Is there LTE in V2V? (Yes)
V2X: ITS Applications

Access Technologies

3GPP V2X

Continuous Access for Land Mobiles (Hybrid Communications)

Last Words

Agenda
This workshop session address the potential roles of LTE in Intelligent Transportation Systems (ITS). The session serves to give insight into trends and choices that satisfy emerging ITS applications and perhaps those that have yet to be conceived.

We begin with a broad definition of 'connected vehicles' and the plethora of ITS applications that are envisioned by such a concept. This enables categorization of applications by physical and architecture characteristics, and allows us to determine key performance indicators required for the communication link.

From this basis, the session will address the access technologies that are currently available and, importantly, that may be available in the coming decade: DSRC (described in more depth elsewhere in the workshop) is of course a necessary and primary aspect of this mix, but there are in various parts or this world emerging research and standardization activities that envision LTE expansion into "LTE V2X" and a pan-European "5G Automotive Vision".

This brings a mix of match of other over the air technologies, potential timelines and different emphases in different regions of the world into consideration. Moreover, there are ISO Communications Access for Land Mobile (CALM) standards that are communication link-agnostic but are conceived as an alternative to proprietary gateways for this broad array of communication links; these ISO standards and propriety gateway techniques are necessary consideration in the mix and match of technologies that deliver 'connected vehicle' communications.

At the end of this segment, the attendee will have an understanding of the applications, over-the-air technologies and standards that may integrate them into the vehicles.
V2X: ITS Applications
Consumer expectations are driving
the connected car experience
V2X Applications

- Environmental – AERIS
  - Connected Eco-Driving
  - Dynamic Eco-Routing
  - Eco-Approach and Departure at Signalized Intersections
  - Eco-Cooperative Adaptive Cruise Control
  - Eco-Freight Signal Priority
  - Eco-Integrated Corridor Management Decision Support System
  - Eco-Lanes Management
  - Eco-Multimodal Real-Time Traveler Information
  - Eco-Ramp Metering
  - Eco-Smart Parking
  - Eco-Speed Harmonization
  - Eco-Traffic Signal Timing

- Eco-Transit Signal Priority
- Electric Charging Stations Management
- Low Emissions Zone Management
- Roadside Lighting
- Environmental – Road Weather
- Enhanced Maintenance Decision Support System
- Road Weather Information and Routing Support for Emergency Responders
- Road Weather Information for Freight Carriers
- Road Weather Information for Maintenance and Fleet Management Systems
- Road Weather Motorist Alert and Warning
- Variable Speed Limits for Weather-Responsive Traffic Management

V2X Applications

- Mobility
  - Border Management Systems
  - Container Security
  - Container/Chassis Operating Data
  - Electronic Work Diaries
  - Intelligent Access Program
  - Intelligent Access Program - Mass Monitoring
  - Intelligent Speed Compliance
  - Smart Roadside Initiative
  - Electronic Toll Collection
  - Road Use Charging
  - Freight Drayage Optimization
  - Freight-Specific Dynamic Travel Planning
  - Performance Monitoring and Planning
  - Advanced Automatic Crash Notification Relay
  - Incident Scene Pre-Arrival Staging Guidance for Emergency Responders
  - Incident Scene Work Zone Alerts for Drivers and Workers
  - Cooperative Adaptive Cruise Control
  - Queue Warning
  - Speed Harmonization
  - Emergency Communications and Evacuation
  - Vehicle Data for Traffic Operations
  - Emergency Vehicle Preemption
  - Freight Signal Priority
  - Intelligent Traffic Signal System
  - Pedestrian Mobility
  - Transit Signal Priority
  - Dynamic Transit Operations
  - Integrated Multi-Modal Electronic Payment
  - Intermittent Bus Lanes
  - Route ID for the Visually Impaired
  - Smart Park and Ride System
  - Transit Connection Protection
  - Transit Stop Request
  - Advanced Traveler Information Systems
  - Receive Parking Space Availability and Service Information
  - Traveler Information- Smart Parking

V2X Applications

- Safety
  - Transit Pedestrian Indication
  - Transit Vehicle at Station/Stop Warnings
  - Vehicle Turning Right in Front of a Transit Vehicle
  - Curve Speed Warning
  - In-Vehicle Signage
  - Oversize Vehicle Warning
  - Pedestrian in Signalized Crosswalk Warning
  - Railroad Crossing Violation Warning
  - Red Light Violation Warning
  - Reduced Speed Zone Warning / Lane Closure
  - Restricted Lane Warnings
  - Spot Weather Impact Warning
  - Stop Sign Gap Assist
  - Stop Sign Violation Warning
  - Warnings about Hazards in a Work Zone

- Warnings about Upcoming Work Zone
- Blind Spot Warning + Lane Change Warning
- Control Loss Warning
- Do Not Pass Warning
- Emergency Electronic Brake Light
- Emergency Vehicle Alert
- Forward Collision Warning
- Intersection Movement Assist
- Motorcycle Approaching Indication
- Pre-crash Actions
- Situational Awareness
- Slow Vehicle Warning
- Stationary Vehicle Warning
- Tailgating Advisory
- Vehicle Emergency Response

