Communication Technologies and the Internet of Things in ITS

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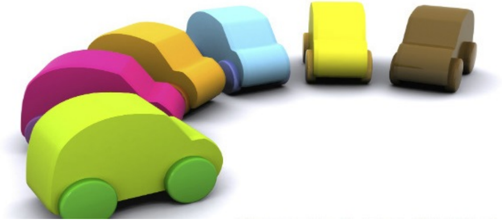
EURECOM

ITS-EduNet Short Course: **The Essentials of ITS**

TU Munich, June 29th 2015



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EURECOM – Teaching & Research

- **‘Grande École’ for Communication Systems**
  - Member of the Elite Cluster SCS
  - Architect and co-founder of Com4Innov
- **Research:**
  - Mobile & Network Communication – Massive MIMO, **connected vehicles**, **IoT**, WiFi, 5G, M2M, SDN
  - Data & Security – Big Data, Cloud computing, cryptography
  - Multimedia – Web Semantics, Open Data, Speech/video recognition
- **Teaching:**
  - Engineering Track - Telecom ParisTech
  - International Master Track – Mobile Communication, Data & Securitty, Multimedia
  - Post-Master Track –
    - **Cooperative Communications for ITS**
    - Security of Computer Systems

Academia

Industry

Institution

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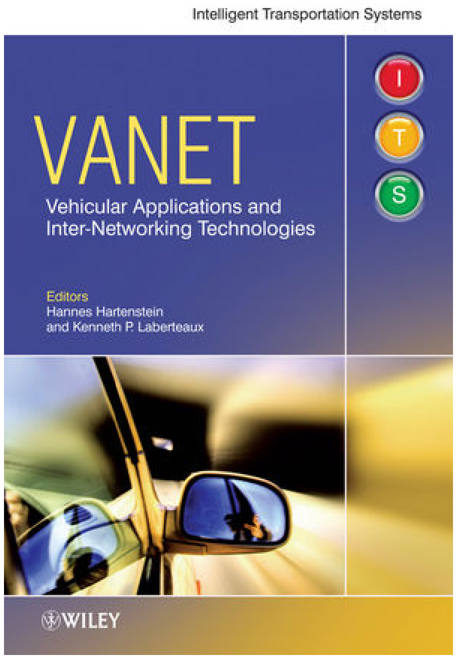
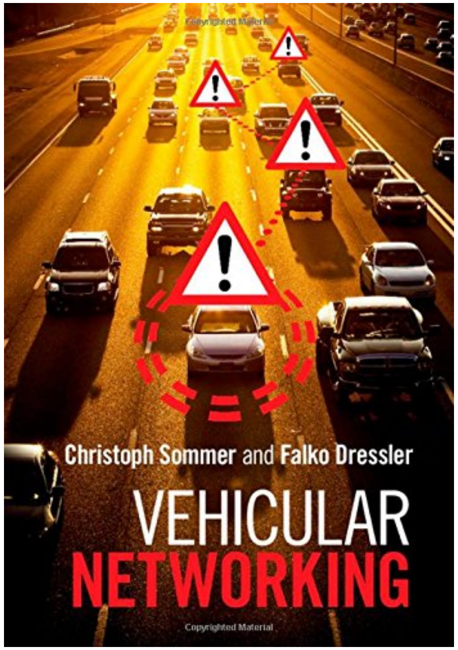
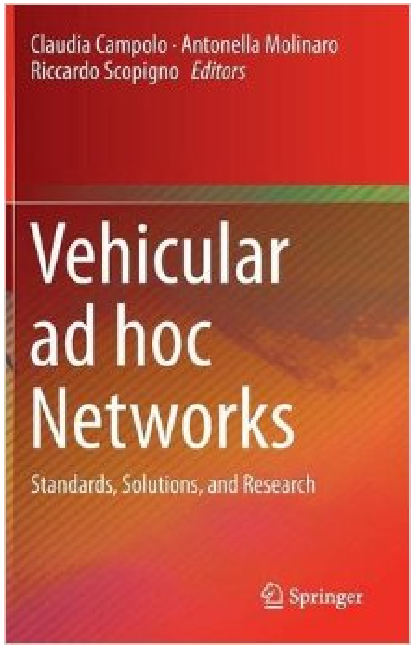
Related Books and References

http://www.amazon.co.uk/dp/1107046718







http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0470740566.html

http://link.springer.com/book/10.1007/978-3-319-15497-8

Related Books and References

- IEEE 802.11-2012 standard
- IEEE 1609.x trial standard
- ETSI Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band
- ETSI ; Intelligent Transport Systems (ITS); Cross Layer DCC Management Entity for operation in the ITS G5A and ITS G5B medium

- C2CCC Manifesto, 2008
- C2CCC Profile Document, 2013

- 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

- Hartenstein, Laberteaux, "**A tutorial survey on vehicular ad hoc networks**" *Communications Magazine, IEEE* , vol.46, no.6, pp.164,171, June 2008
- Hartenstein, Labertaux (Eds), **Vehicular Applications and Inter-Networking Technologies (VANET)**, Wiley & Sons, 2010.
- Laurent Gallo, Jérôme Härri, “**A LTE-Direct Broadcast Mechanism for Periodic Vehicular Safety Communications**”, in Proc. if IEEE Vehicular Networking Conference (VNC), 2013.

V2X Communication – Back to the Future !!

- GM Futurama - 1939

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

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

Europe

- **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)

Japan

- **ASV I** (1991-1995)
- **ASV II** (1996-2000)
- **ASV III** (2001-2005)
- **ASV VI** (2006-2010)

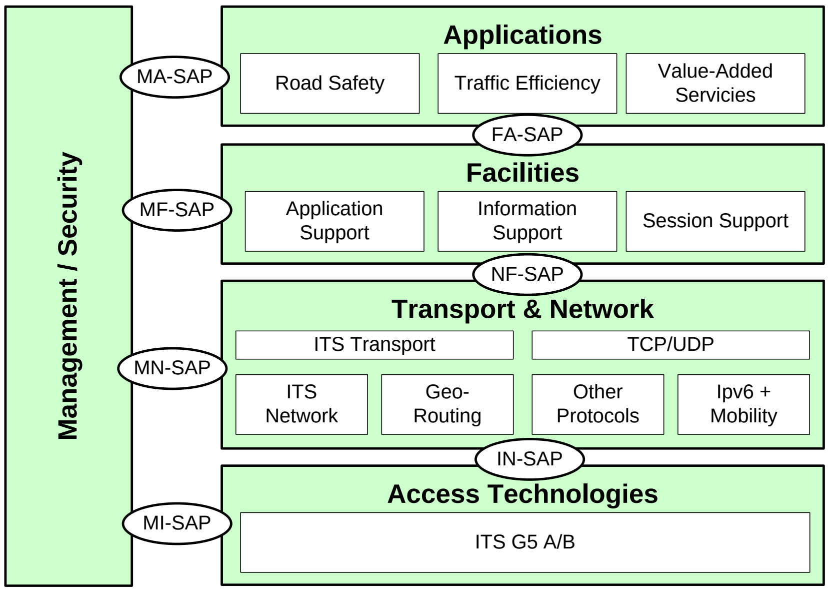
USA

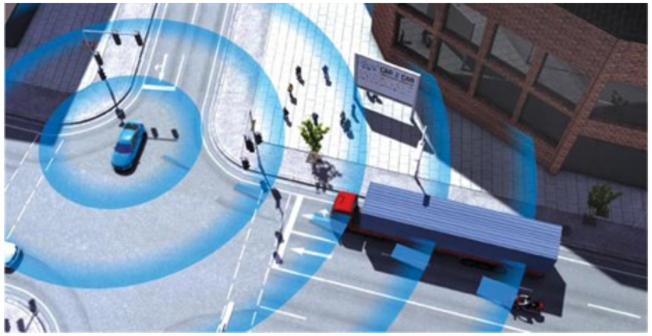
- **PATH** (1986)
- **IVI** (1998-2004)
- **VII / IntelliDrive** (2004-2009)
- V2V Decision (2013)
- **DSRC** (1999)
- **WAVE** (2004)
- ***ITS Strategic Research Plan,*** (2010-2014)

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

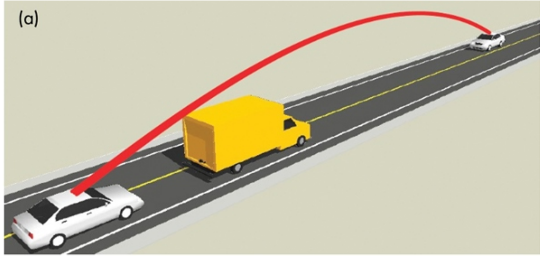
V2X Communication – Day 1
Architecture, Technologies & Applications

- ETSI Technical Committee 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**

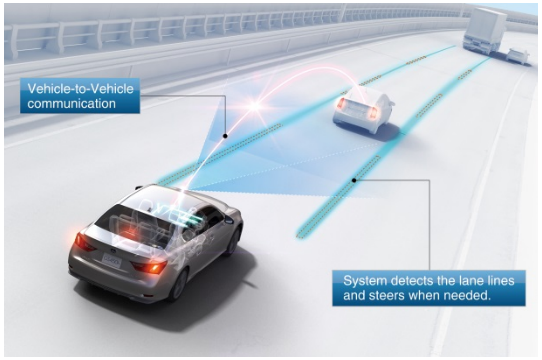
- Not such a new idea

- A very **marketized** idea…

Source: google

- …yet a very **ambitious** idea

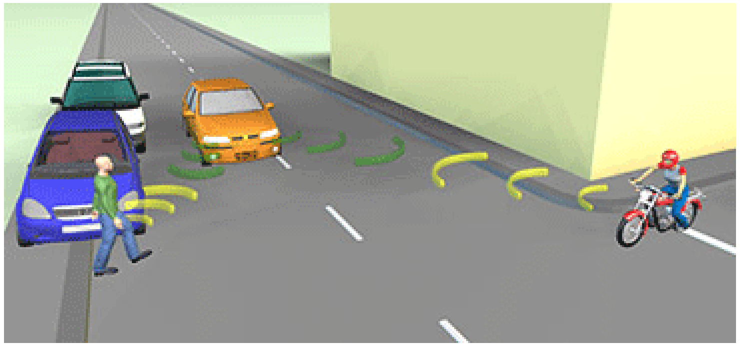
Source: US Peloton



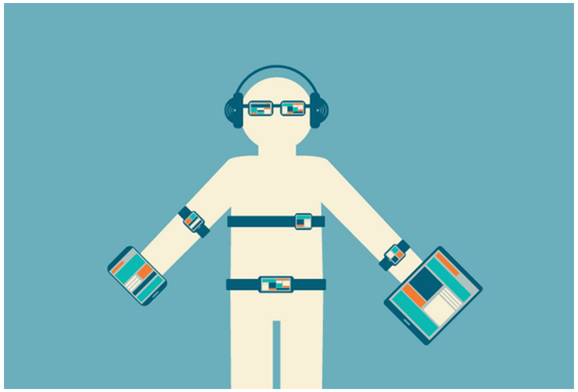
Source: toyota

V2X Communication - DAY 2
Objective: **Vulnerable Road Users**

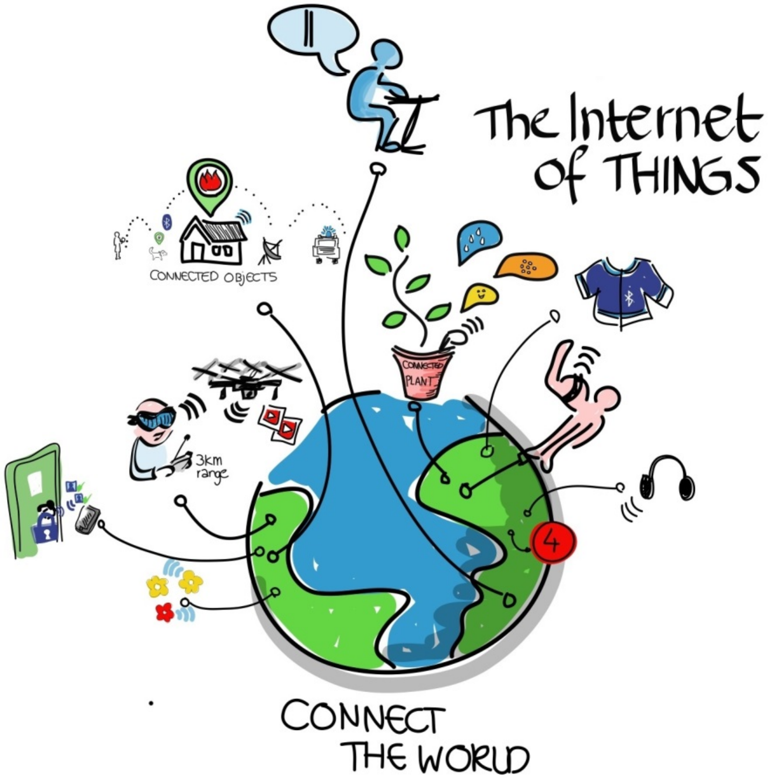
- V2X not only between Vehicles



- V2X connects to wearable devices



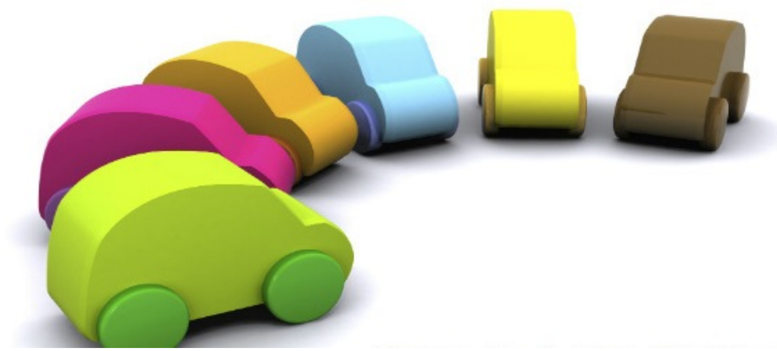
- V2X is part of the Internet-of-things (IoT)



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

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

DAIMLER BMW Audi Ford

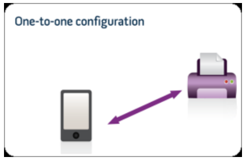


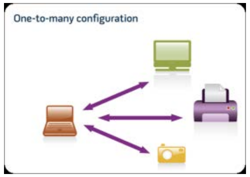
- **Connected things**
  - driven Internet & wireless industry

intel QUALCOMM HUAWEI Alcatel·Lucent ERICSSON

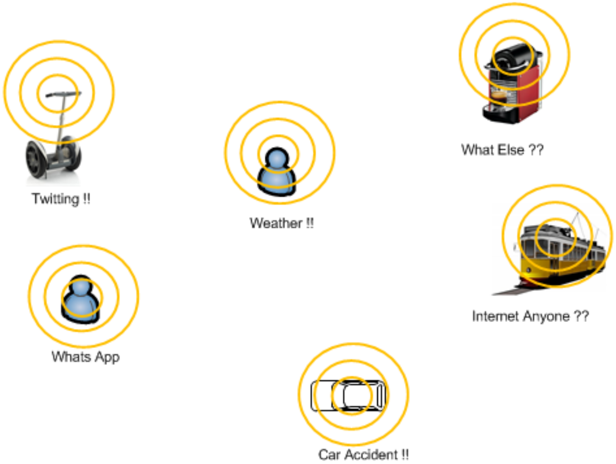
Towards a Connection-of-Everything

- Evolution of Proximity Services





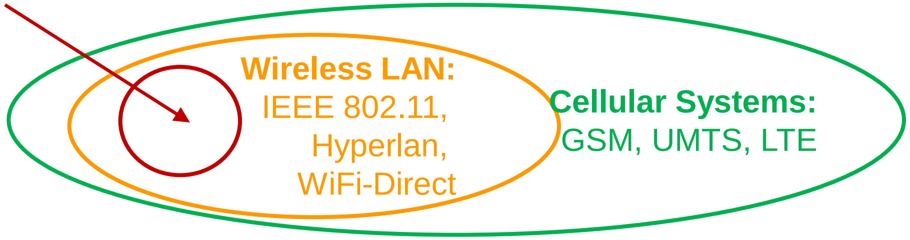
Convergence of Actors:
- Pedestrians
- Cars, Buses, Trains
- Any-'Wheelers'
- Your coffee machine !!



