Vehicle to Everything (V2X)
Introduction
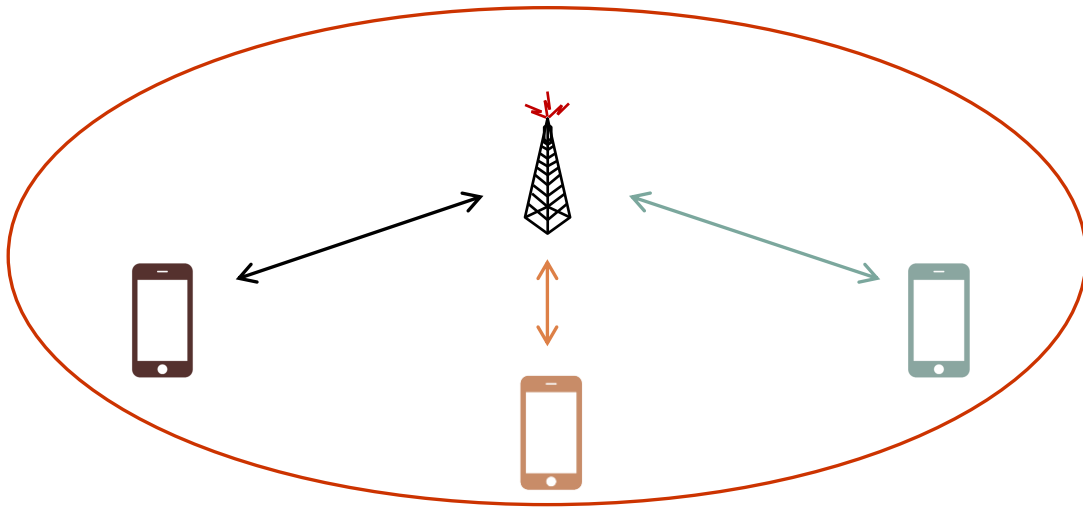
@3g4gUK

Connected and Autonomous Vehicles (CAVs)

Summary: Connected & Autonomous Vehicles (CAVs)

Autonomous Driving: HD Maps, Road safety applications, collision avoidance, extended sensors etc.

Remote monitoring, software updates

Infotainment: Advertisement , personal information management, connected media, audio and video streaming etc.

Emergency service: eCall, crash info

Vehicle Apps: Vehicle related apps (parking, meters), traffic efficiency etc...

Warning: Road hazard warning, traffic jam ahead warning, emergency vehicle approaching etc

Remote control: Remote control of the car, warmup/down, etc...

Unicast & Broadcast

- Unicast is one to one communication
- Users transmit and receive separately
- Also known as Point-to-point (PTP) communication
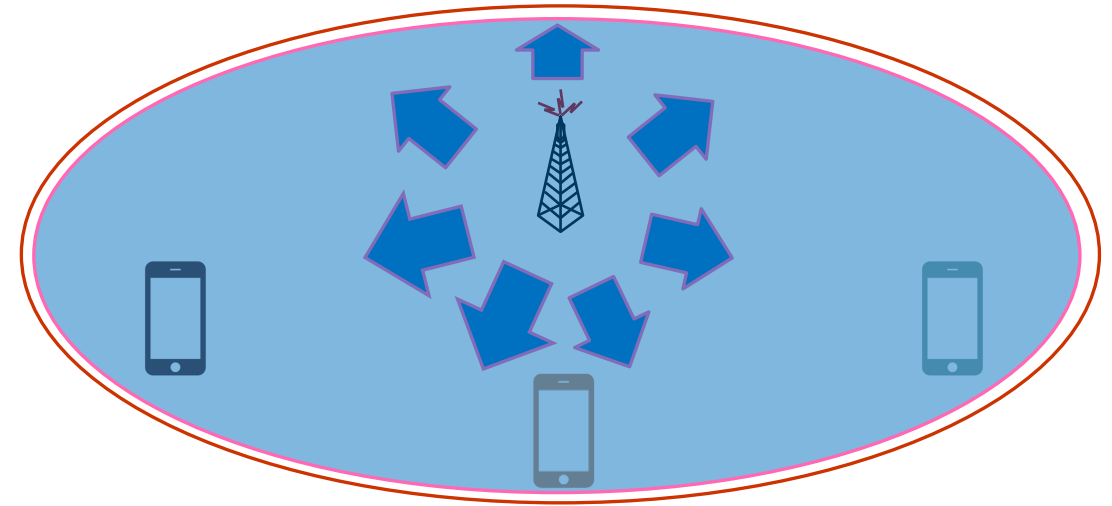
- Broadcast is one to many communication
- Transmission from single point is received by multiple receivers
- Also known as Point-to-multipoint (PTM) communication

