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

Jérôme Härri

Keynote - Net4Cars 2015, Sousse, Tunisia

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**
- **1988 – 1994 EUREKA - PROMETHEUS – EU**
- **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

Game Changer: IEEE 802.11-2012 OCB @ 5.9 GHz

- **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/CVIS/SAFESPOT (2006-2010)

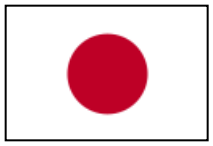
CoCAR I and II (2007-2011)

FleetNet (2000-2003)

NoW (2004-2007)

PreDrive (2008-2010)

SIM-TD (2008-2012)



ASV I (1991-1995)

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)

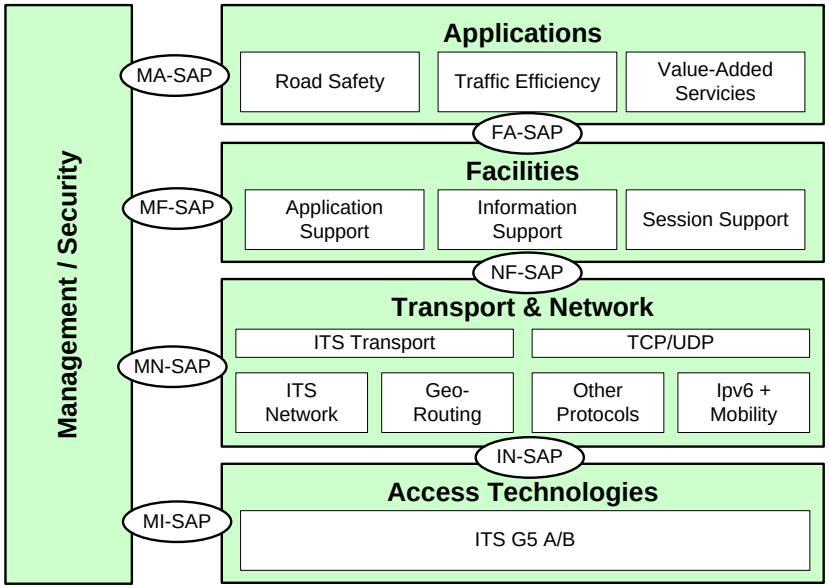
WAVE (2004)

ITS Strategic Research Plan, (2010-2014)

[Partial Reproduction of : H. Hartenstein, *VANET: Vehicular Applications and Inter-Networking Technologies"*, Chapter 1 – Introduction, Wiley, 2010]

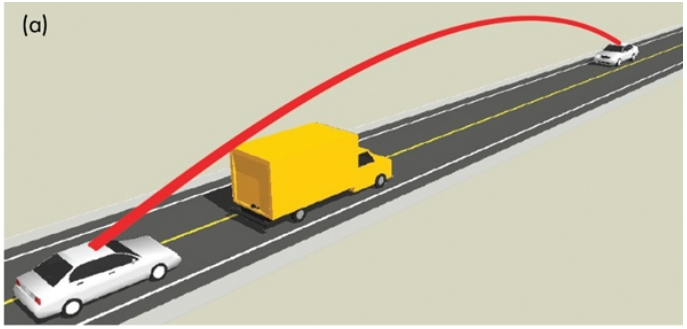
V2X Communication – Day 1
Architecture, Technologies & Applications