- Evolution of Proximity Technology

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

PAN:
Bluetooth, Zigbee



Focus for Proximity Services → Personal Area | Local Area | Wide Area

Communication Technologies and the Internet of Things in ITS

DEDICATED SHORT RANGE COMMUNICATION (DSRC)

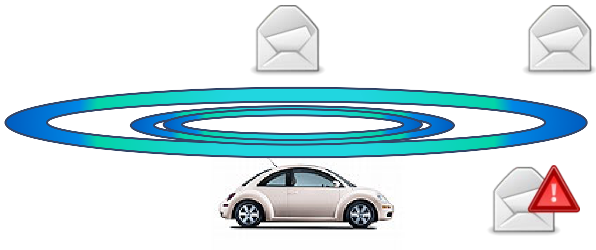
DSRC: Key Messages for Safety-related ITS Applications

Periodic
Cooperative Awareness Message (CAM)

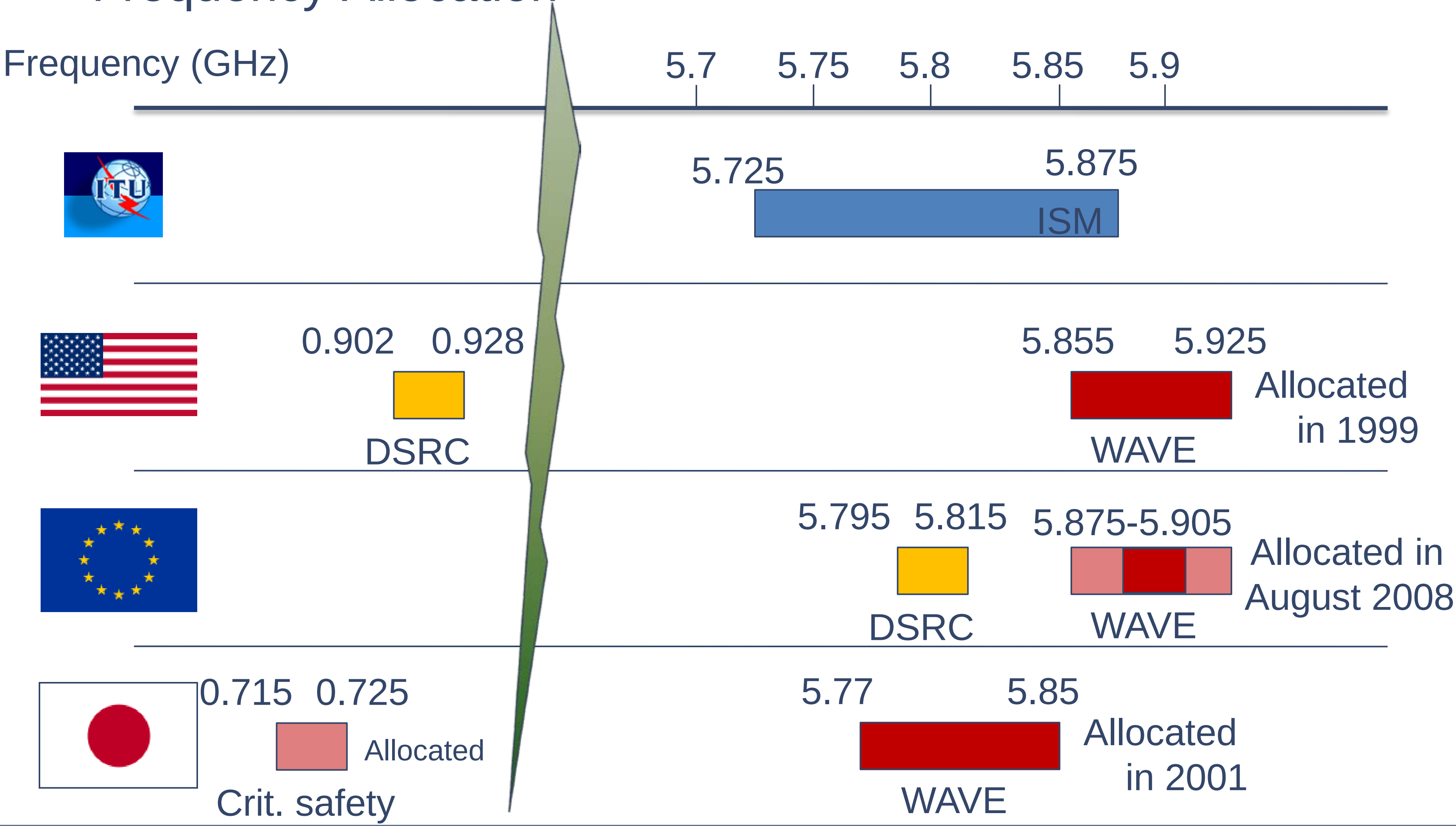
- One-Hop **broadcast**
- Transmit the status and position of a vehicle.

Event-driven
Decentralized Environment Notification Message (DENM)

- Multi-Hop **broadcast**
- Transmit emergency or application-based messages



Frequency Allocation



Three Frequency Bands in 5 GHz Band

RLAN bands (U-NII2, WLAN, BRAN, HiperLAN2)

Power: 1W EIRP

ITS G5 C
Shared Spectrum
Dynamic Channel Selection & Power Control

ITS G5 B – **ITS Dedicated Spectrum**
ITS G5 A – **ITS Dedicated Spectrum**
ITS G5 D – **Future Usage**

EIRP : Effective Isotropic Radiated Power

Dedicated ITS bands

Bandwidth: 10Mhz

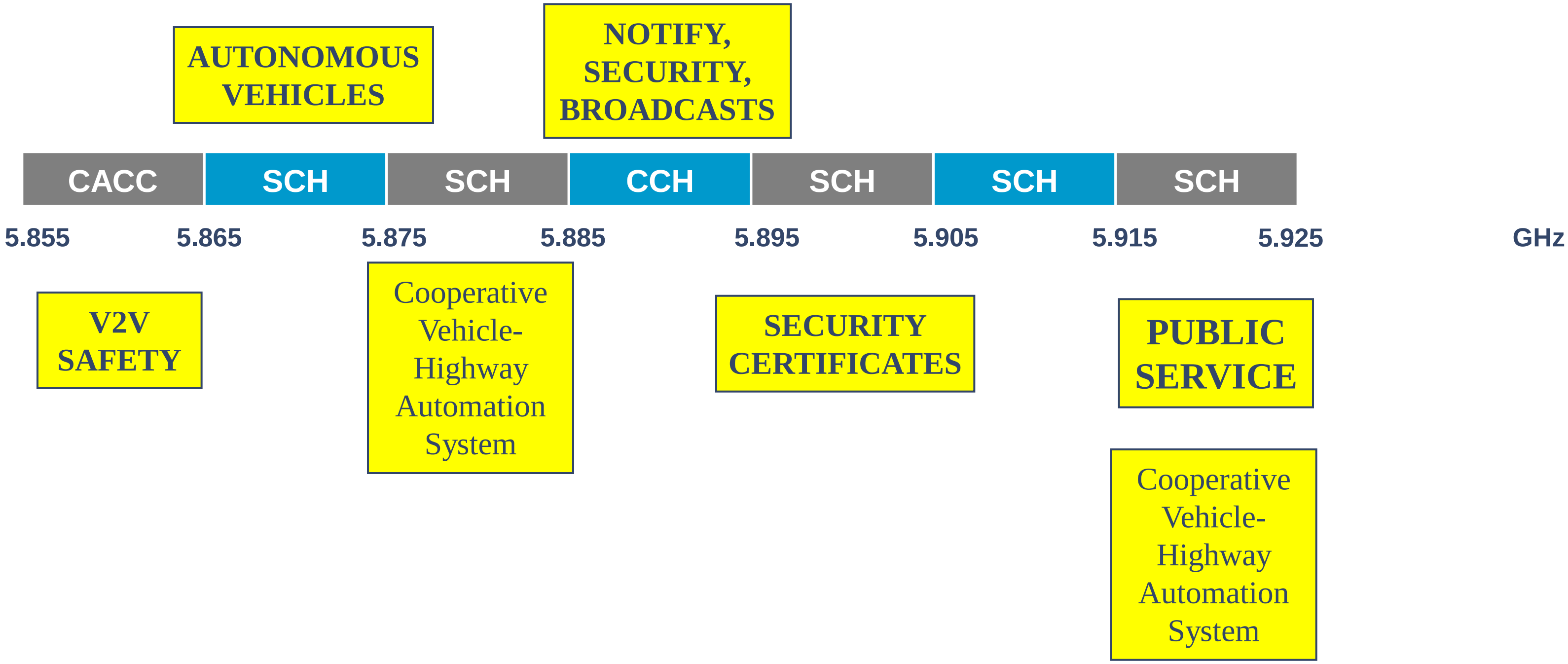
SCH – ITS Service Channel

CCH – ITS Control Channel

Power: 2W CCH &SCH1; 200MW SCH2 & 3; 1mW SCH4

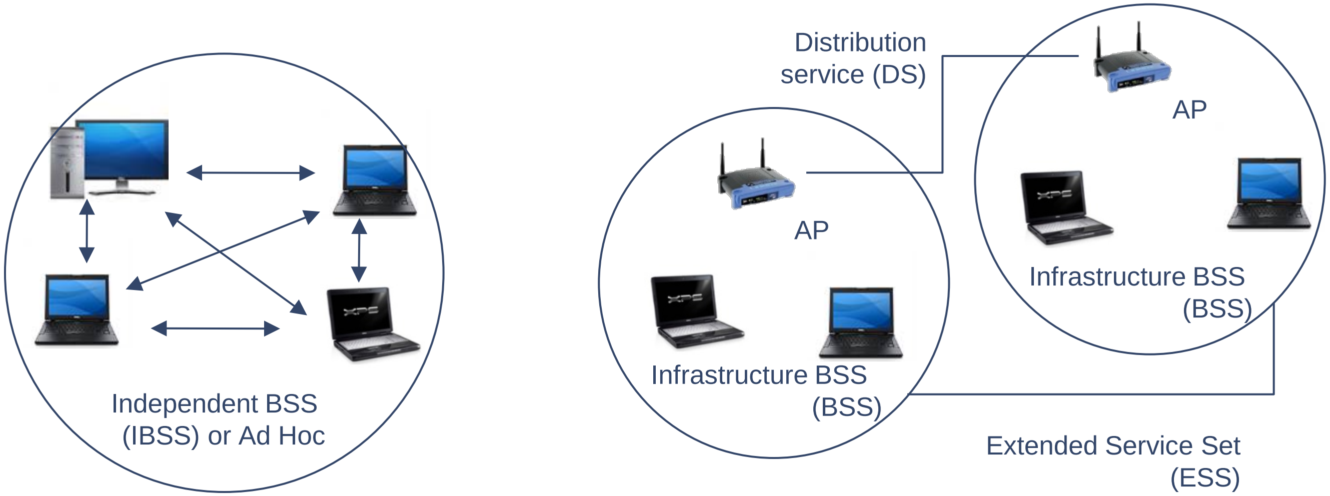
Channel Usage in the US

Dedicated ITS bands - US

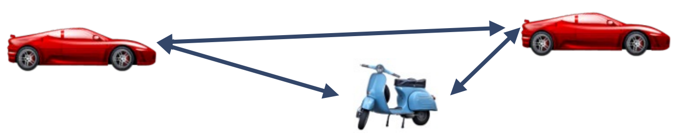


Forming a Wireless Network: Architecture

- Basic Service Set (BSS)
  - A station must join a BSS and an AP before being allowed to communicate

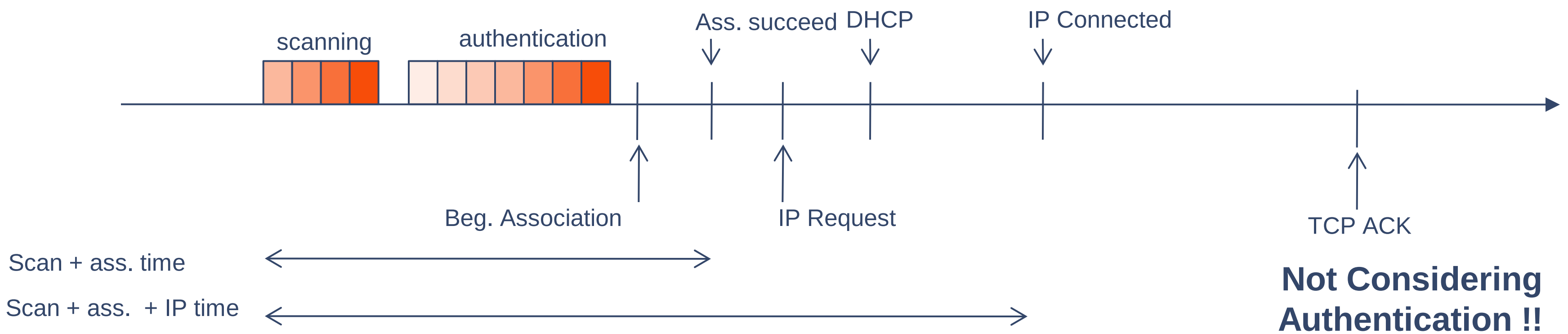


- Communicating Outside of the Context of a BSS
  - Vehicular-specific extension of the IEEE 802.11 not requiring a BSS to communicate

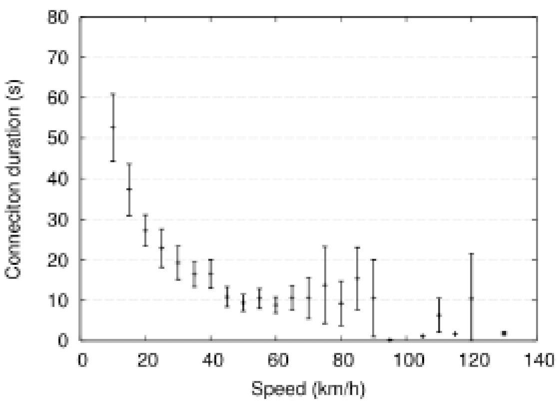


Connecting to a WLAN

- Connecting to WI-FI Access Points:



Not Considering Authentication !!



