Panel Discussion:
LTE vs. IEEE 802.11p – which technology to go for?
Poll

• Vote at http://www.ieee-vnc.org/polls/
• Four Questions
  1. Will we use 802.11p or LTE for safety applications?
  2. Will we use 802.11p RSUs or cellular networks for connecting to backend infrastructure?
  3. Which system offers the better scalability to full-deployment scenarios of vehicular communication systems, 802.11p or LTE?
  4. Which technology is more mature and deployment ready, 802.11p or LTE?
Introduction of Participants

• Falko Dressler, University of Innsbruck
• Javier Gozálvez, University Miguel Hernández
• Jeffrey Miller, University of Alaska
• Erik Lambers, NXP
• Rene Rembarz, Ericsson
DSRC/WAVE – a brief tutorial

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DSRC/WAVE

WAVE

- IEEE 1609.1: “Core System”
- IEEE 1609.2: Security
- IEEE 1609.3: Network Services
- IEEE 1609.4: Channel Management


IEEE 802.11p

- **PHY layer almost identical to IEEE 802.11a**
  - OFDM using 16 QAM
  - Reduced inter symbol interference (multipath effects and Doppler shift)
    - Doubled timing parameters
    - Channel bandwidth (10 MHz instead of 20 MHz)
    - Reduced throughput (3 ... 27 Mbit/s instead of 6 ... 54 Mbit/s)
    - Communication range of up to 1000 m
    - Vehicles’ velocity up to 200 km/h

- **MAC layer with extensions to IEEE 802.11a**
  - Randomized MAC address
  - QoS (Priorities, see IEEE 802.11e, ...)
  - Support for multi channel and multi radio
  - New ad hoc mode
IEEE 802.11 Basic Service Set (BSS)

- **New: 802.11 WAVE-mode**
  - Main mode for all WAVE nodes
  - Suggests the use of “Wildcard-BSS” in transmitted packets
  - Every node is required to receive all packets using a wildcard BSS
  - Inherently allows simultaneous transmission from and to a BSS
  - Membership management just by using a BSS
WAVE BSS

- Every node is member of at most one WAVE-BSS

Access Control and QoS in WAVE

- Use of EDCA equivalent to IEEE 802.11e EDCA
- DCF -> EDCA (Enhanced Distributed Channel Access)
- Definition of four Access Categories (AC)
  - AC0 (lowest) to AC3 (highest priority)
- Introduction of AIFS (Arbitration Inter-Frame Space)

ACs define...
- \( CW_{\text{min}}, CW_{\text{max}}, \) AIFS, TXOP-Limit (max. continuous channel use)
- Management data are transmitted using DIFS instead of an AIFS
Channel Management

- WAVE uses a dedicated frequency range in the 5.9 GHz band
  - Exclusive for V2V and V2I communication
  - Strictly regulated but no license costs
  - In the US, FCC reserved 7 channels a 10 MHz ("U.S. DSRC")

<table>
<thead>
<tr>
<th>Critical Safety of Life</th>
<th>Control Channel (CCH)</th>
<th>Hi-Power Public Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>ch 172 5.860GHz</td>
<td>ch 178 5.890GHz</td>
<td>ch 184 5.920GHz</td>
</tr>
<tr>
<td>ch 174 5.870GHz</td>
<td>ch 180 5.900GHz</td>
<td></td>
</tr>
<tr>
<td>ch 176 5.880GHz</td>
<td>ch 182 5.910GHz</td>
<td></td>
</tr>
</tbody>
</table>

- 1 control and 4 service channels to be used by applications

- In Europa, ETSI reserved 5 channels a 10 MHz

<table>
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<th>SCH 5.860GHz</th>
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[1] ETSI ES 202 663 V1.1.0 (2010-01) : 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
Channel Management

- Channel Management
  - Management and safety information on the Control Channel (CCH)
    - Single radios have to switch to the CCH at known times
  - Two-way communication on the Service Channel (SCH)

- Slot management
  - Synchronization using GPS
  - Standard: 100ms sync interval including 50ms on the CCH
  - Slots start with a guard interval

\[ t = n \times 1s \]
Application Layer

- Car-2-Car Communication Consortium & ETSI TC ITS
  - Not defined by DSRC/WAVE
    but frame formats are provided (e.g., WAVE Short Messages)

- First application: Cooperative Awareness Messages (CAM)
  - Periodic beacons containing
    - Time
    - Speed
    - Position
    - Heading
    - ...
  - Period fix in the interval of 1 to 10 Hz
LTE for vehicular Applications

René Rembarz
Automotive competence center
Ericsson eurolab, Aachen, Germany
LTE Technical innovations

1. Improved air interface
   – Uplink: SC-FDM
   – Downlink: OFDM

2. Multi-antenna technology
   – Diversity
   – Multi-layer transmission (MIMO)
   – Beam-forming

3. High spectrum flexibility
   – Flexible bandwidth
   – New and existing bands
   – Duplex flexibility: FDD und TDD
LTE car-to-Car delay

Source: CoCarX measurements
LTE system capacity

› Capacity analysis – result summary
  – Event-driven messages (DENM):
    Typical cases can be handled
  – Periodic “Here I am” messages (CAM):
    Not scalable for most cases

› Options to accommodate growing demand
  – Multicast/Broadcast (MBMS)
  – Priority for critical services
  – Complementing low-power cells (HetNets)
LTE Broadband Coverage

UMTS/HSPA today  Future LTE/HSPA

Source: CoCarX, Vodafone D2 projections
LTE Advanced

Dense deployments

- Relaying
- Enhanced HetNet support

Peak data rates

- MIMO extensions
  *Up to 4x4 UL and 8x8 DL*

- Carrier Aggregation
  *Contiguous and Non-contiguous*
Will we use 802.11p or LTE for safety applications?

- Will cellular networks / LTE delay be prohibitive for safety applications?

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**Poll Results**

- **IEEE 802.11p** (32 votes) - 82.05%
- **LTE** (7 votes) - 17.95%

Total Votes: 39
Will we use 802.11p RSUs or cellular networks for connecting to backend infrastructure?

- 802.11p networks might rely on connectivity to backend systems for many applications and security management. Is it reasonable to deploy a large scale RSU infrastructure, given that cellular networks are already there?
Which system offers the better scalability to full-deployment scenarios of vehicular communication systems, 802.11p or LTE?

- Assuming hundreds or thousands of equipped cars in a small area, will LTE scale to such full-deployment scenarios?
Which technology is more mature and deployment ready, 802.11p or LTE?

• 802.11p has not proven its reliability in really large scale, high-density tests. How can we be sure it really provides a reliable communication system?