- **ETSI Technical Comitee on ITS**



Source: C2C-CC

- **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

V2X Communication - DAY 2
Objective: Highly Autonomous Driving

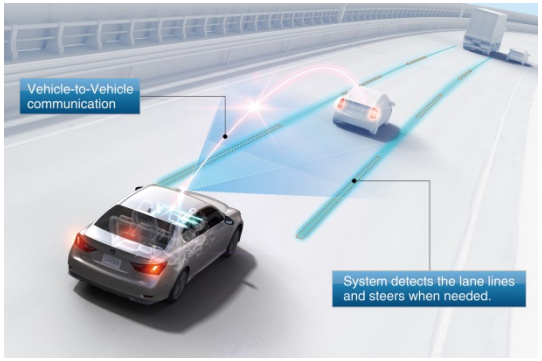
- **Not such a new idea**

- **A very marketized idea…**

Source: google

- **…yet a very ambitious idea**

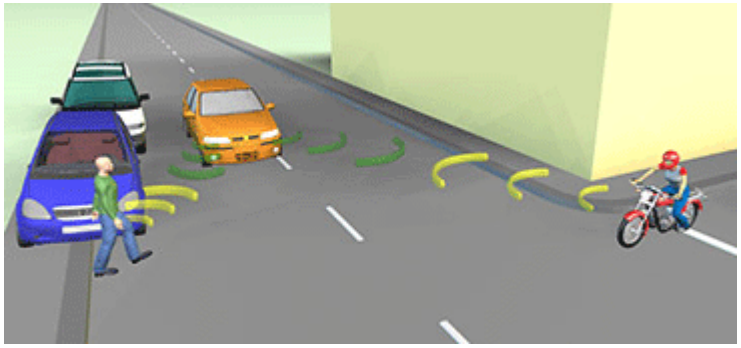
Source: US Peloton



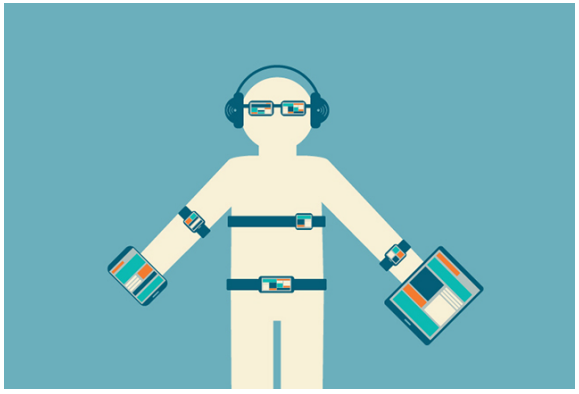
Source: toyota

V2X Communication - DAY 2
Objective: Vulnerable Road Users

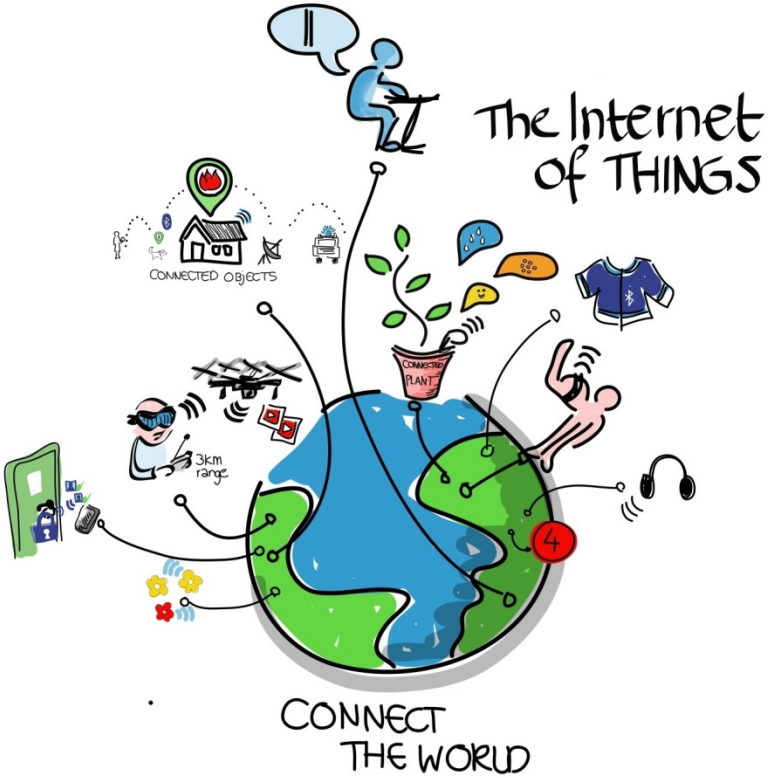
- **V2X not only between Vehicles**



- **V2X connects to wearable devices**



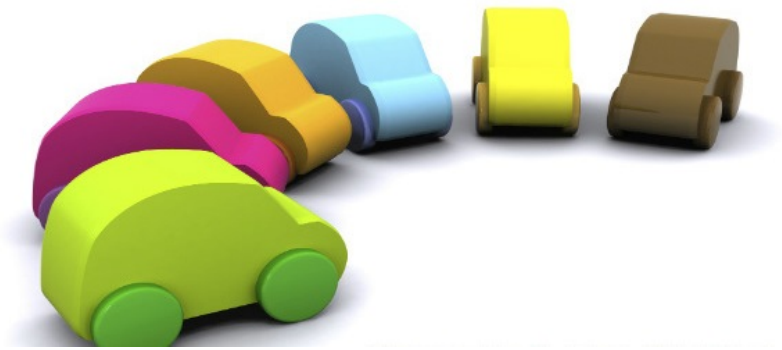
- **V2X is part of the Internet-of-things**



From Connected ‘Vehicles’ to Connected ‘Things’ - A Change in the Eco-System

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

DAIMLER BMW Audi Ford

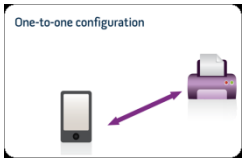


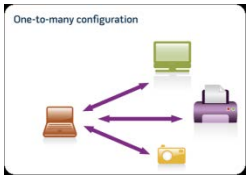
- **Connected things**
  - driven Internet & wireless industry

intel QUALCOMM HUAWEI Alcatel·Lucent ERICSSON

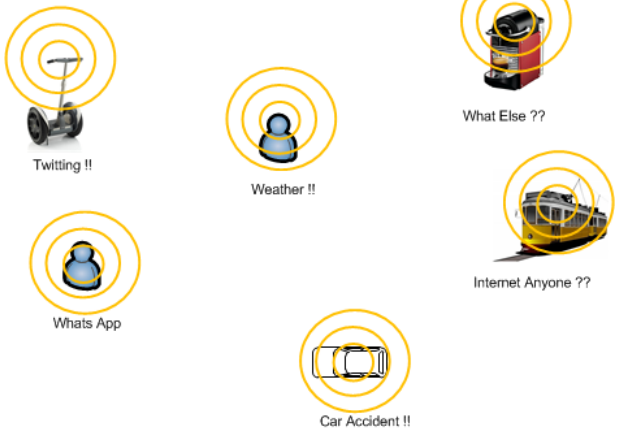
Towards a Connection-of-Everything

- **Evolution of Proximity Services**





Convergence of Actors:
- Pedestrians
- Cars, Buses, Trains
- Any-'Wheelers'
- Your coffee machine !!



