5G & Connected Cars
Infrastructure for the GigaBit Society

Hartmut Kremling
Vodafone Ambassador
5G IEEE Summit Berlin,
November 2th. 2016
Our vision for 2020

- 4G+/5G
- Fiberisation
- Gigabit Vodafone
- Cloud
- Internet of Things
## Investing for the Gigabit Society

Vodafone organic investment 2014 - 2016: £19 billion

<table>
<thead>
<tr>
<th>Technology</th>
<th>Investment Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G+</td>
<td></td>
</tr>
<tr>
<td>IoT</td>
<td></td>
</tr>
<tr>
<td>5G</td>
<td></td>
</tr>
<tr>
<td>FTTH/B</td>
<td></td>
</tr>
<tr>
<td>DOCSIS 3.x</td>
<td></td>
</tr>
<tr>
<td>NG-PON2</td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td></td>
</tr>
<tr>
<td>Network virtualisation</td>
<td></td>
</tr>
<tr>
<td>Cloud platforms/solutions</td>
<td></td>
</tr>
<tr>
<td>Open APIs</td>
<td></td>
</tr>
<tr>
<td>CRM/E - systems</td>
<td></td>
</tr>
</tbody>
</table>
5G is an opportunity to enable & support new business opportunities and deliver the Gigabit Society

- Massive MTC
- Ultra reliable MTC
- Enhanced MBB

- ultra low cost
- 1ms latency
- >10Gbps peak
- 100x connected
- robust connection
- 10-100Mbps everywhere
- +10y battery life
- Higher efficiency
- Lower energy consumption
- Lower cost to operate
5G preparation is happening now

<table>
<thead>
<tr>
<th>Year</th>
<th>Preparation</th>
<th>Standards</th>
<th>Availability</th>
<th>mmWave spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>5G preparation incl. NB-IoT, Cloud transformation, …</td>
<td>Non standalone</td>
<td></td>
<td>mmWave spectrum</td>
</tr>
<tr>
<td>2017</td>
<td></td>
<td>Standalone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td></td>
<td></td>
<td>WRC 2019: Global identification of mmWave band</td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Vodafone is leading the future of 5G

To deal with complex road situations, automated vehicles will have to rely not only on their own sensors, but to cooperate with each other by being connected.

- **5G will help to reach a better coverage and will support higher mobility (e.g., 500 km/h for high-speed trains).**
- **5G will improve network reliability for safety-critical services.**
- **Automated driving requires a very low latency to be able to react in real time to drivers’ behaviour and to moving obstacles.**

### What is 5G? Steering & Control Communications!

- An innovative step-change in performance compared to 4G and WiFi: **1ms delay**
- Complementary to LTE/WiFi and their evolutions
- Allows same experience over fixed & mobile network
- Combines existing with new operator assets (spectrum, deployment, locations)
- Is designed for a global adoption, scalable, virtualized, software based

### Why do we need 5G?

- Enable real-time M2M services (IoT) in vertical industries
- **1000 times more capacity & speed**
- **Lower cost and energy consumption**

5G = 1ms + 10GBit/s + 99.9999% + E2E-Security + 10 years + 500 billion devices (not all at the same time)
How could a smart car look like in 5 or 10 years from now?

- Connected Infotainment
- Virtual Interior
- Future Driving Experience
- Connected HD Navigation
- Smartphone as the Car Key
- V2V & V2X + Security
- eMobility, Platooning, Sensor Sharing „see through“, Cooperative Vehicle Safety

The Future of Cars: Vorsprung durch Technik erhöht Freude am Fahren
Vodafone Member of 5G Automotive Association (5GAA) with Audi, BMW & Daimler partner on 5G for cars

Audi, BMW Group, Daimler AG are teaming with Ericsson, Huawei, Intel, Nokia, and Qualcomm to create the 5G Automotive Association (5GAA), which will help develop, test, and promote **5G standards**.

Scope of the alliance is focused on bringing **connectivity solutions** to market addressing technical, business, and regulatory challenges.
Vodafone is Your Ideal Partner to Unlock Multiple Use Cases for Automatic, Autonomous and Cooperative Driving

- Contextual Speed Limits
- High Density Platooning
- HD Live Maps Updates
- Tele operated Driving
- Sensor Sharing & “SeeThrough” Service
- Wrong Way Driving Warning
- Precise & Predictive Localisation
- Smartphone as a Sensor
- Automatic Parking Access Control
- Emergency trajectory replanning (overtaking)
- Cooperative Collision Avoidance
- Bird's Eye View
- Test Bed Involvement
  - Highways
  - Country Roads
  - (Smart) City Traffic
  - Closed Testtrack
  - State Level
  - Federal Level
  - EU Level
Vodafone Drives Network Evolution in Major Research Projects

CONVERGE: Architecture and corresponding interfaces for a Vehicle2X Systems Network

Wrong Way Driver Alert

1. Entering highway on the wrong way

2. Wrong way – in car and roadside detection with urgent driver alert
At the A9 Testbed Innovative Technologies Towards 5G Form the Basis For Future Mobility Evolution

**LTE-V2X**

3GPP LTE-V2X

<table>
<thead>
<tr>
<th>Application server</th>
<th>eNodeB</th>
<th>RSU (eNodeB)</th>
<th>UE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE (Uu)</td>
<td>LTE-D (PC5)</td>
<td>LTE-D (PC5)</td>
<td>LTE-D (PC5)</td>
</tr>
<tr>
<td>LTE (Uu)</td>
<td>LTE (Uu)</td>
<td>LTE (Uu)</td>
<td>LTE (Uu)</td>
</tr>
</tbody>
</table>

Uu interface will operate in existing licensed MBB spectrum.

Question: How about the PC5 interface?

Estimates for bandwidth required for PC5 range between ~10 to 30 MHz.

**Geo-Messaging**

Hazard Warning:
accident, emergency breaking, bad road condition, road works, slow vehicle

Traffic Information updates:
traffic condition & warnings

Traffic Management Center

Core Network Infrastructure

Filtering/GeoMessaging

NodeB

Cellular Car-to-car...
Reference Project in UK – CITE
LTE Based Vehicle-to-Vehicle Communications

**What is it?**
Vehicle to Vehicle (V2V) capability based on *standardised LTE* Proximity Services

**Why?**
- Provides continuity of service in *poor coverage areas*
- Enables a *single technology, LTE*, based solution for all connected car requirements

**Progress to date**
Emergency braking alerts between vehicles *demonstrated on test track* using Huawei equipment in conjunction with Jaguar & LandRover

**UK CITE:** 10 partner consortium, 2 year project, using a mix of technologies over 35 miles of different road types (vendor support: Huawei)
5G is coming!

In 2025 these teenagers will be the young professionals innovating the way that we will be communicating and interacting with our information, our friends, and the machines that help us.

They have NEVER known a world with a wire!

Would they use a car like we did?
Thank you!

Hartmut Kremling
Vodafone Ambassador
Mobile: +49 1725332701
Hartmut.kremling@vodafone.com