Vehicle-to-Everything Communication - Is there any future for DSRC?

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Acknowledgement: Thanks to Laurent Gallo for his help and contributions to this Keynote
V2X Communication – Back to the Future !!

- GM Futurama - 1939

https://www.youtube.com/watch?v=1cRoaPLvQx0 (time code: 14:27)

[acknowledgement: H. Hartenstein, KIT]
From the early steps to current achievements

- Visionary aspect: GM Futurama in 1939 and 1964 !!

- 1970-1987: Electronic Route Guidance System (ERGS) - USA
  - Deployment stopped due to expensive roadside infrastructure

- 1973-1979: Comprehensible Automobile Traffic Control (CACS) – Japan


- 1997: Cooperative autonomous driving demo: PATH, USA

- From the mid 1990:
  - Game Changer: 5.9 DSRC – 802.11p, later known as IEEE 802.11-2012 OCB / ITS G5
In 1994, the US Federal Communication Commission (FCC) allocated a 16 MHz band (unlicensed) at 902 MHz for ETC called Dedicated Short Range Communication (DSRC)

- In Europe, DSRC has been introduced solely for ETC at 5.8 GHz

In 1999, the FCC allocated a second DSRC frequency band at 5.9 GHz to be used specifically for inter-vehicular communication.

- **Primary Application:**
  - Saving lives by avoiding accident
  - Saving money by reducing traffic congestion
- **Secondary Application:**
  - Comfort (infotainment) application to ease the early deployment of this technology.

Since 2001 Japan has developed, implemented and deployed DSRC applications under the name ARIB STD T-75 & 88.

The European Commission allocated a 30 MHz frequency band at 5.9 GHz for safety applications in **August 2008**
Non-exhaustive Overview of Projects

- **C2C-CC** (2001)
- **CarTalk** (2001-2004)
- **SeVeCom** (2006-2008)
- **ETSI ITS** (2009)
- **Drive** (2011-2014)

- **Chauffeur I and II** (1996-2003)
- **PreVent/WILL WARN** (2005-2008)
- **Coopers/CVI S/SAFESPOT** (2006-2010)
- **CoCAR I and II** (2007-2011)

- **FleetNet** (2000-2003)
- **NoW** (2004-2007)
- **PreDrive** (2008-2010)
- **SIM-TD** (2008-2012)

- **ASV II** (1996-2000)
- **ASV III** (2001-2005)
- **ASV VI** (2006-2010)

- **PATH** (1986)
- **IVI** (1998-2004)
- **VII / IntelliDrive** (2004-2009)
- **V2V Decision** (2013)

- **DSRC** (1999)
- **WAVE** (2004)
- **ITS Strategic Research Plan, (2010-2014)

ETSI Technical Committee on ITS

- **Applications**
  - Active Road Safety
    - Cooperative awareness
    - Hazard warning
  - Cooperative Traffic Efficiency
    - Adaptive speed management
    - Cooperative navigation

- **Technology**
  - DSRC
    - IEEE 802.11 for vehicular environment
    - a.k.a: 802.11p, ITS-G5

Source: C2C-CC
V2X Communication - DAY 2
Objective: Highly Autonomous Driving

- Not such a new idea

- A very marketized idea...

- ...yet a very ambitious idea

Source: google

Source: US Peloton

Source: toyota
V2X Communication - DAY 2
Objective: Vulnerable Road Users

- V2X not only between Vehicles
- V2X is part of the Internet-of-things
- V2X connects to wearable devices
From Connected ‘Vehicles’ to Connected ‘Things’ - A Change in the Eco-System

- **Connected vehicle**
  - driven by car industry

- **Connected things**
  - driven Internet & wireless industry
Towards a Connection-of-Everything

- Evolution of Proximity Services
  - Convergence of Technologies:
    - LTE-Direct
    - WiFi-Direct
    - DSRC
  - Focus for Proximity Services
    - Personal Area
    - Local Area
    - Wide Area

- Evolution of Proximity Technology
  - Wireless LAN:
    - IEEE 802.11, Hyperlan, WiFi-Direct
  - Cellular Systems:
    - GSM, UMTS, LTE
  - PAN:
    - Bluetooth, Zigbee

Convergence of Actors:
- Pedestrians
- Cars, Buses, Trains
- Any-'Wheelers'
- Your coffee machine!!
DSRC is challenged by 3GPP

