C-V2X Technology

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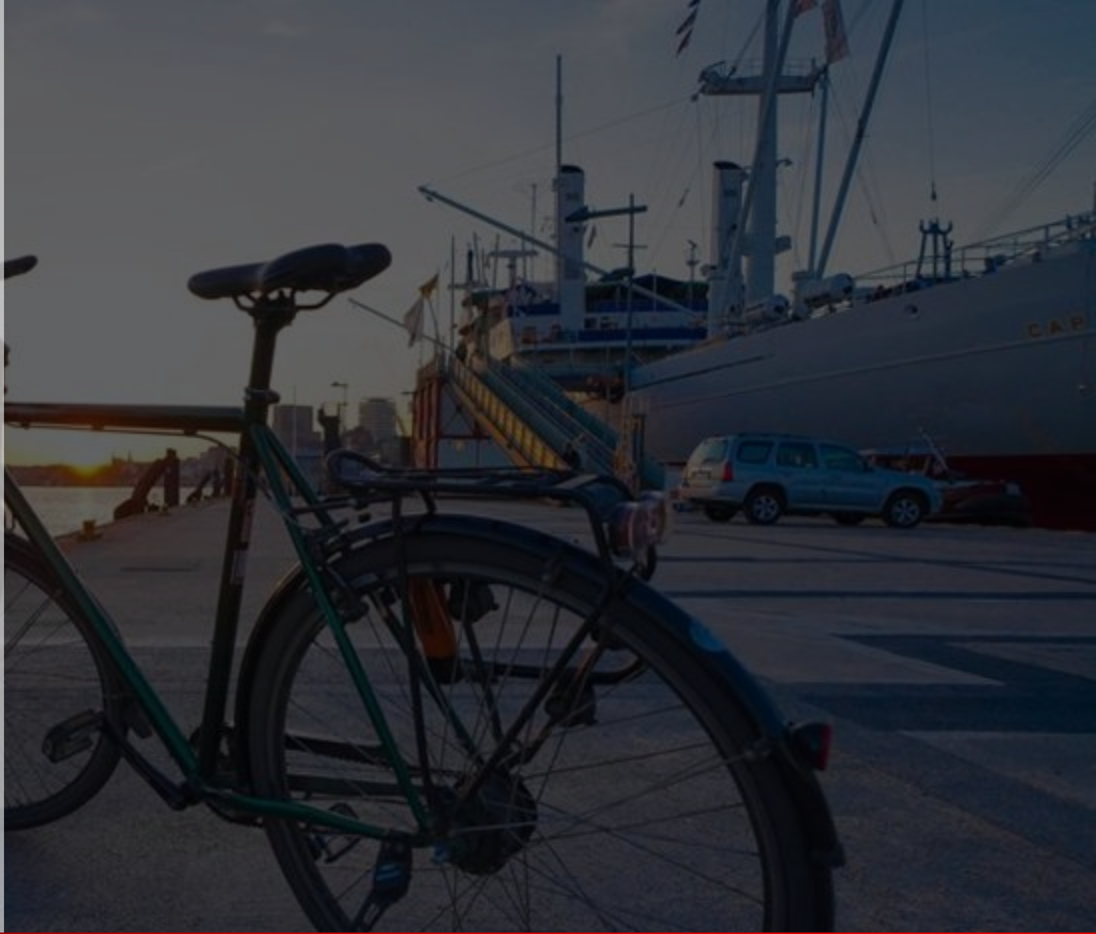


1 Background

Background:

How was Qualcomm Technologies, Inc. engaged in CONCORDA?

- Early enablement of the different corridors with C-V2X HW/SW
- Most moved from Qualcomm Technologies Development platforms to precommercial/commercial solutions
- Finally a variety of solutions used, which interoperate with each other