Basic V2X Concept

Together, these form part of what we describe as Cooperative Intelligent Transport Systems (C-ITS).
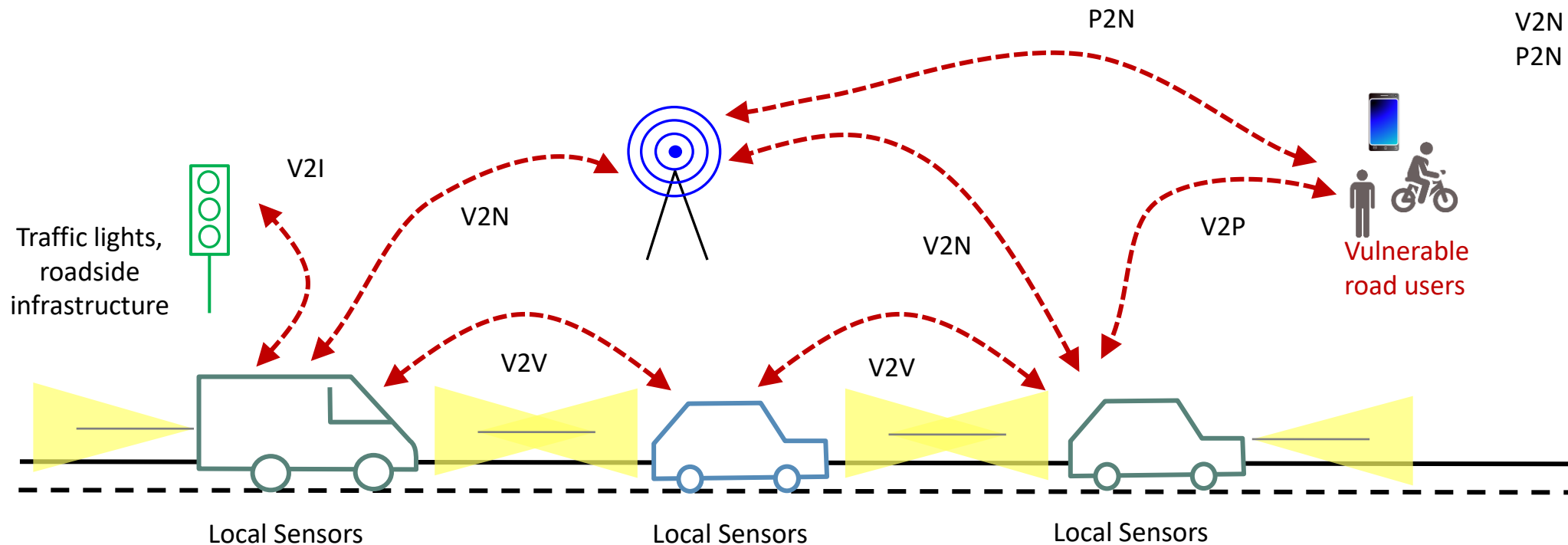
V2X – Vehicle to Everything
V2I – Vehicle to Infrastructure
V2P – Vehicle to Pedestrian
V2V – Vehicle to Vehicle
V2N – Vehicle to Network
P2N – Pedestrian to Network

P2N

V2I

V2N

V2N

V2P

Traffic lights, roadside infrastructure

Vulnerable road users

V2V

V2V

Local Sensors

Local Sensors

Local Sensors

Two Different Types of V2X

V2X

- **IEEE 802.11p**
  - USA - Dedicated Short-Range Communication (DSRC)
  - Europe - ITS-G5
  - Japan - ARIB STD-T109

- **IEEE 802.11bd**
  - Evolution of 802.11p, expected to be available in 2021

- Cellular V2X (**C-V2X**) – defined by 3GPP
  - Release-12: D2D
  - Rel-13: eD2D
  - Rel-14: V2V, V2X basic services
  - Rel-15: eV2X
  - Rel-16: 5G NR V2X

Spectrum for C-ITS

Country	Spectrum (MHz)	Allocated bandwidth (MHz)
Australia	5855 – 5925	70
China	5905 - 5925 (trials)	20
Europe	5875 – 5905	30
Japan	755.5-764.5 and 5770 – 5850	9 and 80
Korea	5855 – 5925	70
Singapore	5875 – 5925	50
USA	5850-5925	75

Source: Wikipedia

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LTE Band 47 – TD V2X

Band	Name	Downlink (MHz)			Bandwidth DL/UL (MHz)	Uplink (MHz)			Duplex spacing (MHz)	Geographical area	3GPP release
		Low	Middle	High		Low	Middle	High			
		Earfcn				Earfcn					
47	TD V2X	5855 54540	5890 54890	5925 55239	70					Global	14.1

