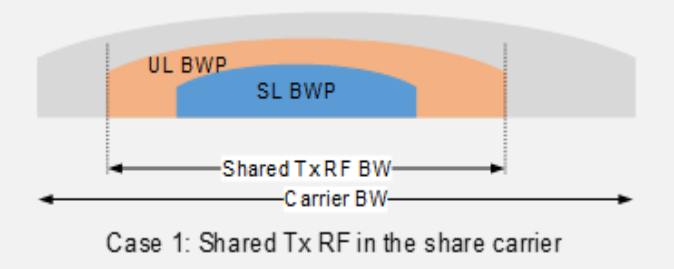
Sidelink Broadcast

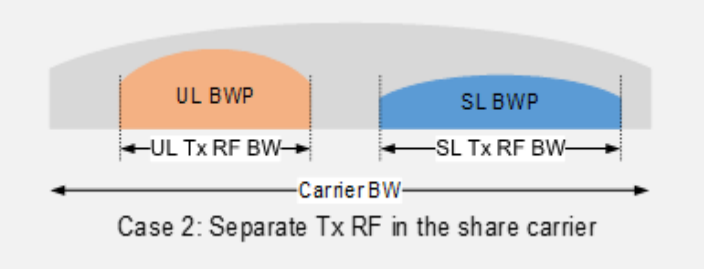
- **Motivation**
  - Support the same transmission mode as LTE-V
- **Broadcast support in NR V2X**
  - Mainly re-use the LTE-V design



