5G BLUEPRINT – NEXT GENERATION CONNECTIVITY FOR ENHANCED, SAFE AND EFFICIENT TRANSPORT & LOGISTICS

Johann Marquez-Barja, imec & University of Antwerp

Global IoT 5G CAM Session, 21/06/22, Dublin, Ireland
5G-Blueprint designs and validates a technical architecture, business and governance model for uninterrupted cross-border Tele-Operated transport based on 5G connectivity
5G-BLUEPRINT IN A NUTSHELL

TELE-OPERATED TRANSPORT

TECHNOLOGY – 5G NETWORK & ENABLING FUNCTIONS

- Fast
- Reliable
- Secure
- Guaranteed
- Cross-border

ECONOMICS

- Reduction of waiting time
- Reduction labour shortage
- Economic growth
- Safer driving
- Facilitator automated mobility
- Complex business model

GOVERNANCE

- MNO SLA's
- ToD service SLA’s
- Legislation
- Certification
- Liability
- Data sharing and GDPR
OBJECTIVES

TECHNOLOGICAL

• Design and implement a 5G network for CAM services
• Develop and implement the prototype of a TO system
• Implement and deploy enabling functions guaranteeing safety and increasing value
• Validate the end-to-end TO transport solution supported by 5G in real-life cross-border scenarios

BUSINESS

• 5G TO transport market analysis
• Commercial possibilities
• Positions the possible role of TO transport based on 5G in CAM
• TO transport based on 5G connectivity market adoption

REGULATORY

• Identify regulatory issues
• Recommended actions
• Standardization and best practices
THE CHALLENGES
5G-BLUEPRINT CHALLENGES

5G Network requirement
- Low latency
- High throughput
- High availability at cross-borders
- Security and Reliability
- Radio RF - Spectrum

Technical challenges

Safe direct control T-O
- Vehicle safety fallback at ASIL
- Security on all levels
- Sufficient situational awareness operator
- Safe operator handover during active ToD session
- Applicability on public road

Autonomous mobility
- Automated docking
- CACC
- CCAS
5G-BLUEPRINT CHALLENGES

- Stakeholders needs
- Regulatory frameworks for T-O on public road
- Stakeholder service-level agreements
- Most satisfactory business case
- Liability agreements
- Political Acceptance

Business & regulation challenges
THE BASICS
FACTS & FIGURES

Project Acronym: 5G-Blueprint
Project Name: Next generation connectivity for enhanced, safe & efficient transport & logistics

Funded Under: H2020-ICT-2018-20
Topic: ICT-53-2020: 5G PPP (5G for Connected and Automated Mobility)
Type of action: Innovation action (IA)
Call for proposal: H2020-ICT-2019-3

Starting Date: 01/09/2020
Duration: 36 Months
Total cost: EUR 13,9 M
EU contribution: EUR 10 M

Project Coordinator: Dr Wim Vandenberghhe, Ministerie van Infrastructuur en Waterstaat
Technical Coordinator: Prof. Johann Marquez-Barja, Interuniversitair Micro-Electronica Centrum (IMEC)
USE CASES

**UC1:** Automated barge control
Vlissingen

**UC2:** Automated docking
Vlissingen and Antwerp

**UC3:** CACC-based platooning
NL – BE Cross-border

**UC4:** Remote take over
NL – BE Cross-border

Teleoperated crane
## ENABLING FUNCTIONS

<table>
<thead>
<tr>
<th>EF1</th>
<th>Enhanced awareness dashboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF2</td>
<td>Vulnerable Road User (VRU) interaction</td>
</tr>
<tr>
<td>EF3</td>
<td>Timeslot reservation at intersections</td>
</tr>
<tr>
<td>EF4</td>
<td>Distributed perception</td>
</tr>
<tr>
<td>EF5</td>
<td>Active collision avoidance</td>
</tr>
<tr>
<td>EF6</td>
<td>Container ID recognition</td>
</tr>
<tr>
<td>EF7</td>
<td>ETA sharing</td>
</tr>
<tr>
<td>EF8</td>
<td>Scene analytics</td>
</tr>
</tbody>
</table>