Mean scan duration	750 [ms]
Mean association duration	560 [ms]
Mean DHCP IP Acquisition	1830 [ms]
Mean time before first TCP ACK	4900 [ms]
Total	8040 [ms]

Throughput during Association	Data Exchanged during connection
30 Kbytes/s	**216 Kbytes**

[Source: Bychkovsky et al. , "A Measurement Study of Vehicular Internet Access Using In Situ WiFi Networks, ACM Mobicom, 2006]

Communication outside of a BSS – OCB mode

- Nodes should form network spontaneously
  - Always varying due to mobility
  - Not existent over longer time intervals
- No time should be lost to establish the network

Classic 802.11 WLAN	DSRC / ITS-G5
Synchronization	**HIGHER LAYER** Synchronization
Scanning	**NO** Scanning
Authentication	**HIGHER LAYER** Authentication
Association	**IMPLICIT** Association
Communication	**DIRECT** Communication
Concept of Basic Service Sets (BSS)	"Communication outside of a BSS" (OCB)

Communication outside of a BSS

- For BSS:
  - A station can only respond to an AP communication
    - once it joined the BSS of the AP

      OR
    - if the message is a wildcard BSSID AND it is a broadcast message
- OCB:
  - A STA MUST accept and respond to communication from other STAs
    - Broadcast AND Unicast
  - A STA in OCB does not have a valid BSSID
  - Use the wildcard BSSID : 0xFFFFFF

To DS	From DS	Addr 1	Addr 2	Addr 3	Addr 4
0	0	DA	SA	BSSID	

802.11 - MAC management functions

- Synchronization
  - try to find a LAN, try to stay within a LAN
  - timer etc.
- Association/Re-association
  - integration into a LAN
  - roaming, i.e. change networks by changing access points
  - scanning, i.e. active search for a network
- Power management
  - sleep-mode without missing a message
  - periodic sleep, frame buffering, traffic measurements
- Coordination Function (CF) Mode
  - Distributed Coordination Function (DCF) – Contention Phase
  - Polling Coordination Function (PCF) – Contention-free Phase
- MIB - Management Information Base
  - managing, read, write

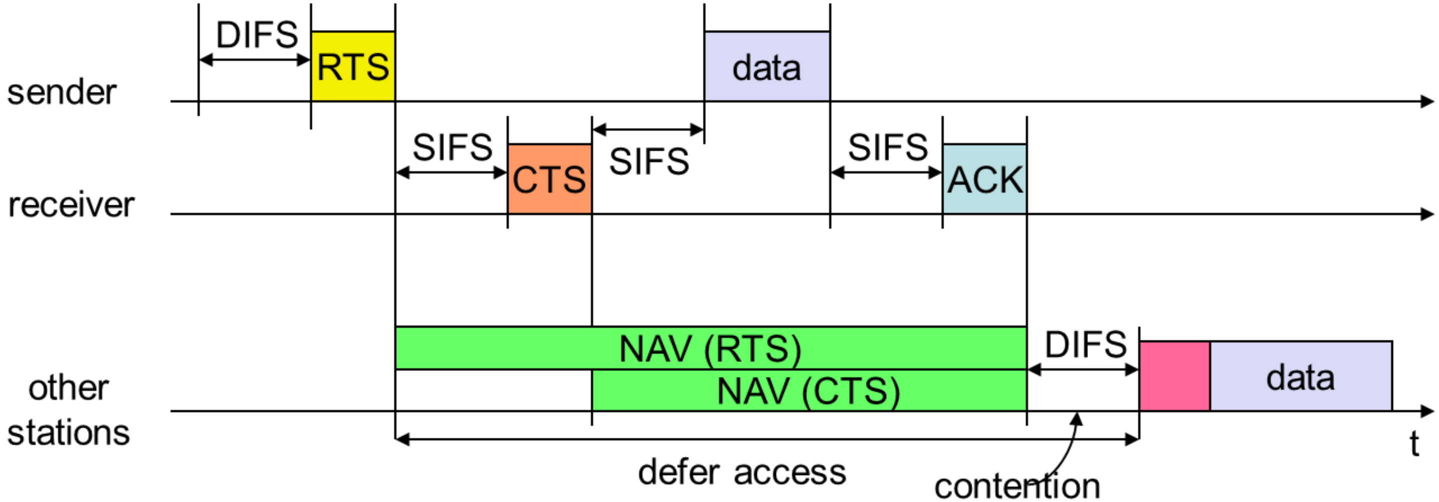
- Beacon messages
  - Used to coordinate the various management functions between AP and STA
    - BSS
  - Contains information to
    - Synch
    - Communication Quality
    - Sleep mode
    - DCF/PCF modes

DSRC/ITS-G5 OCB mode – Synchronization and Scanning

- Management Frames:
  - Beacon frames are not used in DSRC/ITS-G5
    - Beacons include information related to a BSS and are mostly not required in OCB
  - New Frame:
    - **Timing Advertisement (TA) frame**
      - Kind of replacement for a beacon for transmission of higher layer data (vendor specific)
      - TSF function can be sent in such frame
  - Other beacon related information are transmitted by higher layers (Wave Service Announcements (WSA) for instance)
- Synchronizing
  - 802.11p OCB does not require to be synchronized
    - Power management not supported
    - High mobility / topology changes
  - Yet, a synchronization between stations may be provided by higher layers (1609.x, GPS) is required
    - Multi-channel operation (only supported by US IEEE WAVE so far)
- Scanning
  - Scanning is not required, as the CCH is the reference channel.

IEEE 802.11 Distributed Coordination Function (DCF)

- Listen before Talk Principle
  - If medium is free for a DIFS time, station sends data or control packet
  - receivers acknowledge at once (after waiting for SIFS) if the packet was received correctly (CRC)
  - automatic retransmission of data packets in case of transmission errors
- Contention-based Access
  - Contend for the channel access, back-off if you loose

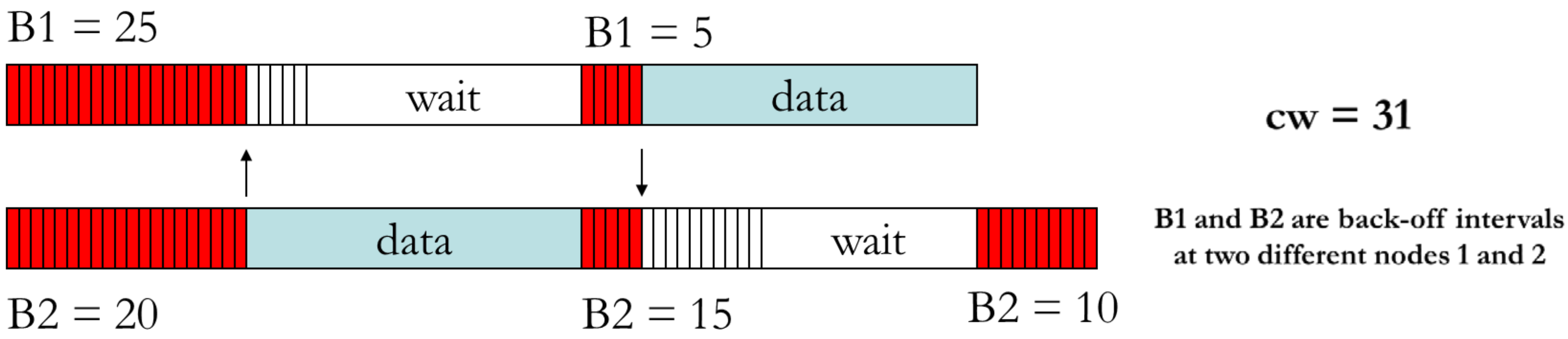


IEEE 802.11 DCF – Back-off Strategy

- Back-off Algorithm
  - Defer time = DIFS + Random Time Period
  - Random Time Period = Int (CW* random()) * aSlot time

- CW is the Contention Window: Its initial value is 31 (size 32) and can take the following values:
  - 31, 63, 127, 255, 1023

- Back-off decrementation strategy:
  - Back-off counter should be decremented when medium is free
  - Back-off counter is never decremented when medium is busy

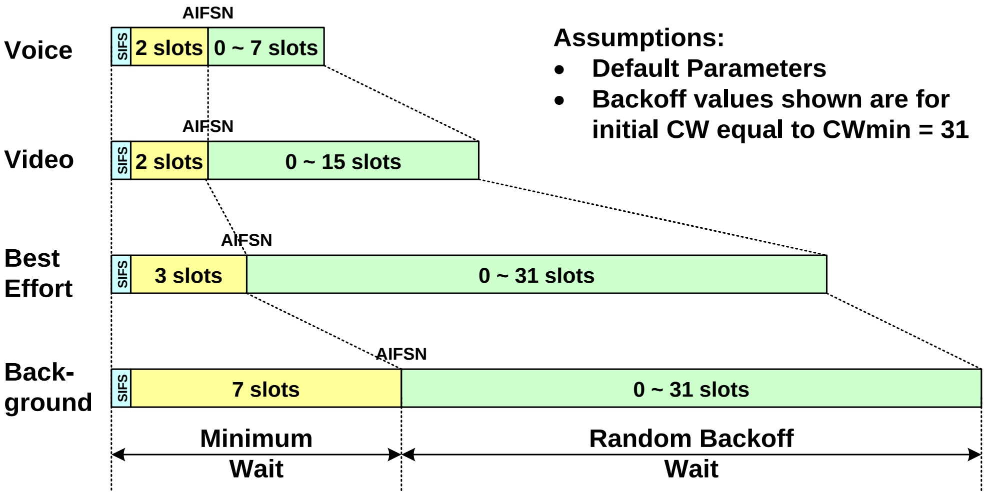


IEEE Enhanced Distributed Coordination Access (DCA) - WiFi QoS (Traffic Differentiation)

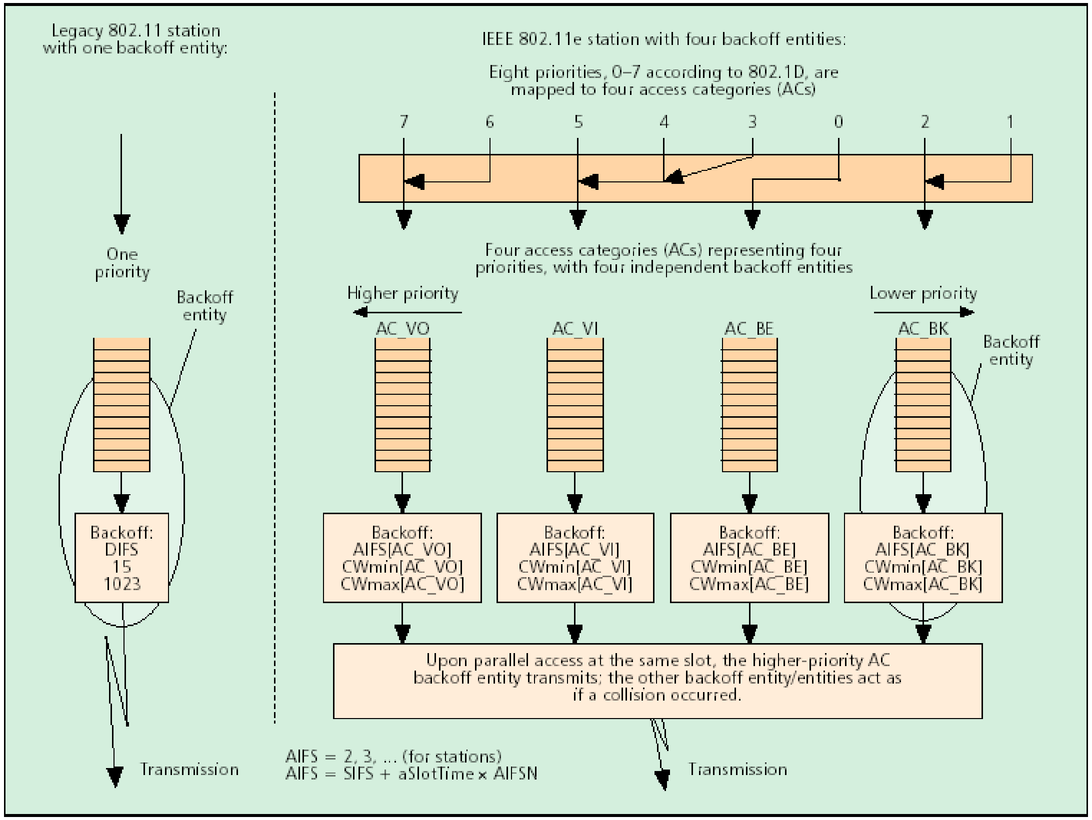
- The QoS support in EDCA is provided by the introduction of Access Categories (ACs)

- 4 different ACs within one station
  - AC_VO: voice
  - AC_VI: video
  - AC_BE: best effort
  - AC_BK: background

- Each AC has its own parameter set defined by the EDCA:
  - Inter-frame spacing : **Arbitration Inter-Frame Space (AIFS)**
  - Contention windows : CWmin, Cwmax



IEEE EDCA – Access Categories

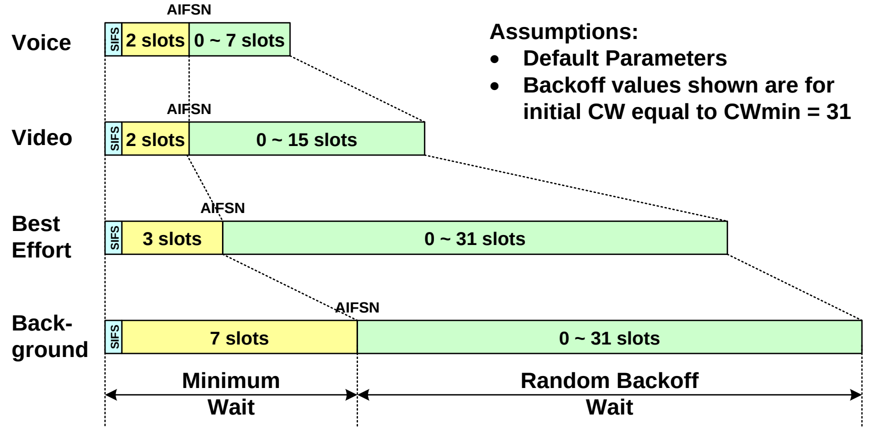


Source: IEEE 802.11-2012

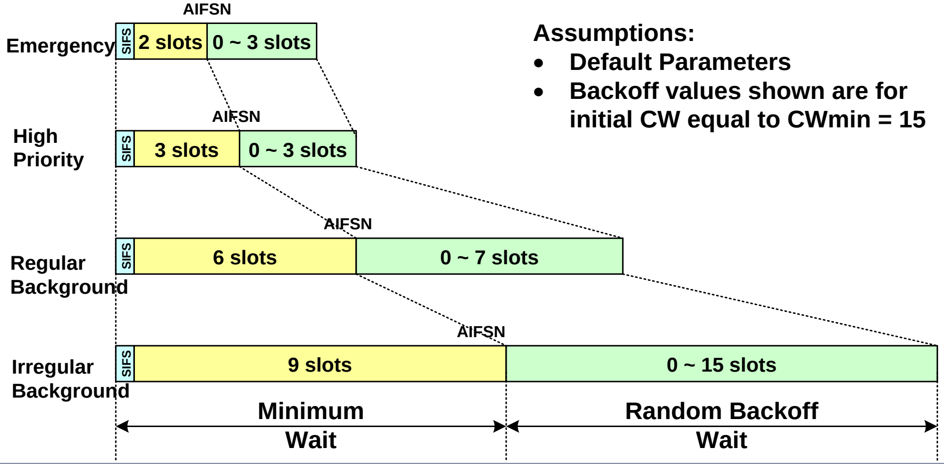
- 4 Access Categories (ACs) within one station
- AIFS: Arbitration Inter-Frame Space

EDCA Parameter Results – DSRC/ITS-G5 OCB

- The IEEE EDCA is modified to improve the prioritization of messages
  - **IEEE 802.11e EDCA**



  - **DSRC/ITS-G5 EDCA**



DSRC/ITS-G5 Channel Characterization

- How does the channel characteristic at 5.9 GHz for 802.11p look like?

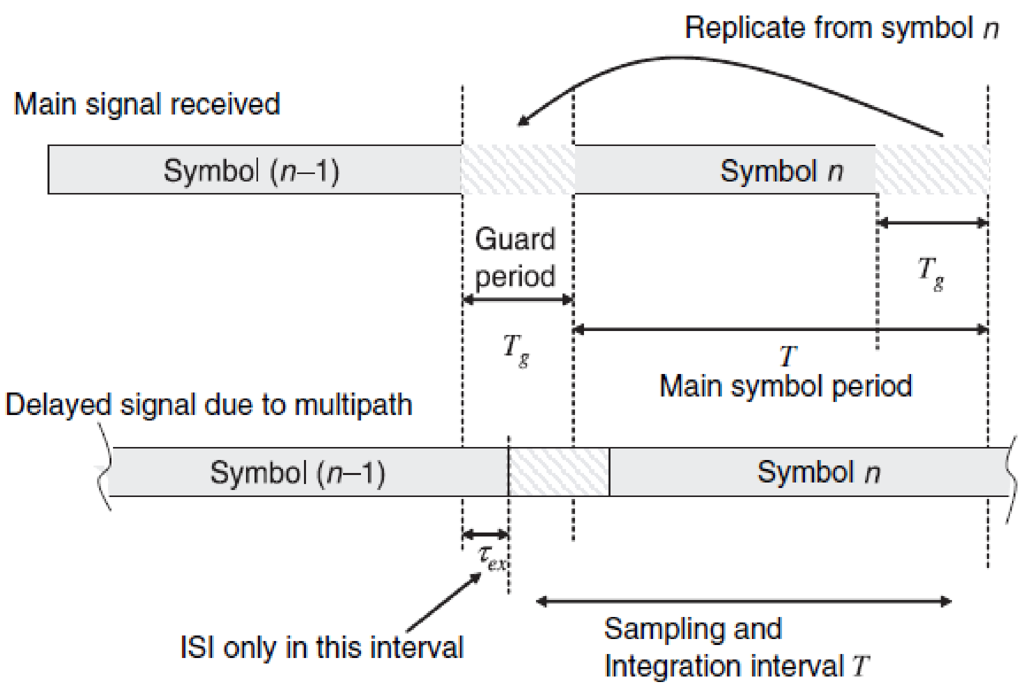
Delay spread	**~ 0.8 µs**
Coherence Bandwidth	**~ 1.25 MHz**
Coherence Time	**~ 1.02 ms**
Doppler spread	**~ 2 kHz**

Source: Measurement and Analysis of Wireless Channel Impairments in DSRC Vehicular Communications, Laberteaux et al, 2008