### Final SA1 (3GPP Architecture Working Group) Use Cases (TR 22.885)

- Additional use cases are being developed for 5G, for scenarios where it is believed LTE may not be sufficient

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**PC5:** Device-to-Device

**Uu:** Through roadside unit

...more later
Access Technologies
A New Era of Connected Car Capabilities

The variety of connected vehicle applications can be handled by a variety of over the air technologies, depending on application requirements.
V2X Global Landscape

V2X been discussed for ~15 years

Technology

• 802.11 (DSRC)
  - Specs published in 2010
  - Hasn’t matured as WiFi tech evolved
  - Many concerns about lack of features to support new use cases, privacy & security

• LTE V2X
  - Study started end of 2014 in 3GPP
  - Normative specification targeted for 2017
    - Product: ~ 2019 (dep. on market pull)
  - Key advantage is ability to leverage the whole cellular ecosystem & capability set

• 5G
  - Next generation cellular radio
  - Over time, it will augment LTE V2X

Regional Adoption

• United States
  - IEEE 802.11 (DSRC) specified in FCC Report and Order, since 1999
  - Probable NHTSA rulemaking – late 2016
  - Expected mandated V2V deployment – 2020 or 2021
  - Must address and resolve privacy and security issues in an scalable manner

• Europe
  - Will LTE V2X technology gain momentum?

• China
  - Competitor H promoting non-standard “LTE-V”
  - Field trials will compete 802.11 against LTE
  - Expected to harmonize to mainstream 3GPP path
Overall Cellular Industry Trend

From LTE to 5G

- **LTE** strongly established as mobile broadband solution globally
- Ability to aggregate multiple pieces of spectrum
  - Carrier Aggregation / Dual Connectivity (CA/DC)
  - Licensed Assisted LTE in Unlicensed Spectrum (LAA)
  - LTE-WiFi aggregation (LWA)
- LTE also expanding into vertical markets
  - Public Safety, Machine-Type/IOT, Broadcast, **V2V/V2X**
- Activities on **5G** getting started with likely initial focus on mobile broadband
  - Vertical markets (including V2V) expected to stay on the LTE baseline for significant time
5G & LTE Broadband

5G will be introduced gradually in conjunction w/ LTE (no “rip & replace”)

R13
- LTE Anchor
- Dual Conn.
- Carrier Aggr.
- LTE
- LAA

R14
- LTE Anchor
- Dual Conn.
- Carrier Aggr.
- LTE
- LAA

R15
- LTE Anchor
- Dual Conn.
- Carrier Aggr.
- LTE
- WLAN
- LAA
- licensed
- unlicensed

R16
- LTE Anchor
- Dual Conn.
- Carrier Aggr.
- LTE
- WLAN
- LAA
- licensed
- 5G
- unlicensed
- licensed
- 5G mmW
- unlicensed
From LTE to 5G

Is LTE V2V “the real thing” or should we wait for 5G?

- First iterations of 5G will focus on mobile broadband & will occur in 2020/2022

- As for other major technology transitions, 5G won’t be ubiquitous from day 1
  - First deployments will be in dense areas
  - First deployments will also most likely in relatively high frequency bands (eg ~4GHz)
  - Initial 5G deployments will be about capacity (and not about coverage)
  - NOTE: history of LTE more or less went as follows
    - 2004: concept proposed in standards
    - 2008: first end-to-end demo at MWC
    - 2009 (December): first commercial deployment in 2 cities
    - 2015: ~70% population under LTE coverage in Germany (not territory)

- Vertical markets are developing now over LTE & will remain on LTE for a long time

- LTE V2V is real & is here to stay
  - 5G will augment it & complement it over time
5G - timeline

- 5G expected to come in phases, alongside continued LTE evolution (incl. LTE V2V/V2X)

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<tr>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022...</th>
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<td>Rel 13</td>
<td>Rel 14</td>
<td>Rel 15</td>
<td>Rel 16</td>
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<td>1st phase 5G WI(s)</td>
<td>2nd phase 5G WI(s)</td>
<td>5G Phase 1 deployment</td>
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**Key:***
- **Rel** denotes release numbers for 5G.
- **WI** denotes Work Items.
- **LTE** refers to Long-Term Evolution
- **V2V/V2X** refers to Vehicle-to-Vehicle/Vehicle-to-X communications
KPIs from 5G Automotive Vision

“Technical”

- **End-to-end latency (ms)**
  - Automated Overtake: 10 ms
  - Cooperative Collision Avoidance (CCA): 100 ms/10 ms
- **Reliability (10^-x)**
  - Automated Overtake: x = 5
  - CCA: x = 5 (trajectory handshake), 3 (status)
- **Data Rate (Mbit/s)**
  - 10 Mbit/s peak except for Birds Eye View: 40 Mbit/s
  - Urban average: 0.5 Mbit/s
- **Communication Range (m)**
- **Node mobility (km/h): 280 km/h (3GPP)**
- **Network density (veh/km²)**
- **Positioning accuracy (cm)**
  - Automated Overtake and CCA: 30 cm
  - VRU Discovery: 10 cm
- **Security** – use authentication, authenticity and integrity of data, confidentiality, use privacy