- **Penetration rate**
  - Device Market Penetration:
    - DSRC: Enabled cars ➞ 50% in 15 years
    - LTE: Smartphones/things ➞ 50% in 2 years
  - Network:
    - DSRC: Road Side Units will be deployed in the next years
    - LTE: Network already available and in expansion

- **Ubiquity**

- **Frequency bands**

![Frequency bands diagram](image-url)
3GPP LTE technology for Connected Things

- **3GPP Long Term Evolution (LTE)**
  - Successor of the cellular 3G networks
  - LTE provides **Vertical Services**

- **LTE is a living project…**
  - enhancements based on releases
  - Current LTE networks:
    - ~Release 8 (Rel.8)

- **Since Rel. 12, LTE has a new application domain:**
  - Proximity Services (LTE ProSe)
  - ProSe aims at creating **Horizontal Services**
LTE D2D ProSe Rel. 12 Strategy

- LTE D2D ProSe aims at competing other proximity technologies
  - WiFi-Direct, Bluetooth, etc..

- LTE D2D ProSe has two functions:
  - LTE D2D Discovery
  - LTE D2D Communications

Source: Qualcomm

V2X Safety
LTE ProSe D2D Service Discovery for V2X (Rel. 12 ++)

- Four Scenarios under study

1. **Out-of-UTRAN**
   - *Case 1:* Already under study for normal D2D ProSe

2. **U2 out-of-UTRAN**
   - *Case 2:* Critical for V2X

3. **Intra-Cell**

4. **Adjacent Cell**
QPSK, packet size: 102 bytes, discovery period: 1 – 10s

- Discovery Strategies:
  - random in given RBs
  - random in group of RBs
  - random with probabilistic transmission
  - Semi-statically assigned
  - ...

- Powerful stakeholders!!

- Fits to case 1
- What about case 2?
  - asynchronous discovery resources between cells

Source: 3GPP TR 36.843
Synchronous vs Asynchronous Deployment

- **Synchronous Deployments**
  - **Pros**
    - Can discover vehicles between cells
    - Optimal energy cycle
  - **Cons**
    - Difficult deployment

- **Asynchronous Deployments**
  - **Pros**
    - Normal deployment
  - **Cons**
    - Need to multiple cell’s SIB
    - Suboptimal energy cycle
    - Potential conflict between cells

Source: ZTE – 3GPP R1-140273
Case Study

LTE-D2D V2X AWARENESS
TDMA-based LTE D2D V2X Awareness (Discovery)

- **Observation:**
  - LTE D2D communication phase is for throughput demanding services
    - V2X safety applications require few bytes
  - LTE D2D communication in broadcast remain complicated
    - LTE D2D discovery in broadcast is feasible

- **Proposal:**
  - Transmit CAM data in LTE D2D discovery procedure
  - Discovery schema – TDMA-like

- **LTE Type 1 Discovery:**
  - **Resource Allocation**
    - performed by the network
    - inspired by eMBMS
    - allocates a pool of resources to be shared by UEs (vehicles)
  - **Distributed Resource Access Scheduling**
    - performed locally by every UE (vehicle)
    - determines the access to the pool of resources allocated in phase 1
    - can be treated as a TDMA-like system
Pool is allocated over multiple cells (Multicast Broadcast Single Frequency Network):

- Ideal for broadcast scenarios in which users can be spread over multiple cells.
- Users can move within the area and exploit the same resources
  - no mobility management required
**LTE D2D V2X Synchronous Awareness Resource Allocation (eMBMS-like)**

- A pool of resource blocks is allocated for Awareness communications:

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- Time / frequency coordinates of the RBs are broadcast by the network on a **public control channel** ➞ no connection procedure with the eNodeB is required

- Awareness Resource Block
  - Not used by the Network
  - All UEs listen to them (as DL RB)
  - Used for **V2V CAM** transmission

- Allocation pattern is **periodical** ➞ transceiver **energy duty cycle**

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LTE D2D V2X
Distributed Resource Access Scheduling

- Locally, vehicles group RBs into slots the size of one CAM packet:

- Slots are then grouped into frames 100 ms long (to support a 10 Hz TX rate):

- Process is then periodically repeated...
The channel access can be treated as a TDMA-like system