- Note that permitted bandwidth is:
  - 10 MHz
  - 20 MHz

M2M vs D2D
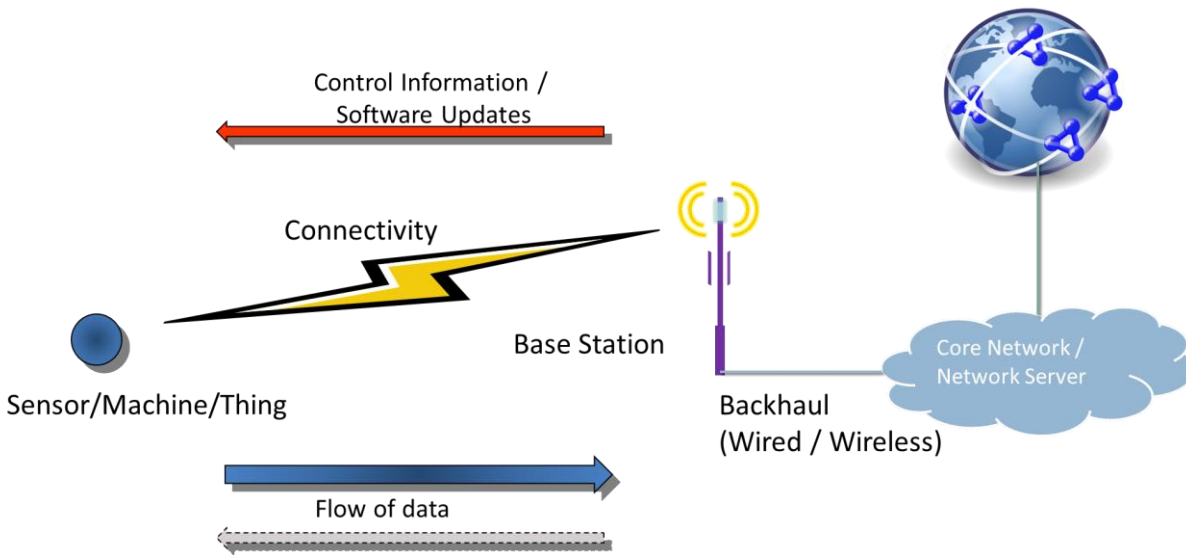
An example of M2M / MTC Network

Control Information / Software Updates

Connectivity

Base Station

Sensor/Machine/Thing

Backhaul (Wired / Wireless)

Core Network / Network Server

Flow of data

Light

Proximity

Microphones (inc. ultrasound reciver)

Camera (front & back)

Gyroscope

Accelerometer

Magnetometer

Barometer

Humidity

Positioning
◦ GPS / GLONASS / GALILIEO
◦ Wi-Fi
◦ Cellular (A-GPS)

NFC

Pressure

Temperature

Gesture

Fingerprint

Heartbeat monitor

An example of Device

Device-to-Device (D2D)