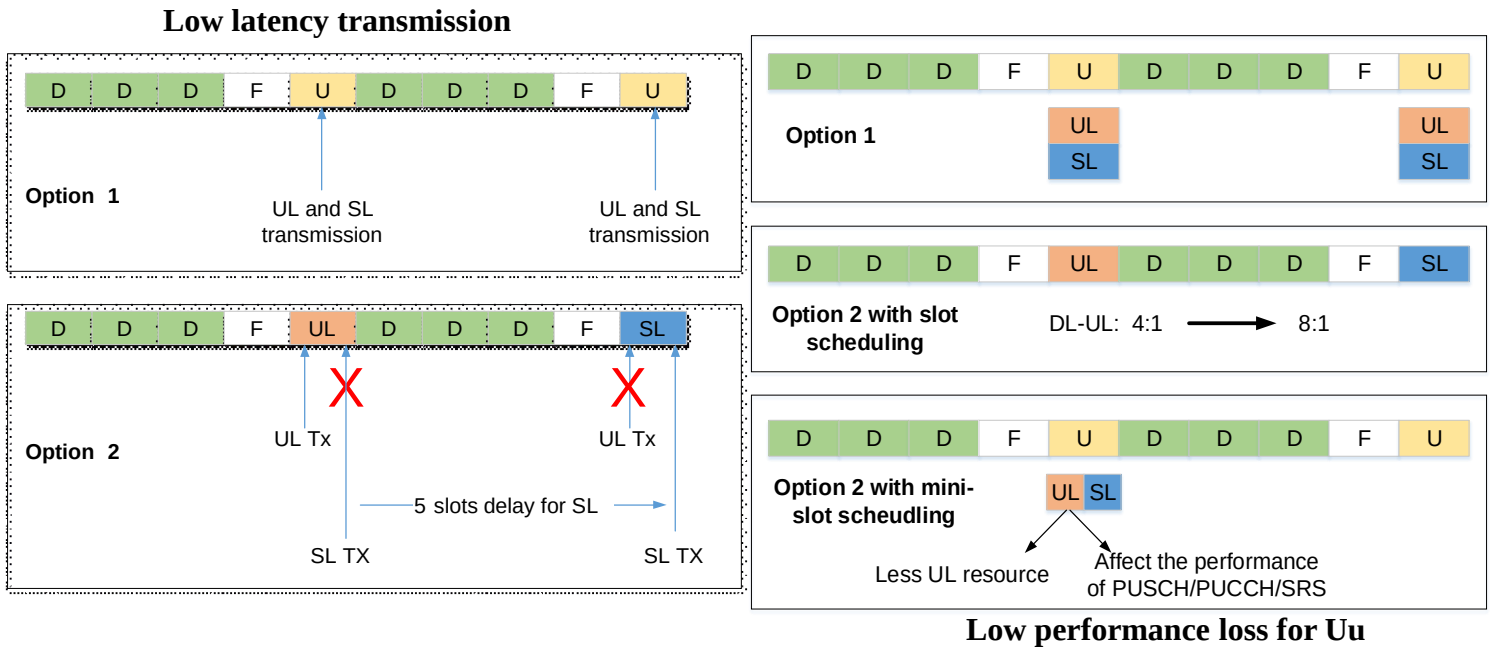
Sidelink Shared Licensed Band Support

- **Motivation**
  - ITS spectrum support
  - Licensed Spectrum support





- **BWP is defined for NR sidelink**
  - Support simultaneous transmission in SL BWP and UL BWP when the same numerology is configured in both BWPs
    - Shorter delay for SL transmission
    - Less performance loss to Uu, especially in typical DL-heavy UL-DL configurations
  - Achieved by configuring UL BWP and SL BWP within UE's RF BW
  - Different TAs are handled by adding two time-domain OFDM signals



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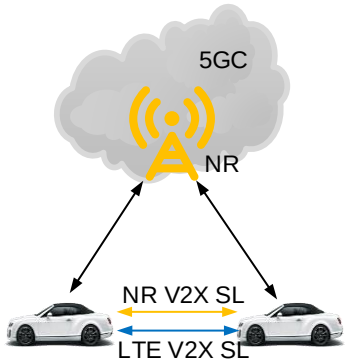
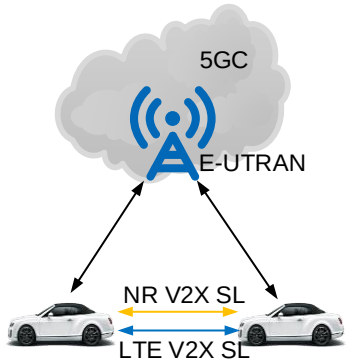
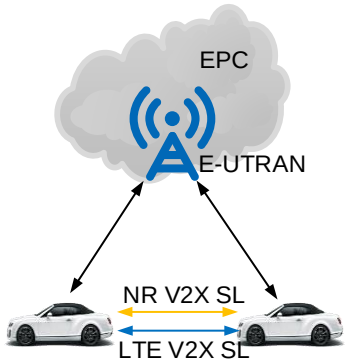
‘Cross-RAT’ control

- NR V2X defined:
  1. NR Uu to control LTE mode 3/4 sidelink
  2. LTE Uu to control NR mode 1/2 sidelink
- Both allow smooth evolution within 3GPP V2X as MNOs' RAT availability, and automotive industry choices, develop over lifetime of vehicles