- **Evolution of Proximity Technology**

PAN:
Bluetooth, Zigbee

Convergence of Technologies:
- LTE-Direct
- WiFi-Direct
- DSRC

Wireless LAN:
IEEE 802.11,
Hyperlan,
WiFi-Direct

Cellular Systems:
GSM, UMTS, LTE

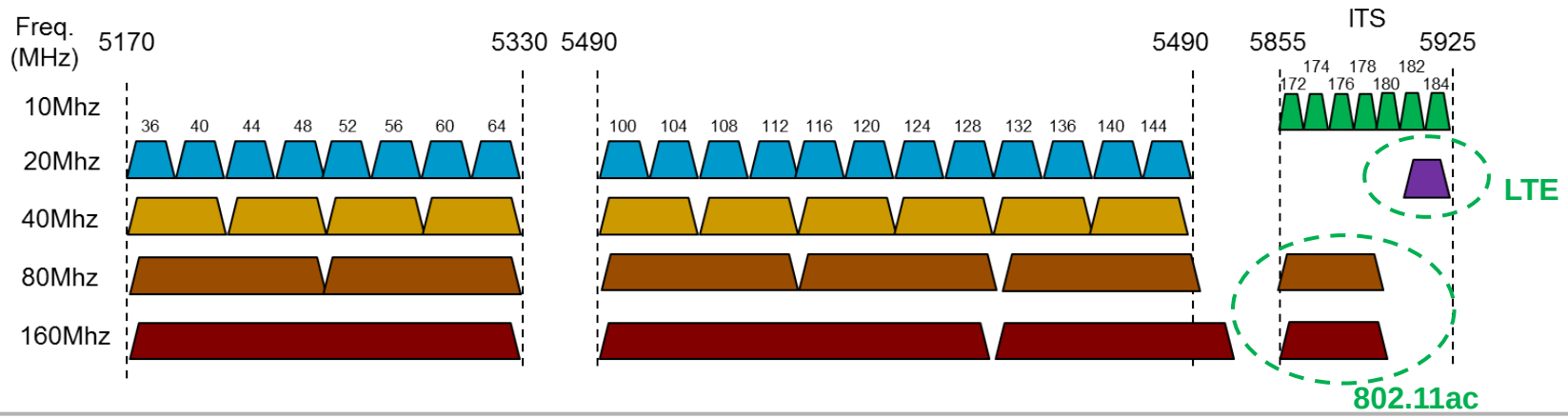
Focus for Proximity Services

Personal Area | Local Area | Wide Area

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**

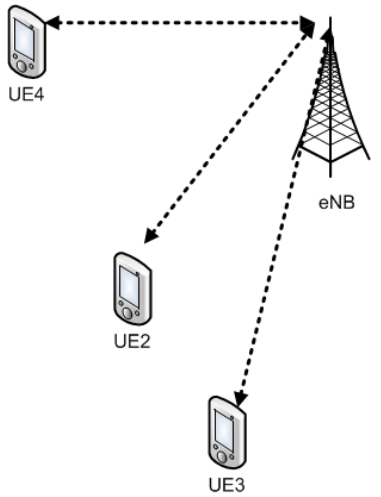
- **Frequency bands**



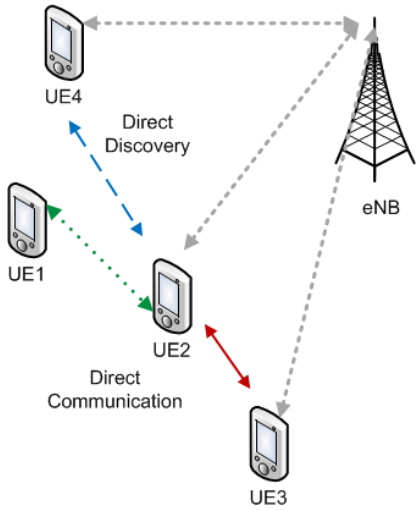
3GPP LTE technology for Connected Things

- **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)

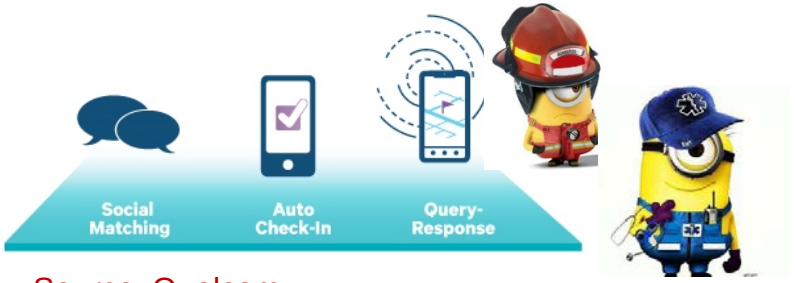


- **Since Rel. 12, LTE has a new application domain:**
  - Proximity Services (LTE ProSe)
  - ProSe aims at creating **Horizontal Services**



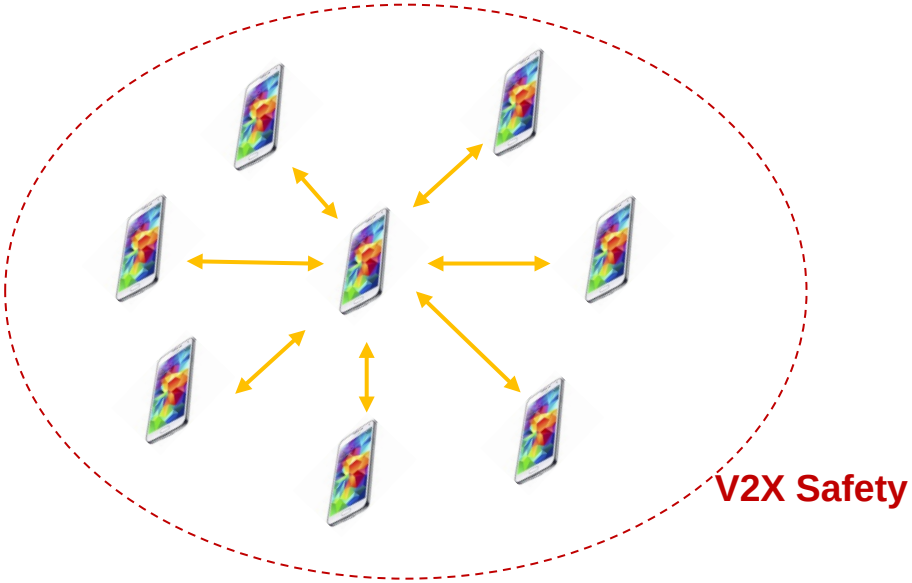
LTE D2D ProSe Rel. 12 Strategy

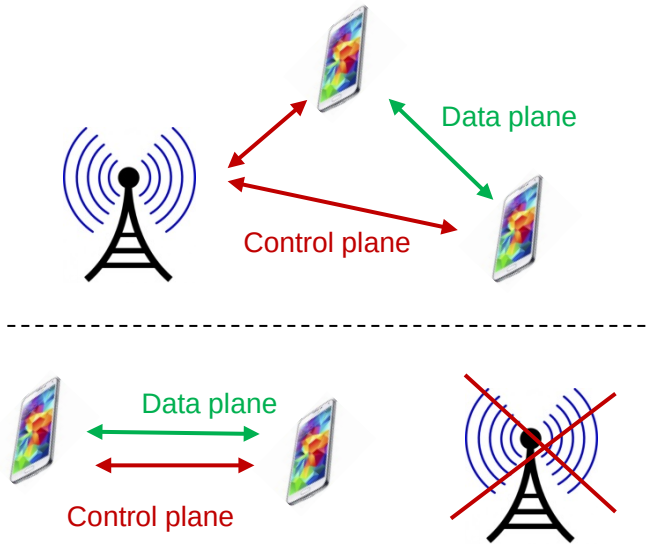
- **LTE D2D ProSe aims at competing other proximity technologies**
  - WiFi-Direct, Bluetooth, etc..