- D2D in LTE standards is called Sidelink.
- The new radio interface is called PC5
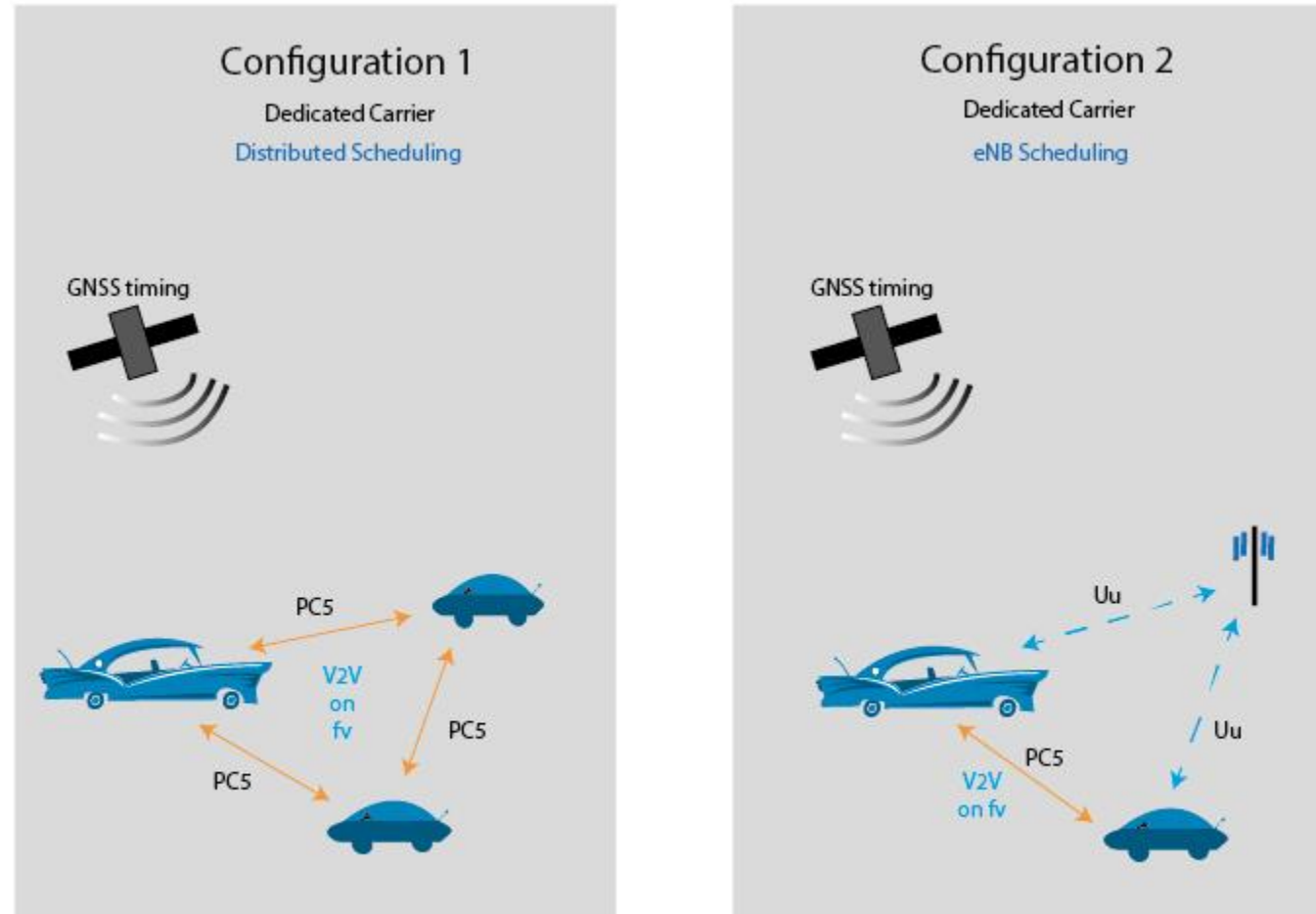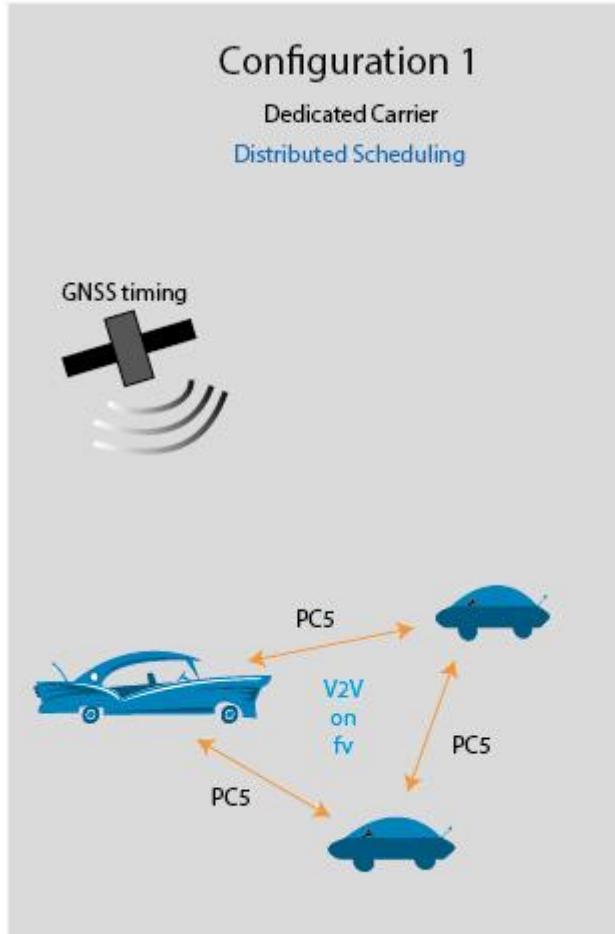
# High-level Deployment Configurations

Figure 3

Source: 3GPP

Configuration 1: Distributed Scheduling (TM 4)

Configuration 1
Dedicated Carrier
Distributed Scheduling

GNSS timing

PC5

V2V on fv

PC5

PC5

Source: 3GPP

- Scheduling and interference management of V2V traffic is supported based on distributed algorithms implemented between the vehicles
  - Distributed algorithm is based on sensing with semi-persistent transmission.
  - V2V traffic from a device is mostly periodic in nature.
- Additionally, a new mechanism where resource allocation is dependent on geographical information or Zones is introduced.
  - Such a mechanism counters near far effect arising due to in-band emissions.
- V2X spectrum is used for communication over PC5

Configuration 2: eNB Scheduling (TM 3)