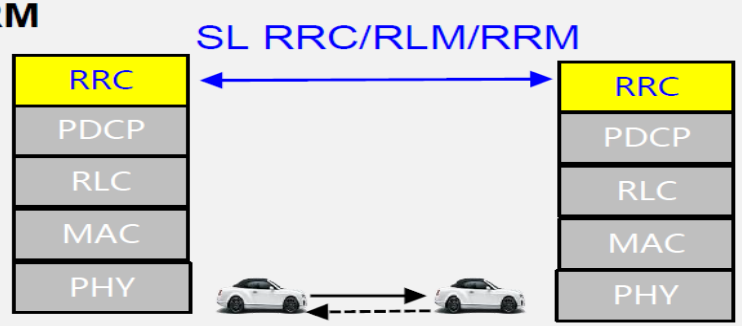


…and MR-DC equivalents under MNO control of sidelink

5G V2X Radio Protocol Design

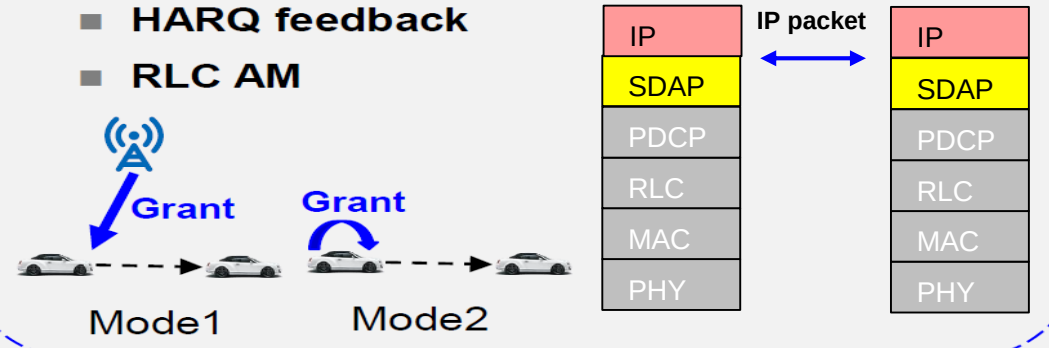
1、SL control plane

- SL RRC
- SL RLM
- SL RRM



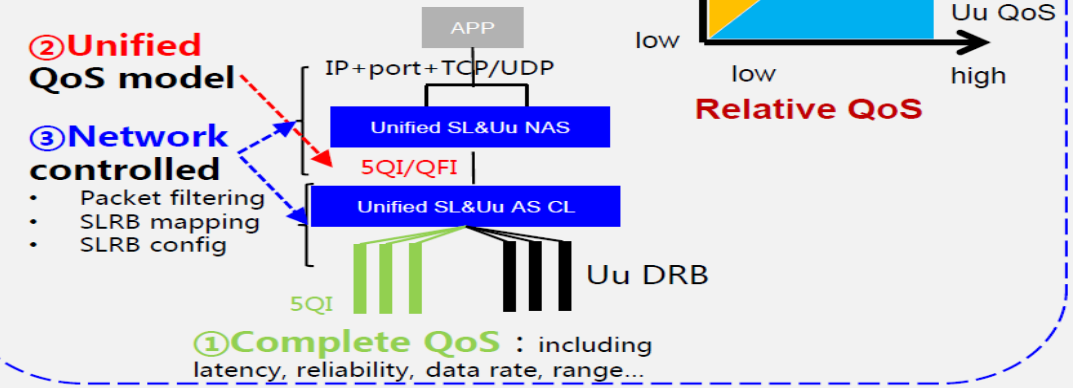
2、SL user plane

- Mode1/Mode2
- Simultaneous mode1&2(lower priority)
- HARQ feedback
- RLC AM



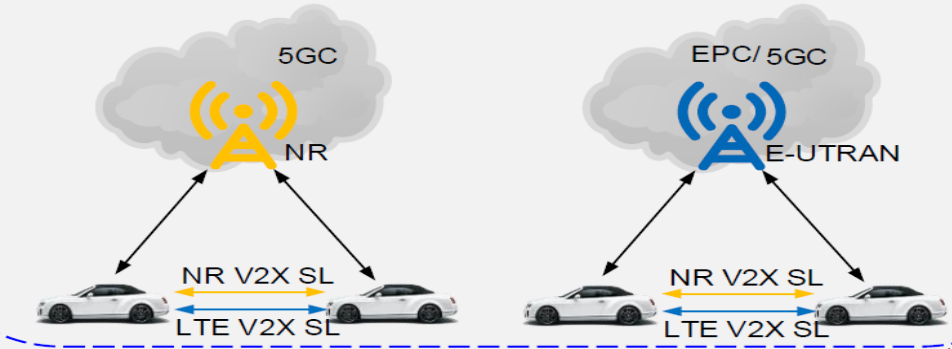
3、QoS

- Unified QoS
- Relative QoS



4、X-RAT scheduling / Architecture

- gNB connecting 5GC
- eNB connecting EPC/5GC



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5G V2X Spectrum/Band Definition