“Holistic”

- **Availability**
- **Traffic Bottleneck**
- **Single Point of Failure**
- **QoS Guarantees (latency, bandwidth, reliability)**
- **Security**
- **Range**
- **Robustness to Doppler Effect**
- **MIMO Support**
- **Channel Coding (turbo)**
- **Synchronization**
- **Pilot Design**
3GPP LTE V2X
Start with 3GPP V2X...Some Basics

- TSGs are the “plenaries”
  - 4 round of plenaries per year
- WGs are the Working Groups
  - 4-8 meetings per year
  - Where the work gets done
- PCG deals with legal & administrative issues
3GPP Standardization Timeline


SA1, SA2, SA3/CT, RAN

- Rel. 13 ASN.1 freeze in 2016
- Rel. 14 ASN.1 freeze in 2017
- Rel. 15 ASN.1 freeze in 2018
SA1 (Requirements)

- Study has been concluded in SA1
  - List of agreed use cases on following slide
  - Derived requirements available in TR 22.815 being sent to SA plenary for approval next week

- Normative work expected to occur in February 2016 SA1 meeting
  - Should be relatively trivial given the stability of the service requirements
  - Definition changes are more likely to give additional steer to downstream groups

SA2 (Architecture)

- 5 key issues identified and under study:
  - Service authorization for V2X
  - V2X message Tx/Rx for V2V and V2P
  - Parameter provisioning for V2V, V2I, and V2P
  - Message prioritization for V2V and V2P
  - V2X message Tx/Rx between UE and RSU
What are PC-5 and Uu interfaces?

- This is PC-5: note short range, direct communication, no direct network access

- This is Uu: note long range, via network. Downlink could be unicast or broadcast

Image Source: Daimler, 2012

Image Source: Automotive News, 2015
## Additional use cases are being developed for 5G, for scenarios where it is believed LTE may

### Final SA1 Use Cases Redux

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LTE V2X in standards

V2V Scenario 1
no infra, out of coverage

V2V Spectrum

V2V Scenario 2
single operator operates a “V2V license” for a geography

V2V Spectrum

MNO 1 (f1)

Uu

MNO 2 (f2)

Uu

V2V Spectrum

MNO 3 (f3)

Uu

V2V Scenario 3
common spectrum shared by multiple operators

V2V Spectrum

- 3GPP expected to work on definition of all three scenarios for LTE
  - Note that 3GPP routinely defines multiple options for new technology as a matter of practice; Audi, QC & partners can affect & guide what actually gets deployed
- V2V to be based on LTE Device to Device Communication introduced in 3GPP Release 12
- Project ongoing in 3GPP, target completion Release 14 (mid 2017, possibly sooner)
- Further enhancements expected with 5G (but not a complete redesign)
3GPP LTE V2X Standardization Timeline
RAN 1 (Physical Layer) and RAN 2 (MAC and Upper Layers)

- RAN1 (physical layer) completed study on using LTE-D2D for V2V communication
  - Signal design: support higher speed and higher frequency offset
  - Resource allocation: efficient allocation for high density
  - Synchronization: allow support for GPS as a synchronization support

- RAN2 (MAC and other upper layers) has started working on using LTE WAN for V2V communication
Continuous Access for Land Mobiles (Hybrid Communications)
ISO TC 204 Communications Access for Land Mobile Standards

- Predicated on ITS-Station (ITS-S) management entity* to determine best ITS-S path for each flow:
  - Capabilities (interfaces, flows, functionalities)
  - Network availability

* Note: ITS-S accepted in ITS community but not necessarily with OEMs – defines interfaces and access to on-board systems

- ISO 21217 / EN 302 665 (ITS Station Architecture)
- ISO 212210 (IPv6 Networking)
- ISO 24102.6 (Flow and Path Management) – WIP
- ISO 17429 (Generic ITS Stations Facilities) – WIP
- ISO 17423 (ITS Application Requirements and Objectives for Selection of Communication Profiles)
- ISO 17419 (Classification and Management of ITS Applications in a Global Context)
- ISO 21186 (Secure Sessions) – WIP
Last Words
802.11, 4G and 5G

All Enable V2X Communications. ISO CALM Standards is one technology-neutral approach. Individual OEM implementation – chosen by region, by application – are more likely.

- Landscape
  - 802.11
    - DSRC highly likely in US
    - ITS-G5 somewhat likely in Europe...
  - But 4G/5G may be the V2X technology of choice – China...and beyond?

- For V2X applications, 5G will likely start with 4G (LTE V2V)
  - LTE V2V will be the cellular V2V solution for several years to come
  - The new 5G radio will augment it / complement it over time
    - No “rip or replace”
  - Technology being studied and rapidly standardized
  - Target completion for LTE V2V standard mid 2017, maybe sooner