Configuration 2
Dedicated Carrier
eNB Scheduling

GNSS timing

Uu

Uu

PC5

V2V
on fv

Source: 3GPP
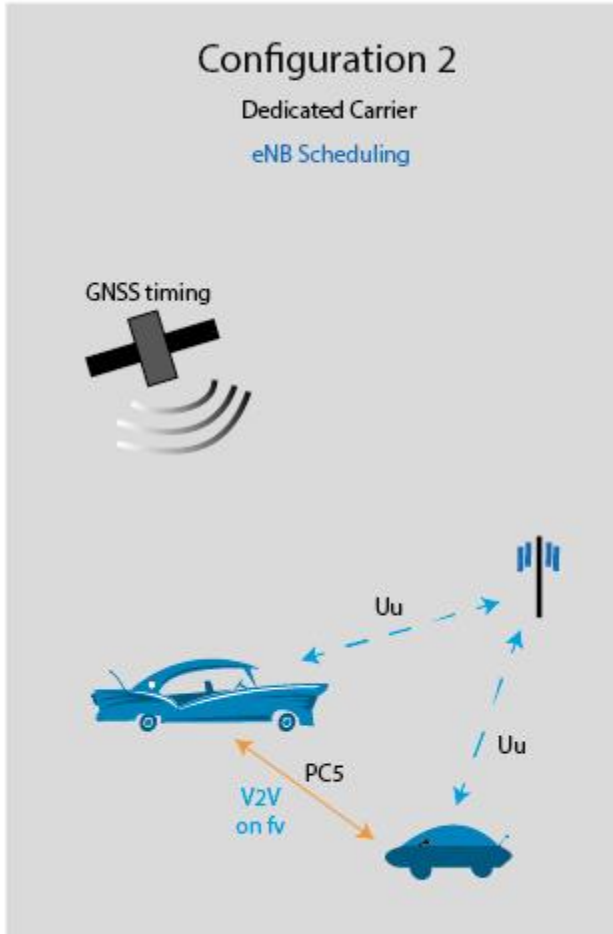
- In this case the device is in coverage of the network and in RRC Connected state
  - UE sends eNB a scheduling request
- Scheduling and interference management of V2V traffic is assisted by eNBs via control signaling over the Uu interface.
- The eNodeB will assign the resources being used for V2V signaling in a dynamic manner.
- Licensed spectrum is used for communication with the eNodeB while unlicensed V2X spectrum is used between the vehicles

System Information Blocks (SIB) carrying Sidelink Info

- The IE SystemInformationBlockType18 indicates E-UTRAN supports the sidelink UE information procedure and may contain sidelink communication related resource configuration information.

- The IE SystemInformationBlockType19 indicates E-UTRAN supports the sidelink UE information procedure and may contain sidelink discovery related resource configuration information.

- The IE SystemInformationBlockType21 contains V2X sidelink communication configuration.

- The IE SystemInformationBlockType26 contains V2X sidelink communication configurations which can be used jointly with those included in SystemInformationBlockType21.

- The IE SystemInformationBlockType28 contains NR sidelink communication configuration.

4G/5G Sidelink Operation Scenarios

Release 16

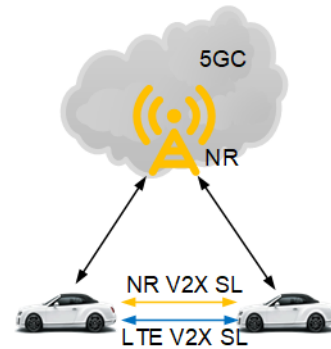3GPP TR 38.885 V16.0.0 (2019-03)

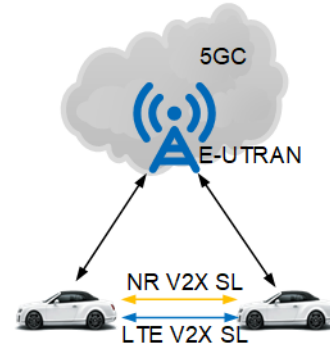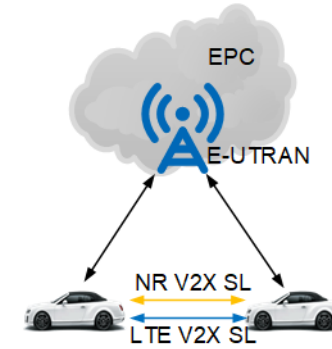
Figure 4.1-1: Scenario 1