- **ITS spectrum**
  - › RAN4 to define re-farmed band n47 for NR V2X Communication Service

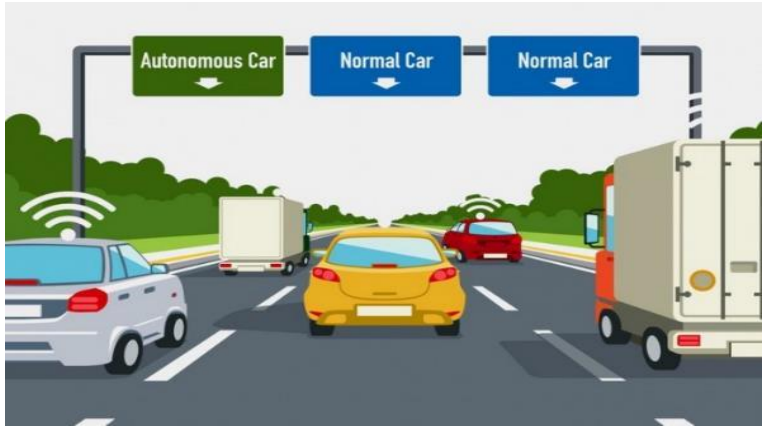
NR operating band	Sidelink (SL) Transmission operating band $F_{\_low}$ – $F_{\_high}$	Sidelink (SL) Reception operating band $F_{\_low}$ – $F_{\_high}$	Duplex Mode	Interface
n47	5855 MHz – 5925 MHz	5855 MHz – 5925 MHz	TDD	PC5