=> Shows how C-V2X matured during project run-time

- Help and consultancy on parameters/settings and technical details of C-V2X

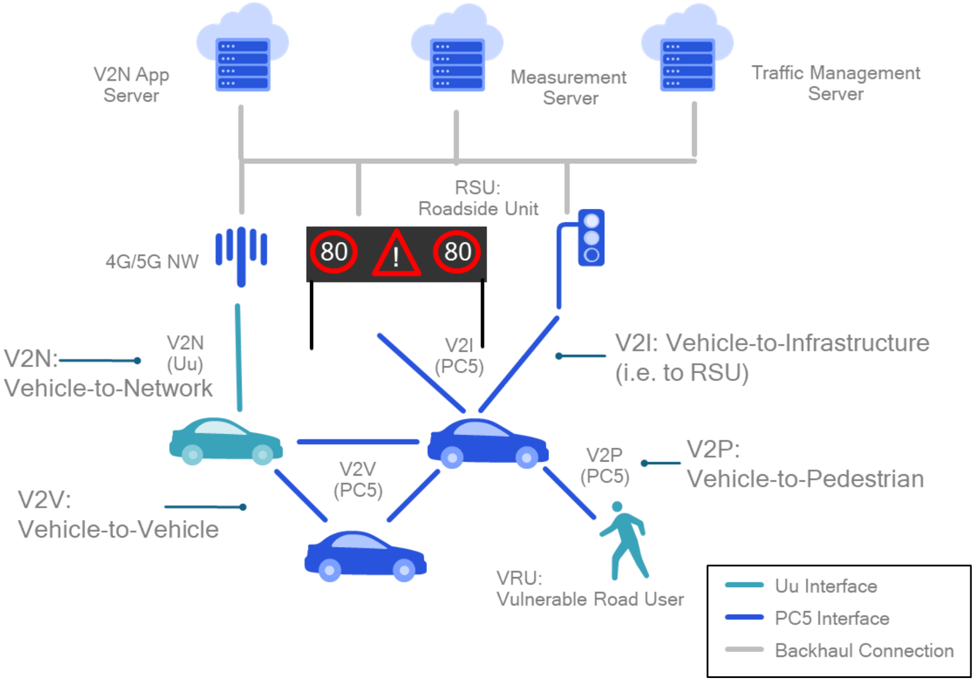
=> This is also the topic of this presentation

RSU at motorway in Antwerp, Belgium

2 C-V2X Technology

C-V2X Introduction

Cellular V2X: 3GPP defined V2X technology covering both LTE & future 5G based V2X systems



- V2X :"Vehicle-to-Everything" communication encompasses vehicles exchanging data with each other and the infrastructure
- V2X Objectives: Improve road safety, increase traffic efficiency, reduce environmental impacts and provide additional traveler services
- 3GPP Standards defines four types of V2X Communication:
  - Vehicle – to – Vehicle (V2V)
  - Vehicle – to – Infrastructure (V2I)
  - Vehicle – to – Network (V2N)
  - Vehicle – to – Pedestrian (V2P)

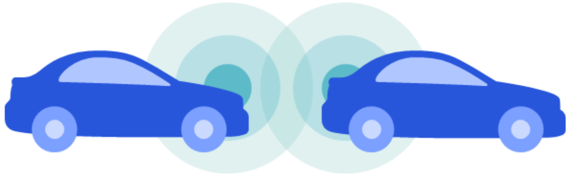
C-V2X Communication Modes

C-V2X Supports two types of communication modes

Direct Communication (V2V, V2I)

PC5 interface

E.g. location, speed



Uses **LTE Sidelink** derived from LTE Device-to-Device Communication and enhanced for vehicle usage

- Proximal direct communications (100s of meters)
- Supports operation independent of mobile network coverage
- ITS Bands used (5.9 GHz)
- Tailored for Latency-sensitive use cases, e.g. V2V safety

Network Communication (V2N)

Uu interface

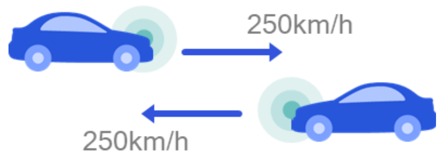
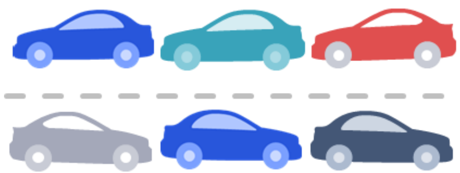
E.g. accident 3 kilometer ahead

Uses **Wide area networks** communications, e.g. LTE

- Uses existing commercial LTE Networks
- For less latency-sensitive use cases, e.g. V2N situational awareness
- LTE NW provides the “long range” communication

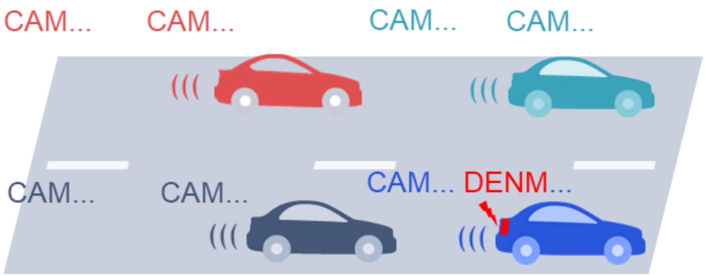
C-V2X Solution

C-V2X addresses the current challenges of connected vehicles

	Connected Vehicle Challenge	C-V2X Solution
	**High relative speeds** Leads to significant Doppler shift / frequency offset	**Enhanced Signal Design** E.g. increasing # of ref. signal symbols to improve synchronization and channel estimation
	**High node densities** Random resource allocation results in excessive resource collisions	**Enhanced transmission structure** Transmit control and data on the same sub-frame to reduce in-band emissions **More efficient resource allocation** New methods using sensing and semi-persistent resource selection **Congestion Control**

Distributed Congestion Control:

Resource Selection



Usage pattern on PC5:

- Periodic broadcast of ITS messages (e.g. 1 Hz, 10 Hz)
- Small sizes like 300 bytes
- Also Event Driven possible

User Equipment (UE) that wants to start transmission, senses for 1s

- Ranks resources according to energy received (Sidelink RSSI per sub channel)
- Would select the ones with low energy
- Furthermore, attempts in 100 ms window to decode PSCCH and exclude candidates with PSCCH-RSRP > threshold
- Checks Priority value (PPPP) to avoid transmission of lower priority packets on a resource used for higher priority transmissions by others

Semi-Persistent Scheduling

After UE identified a suitable/good transmission resource

- UE indicates in Resource Reservation field (part of SCI1) the periodicity of transmissions (e.g. 100 ms, 1000 ms)
- Would be determined by higher layers (=> ITS stack)
- UE would keep using the same resource in frequency and time space
  => Predictable interference / resource usage among all UEs in the area
  => Collisions can be avoided
- How long resource can be kept depends on a couple of rules, parameters and random choices
- If UE needs to give up the resource, a new selection of the new “best” resource is performed taking the measurement history of the last 1s

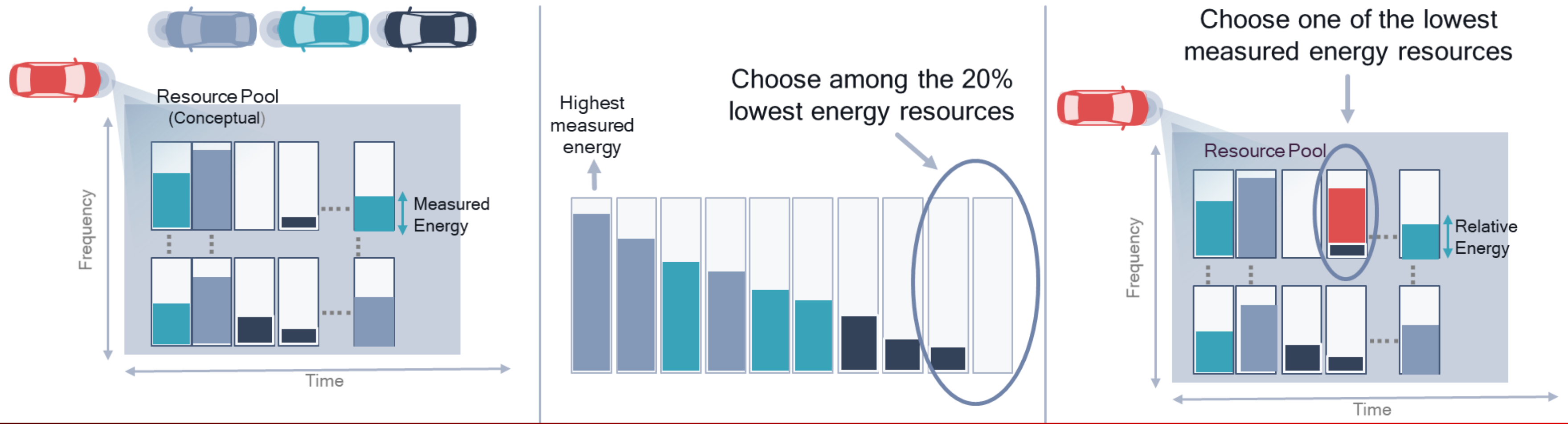
Deterministic access control & resource scheduling

Chooses blocks with lowest energy levels, while meeting latency requirements

1 Measure relative energy of next "n" resources

2 Rank the resources according to the measured energy

3 Choose one of the lowest energy blocks for transmission



Priority and Packet Delay Budget

Packet Delay Budget (PDB):

- Determines the time a transmitter can keep a packet before sending it
- Helps to create a predictable, periodic traffic pattern
- Impact: Latency remains the same with increasing congestion

=> Big difference to CSMA (Carrier Sense Multiple Access) where latency drastically increases with system load

Different PDB according to needed latency can be selected by higher layers

- Mapped with PPPP priority level

Congestion Control

Kicks in when many users are around

- Flexible mechanisms are defined
- UE monitors usage of resources (“channel busy rate“)
- At defined levels, forced to reduce own transmissions, depending on priority (PPPP)
- HARQ Re-Transmissions might be stopped
- Other limitations of channel usage like max RBs / MCS
- Reduction of TX power

Note: Also ITS Layer has congestion related measures in place

- E.g. Message generation reduction
- CAM periodicity anyway dependent on movement/speed: 100 ms down to 1 s

Congestion Control …works

Tests in San Diego with a huge setup of devices creating a loaded scenario:

- 50 C-V2X pots, emulating ITS traffic of 5 cars each => 250 cars
- Additionally, cars executing safety Use Cases in this environment
- See video: https://www.qualcomm.com/videos/cv2x-ces-scalability-14c

Thank You

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