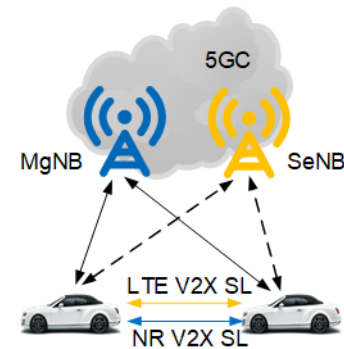Figure 4.1-2: Scenario 2

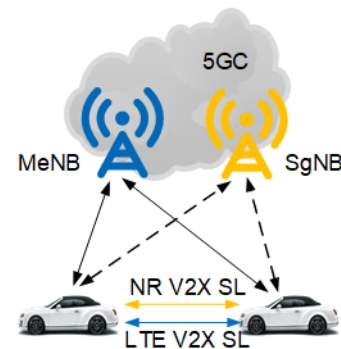Figure 4.1-3: Scenario 3

Figure 4.1-4: Scenario 4
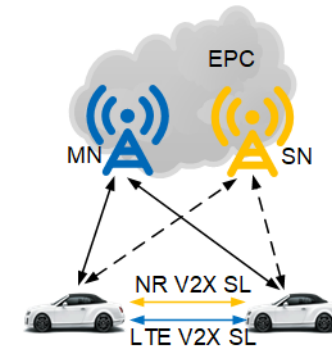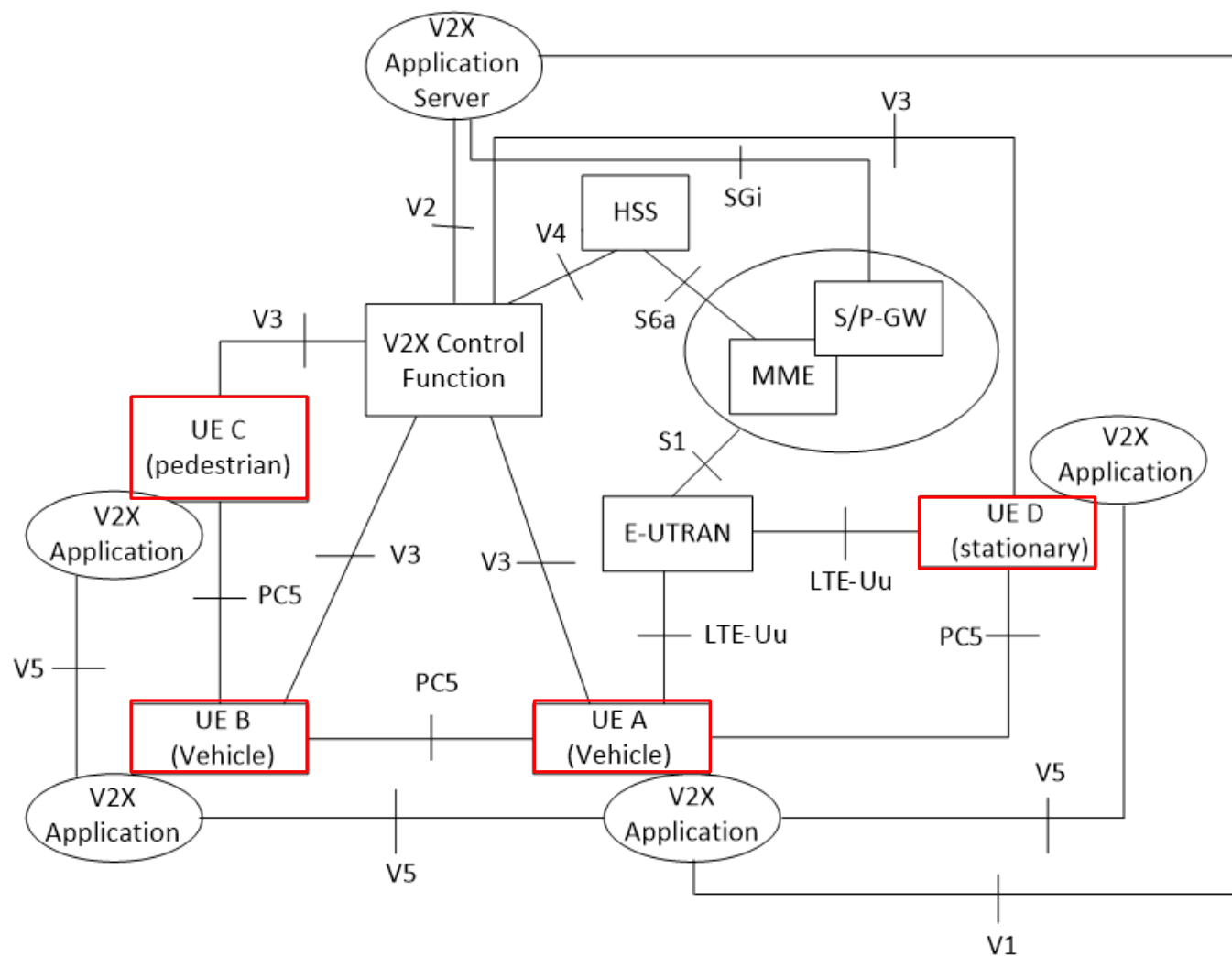
Figure 4.1-5: Scenario 5