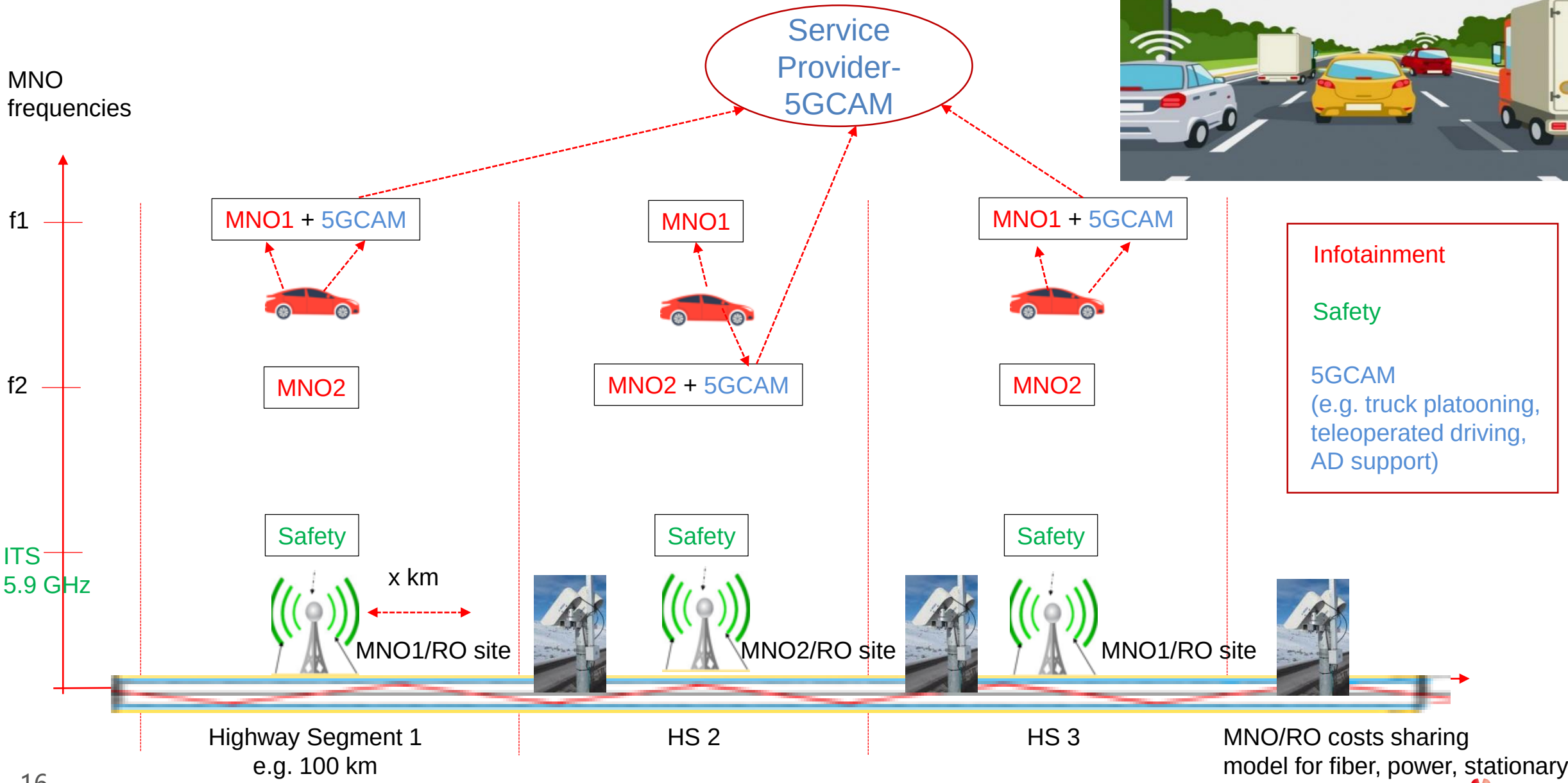
- **Licensed spectrum**

  For co-existence study for licensed band with slidelink operation, the example bands will be

  - Option 1: 2GHz (Uplink part of a FDD band 1 and band 3)
  - Option 2: 3.5GHz (TDD bands)
  - Option 3: 28GHz (FR2)

What is a 5GCAM Highway (Road) ?