- What does it tell us?
  - We have a **time- and frequency-selective** channel
  - We have a **doppler spread** which needs to be considered
- Actions:
  - We have to use narrow-band communication to mitigate frequency-selective channel
  - We have to make sure that successive OFDM symbols are sufficiently separated in time to avoid ISI
  - We have to make sure that the 52 OFDM sub-carriers are have an inter-carrier distance of at least 2 kHz to avoid ICI

DSRC/ITS-G5 PHY Countermeasures

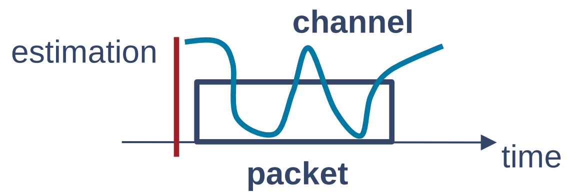
- Mitigating Inter-Symbol Interference
  - OFDM introduces a guard period after each OFDM symbol to protect symbols from ISI



Source: Antennas and Propagation for Wireless Communication Systems,
Simon R. Saunders and Alejandro Aragón-Zavala, 2007, John Wiley & Sons, Ltd

DSRC/ITS-G5 PHY Countermeasures

- Mitigating Inter-Carrier Interference
  - 802.11p OFDM uses a carrier spacing of 156.25 kHz
  - The Doppler Spread of 2 kHz is easily covered by this spacing
- Mitigating Time-selectivity (or narrowband fast fading)
  - Problem: the channel estimation at the beginning of a packet may be invalid at the end of the packet



    - This results in an increased Bit error rate and decreased Packet reception rate
  - Several solutions:
    - Increase data-rate to reduce transmission time below channel coherence time
    - Estimate the channel several times during the transmission
    - Use modulation schemes which overcome the channel fading, e.g. differential BPSK

DSRC/ITS-G5 - Summary

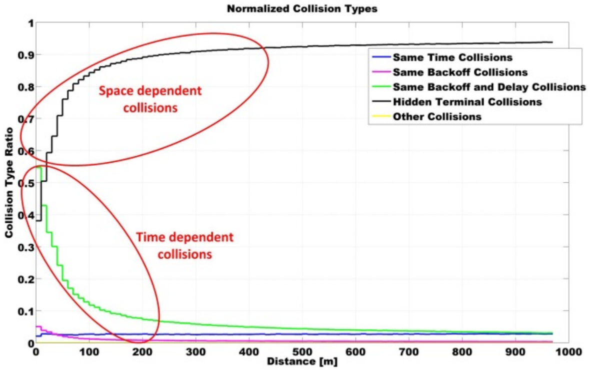
- **Key PHY characteristics**
  - 5.9 GHz frequency domain
  - Based on IEEE 802.11a (OFDM PHY)
  - 10 MHz channel bandwidth
  - Rates: 3, 4.5, 6, 9, 12, 18, 24, 27 Mbps
  - Symbol time: 8µs (1.6µs guard interval + 6.4µs data symbol)
- **Key MAC characteristics**
  - EDCA QoS Provisioning
  - Multi-channel Operation (1 CCH, several SCHs) (not discussed here..)
  - Congestion Control (adaptive TX power, TX rate, multi-channel)

Classic 802.11 WLAN	DSRC/ITS-G5
Synchronizing	**OPTIONAL HIGHER LAYER** Synchronization
Scanning	**NO** Scanning
Authentication	**HIGHER LAYER** Authentication
Association	**IMPLICIT** Association
Communication	**DIRECT** Communication
Concept of Basic Service Sets (BSS)	“Communication outside of the context of the BSS”

Enhancing the Reliability of DSRC

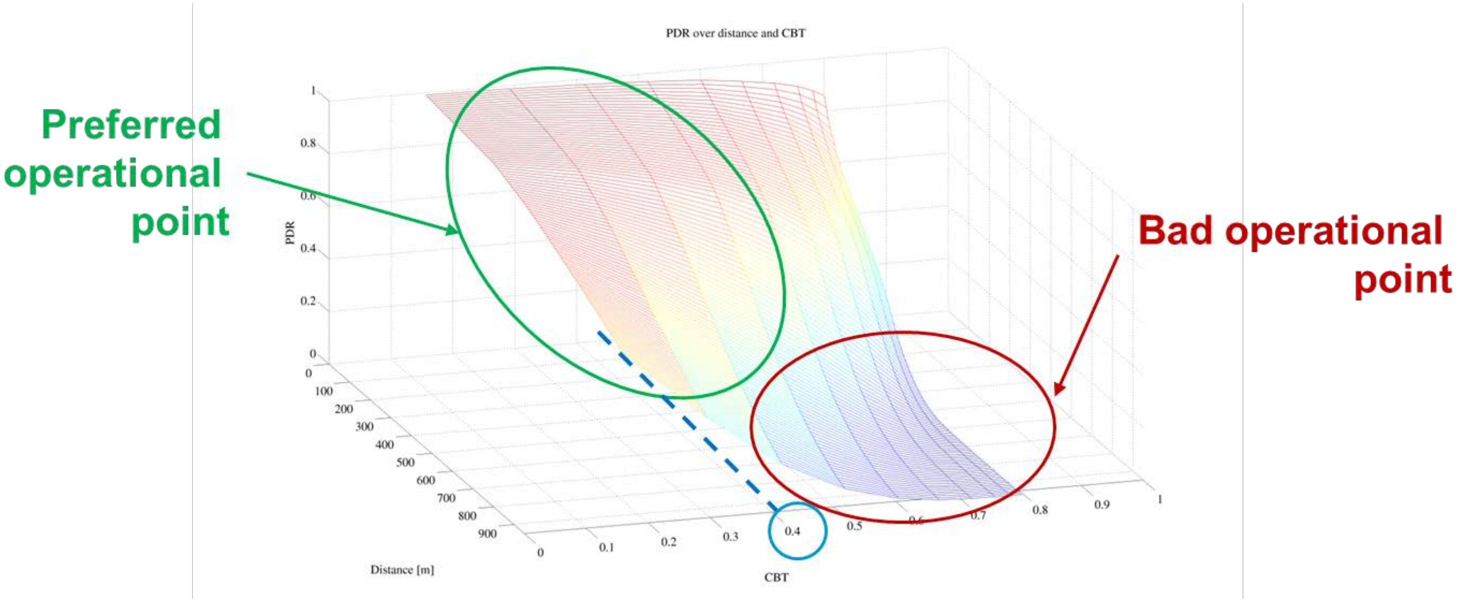
- Vehicular Communication on DSRC are challenging for the following reasons:
  - Safety-critical application **require 'periodic TX'**
    - DSRC has been optimized for busty traffic
  - **Unacknowledged broadcast traffic** – reliable for low traffic density
    - All cars TX at 10Hz up to 500m – congested channel
  - **Hidden Terminal** – DSRC cannot detect a transmission on the channel
    - Solutions exist for Unicast; not for Broadcast
    - Low mutual mobility & Similar transmit range
      - Recurring hidden terminal on same nodes

- The underlying challenge:
  - **Reliable 1-hop broadcast !!**
    - In space & in time

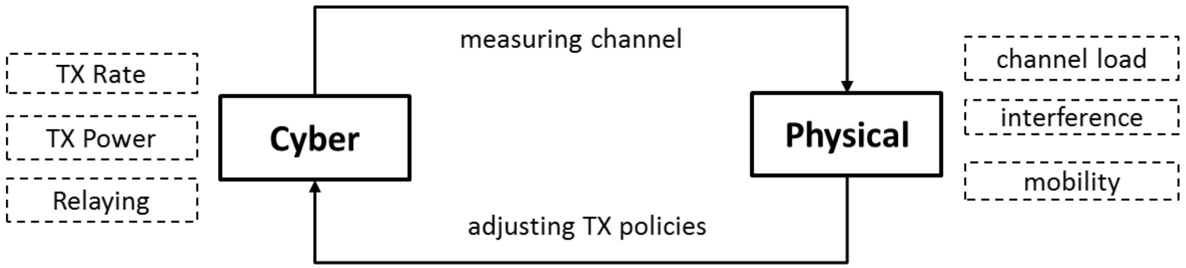


Dependable 1-Hop Broadcast

- Reminder: WLAN does not provide real QoS services
  - Using broadcast: not any feedback on correct transmission !
  - Need to 'trust' WLAN
- Rule of thumb:
  - The IEEE 802.11p system works fine at **'low' channel load**
  - How low??



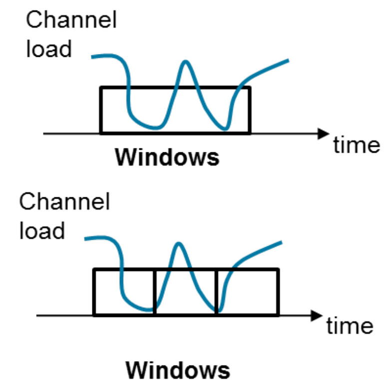
Controlling Congestion on Wireless Channel

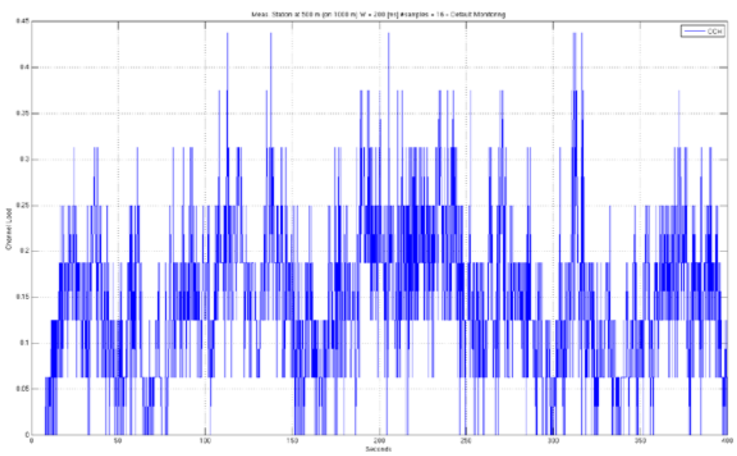


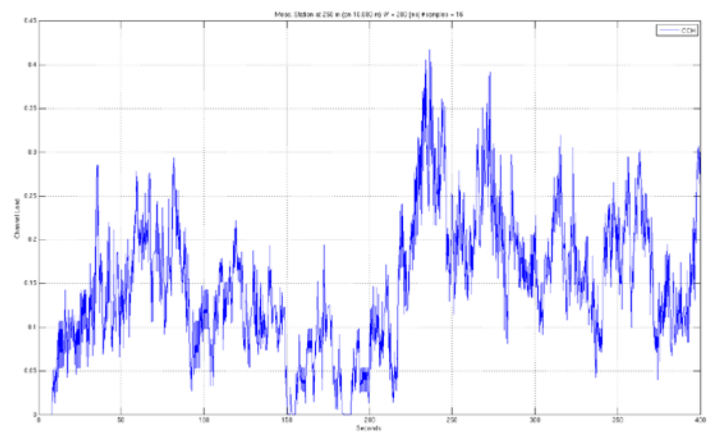
- Sensing:
  - Channel load – representing the quality of the wireless channel
- Control:
  - Adjusting transmit power, transmit rate or relay selections
- Methodology:
  - Efficient and stable evaluation of channel congestion:
    - Provide close-to-reality channel quality estimation
    - Provide stable values
    - Oscillations must be avoided – Control influences the channel in return !!
      - Trend: Sacrifice accuracy over stability
  - Mitigation of channel congestion
    - Reducing number of bits transmitted on the channel

Measuring Channel Load

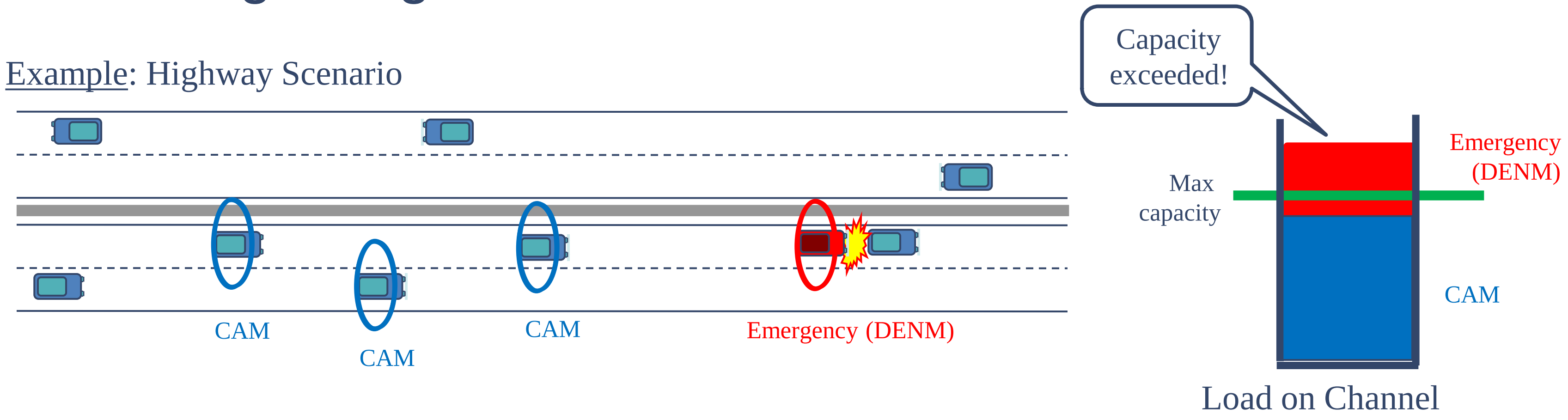
- Channel Load metric:
  - Channel Busy Time (CBT) – ratio of CCA busy/idle over time
- Measuring mechanisms:
  - Adjusting window measurement
  - Adjusting sampling rate (CCA samples)
- Optimization:
  - Filtering the CBT over several measurement windows







Controlling Congestion on Wireless Channel

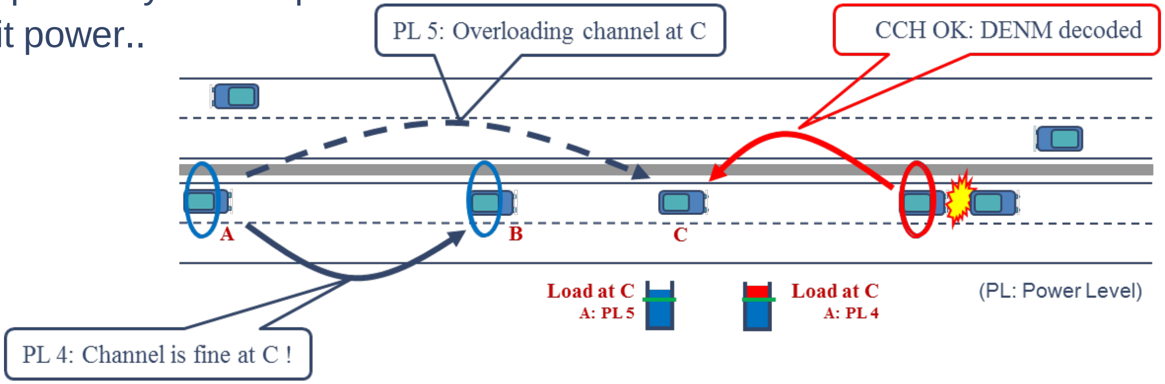


- Load on Channel:
  - Per node: bits transmitted by neighbors load a node‘s Channel
  - CAM periodically transmitted: major contributor to the load on the Channel
  - The higher the load from CAM: the harder it is for DENM to be decoded

- Need to regulate the load generated on Channel
  - Topology Control: controlling the number of transmitters
  - Congestion Control: all transmitters transmit
    - Temporal Influence: number of bits transmitted
    - Spatial influence: distance reached by transmitted bits

Transmit Power Control (TPC) to mitigate Channel Load

- TPC: Locally measure channel load
  - If too high, reduce transmit power by one step..
  - If too low, increase transmit power..