Source: Qualcom

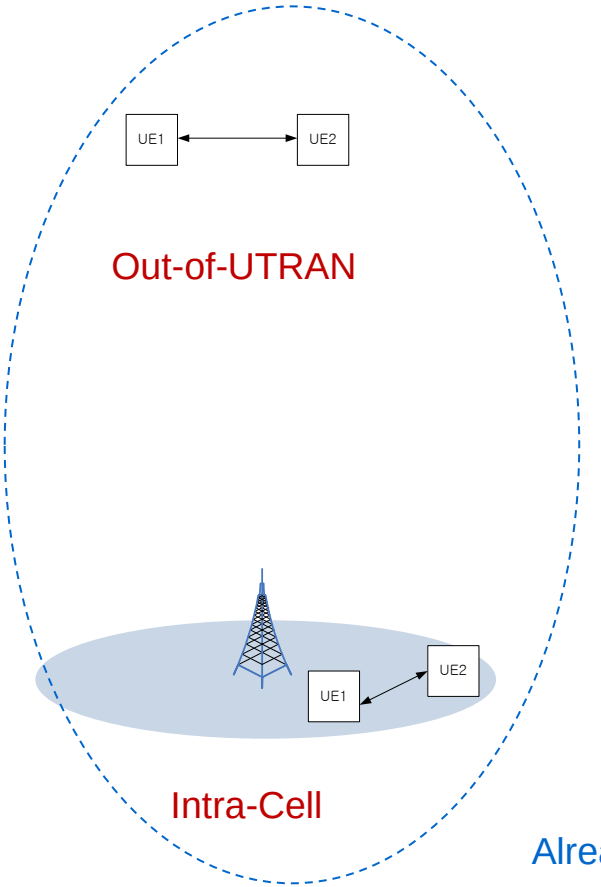
- **LTE D2D ProSe has two functions:**
  - LTE D2D Discovery
  - LTE D2D Communications



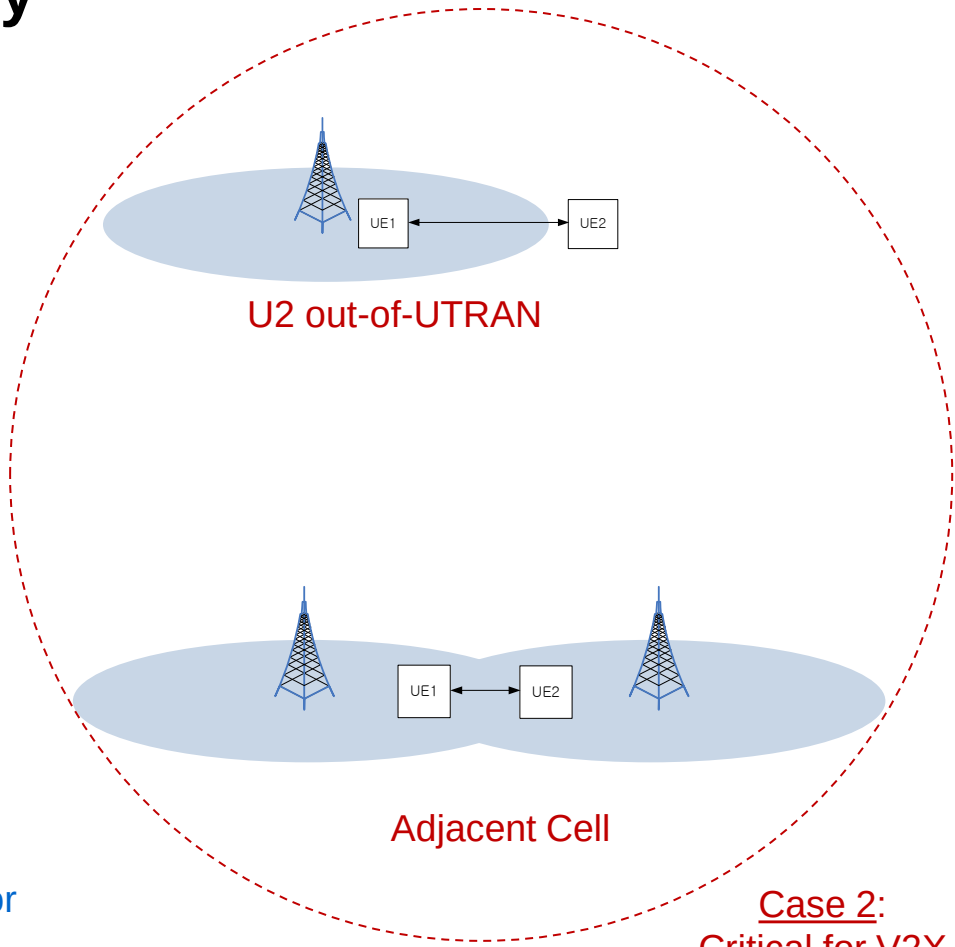


LTE ProSe D2D Service Discovery for V2X (Rel. 12 ++)

- **Four Scenarios under study**



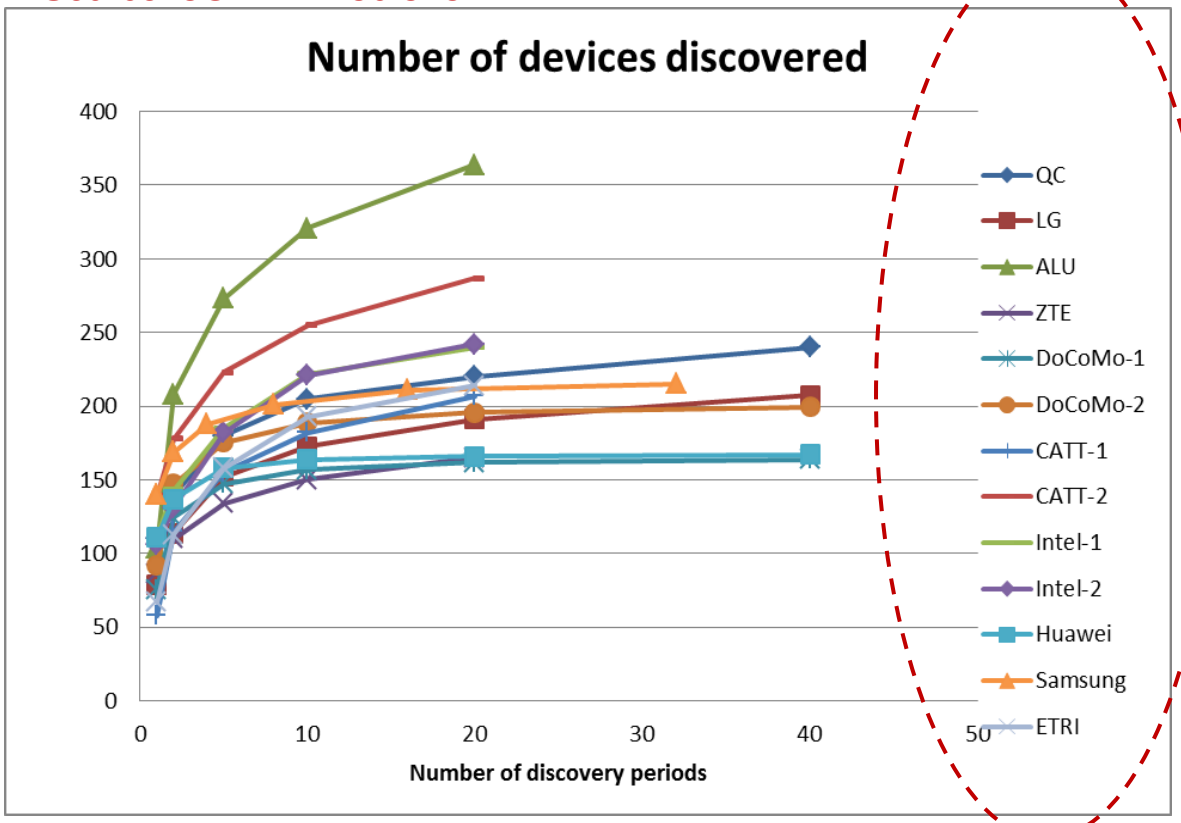
Case 1:
Already under study for normal D2D ProSe