RO: Road Operator, MNO: Mobile Network Operator

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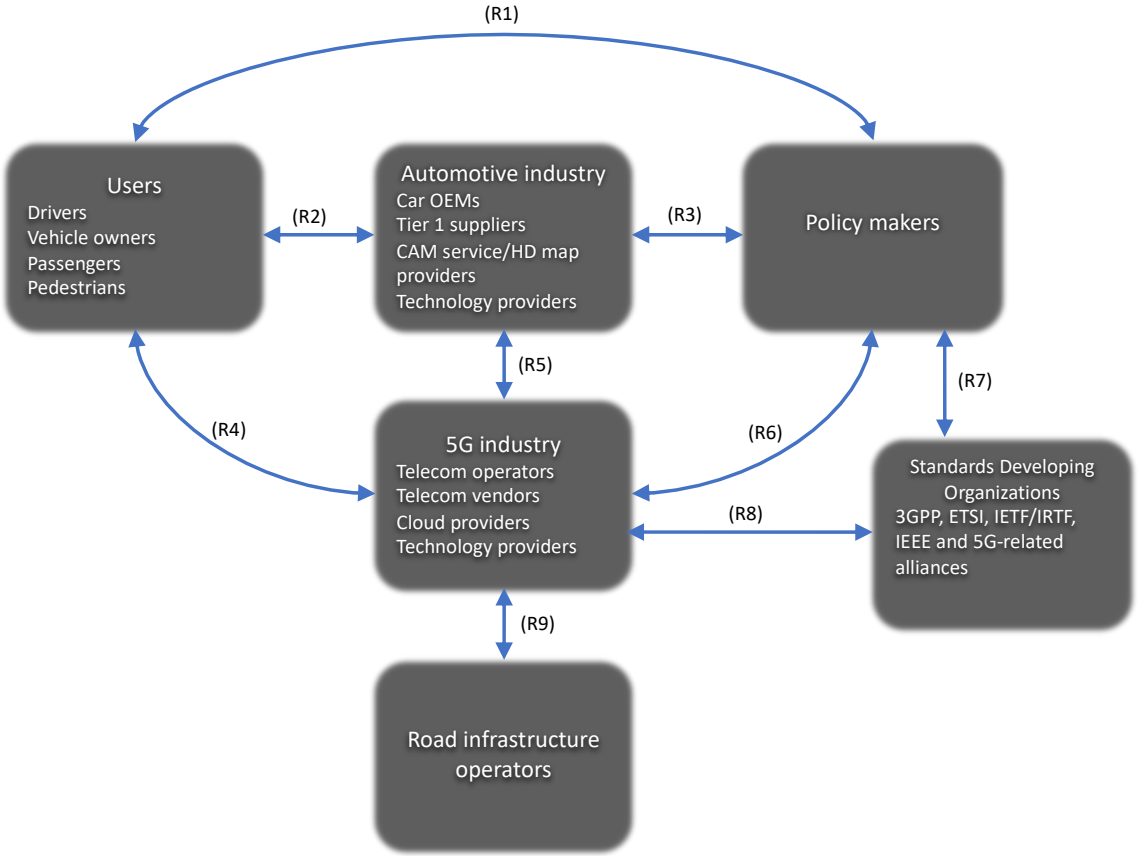
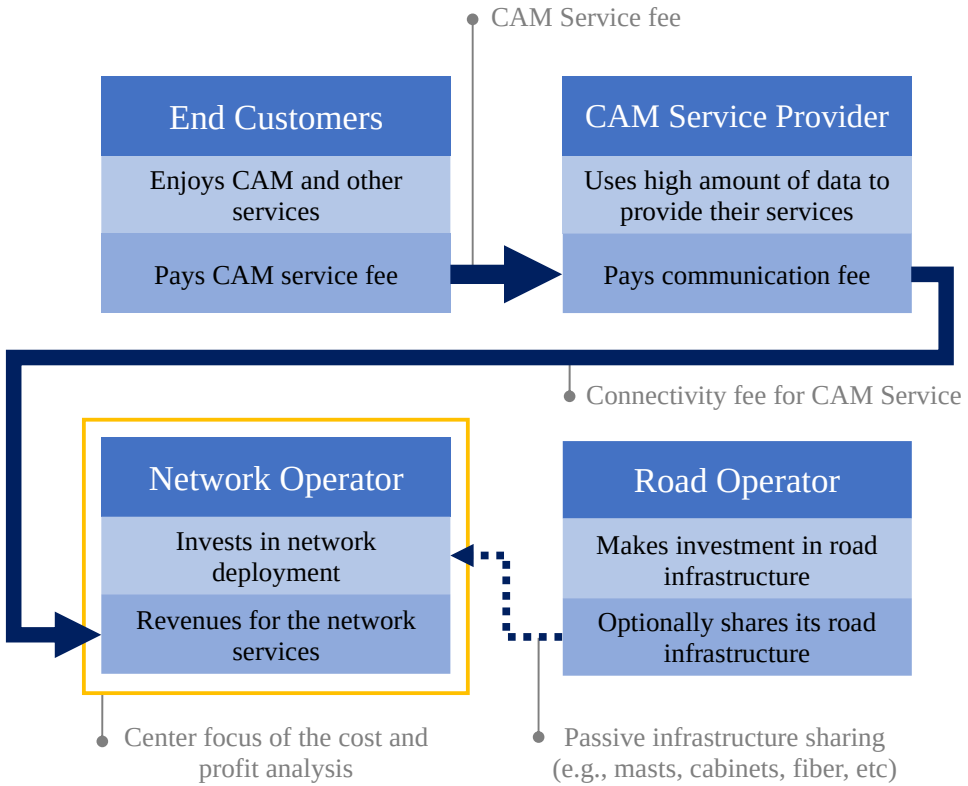
5GCAM ecosystem and business models





Source: 5G Automotive Working Group, "A Study on 5G V2X Deployment", February 2019 5G