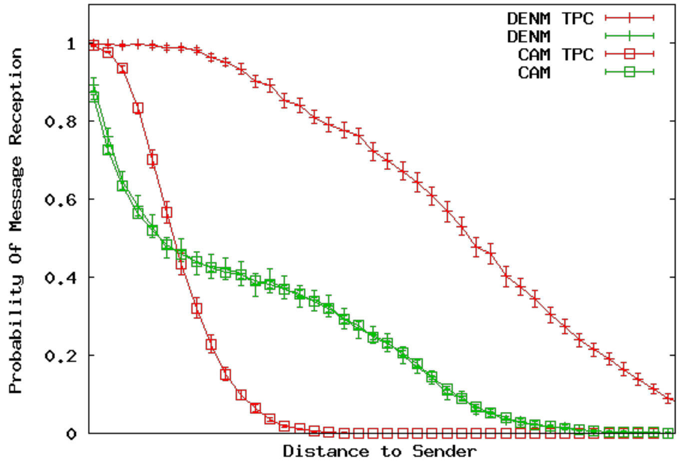


- Observations:
  - **Channel Sensing requires remote knowledge**
    - Information must be exchanged between nodes !
  - **Transmit power adjustments only impact neighbors**
    - Cooperative strategies to gain local benefits !

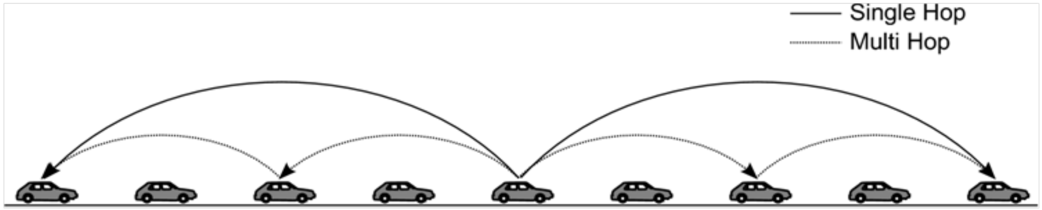
- Conclusion:
  - TPC power adjustments are a good option. But:
    - Must obtain a networked channel sensing
      - <u>Challenge</u>: **delayed and inconsistent values**
    - Must cooperate with other devices
      - <u>Challenge</u>: **selfishness** !!

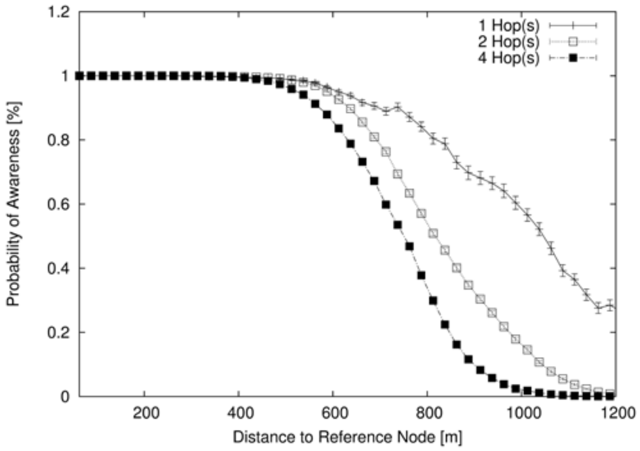
Transmit Power Control - Example

- Fair Transmit Power Adjustment (DFPAV/SPAV)
  - **Analysis and Design of Effective and Low-Overhead Transmission Power Control for VANETs**, J. Mittag, F. Schmidt-Eisenlohr, M. Killat, J. Härri and H. Hartenstein, ACM VANET 2008.

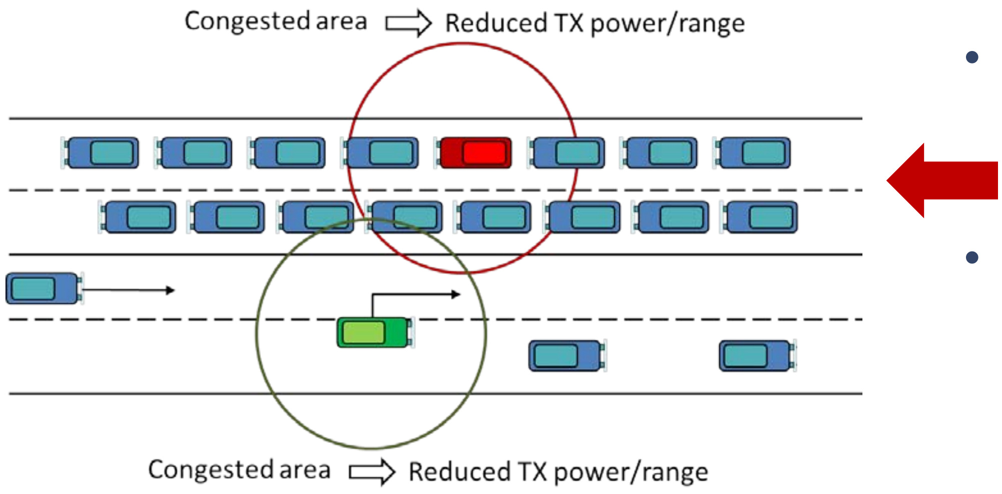


- Alternative approach:
  - Reduce power and rely on multi-hop relaying to cover same distance
  - **A Comparison of Single- and Multi-hop Beaconing in VANETs,** J. Mittag, F. Thomas, J. Härri, H. Hartenstein, ACM VANET 2009



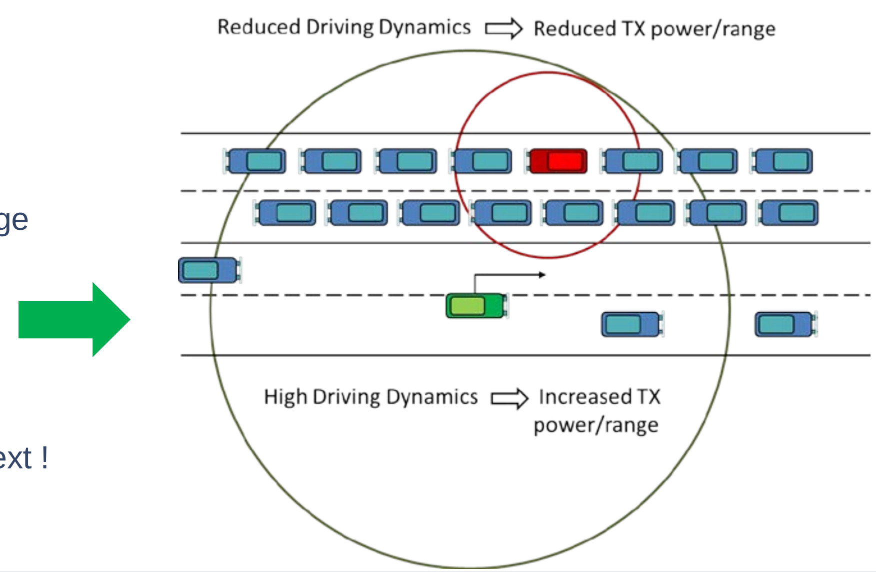


Limitation of TPC for C-ITS Applications



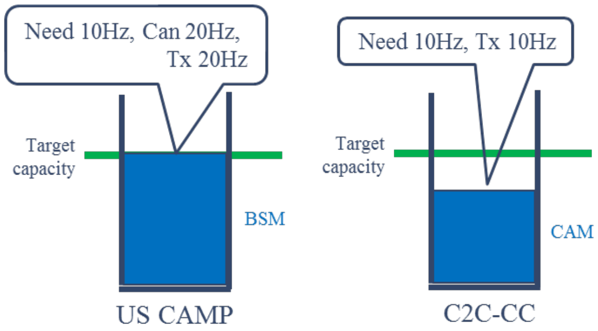
- High Channel Load
  - Reduction of TX power
    - Might not provide the required range for Safety applications
- Multi-hop not beneficial
  - Need a different approach

- Awareness Control:
  - Fix Transmit power to cover the required range
  - Adjust the channel load with transmit rate
- Change of paradigm:
  - Range depends on mobility, not load !
  - Adjusting rate should not be done based on channel measurements, but application context ! (ex. Mobility)

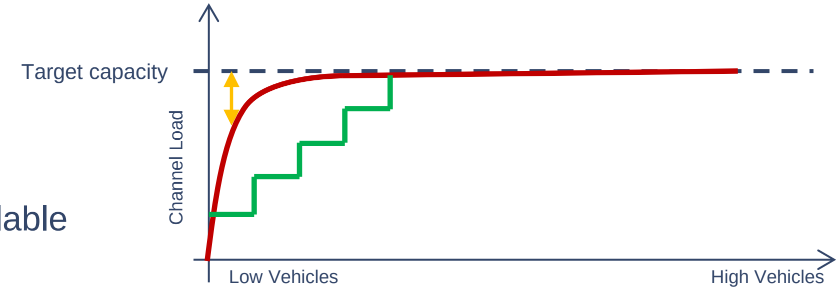


Transmit Power Control (TPC) to mitigate Channel Load

- Transmit Rate Control (TRC)
  - Keep TX power fixed, adapt TX rate
- In the US and in EU, TRC is considered as a best option to efficiently control congestions
  - But they do not share the methodology to reach that target



- Strategies:
  - US CAMP
    - Transmit as much as you can !
  - EU C2C-CC
    - Transmit as much as you need !



- Two Algorithms:
  - Table-driven Rate Control
    - TX rate is restricted per channel load step
  - EU C2C-CC
    - TX rate is adapted to the remaining load available

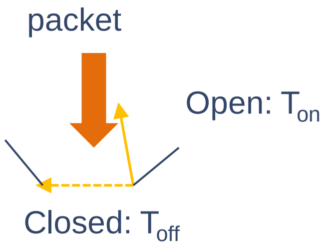
Transmit Rate Control Examples

- LIMERICS:
  - Algorithm

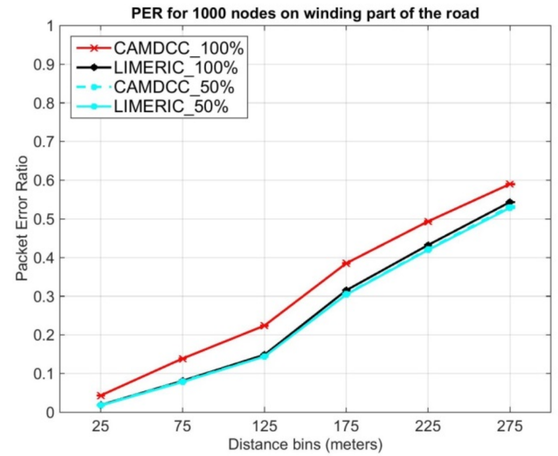
$$T_{on}(t+1) = (1 - \alpha) \times T_{on}(t) + \beta \times (CBR^{target} - CBR(t)),$$

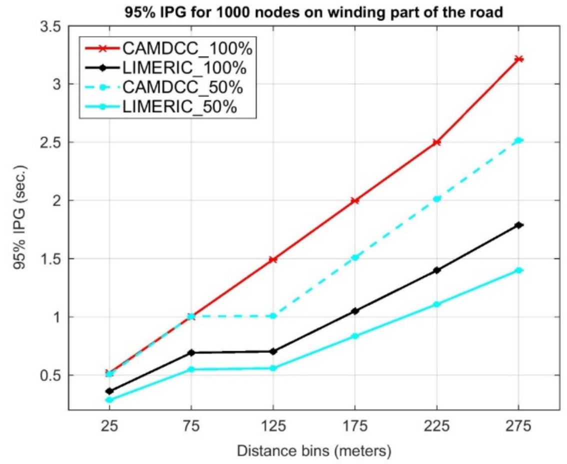
Parameters	Value
CBP_{Target}	79%
α	0,1
β	0,033
δ	200 ms

- C2C-CC
  - Algorithm: Leaky-Bucket
  - Look-up Table



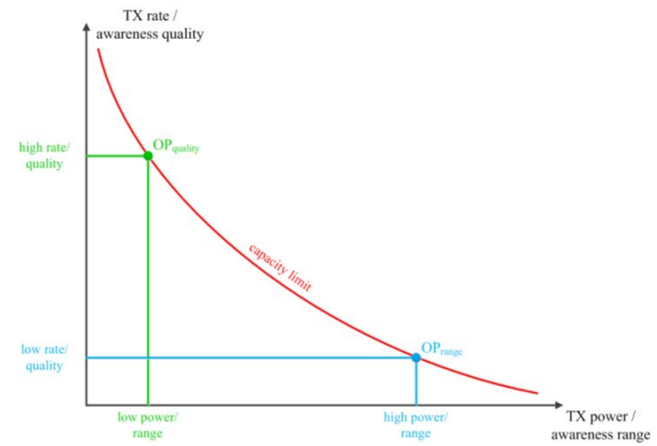
Channel Load	State	Packet Tx Interval	Packet Rate
< 30 %	RELAXED	100 ms	10 Hz
30-39%	ACTIVE 1	200 ms	5 Hz
40-49%	ACTIVE 2	300 ms	3,33 Hz
50-59%	ACTIVE 3	400 ms	2,5 Hz
≥60%	RESTRICTED	500 ms	2 Hz



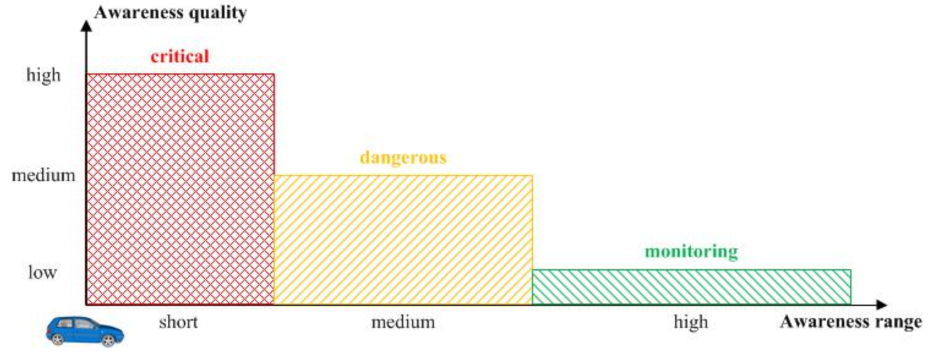


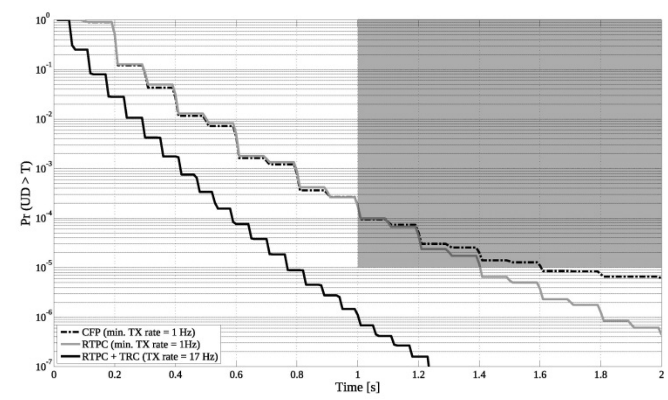
Reliable DSRC in Space & Time – Getting the Cake and eating it too !

- Considering reliable DSRC communication – tradeoff
  - High reliability in space but not in time
  - High reliability in time, but not in space



- Need smart Transmit Strategies
  - Safety-critical applications do not need both space and time high reliability !





- Random TX Power and Spatial Awareness
  - Showed we could have a higher reliability & a lower congestion
    - We could get the cake AND eat it too !!