### TELE-OPERATION COCKPIT

**Concise messages on**
- Speed advice
- Warnings
- Navigation and routing features

- **EF2**
- **EF3**
- **EF4**
- **EF5**
- **EF6**
- **EF7**
- **EF8**
PILOT AREA

5G PILOT SITES

VLissingen
- Teleoperation on roadways
- Docking
- Supporting enabling functions

Antwerp
- Teleoperation on roadways and waterways
- Platooning
- Supporting enabling functions

Zelzate (cross-border site)
- Teleoperation on roadways and waterways
- Platooning
- Seamless roaming
- Supporting enabling functions

NORTH SEA PORT ANTWERP-ROTTERDAM TRANSPORT CORRIDOR
CONSORTIUM AS A WHOLE

Network operators
- kpn
- eurofiber

Vehicle OEMs
- TOYOTA

Teleoperation OEMs
- v-tron
- roboauto
- Kloosterboer
- TENNEBROOKS INTERNATIONAL
- TRANSPORT Roosens

Teleoperation
- Port of Antwerp
- MWLC
- SEAFAR
- [sentors]
- room 40
- NxtPort

Logistics
- Transport
- BEMOBILE
- Swarco

Connected Mobility sector
- HAN UNIVERSITY OF APPLIED SCIENCES
- UNIVERSITY OF APPLIED SCIENCES
- Martel

Research institutes
- Imec

Governments
- Ministry of Infrastructure and Water Management
- Flanders State of the Art

Business accelerator
- Impuls Zeeland
# ADVISORY BOARD

<table>
<thead>
<tr>
<th>Regional government</th>
<th>Vehicle OEMs</th>
<th>Logistics sector</th>
<th>Associations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provincie Zeeland</td>
<td>Ford, Otosan</td>
<td>Port of Amsterdam International</td>
<td>Here</td>
</tr>
<tr>
<td>Stad Antwerpen</td>
<td>DAF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agentschap Telecom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© 5GBlueprint.eu
USE CASES & PILOT SITES – CONNECTIVITY REQUIREMENTS
## USE CASES AND SITES

<table>
<thead>
<tr>
<th>Use-case</th>
<th>Vlissingen</th>
<th>Zelzate</th>
<th>Antwerp</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC1 Automated Barge Control</td>
<td></td>
<td></td>
<td>“Hard” conditions</td>
</tr>
<tr>
<td></td>
<td>Cross-border</td>
<td></td>
<td>no test/demo only deployment</td>
</tr>
<tr>
<td></td>
<td>• Navigating canal with obstacle (bridge) at the border location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC2 Automated driver-in-loop docking</td>
<td>Full use case</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Truck docking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Crane operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC3 CACC based Platooning</td>
<td>Milk run</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Between terminal and MSP factory (same trajectory as UC4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC4 Remote Takeover Operation</td>
<td>Terminal traffic &amp; basic milk runs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Confined area (terminal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Short route over 50 km/h public roads and with limited traffic between terminal and MSP factory</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cross-border, high speed, urban</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Crossing the border on 50 km/h public road, 90 km/h in Flanders</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Urban environment with presence of iTLCs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Enabling functions:
- 1. Enhanced awareness HMI
- 2. VRU interaction
- 3. Time slot reservation intersection
- 4. Distributed perception
- 5. Active collision avoidance
- 6. Container ID recognition
- 7. ETA sharing
- 8. Scene analytics
VLIISSINGEN SITE DETAILS

https://www.google.be/maps/@51.4581162,3.6968918,13.75z
ZELZATE SITE DETAILS

https://www.google.be/maps/@51.207446,3.8004474,15.25z
ANTWERP
SITE DETAILS

https://www.google.be/maps/@51.2894393,4.2511426,13.5z
ANTWERP SITE DETAILS
CONNECTIVITY REQUIREMENTS IDENTIFIED
## CONNECTIVITY REQUIREMENTS USE CASE 1

