An assessment of LTE-V2X (PC5) and 802.11p direct communications technologies for improved road safety in the EU

A study by the 5GAA

Cellular-V2X Technology: Paving the road to 5G, delivering for connected and automated vehicles in Europe

Brussels
5 December 2017
Introduction to the study

- A quantitative analysis of 3GPP LTE-V2X (PC5) and IEEE 802.11p technologies for short-range *ad hoc/direct* communications in reducing fatalities and serious injuries caused by motoring *accidents* in the EU.

- Additional reductions in fatalities and serious injuries are possible via longer-range communications enabled through interactions with a LTE *cellular network*. But these are *outside the scope* of this study.

- Modelling underlying this report has been *peer-reviewed* and validated in detail by the technology and policy consultancy, *Ricardo*.

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1 The report: “An assessment of LTE-V2X (PC5) and 802.11p direct communications technologies for improved road safety in the EU”, 5 December 2017, is available at: [www.5gaa.org](http://www.5gaa.org).
Study framework

- Study examines two independent counter-factual scenarios: one where LTE-V2X (PC5) is the only deployed C-ITS technology, and the other where 802.11p is the only deployed C-ITS technology.

- We consider, as a baseline, the existing and future projected statistics for road traffic fatalities/injuries in the EU. We then evaluate the reduction in fatalities/injuries which may occur by modelling:
  - expected take-up of LTE-V2X (PC5) and 802.11p among road users over time (including vehicles, motorcycles, bicycles and pedestrians), and
  - radio link performance of LTE-V2X (PC5) and 802.11p.
Study framework

**Inputs**
- **Penetration input**
  - Fleet size/turnover rate;
  - Smartphone population;
  - 802.11p in vehicles;
  - LTE in vehicles/phones;
  - LTE-V2X (PC5) in vehicles/phones;

**Accident data (fatalities and serious injuries)**
- % by road type
  - Urban;
  - Rural;
  - Motorway;
- % by transport mode
  - Pedestrian and Bicycles;
  - Motorcycles;
  - Vehicles;
- % by type of accident
  - At junction;
  - Not at junction;

**Calculation modules**
- **Model: Technology penetration**
  - LTE-V2X (PC5)/802.11p
    - By mode of transport;

- **Model: Avoided accidents**
  - LTE-V2X (PC5)/802.11p
    - By technology;
    - By mode of transport;
    - By type of accident;

- **Model: Radio performance and effectiveness**
  - Alert delivery rates
    - LTE-V2X (PC5)/802.11p
      - By road type;
      - By mode of transport;
      - By type of accident;
  - Impact of alert on driver behaviour
    - By road type;
    - By mode of transport;
    - By type of accident;

**Outputs**
- Accidents avoided (fatalities and serious injuries) projected to 2040
  - % of accidents avoided;
  - Absolute number of accidents avoided;
  - Cumulative number of accidents avoided;
  - Societal cost of accidents avoided;
Baseline: Fatalities/injuries in the EU

Statistics released by the European Commission (Eurostat, CARE data)

Extension: 12 serious injuries per fatality.

Year

Note: Baseline does not account for impact of long-range cellular communications (or technologies other than C-ITS), in reducing the number of accidents. For this reason, the results of this study are an upper bound on number of accidents avoided.
Technology penetration: High/low scenarios

Penetration of LTE-V2X (PC5) and 802.11p

Rapid growth despite late start (2022), due to the short lifetime and quick turnover of smartphones.

“High” scenario: Assumed aggressive deployment.
“Low” scenario: More pessimistic deployment based on literature.
Radio link performance: Alert delivery reliability

<table>
<thead>
<tr>
<th>Vehicle to...</th>
<th>At junction</th>
<th>Not at junction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
</tr>
<tr>
<td>... pedestrian or bicycle</td>
<td>96% [78%]</td>
<td>67% [59%]</td>
</tr>
<tr>
<td>...vehicle or motorcycle</td>
<td>96% [78%]</td>
<td>83% [66%]</td>
</tr>
</tbody>
</table>

- Likelihood of successful delivery of warning messages between two road users equipped with LTE-V2X (PC5) is greater than it is for two road users equipped with 802.11p.

- LTE-V2X (PC5) has greater transmit power spectral density (frequency-domain multiplexing), more power-efficient SC-FDM waveform, better (Turbo) channel coding gain, physical layer packet re-transmissions, and better (deterministic) management of radio resources.
Low penetration rates of the technologies only begin to pick up pace in the mid-2020s. Combined with the fact that the probability of avoiding accidents is proportional to the square of the probability of having the technology installed, implies slow initial ramp-up in effectiveness.
Cumulative statistics: Serious injuries

Low penetration rates of the technologies only begin to pick up pace in the mid-2020s. Combined with the fact that the probability of avoiding accidents is proportional to the square of the probability of having the technology installed, implies slow initial ramp-up in effectiveness.
Summary

<table>
<thead>
<tr>
<th>Time-frame: 2018-2040</th>
<th>Avoided fatalities</th>
<th>Avoided serious injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>LTE-V2X (PC5)</td>
<td>59,000</td>
<td>29,000</td>
</tr>
<tr>
<td>802.11p</td>
<td>39,000</td>
<td>20,000</td>
</tr>
</tbody>
</table>

- Deployment of LTE-V2X (PC5) would avoid greater numbers of fatalities and serious injuries on the EU’s roads than would be the case for 802.11p.