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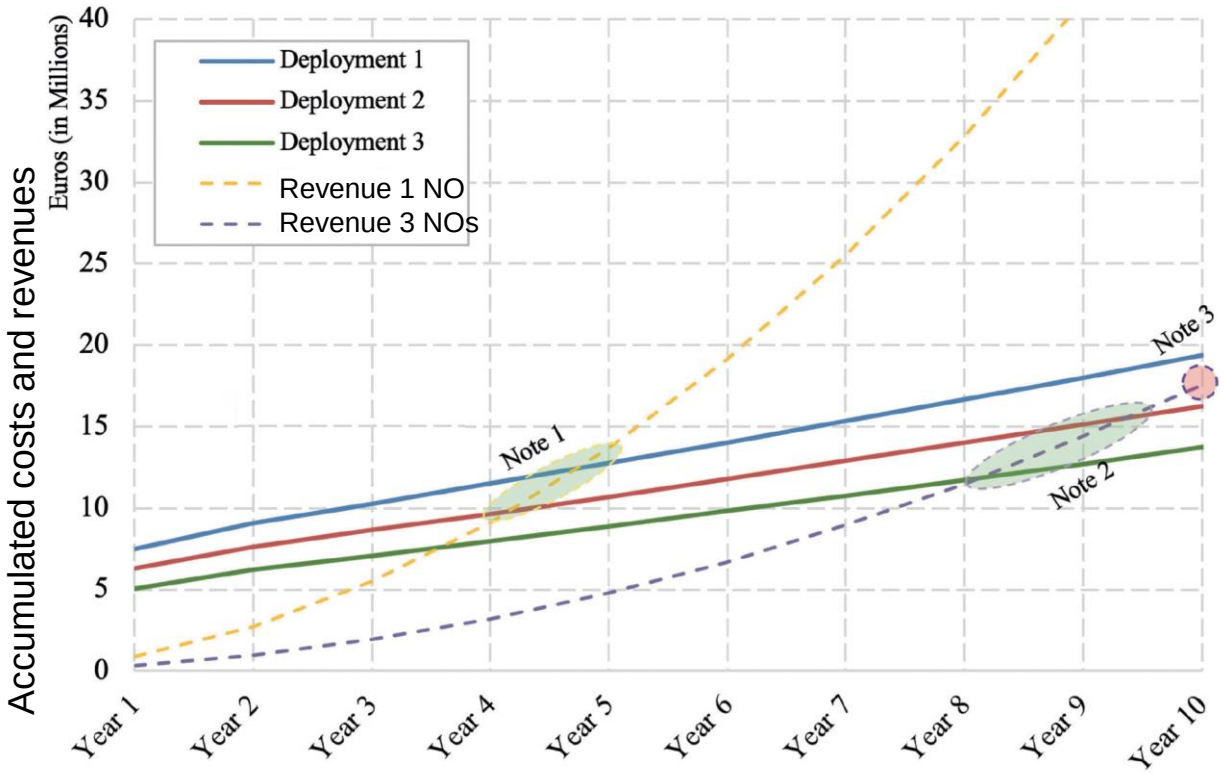
5GCAM Business Case for Pay-As-You-Drive



Return-Of-Investment

	Parameter	Value	Unit
Area and capacity demand	Inter-site-distance (ISD)	1	km
	Deployment length	100	km
	Number of vehicles	50 000	Vehicles/100km/day
Deployment rate	Connectivity cost for CAM	0.5	Euro per 100 km
	Network deployment rate	55	% for year 1 for coverage
		5	% from year 2 to 10 for capacity
	Fiber deployment rate	80	% year 1
		20	% year 2
	Yearly penetration rate	10	% from year 1 to 10
Costs evolution	CAPEX Yearly price evolution	-3	% from year 1 to 10
	OPEX Yearly price evolution	3	% from year 1 to 10

Investment Assumptions

- **Deployment 1**: Passive and active network by a single actor
- **Deployment 2**: Passive sharing, several active NOs
- **Deployment 3**: Passive and active sharing, several NOs

Different ROI time lines can be expected for different 5GCAM cooperation models on highways (Everything Somewhere)

Source: 5G Automotive Working Group, "A Study on 5G V2X Deployment", February 2019 5G

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