Case 2:
Critical for V2X

LTE ProSe Discovery – 3GPP First Evaluations

Source: 3GPP TR 36.843



Powerful stakeholders !!

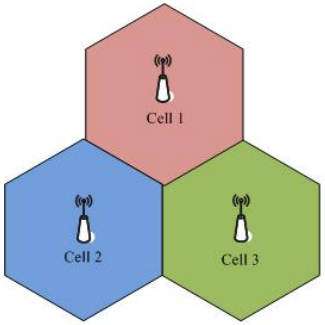
- **Discovery Strategies:**
  - random in given RBs
  - random in group of RBs
  - random with probabilistic transmission
  - Semi-statically assigned
  - …

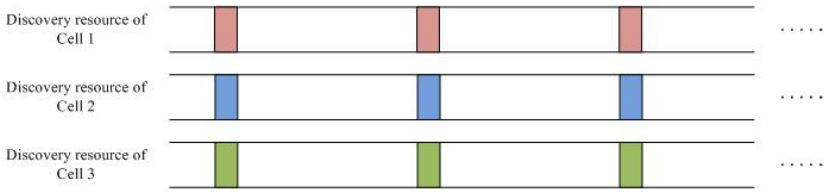
QPSK,
packet size: 102 bytes,
discovery period: 1 – 10s

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

Synchronous vs Asynchronous Deployment

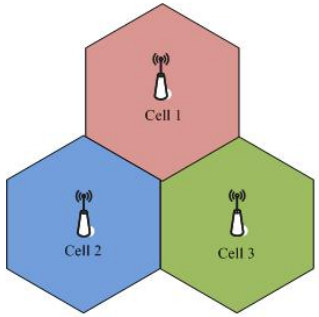
Synchronous Deployments

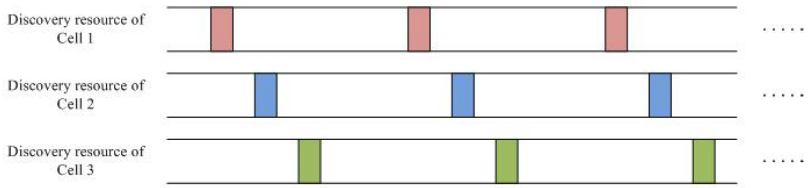




- **Pros**
  - Can discover vehicles between cells
  - Optimal energy cycle
- **Cons**
  - Difficult deployment

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)

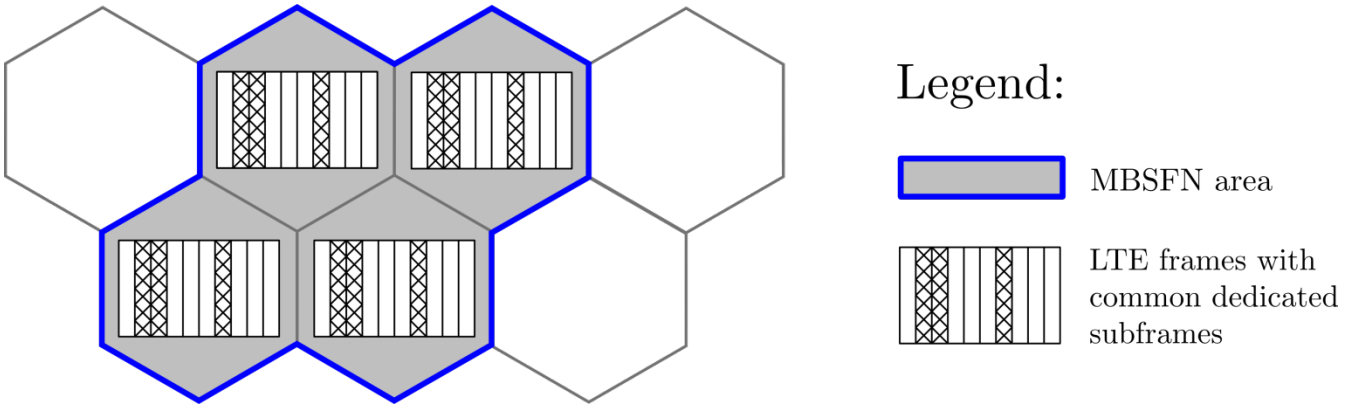
- **Observation:**
  - LTE D2D communication phase is for throughput demanding services
    - V2X safety applications require few bytes
  - LTE D2D communication in broadcast remain complicated
    - LTE D2D discovery in broadcast is feasible

- **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

LTE D2D V2X Synchronous Resource Allocation (eMBMS-like)

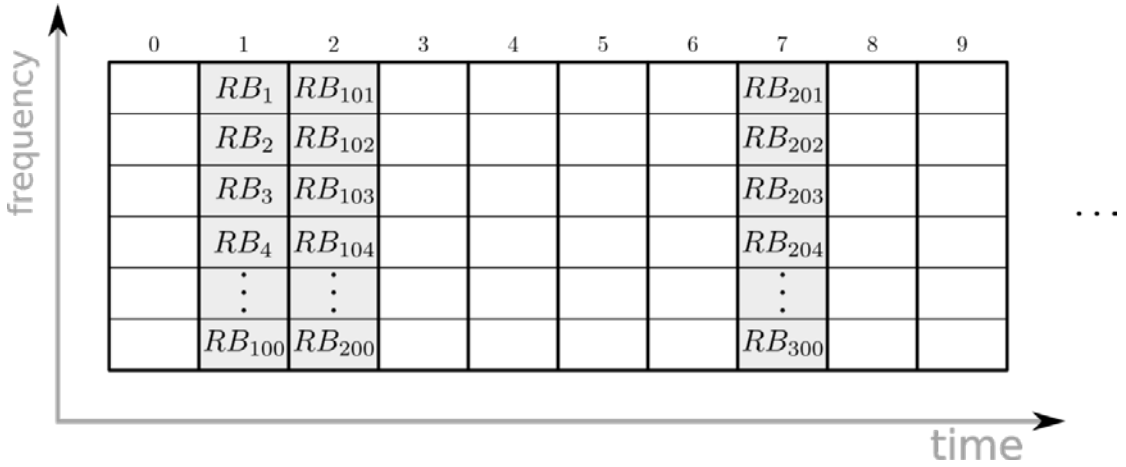
- **Pool is allocated over multiple cells (Multicast Broadcast Single Frequency Network):**