- Expressed in terms of external costs avoided, this amounts to total avoided costs of €61 billion and €22 billion for LTE-V2X (PC5) compared to 802.11p in the “high” and “low” scenarios, respectively.

Even the “low” 802.11p penetration is expected to be overly optimistic: at the time of writing only one European car vendor has announced an intention to deploy 802.11p, expected in 2019. Whereas, the “low” LTE-V2X (PC5) penetration is based on on-going growth of LTE modems in vehicles (for telematics/infotainment), and what we consider to be a realistic future projection of PC5 functionality in such LTE modems.
Conclusions and recommendations (1/2)

- An absence of interoperability at radio link level between LTE-V2X (PC5) and 802.11p is unlikely to present a substantive barrier to reduction of road accidents in the EU in the short to medium term.

- This is because the relatively low penetration of C-ITS technologies in vehicles in the first half of the next decade means that a vehicle equipped with LTE-V2X (PC5) or 802.11p is far more likely to collide with a vehicle that is not equipped with C-ITS technologies at all.

- Any regulations which mandate LTE-V2X (PC5) to be backward interoperable with 802.11p will
  - have only a limited effect in the early years of deployment pre-2025;
  - run the risk of unnecessarily distorting the market in favour of 802.11p, thereby obstructing the adoption of LTE-V2X (PC5);
  - resulting in greater road fatalities and injuries in the longer term.
Conclusions and recommendations (2/2)

- The study indicates that LTE-V2X (PC5) outperforms 802.11p in reducing fatalities and serious injuries on the EU’s roads.

- This is due to a combination of the superior performance of LTE-V2X (PC5) at the radio link level for ad hoc/direct communications between road users, and the market led conditions which better favour the deployment of LTE-V2X in vehicles and in smartphones, and include a clear evolutionary path towards 5G-V2X.

- For these reasons, it is essential that EU regulations remain technology neutral and do not hinder the deployment of LTE-V2X (PC5) in favour of 802.11p for the provision of direct communications among vehicles and between vehicles and vulnerable road users.
Thank you

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## Breakdown by mode of transport

### LTE-V2X (PC5) 2018 - 2040

<table>
<thead>
<tr>
<th>Mode</th>
<th>Fatalities</th>
<th>Serious Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Pedestrians</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td>3,854</td>
<td>2,567</td>
</tr>
<tr>
<td>Vehicles</td>
<td>37,353</td>
<td>26,403</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>58,921</td>
<td>28,970</td>
</tr>
</tbody>
</table>

### 802.11p 2018 - 2040

<table>
<thead>
<tr>
<th>Mode</th>
<th>Fatalities</th>
<th>Serious Injuries</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td>3,569</td>
<td>1,504</td>
</tr>
<tr>
<td>Vehicles</td>
<td>35,318</td>
<td>18,105</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>38,887</td>
<td>19,609</td>
</tr>
</tbody>
</table>
802.11p in new vehicles/motorcycles
LTE-V2X (PC5) in new vehicles/motorcycles

Penetration of LTE-V2X (PC5)

Based on data from IHS Automotive

Optimistic growth

Start

5 years

5 years

2016 2020 2024 2028 2032 2036 2040

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Vehicles: High  Vehicles: Low  Motorbikes: High  Motorbikes: Low
Derivation of LTE-V2X (PC5) low scenario

Penetration of LTE and LTE-V2X (PC5) in vehicles

- a) PC5 functionality in new LTE chips
- b) LTE modems in vehicles

(a×b) PC5 in vehicles

- Vehicles (LTE)
- Vehicles (LTE-V2X)
- LTE chips (LTE-V2X)
LTE-V2X (PC5) in new smartphones

Penetration of LTE-V2X (PC5) in new smartphones

- a) PC5 functionality in new LTE chips
- 80% cap on users of LTE-V2X (PC5) in smartphones

Timeline:
- Start: 2020
- 80% cap: 2024

Graph showing:
- Smartphones: High
- Smartphones: Low
Radio link performance

For each scenario, the range of assumed road user speeds maps to a corresponding range of alert delivery reliability rates. The \textit{average} reliability rate over this range is then calculated as the alert delivery reliability associated with the said scenario.