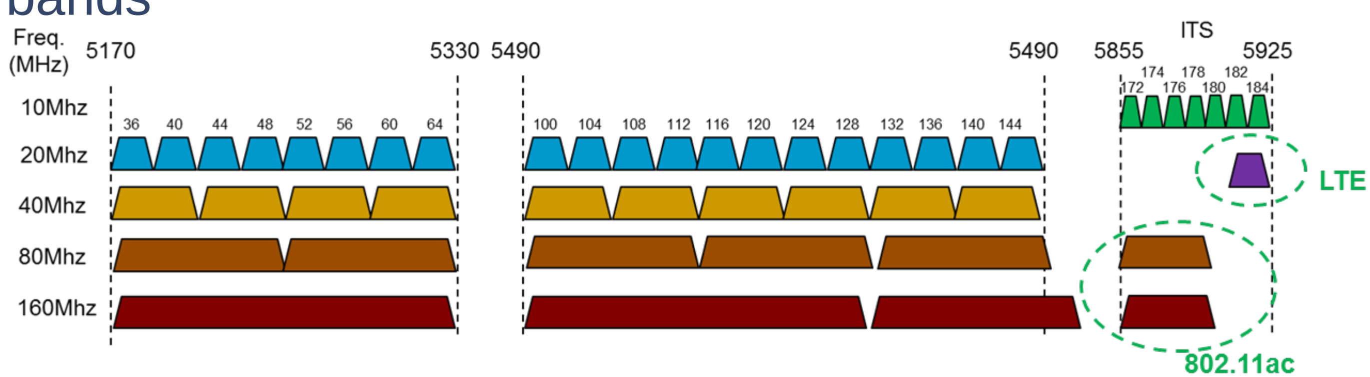
Communication Technologies and the Internet of Things in ITS

COMPETING VEHICULAR COMMUNICATION TECHNOLOGIES

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

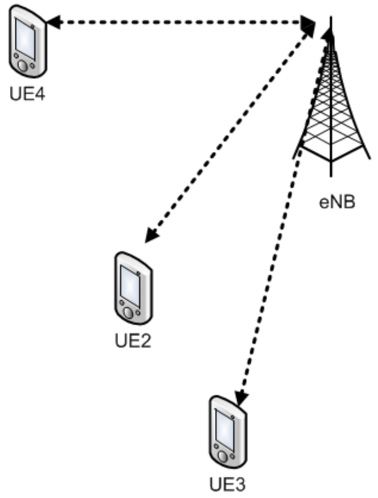


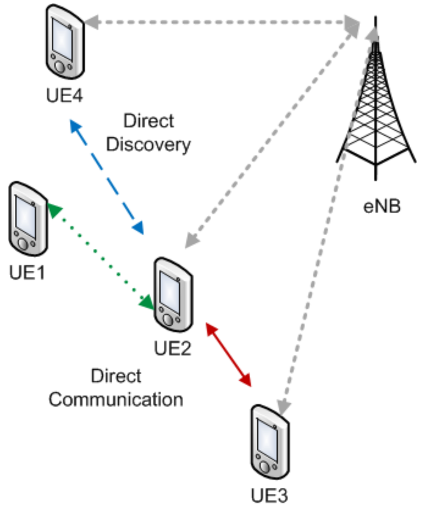
3GPP LTE technology for Connected Things

- 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**



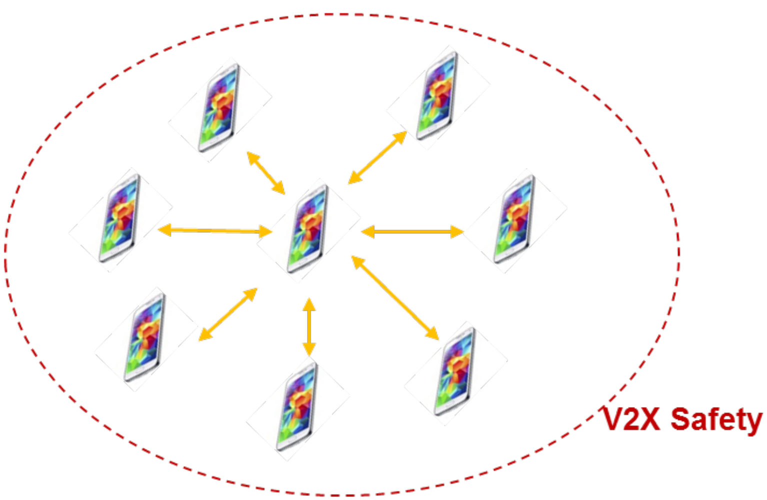


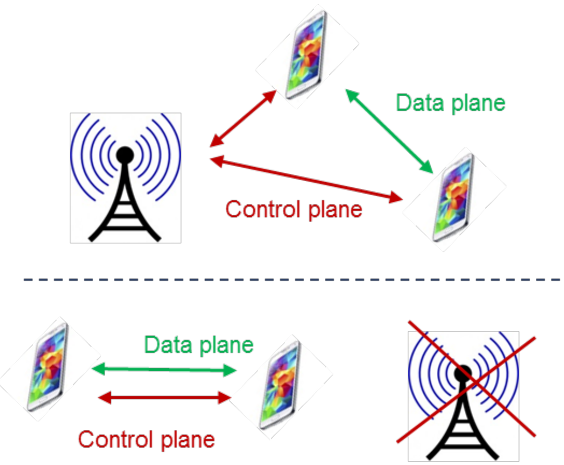
LTE D2D ProSe Rel. 12 Strategy

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

Source: Qualcom

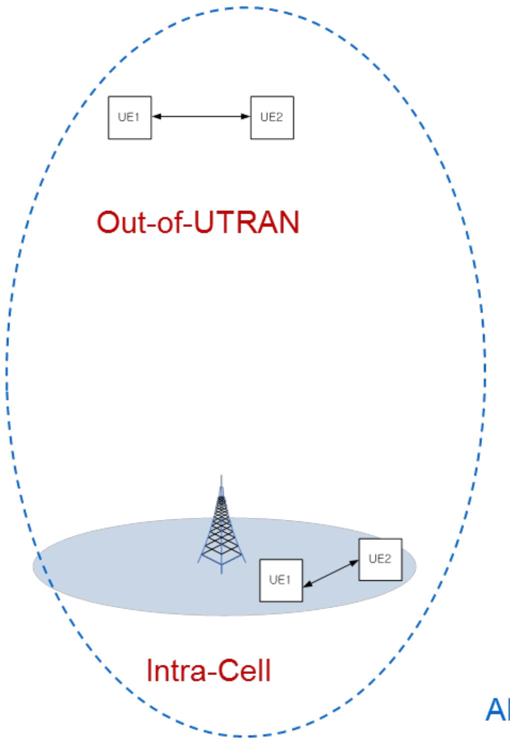
- LTE D2D ProSe has two functions:
  - LTE D2D Discovery
  - LTE D2D Communications

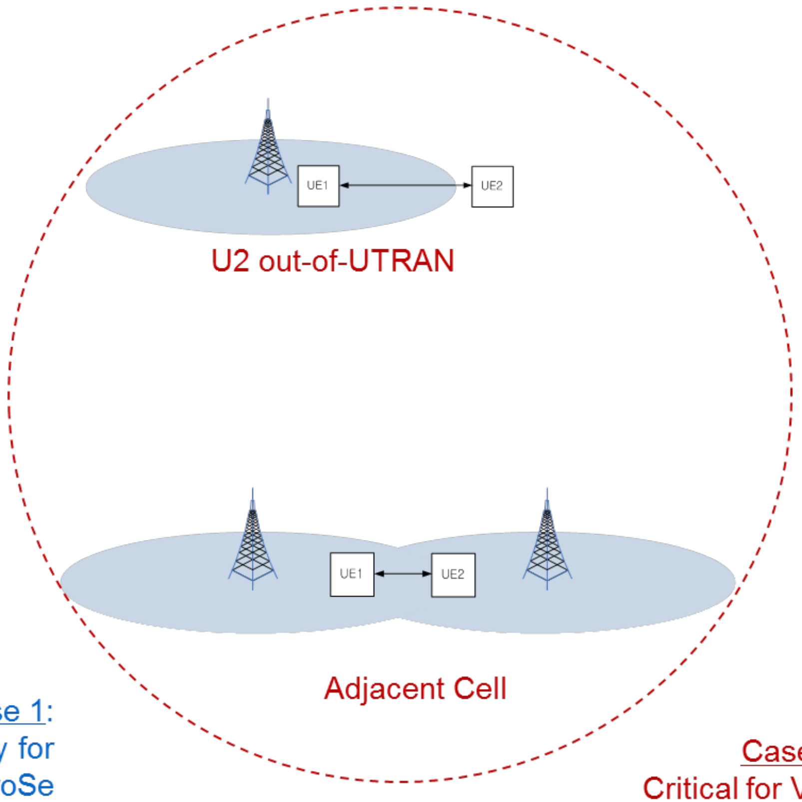




LTE ProSe D2D Service Discovery for V2X (Rel. 12 ++)

- Four Scenarios under study





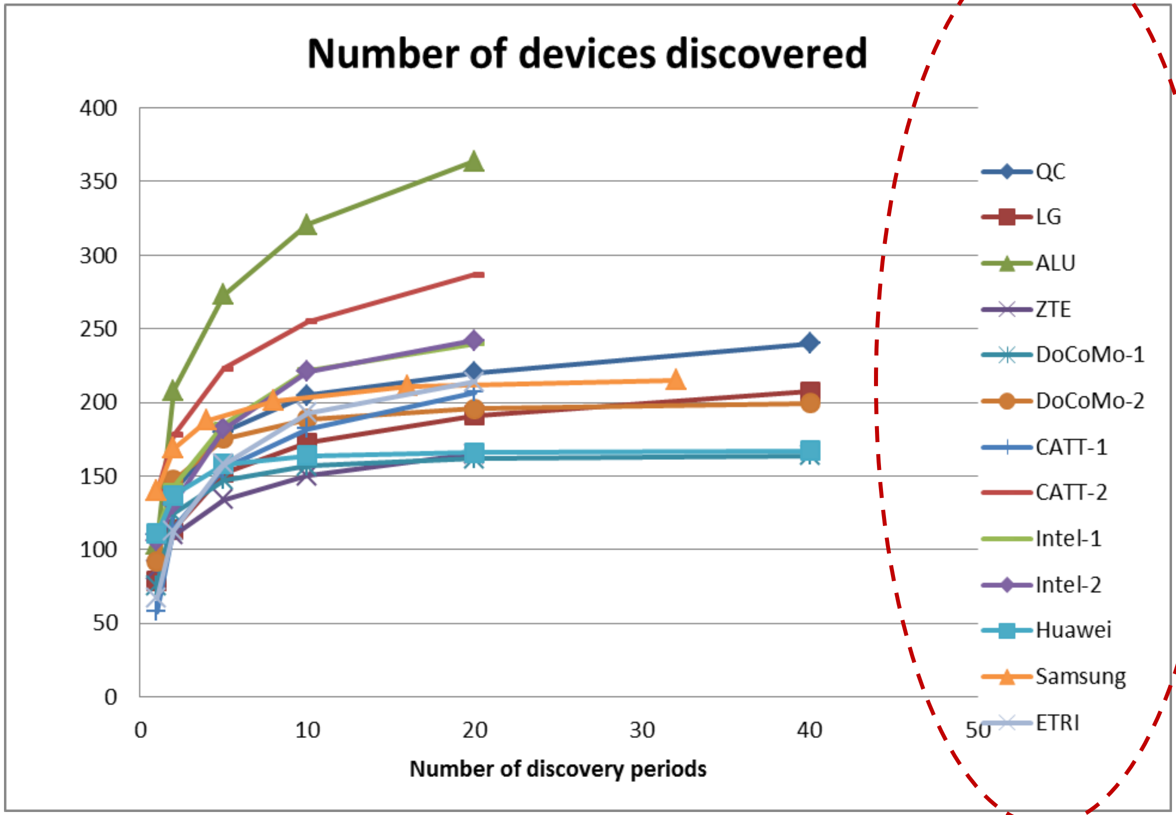
Case 1:
Already under study for normal D2D ProSe

Case 2:
Critical for V2X

LTE ProSe Discovery – 3GPP First Evaluations

Source: 3GPP TR 36.843

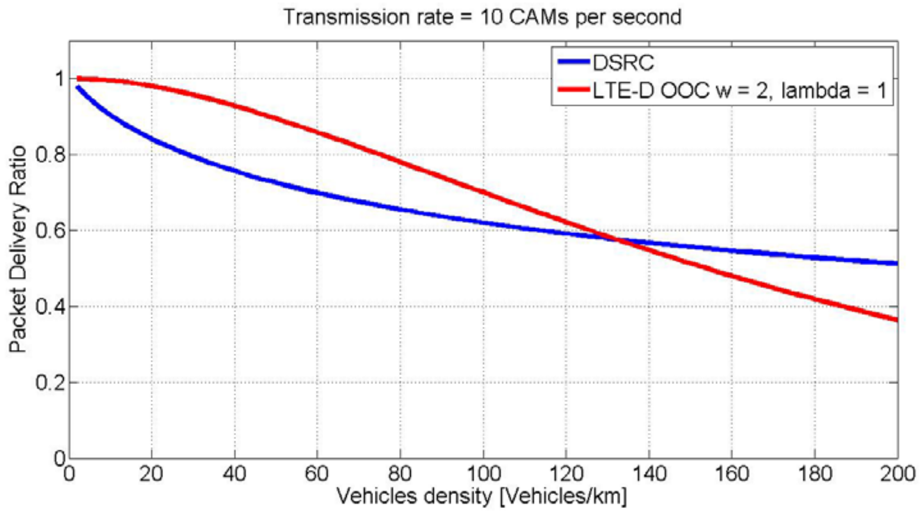
Powerful stakeholders !!



- 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

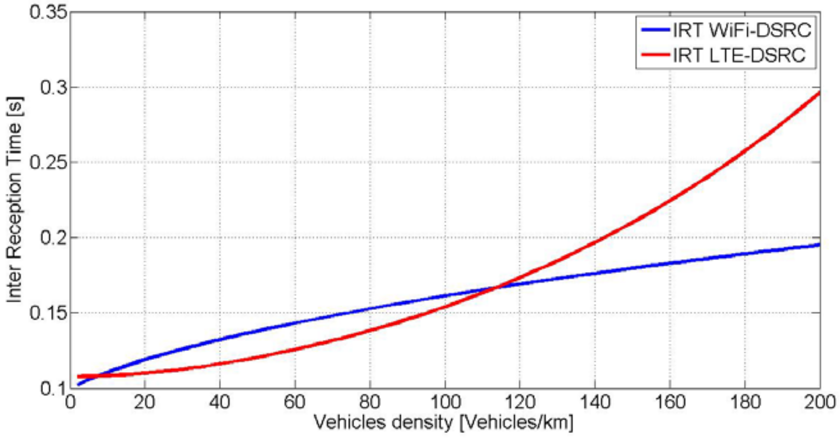
LTE D2D V2X vs. DSRC



PRR

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

IRT



Any Future for DSRC ?

- 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?

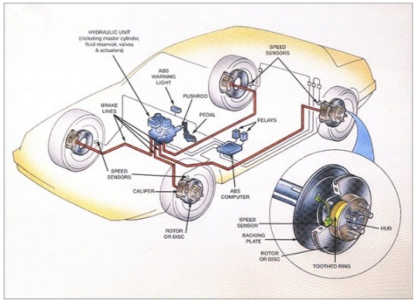
Communication Technologies and the Internet of Things in ITS

C-ITS STANDARDS

Standards in Automotive Industry

- **Motor Vehicle Safety Standards (~500 standards)**

Hydraulic and electric brake systems.



Side and Read Impact Protection

Controls and displays.