  - 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:**



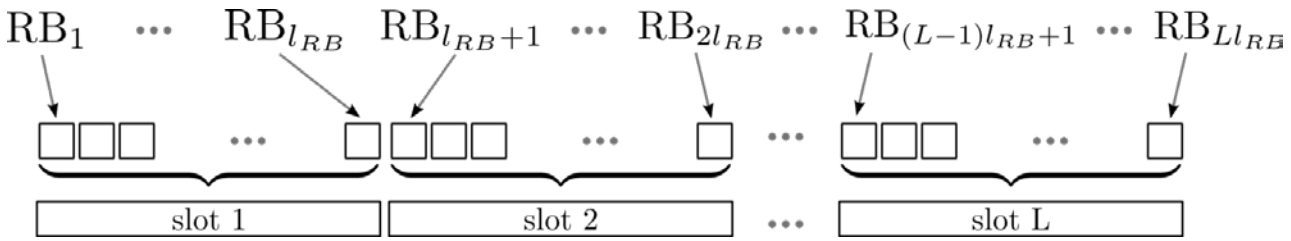
  - Time / frequency coordinates of the RBs are broadcast by the network on a **public control channel** ➟ no connection procedure with the eNodeB is required

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

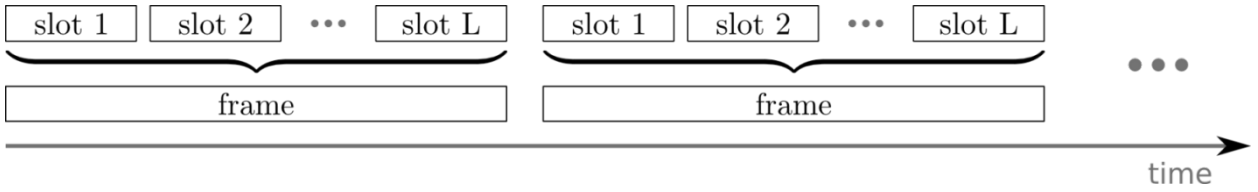
  - Allocation pattern is **periodical** ➟ transceiver energy duty cycle

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):**

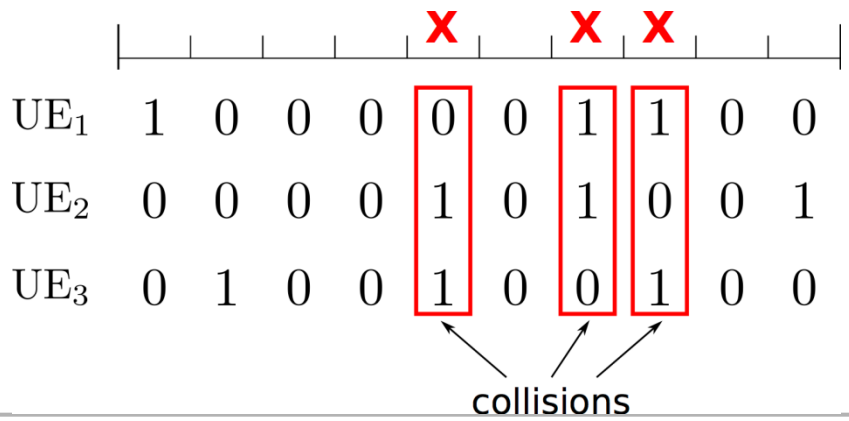


- **Process is then periodically repeated…**

LTE D2D V2X
Distributed Resource Access Scheduling

- **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 ➡ TX | "1" slots ➡ RX)**
  - Hamming weight of the codeword w is the **number of transmissions per frame**
  - Two different codewords have at most λ transmission slots in common (collisions)



w = 3

λ = 1

LTE D2D V2X vs. DSRC

Performance metric:

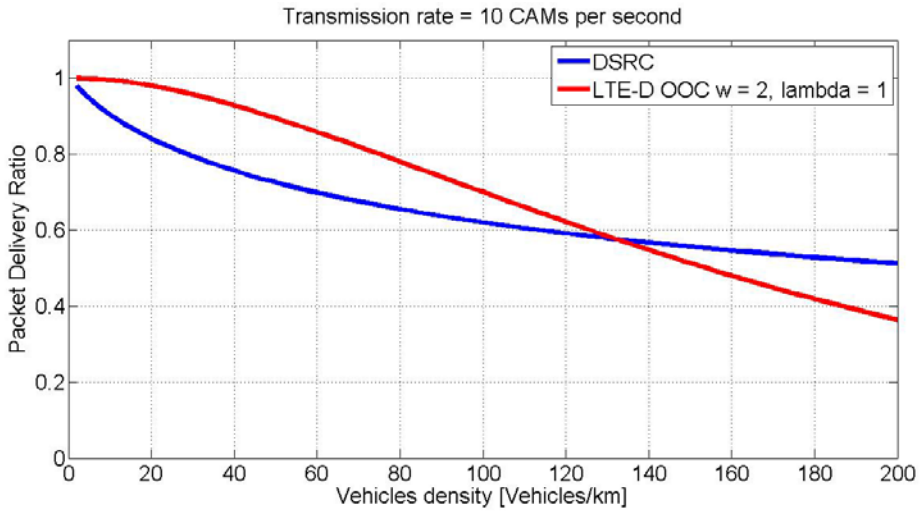
TX-centric - probability of successful packet reception (PRR) (packet delivery rate)