Figure 4.1-6: Scenario 6

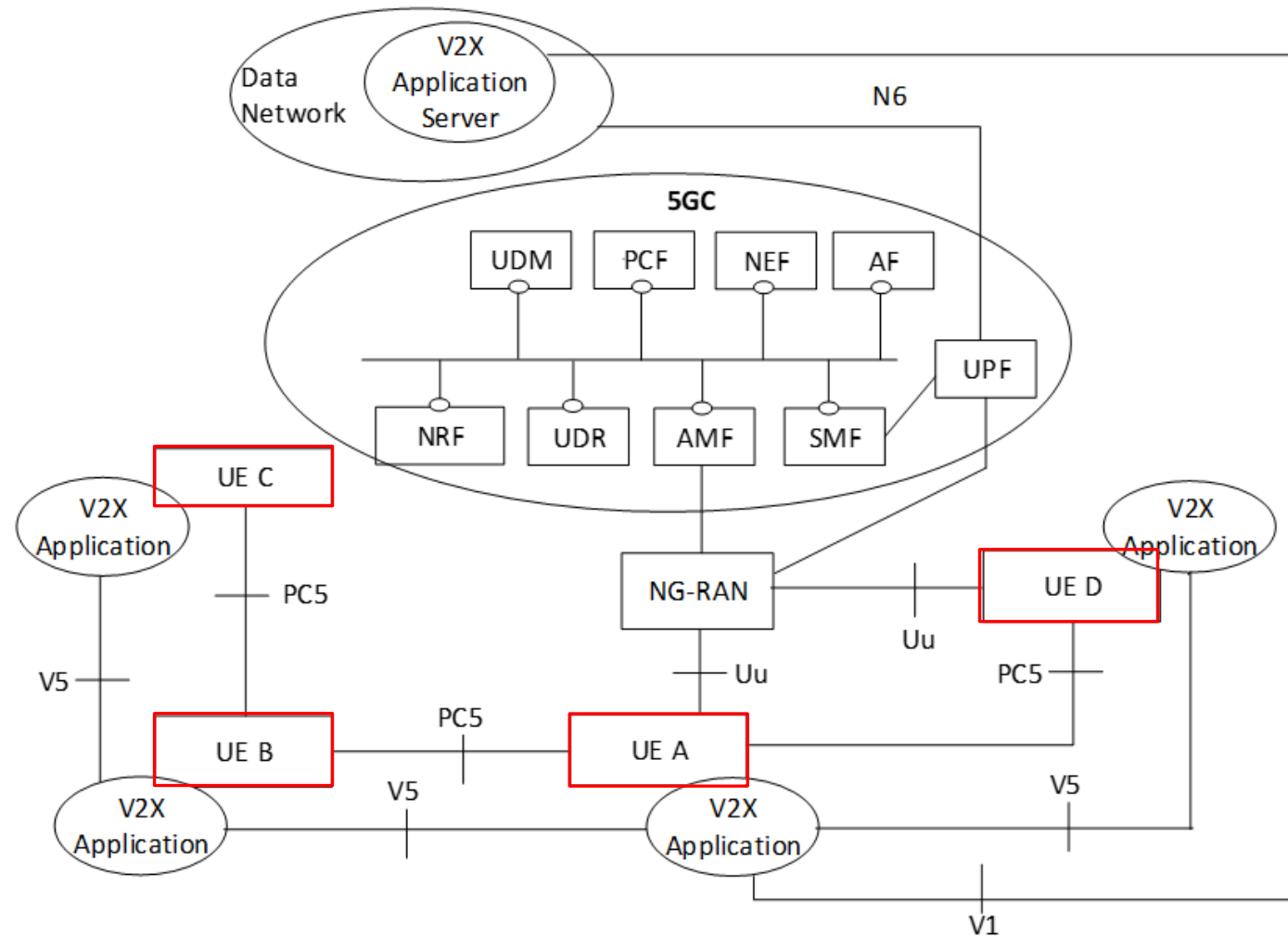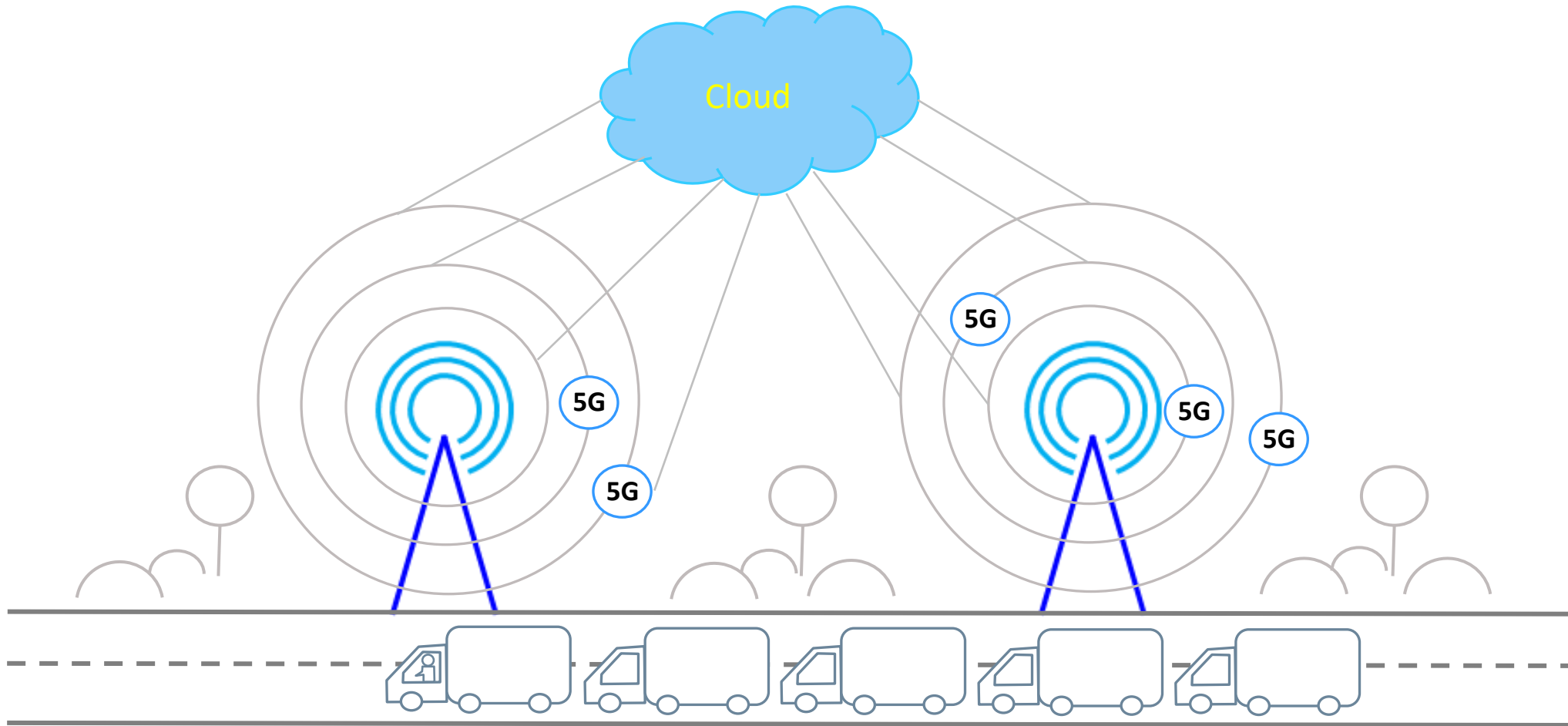**Figure 4.2.1.1-1: Non-roaming reference architecture for PC5 and LTE-Uu based V2X communication**