Safety Belt

Driver License

J2735 Message Set Dictionary

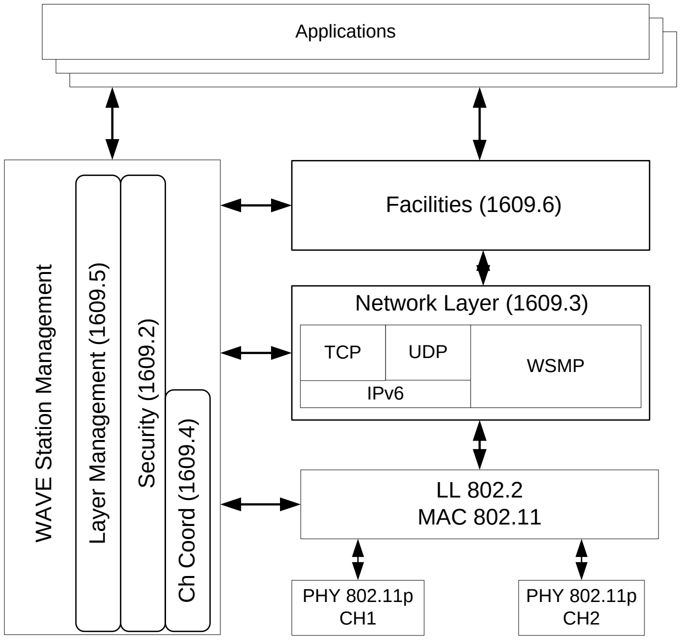
BSM/CAM Message

Major Attributes
Temporary ID
Time
Latitude
Longitude
Elevation
Speed
Heading
Acceleration
Brake System Status
Vehicle Size

Vehicle safety applications envisioned require the frequent transmission of "heartbeat" messages to enable the vehicle's expanded situational awareness to complement autonomous vehicle sensors

IEEE Wireless Access for Vehicular Environment (WAVE)

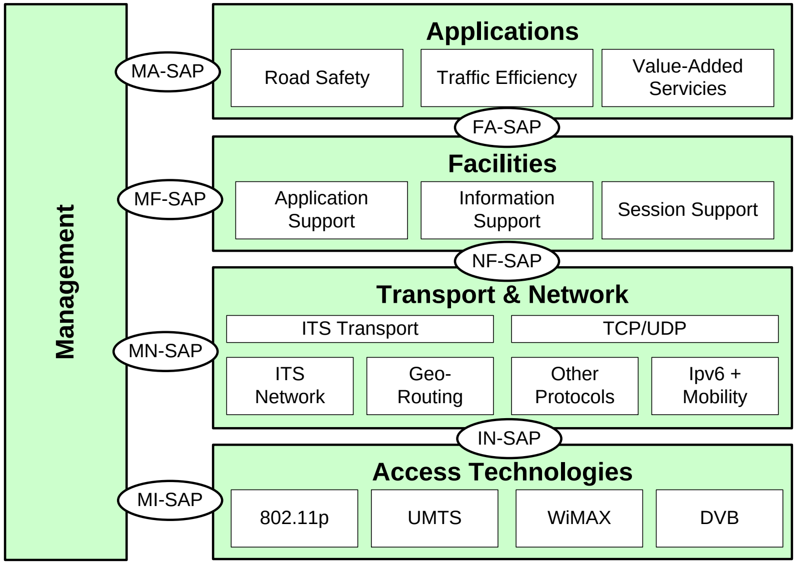
- Protocol stack:
  - **DSRC**: Medium Access
  - **1609.0**: Architecture Description
  - **1609.1**: Resource manager - Withdrawn
    Communication between road side units (RSU) and on board units (OBU) to run remote applications on the OBU
  - **1609.2-2013**: Security Services
    Security services for the network stack (authentication and message encryption)
  - **1609.3-2012**: Networking Services
    Network stack (both TCP/IP and WSMP (WAVE Short Message Protocol))
  - **1609.4-2010**: Multi channel management
    Coordination of control channel and service channels
  - **1609.5**: Communication Manager - Management parts of 1609.3 and 1609.4
  - **1609.11-2010**: Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)
  - **1609.12**: Identifier Allocations



Source: IEEE 1609 Trial Use Standards and http://vii.path.berkeley.edu/1609_wave

ITS Standardization at the ETSI

- ETSI: European Telecommunication Standardization Institute
- Vehicular Communication and ITS is being standardized in Europe jointly by the
  - CAR 2 CAR Communication Consortium
  - The ETSI TC ITS
- The ETSI ITS Protocol Stack
  - WG 1: Applications
    - Basic Set of Applications
  - WG 2: Architecture
  - WG 3: Network and Transport
    - IP and non-IP
  - WG 4: Medium Access
    - Multichannel and Heterogeneous access
  - WG 5: Security



W3C - Automotive and Web Platform Business Group

- *Objectives:*
  - *influence the Open Web Platform on the unique needs of the automotive industry*
  - *determine what vehicle data should be exposed through a Web API(s).*
  - *reducing driver distraction and improving safety*

- *Automotive Grade Linux Workgroup*
  - http://automotive.linuxfoundation.org/

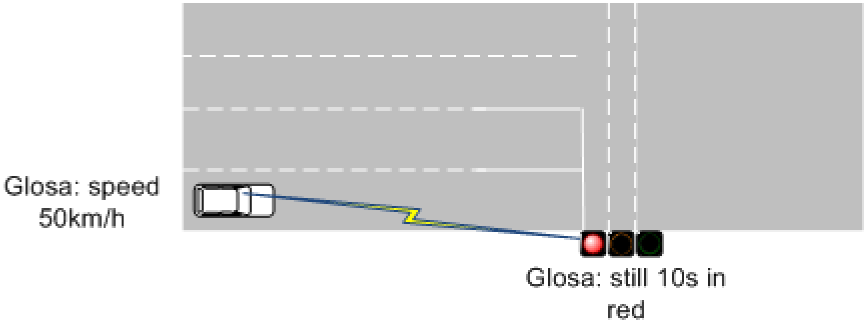
- HTML5-based vehicle APIs
  - Tizen
  - Webinos
  - GENIVI
  - QNX

Communication Technologies and the Internet of Things in ITS

EXEMPLARY APPLICATIONS

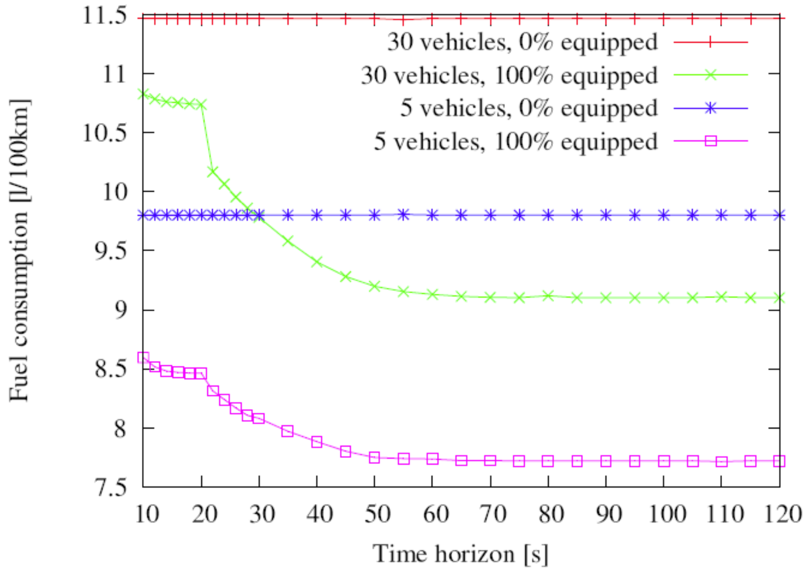
Green Light Optimized Speed Advisory (GLOSA)

- Scenario:
  - A vehicle approaches a traffic light
  - The vehicle receives Car2X message from the traffic light with transition times
  - If green:
    - The vehicle computes the speed to reach the intersection before it is red
      - Can it make it?
  - If red:
    - The vehicle computes its deceleration to reach a minimum speed at the traffic light when it turns back green
      - Can it make it?

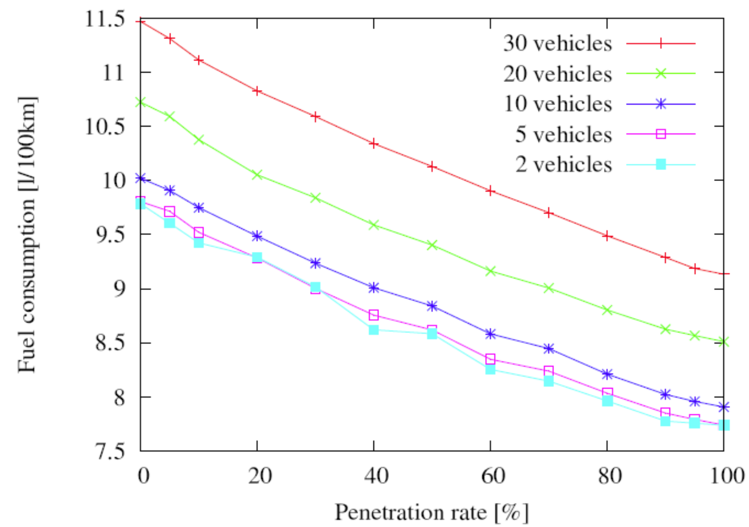


Green Light Optimized Speed Advisory (GLOSA)

- Results:



(a) Influence on fuel consumption for changing time horizon.

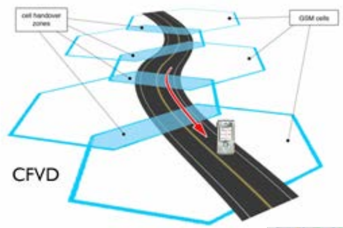


(b) Influence on fuel consumptions for changing traffic density (60 s time horizon, averaged green phase).

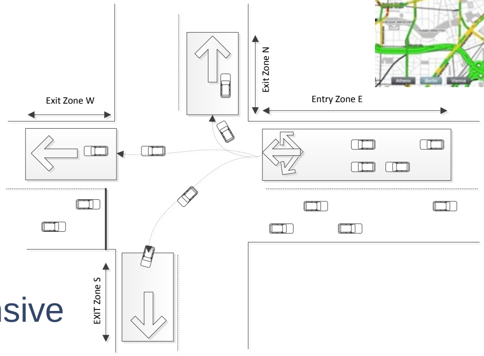
[Source: Axel Wegener, Horst Hellbrück, Christian Wewetzer, "VANET Simulation Environment with Feedback Loop and its Application to Traffic Light Assistance“]

Traffic Density Estimation in Smart Cities

- Traffic Density Estimation
  - Static Sensors: induction loops, pressure sensors, cameras
    - Small scale, real-time traffic estimation
  - Floating (cellular) Car Data (FCD): vehicles/smartphones periodically send their GPS position to the cloud
    - Large scale (city/area wide), 'soft' real time traffic estimation

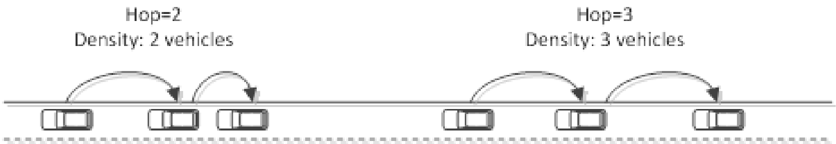


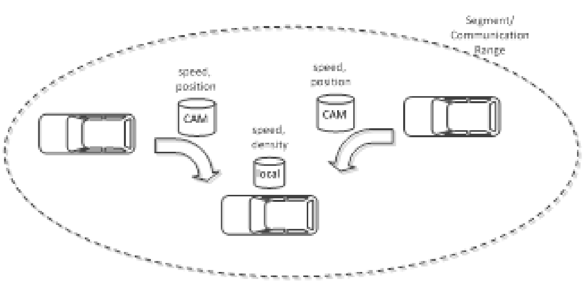
- Applications:
  - Dynamic route planning, road traffic information
    - FCD very efficient and widely used
  - Smart Traffic Lights:
    - FCD not adapted
    - Static Sensors not always reliable / too expensive



Smart Vehicles - Distributed Traffic Density Estimation

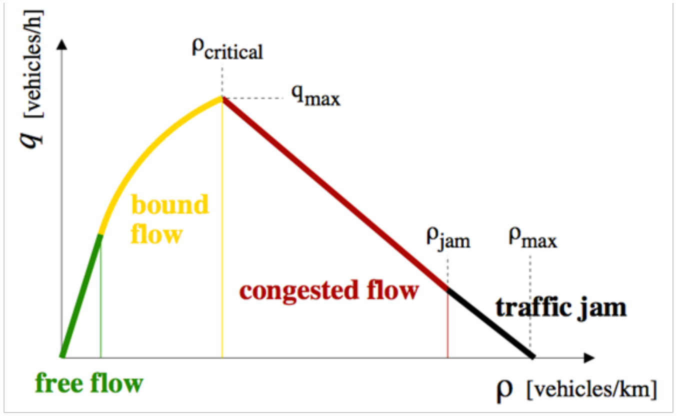
- Distributed Floating Car Data (DFCD)
  - A leader is in charge of the local state estimate in a given area
  - Assets:
    - Local and distributed state estimation
  - Challenges:
    - Zones need not to overlap
    - Zones should have similar traffic samples (density)
    - Sensitive to low V2X penetration
    - Sensitive to GPS estimates



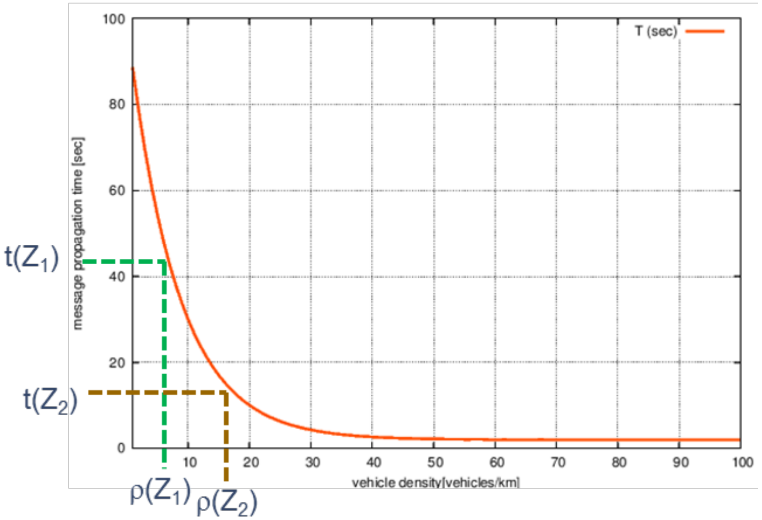


Traffic Estimation - Conceptual Description

- Fundamental Traffic Diagrams
  - Speed / Flow / Density related

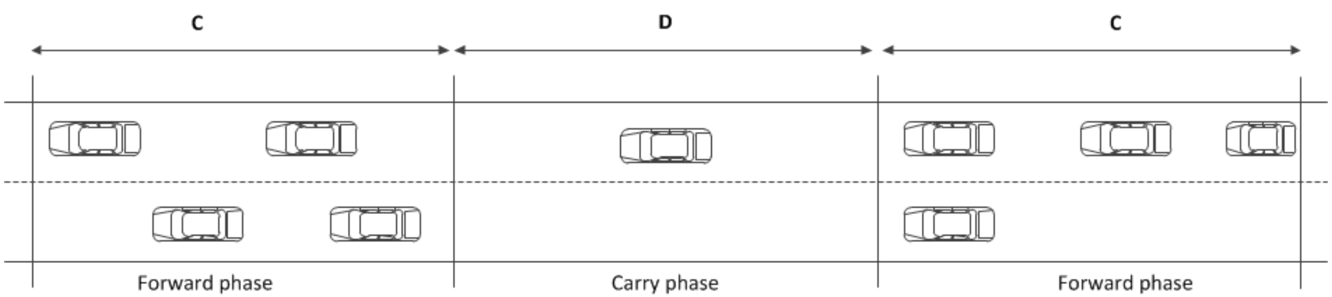


- Fundamental Communication Diagram
  - Dissemination Delay / Traffic Density related



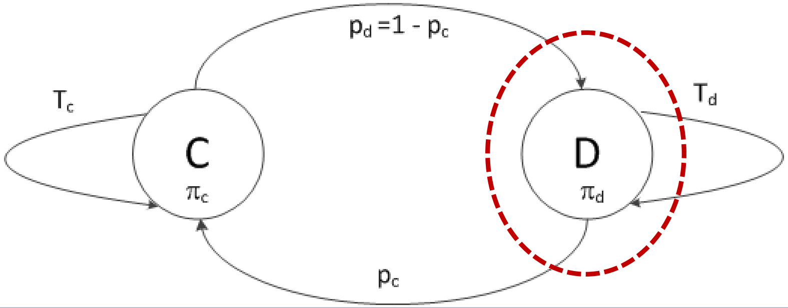
Delay - Density Model

- Data Dissemination goes over ‘connected’ an ‘disconnected’ phases

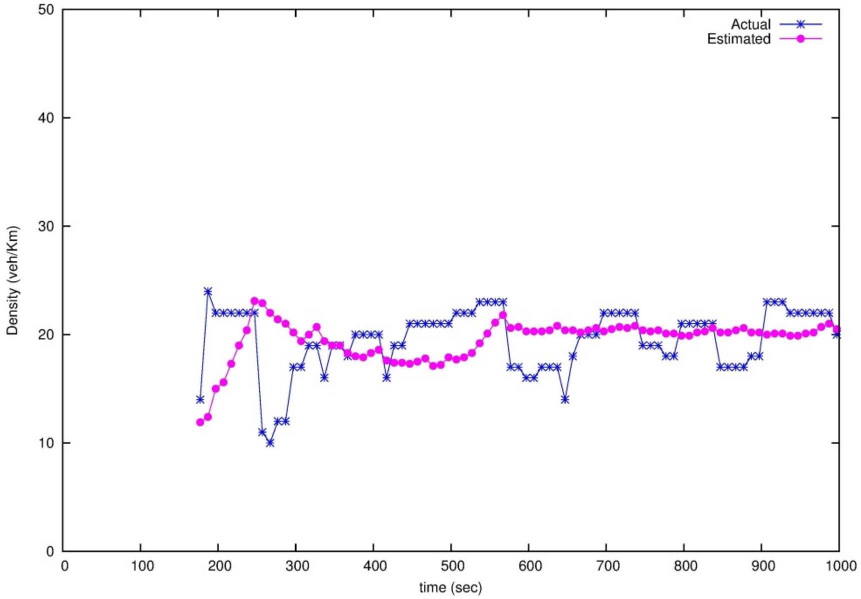


- Modelled as a Renewal Process
  - p_c – probability to move from connected to disconnected
  - p_d – probability to move from disconnected to connected