RX-centric – Inter-reception Time (IRT) between two successive CAM

System Configuration

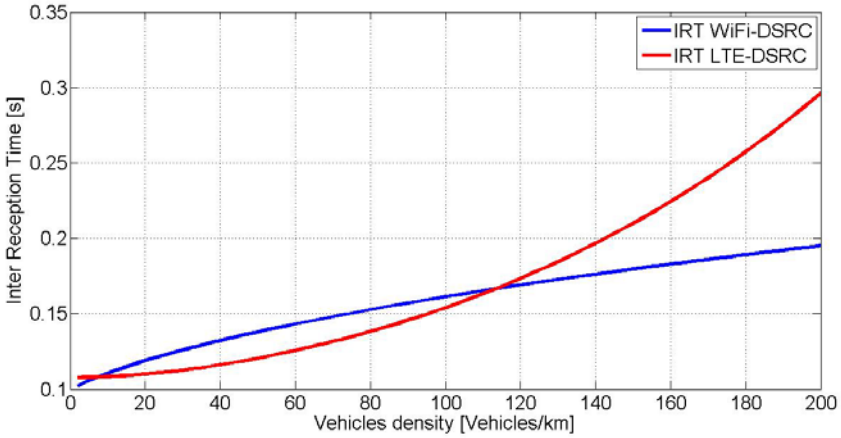
Packet type	*CAM*
Packet size	*300 bytes*
DSRC Channel	*CCH – 5.9 GHz*
Transmission period	*1, 5, 10 Hz*
Channel rate	*6 Mbps*
Modulation	*QPSK*
Bandwidth	10MHz

LTE D2D V2X vs. DSRC



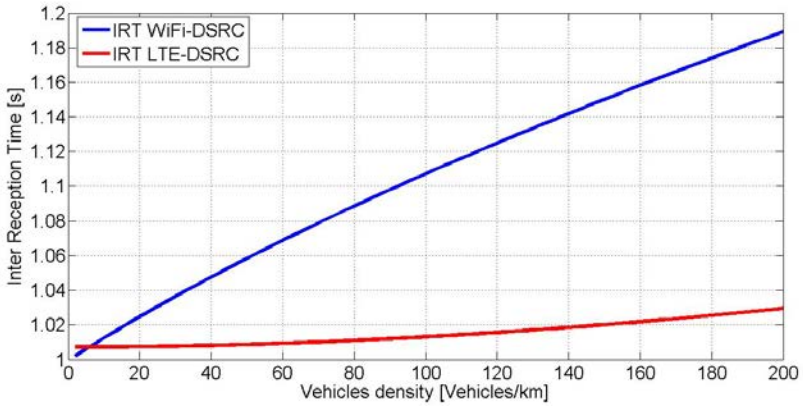
PRR

IRT

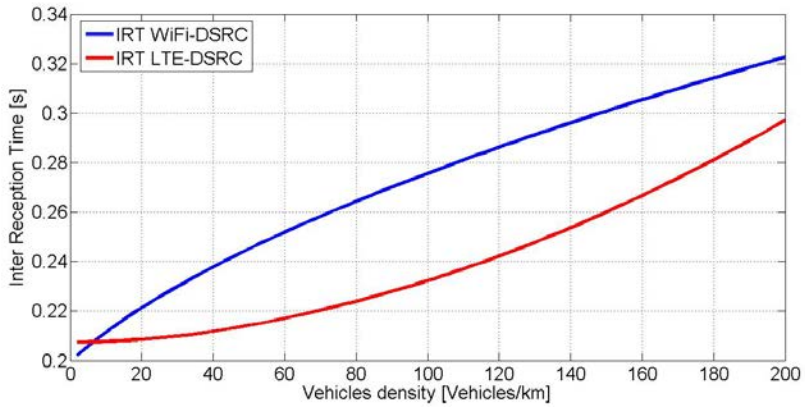


LTE D2D V2X vs. DSRC – Impact of Congestion

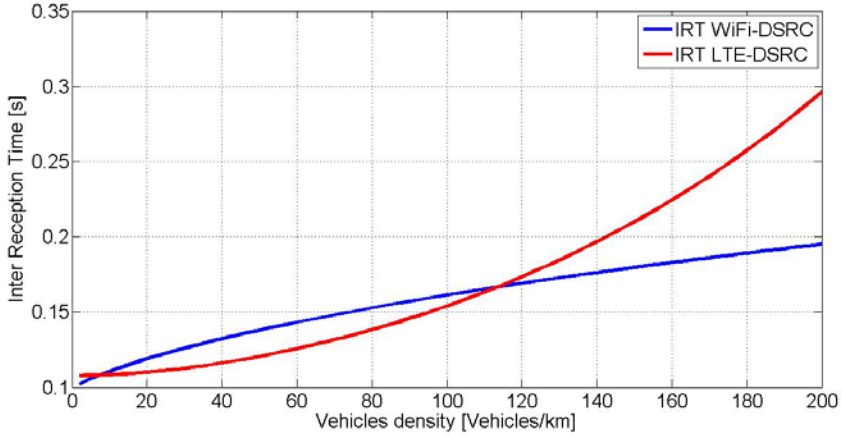
1 Hz



5 Hz



10 Hz



Discussion

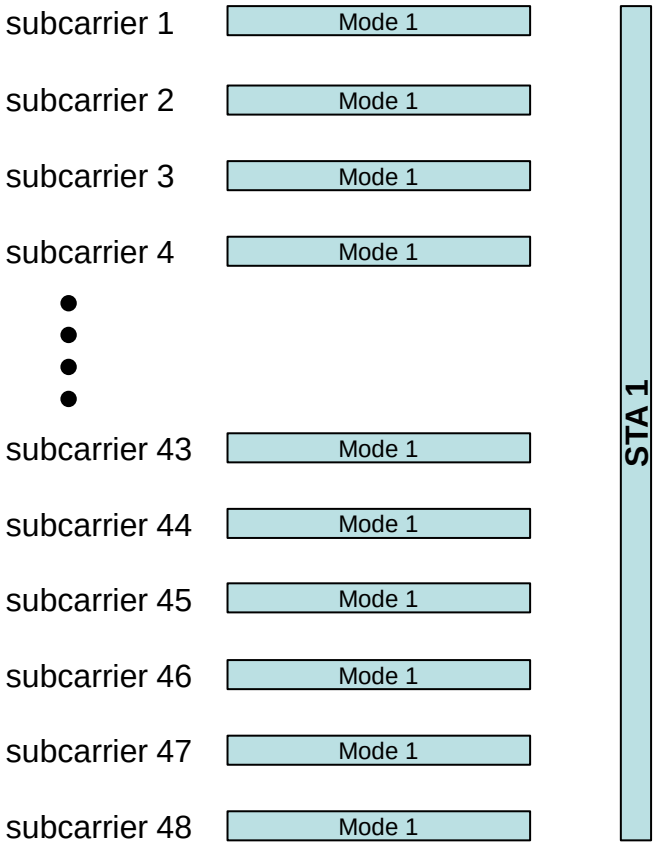
- **LTE D2D V2X**
  - Strong market and industrial support
  - Faster market penetration
  - LTE D2D community very active
    - Huawei wants it ‘now’ (rel. 13)
    - LTE D2D currently also at the ETSI ITS !!
  - Performance at least similar to DSRC
    - If not better !!