Figure 4.2.1.1-1: Non-roaming 5G System architecture for V2X communication over PC5 and Uu reference points

5G Autonomous Driving: Platooning

5G is the most promising enabler of truck platooning in which long convoys of trucks are automatically governed and require only a single driver in the lead vehicle

Based on a picture by Nokia

Further Reading

- 3G4G: V2X - Vehicle to Everything (link)
- Qualcomm: How NR based sidelink expands 5G C-V2X to support new advanced use cases, March 2020 (Blog link, PDF link, webinar link)
- NTT Docomo Initiatives for the Connected Car Era, April 2020 (link)
- GSMA: Spectrum for Intelligent Transport Systems, Oct 2017 (link)
- Nomor Research: Comparison of V2X based on 802.11p, LTE and 5G, May 2019 (link)
- NGMN Alliance: V2X White Paper, June 2018 (link)
- 5G Americas: Cellular V2X Communications Towards 5G, March 2018 (link)
- 5G Americas: V2X Cellular Solutions, October 2016 (link)
- Heterogeneous V2X Networks for Connected and Automated Vehicles, IEEE 5G Summit Pretoria, May 2019 (link)
- The 3G4G Blog: 3GPP Sidelink and its proposed extensions, Oct 2017 (link)
- arXiV: IEEE 802.11bd & 5G NR V2X, Mar 2019 (link)
- 5GAA Whitepaper: C-V2X Use Cases – Methodology, Examples and Service Level Requirements, July 2019 (link)

3GPP Technical Specifications related to V2X

- 3GPP TS 22.185: Service requirements for V2X services; Stage 1
- 3GPP TS 22.186: Enhancement of 3GPP support for V2X scenarios; Stage 1
- 3GPP TS 23.285: Architecture enhancements for V2X services
- 3GPP TS 23.286: Vehicle-to-Everything (V2X) services; Functional architecture and information flows;
- 3GPP TS 23.287: Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services
- 3GPP TS 36.331: Radio Resource Control (RRC);

3GPP Technical Reports related to V2X

- 3GPP TR 22.885: Study on LTE support for Vehicle to Everything (V2X) services
- 3GPP TR 22.886: Study on enhancement of 3GPP Support for 5G V2X Services
- 3GPP TR 23.764: Study on enhancements to application layer support for V2X services
- 3GPP TR 23.776: Study on architecture enhancements for 3GPP support of advanced Vehicle-to-Everything (V2X) services; Phase 2
- 3GPP TR 23.785: Study on architecture enhancements for LTE support of V2X services
- 3GPP TR 23.786: Study on architecture enhancements for the Evolved Packet System (EPS) and the 5G System (5GS) to support advanced V2X services
- 3GPP TR 23.795: Study on application layer support for V2X services
- 3GPP TR 36.786: V2X services based on LTE; User Equipment (UE) radio transmission and reception
- 3GPP TR 36.787: Vehicle-to-Everything (V2X) new band combinations
- 3GPP TR 36.788: Vehicle-to-Everything (V2X) Phase 2; User Equipment (UE) radio transmission and reception
- 3GPP TR 36.885: Study on LTE-based V2X Services;
- 3GPP TR 37.885: Study on evaluation methodology of new Vehicle-to-Everything (V2X) use cases for LTE and NR;
- 3GPP TR 37.985: Overall description of RAN aspects for Vehicle-to-everything (V2X) based on LTE and NR
- 3GPP TR 38.885: Study on NR Vehicle-to-Everything (V2X)
- 3GPP TR 38.886: V2X Services based on NR; User Equipment (UE) radio transmission and reception

Thank You

To learn more, visit:

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Operator Watch Blog – https://www.operatorwatch.com/

Connectivity Technology Blog – https://www.connectivity.technology/

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