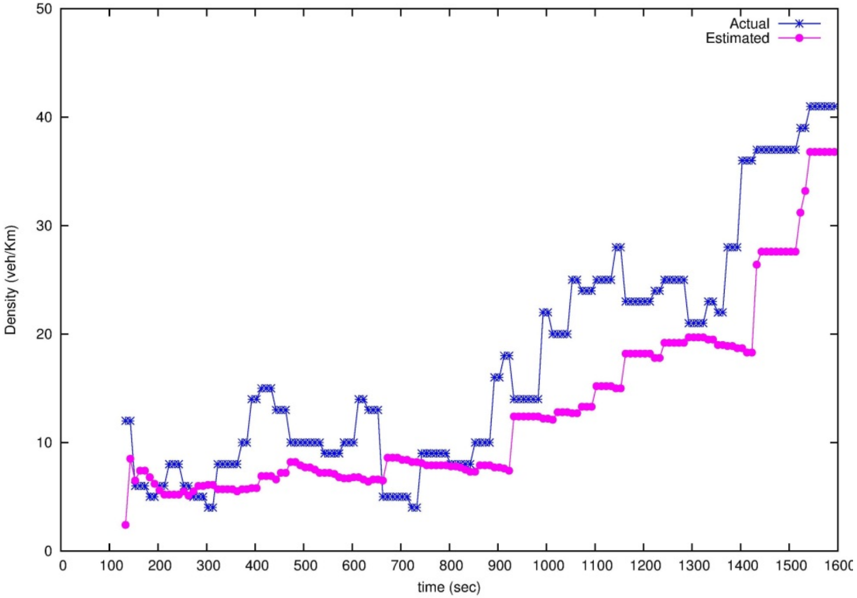
Absorbing state
- if all vehicles have same speed



Traffic Density Estimation – Exemplary Results



Constant Traffic Density



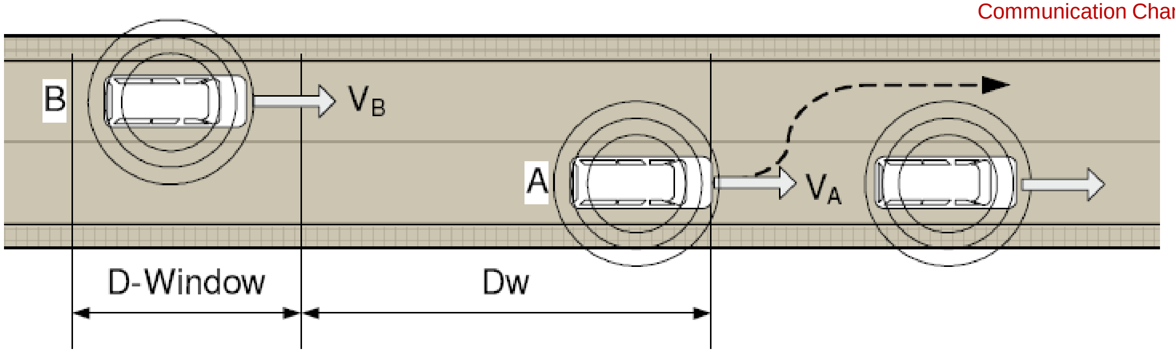
Increasing Traffic Density

- Overhead:
  - 30bytes/second/vehicle (1/50 of CAM overhead)

Lane Change Warning (LCW)

- Scenario:
  - Highway Mobility:
    - Vehicle moving between 120km/h and 60km/h

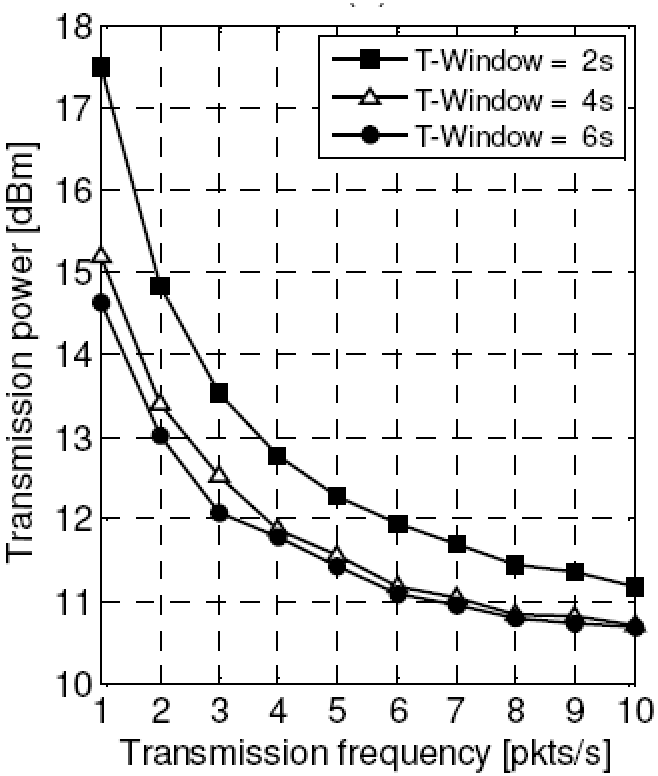
[Source: Miguel Sepulcre, Javier Gozalvez, Jérôme Härri and Hannes Hartenstein, " Application-based Congestion Control Policy for the Communication Channel in VANETs“]



  - **T-Window**: time duration during which CAM messages are transmitted for the purpose of LCW
  - **D-Window:** distance covered by vehicle B in a time window T-Window
  - **Dw:** safety distance before which CAMs must be received by A and B

Lane Change Warning (LCW)

- Results:
  - Application safety requirements:
    - Probability that at least 1 CAM is received
      - before **Dw**
      - in a time window **T-Windows** (time travelle by car in D-Window)
    - **p= 99%**
  - System works if "at least" one of both vehicles receives such packet:
    - Application reliability: **p= 99.99%**



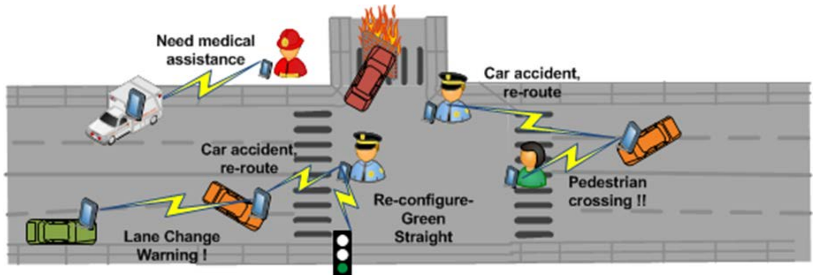
[Source: Miguel Sepulcre, Javier Gozalvez, Jérôme Härri and Hannes Hartenstein, " Application-based Congestion Control Policy for the Communication Channel in VANETs"]
[Reference: N. An, T. Gaugel, H. Hartenstein, "VANET: Is 95% Probability of Packet Reception safe?, ITST 2011, Saint Petersburg, 2011]

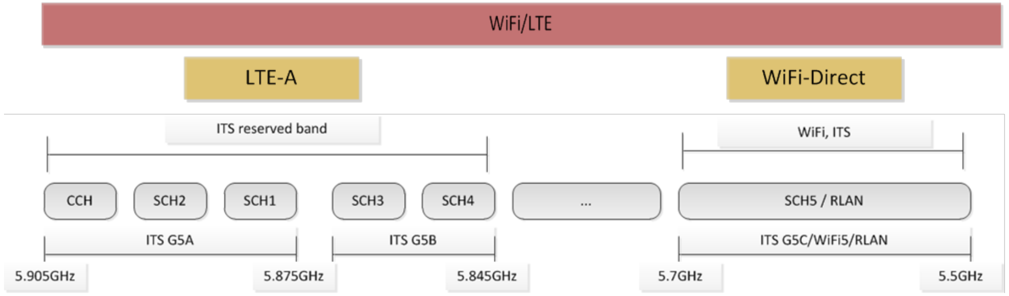
Communication Technologies and the Internet of Things in ITS

PERSPECTIVES – VEHICULAR COMMUNICATION FOR IOT

Perspectives – Dependable D2D communication for Internet-of-Things & Smart Mobility

- Heterogeneous Device-to-Device Communications
  - **More than Cars**
    - Pedestrians, motorcycles, police..
  - **More than DSRC**
    - LTE-Direct, WiF-Direct, Bluetooth…

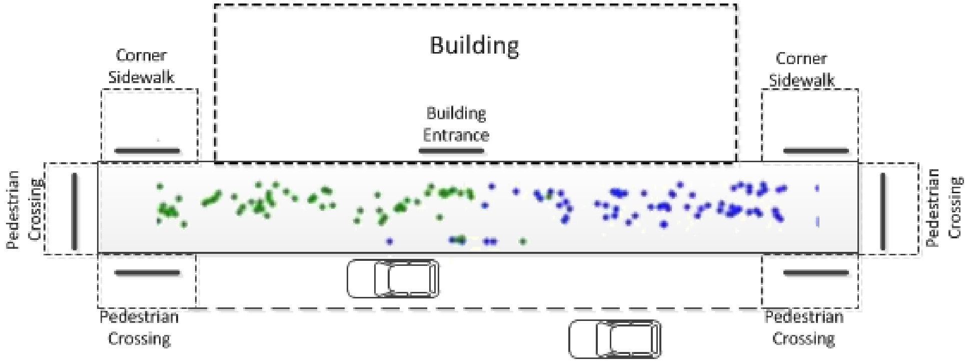




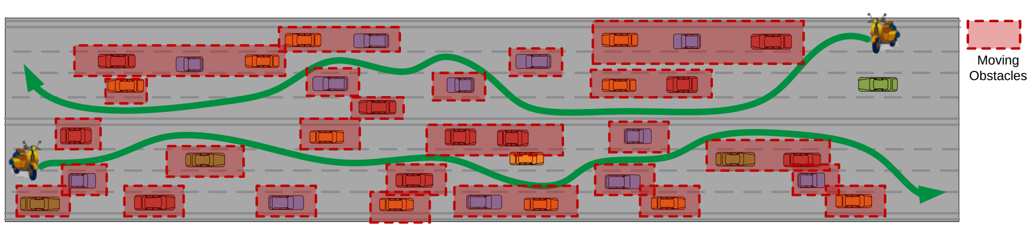
- Co-existence
  - WiFi-Giga / Direct on DSRC frequency band
  - LTE-A/5G on DSRC frequency

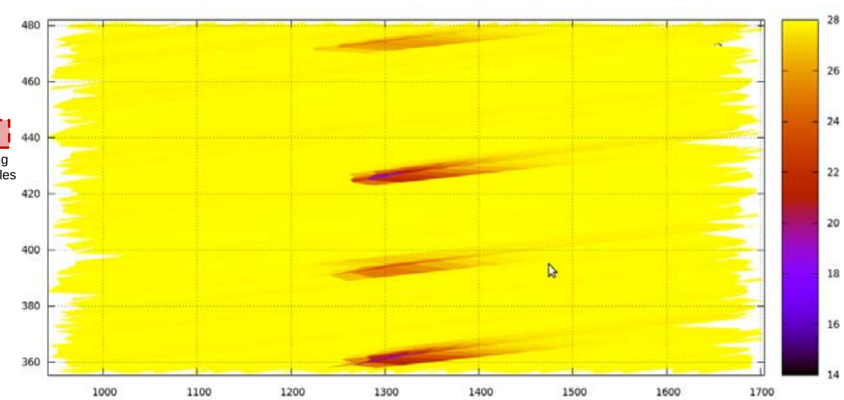
Perspectives – Dependable D2D communication for Internet-of-Things & Smart Mobility

- Heterogeneous D2D: Safety of vulnerable traffic users
  - Pedestrian Mobility



  - Scooter/Motorcycle Mobility





Perspectives – Dependable D2D communication for Internet-of-Things & Smart Mobility

- Heterogeneous D2D: Highly Autonomous Driving Vehicles
  - Critical building block: precise localization **below 2cm**

Price to get it: 80k euros

Price OEM willing to pay: 1.50 euro

- Cooperative Localization and positioning from Dependable D2D
  - Cooperative exchange range estimate (radars, DSRC…)
  - Cooperative exchange of local dynamic maps
- Challenge: High precision positioning service
  - Affordable
  - Transparent to cooperative ITS applications

Discussions & Perspectives

- Connected Vehicles are expected to change how ITS applications will operate
  - Cooperative Communication to provide direct exchange of traffic data
    - Safe Mobility – see what the eyes can't see
    - Sustainable Mobility – help drivers adapt their driving 'style' to reduce congestion

- Challenge – providing dependable vehicular communications
  - Wireless Vehicular Communications make this objective difficult
    - 1-hop broadcast, no feedback mechanism
    - quickly changing vehicular wireless channel
    - Safety-of-live information & ITS stringent requirements in time and space
  - Competing Technologies
    - DSRC – first standardized technology
      - Suboptimal, but optimized by congestion control mechanisms
    - Alternate Technologies in the pipe
      - LTE-D2D, WiFi-Direct – will mostly face similar challenges

Discussions & Perspectives

- Challenge – gradual penetration of vehicular communication
  - Only expect ~20% penetration by 2030
  - How can C-ITS application still work?
    - Cooperation & Interoperability between different standards, different technologies
    - Not a single technology will be sufficient

- Cooperative Vehicular Communications
  - 10 years of R&D targeting Day 1 C-ITS applications
  - **Starting 2015** – beginning of work on Day 2 applications
    - Highly Autonomous Driving
    - Vulnerable Road Users
    - Drone & Train Communications
  - Stakes are high and **competition between DSRC and 5G will be tough**

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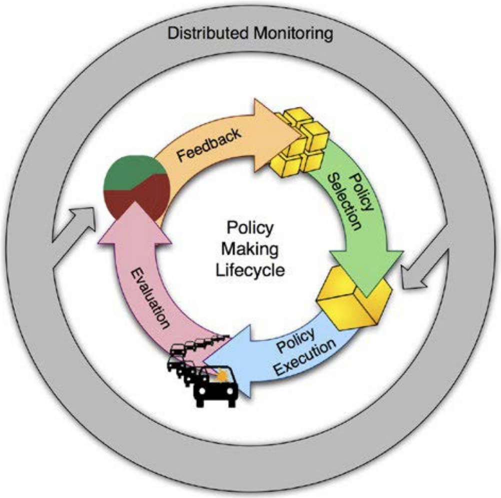
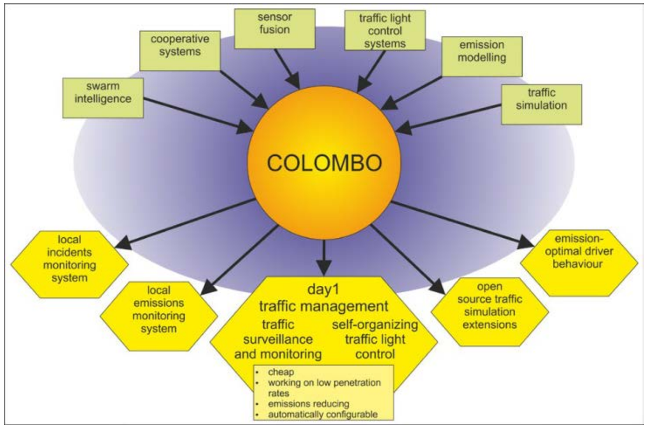
FP7 COLOMBO Project – Smart Traffic Lights

- COLOMBO: Cooperative Self-Organizing System for low Carbon Mobility at low Penetration Rates
  - To start: 1 November 2012



- Topic:
  - Dynamic Traffic Light Systems
  - Using traffic Information from users/drivers for Distributed monitoring

- Situation:
  - Car2X monitoring could help, but..
  - For the next 10-15 years, not enough penetration
  - Objective: distributed monitoring at Low Penetration Rate
    - Use other type of communication devices (PDA, sensors..)



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