Proposed scheme: Optical Orthogonal Codes

- Multiple transmissions per frame
- Channel access regulated by codewords with length equal to the number of slots per frame ("0" slots $\rightarrow$ TX | "1" slots $\rightarrow$ RX)
- Hamming weight of the codeword $w$ is the number of transmissions per frame
- Two different codewords have at most $\lambda$ transmission slots in common (collisions)

$$w = 3$$
$$\lambda = 1$$
LTE D2D V2X vs. DSRC

Performance metric:
TX-centric - probability of successful packet reception (PRR) (packet delivery rate)
RX-centric – Inter-reception Time (IRT) between two successive CAM

System Configuration

<table>
<thead>
<tr>
<th>Packet type</th>
<th>CAM</th>
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<tbody>
<tr>
<td>Packet size</td>
<td>300 bytes</td>
</tr>
<tr>
<td>DSRC Channel</td>
<td>CCH – 5.9 GHz</td>
</tr>
<tr>
<td>Transmission period</td>
<td>1, 5, 10 Hz</td>
</tr>
<tr>
<td>Channel rate</td>
<td>6 Mbps</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>10MHz</td>
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</tbody>
</table>
LTE D2D V2X vs. DSRC

Transmission rate = 10 CAMs per second

Packet Delivery Ratio

Vehicles density [Vehicles/km]

PRR

IRT

Inter Reception Time [s]

Vehicles density [Vehicles/km]
LTE D2D V2X vs. DSRC – Impact of Congestion

1 Hz

5 Hz

10 Hz
Discussion

- **LTE D2D V2X**
  - Strong market and industrial support
  - Faster market penetration
  - LTE D2D community very active
    - Huawei wants it ‘now’ (rel. 13)
    - LTE D2D currently also at the ETSI ITS !!
  - Performance at least similar to DSRC
    - If not better !!

- **So, what is the fate of DSRC?**
  - Wireless ATM like fate?
  - Bound to WiFi fate?
WiFi Strikes Back…

- WiFi has been announced dead on several occasions
  - It is still alive and kicking
    - New IEEE 802.11 amendments
      - WiFi Giga
      - WiFi OFDMA
      - …

- WiFi Strongest assets:
  - Its sub-optimality
  - Its simplicity

- WiFi for V2X – DSRC required?
  - Maybe not !!

- Need to address key challenges
  - Challenge 1 – Better spectrum efficiency
  - Challenge 2 – Fast link setup
Challenge 1 – Efficient Spectrum Usage
OFDMA for WiFi

Legacy OFDM

WiFi OFDMA
Challenge 1 – Efficient Spectrum Usage
OFDMA for WiFi

- OFDMA for 802.11

- Sub-carrier channel estimation

- Multi-user sub-carrier assignment
Challenge 2 – Fast Discovery and Communication

- **802.11aq: Pre-association Discovery**
  - enable pre-association discovery of services

- **802.11ai: Fast Initial Link Set-up below 100ms**
  - Discovery of network and BSS
  - Authentication and Association signaling
  - IP address configuration

- **Safety-critical V2X Communication**
  - Require discovery before associating to BSS
  - Require connection below 100ms
V2X Communication – Is there any future for DSRC?

- **DSRC has been first on the market for V2X**
  - Suffered from several **shortcomings**
    - **Technical** –
      - Too narrow band – congestion issue
      - Low spectral efficiency
    - **Political** –
      - Two community – automotive vs. internet
      - Very slow standardization
  - **Murphy’s Law**
    - A victim of the Internet-of-Things
  - DSRC had its chance
    - Could not be ready on time!

- **DSRC disappearing?**
  - Not in the near future – market natural selection will decide!!
    - C2X Day 1: DSRC
    - C2X Day 2: LTE D2D
  - Maybe in its current shape: 802.11p OCB 10Mhz
    - Could still survive with evolution of WiFi OFDMA and FLS

- **Current Strong Fight:**
  - LTE D2D (LTE 5G) vs. WiFi 5G
    - New/Big market: Train, Flying Devices
Further Readings

- 3GPP TR 36.843 - Study on LTE Device to Device Proximity Services; Radio Aspects
- 3GPP TR 22.885 study on LTE support for V2X services
- 3GPP - V2X Communications in 3GPP – S1-144 374
- 3GPP - Resource Allocation for D2D Discovery - R1-140273
- 3GPP - D2D discovery design with simulation results – R-134627
- 3GPP - Resource Allocation and UE Behavior for D2D Discovery - R1-140337
- 3GPP - D2D discovery resource size and mapping to physical resources - R1-140841

Thank You

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