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

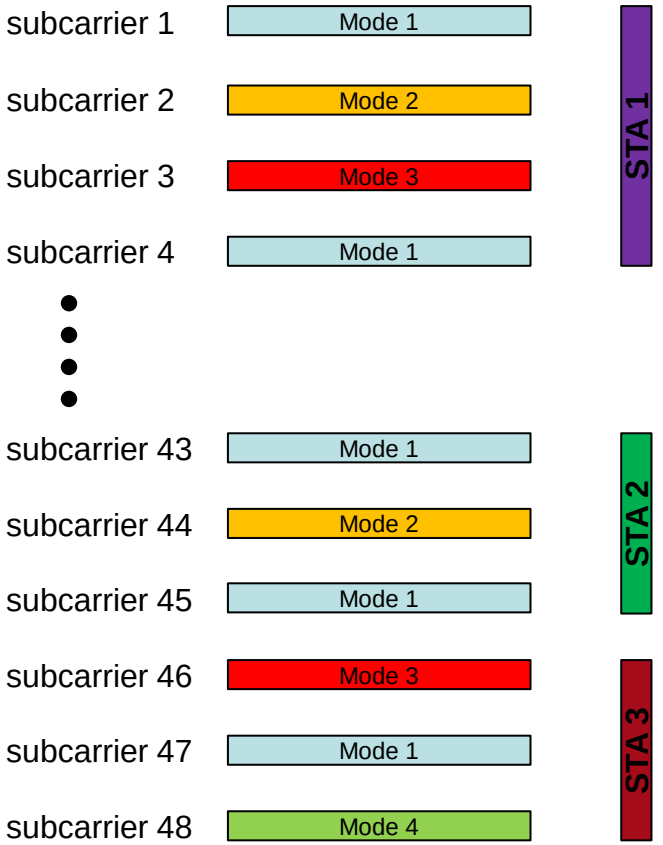
WiFi Strikes Back…

- **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

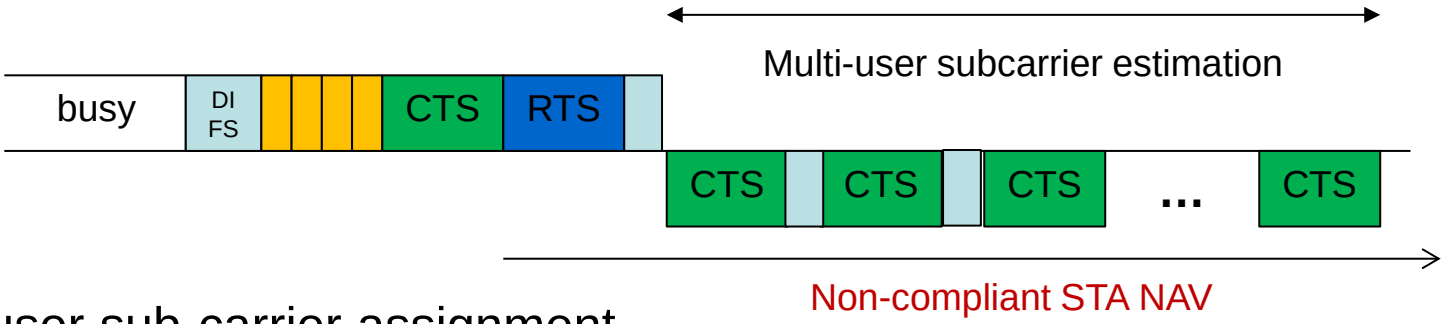


WiFi OFDMA

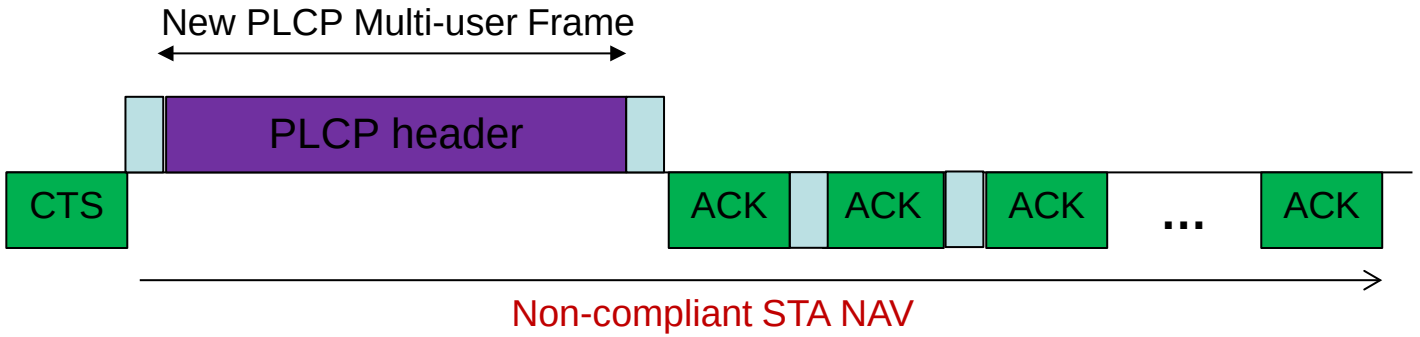
Challenge 1 – Efficient Spectrum Usage
OFDMA for WiFi

- **OFDMA for 802.11**

  - Sub-carrier channel estimation



  - Multi-user sub-carrier assignment



Challenge 2 – Fast Discovery and Communication

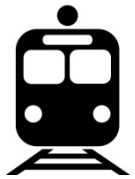
- **802.11aq: Pre-association Discovery**
  - enable pre-association discovery of services
- **802.11ai: Fast Initial Link Set-up below 100ms**
  - Discovery of network and BSS
  - Authentication and Association signaling
  - IP address configuration
- **Safety-critical V2X Communication**
  - Require 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**
- **Laurent Gallo, Jérôme Härri, "A LTE-Direct Broadcast Mechanism for Periodic Vehicular Safety Communications",** in Proc. if IEEE Vehicular Networking Conference (VNC), 2013.
- **Laurent Gallo, Jérôme Härri, "Dedicated Short Range LTE for V2X Direct Broadcast Communications**", IEEE Transaction on Vehicular Technology (to be submitted), 2015

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