### TABLE I
**USE CASE 1 REQUIREMENTS**

<table>
<thead>
<tr>
<th>Description</th>
<th>HD Camera stream</th>
<th>HD Video screens</th>
<th>Ship control interface</th>
<th>Distance/depth sensor in ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>From/To</td>
<td>TOV → TOC</td>
<td>TOV → TOC</td>
<td>TOC → TOV</td>
<td>TOV → TOC</td>
</tr>
<tr>
<td>Service Type</td>
<td>Uplink</td>
<td>Downlink</td>
<td>E2E</td>
<td>Uplink</td>
</tr>
<tr>
<td>Ideal Latency</td>
<td>&lt;22ms</td>
<td>&lt;22ms</td>
<td>&lt;35ms</td>
<td>&lt;100ms</td>
</tr>
<tr>
<td>Service Interruption</td>
<td>&lt;30s</td>
<td>&lt;30s</td>
<td>&lt;150ms</td>
<td>&lt;1s</td>
</tr>
<tr>
<td>Bandwidth Requirement</td>
<td>&gt;5Mbps</td>
<td>&gt;5Mbps</td>
<td>&lt;2Mbps</td>
<td>&lt;1Mbps</td>
</tr>
<tr>
<td></td>
<td>&lt;25Mbps</td>
<td>&lt;25Mbps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device Scenario</td>
<td>Outdoor mobile</td>
<td>Outdoor stationary</td>
<td>Outdoor mobile + Outdoor stationary</td>
<td>Indoor mobile</td>
</tr>
<tr>
<td>Slice Type</td>
<td>eMBB</td>
<td>eMBB</td>
<td>URLLC/ hMTC</td>
<td>V2X</td>
</tr>
<tr>
<td>No. Flow</td>
<td>10 per ship</td>
<td>6 per operator</td>
<td>1 per ship</td>
<td>1 per ship</td>
</tr>
</tbody>
</table>
## Connectivty Requirements Use Case 2

### Table II

<table>
<thead>
<tr>
<th>Description</th>
<th>HD Camera stream</th>
<th>HD Video screens (as fallback)</th>
<th>Vehicle control interface</th>
<th>Telemetry sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>From/To</td>
<td>TOV→TOC</td>
<td>TOV→TOC</td>
<td>TOC→TOV</td>
<td>TOV→TOC</td>
</tr>
<tr>
<td>Service Type</td>
<td>Uplink</td>
<td>Downlink</td>
<td>E2E</td>
<td>Uplink</td>
</tr>
<tr>
<td>Ideal Latency</td>
<td>&lt;50ms</td>
<td>&lt;50ms</td>
<td>&lt;35ms</td>
<td>&lt;100ms</td>
</tr>
<tr>
<td>Service Interruption</td>
<td>&lt;150ms</td>
<td>&lt;150ms</td>
<td>&lt;150ms</td>
<td>&lt;1s</td>
</tr>
<tr>
<td>Bandwidth Requirement</td>
<td>&gt;5Mbps &lt;25Mbps</td>
<td>&gt;5Mbps &lt;25Mbps</td>
<td>&lt;2Mbps</td>
<td>&lt;1Mbps</td>
</tr>
<tr>
<td>Device Scenario</td>
<td>Indoor mobile</td>
<td>Outdoor stationary</td>
<td>Indoor mobile + Outdoor stationary</td>
<td>Indoor mobile</td>
</tr>
<tr>
<td>Slice Type</td>
<td>eMBB</td>
<td>eMBB</td>
<td>URLLC/ hMTC</td>
<td>V2X</td>
</tr>
<tr>
<td>No. Flow</td>
<td>3 per vehicle</td>
<td>3 per vehicle</td>
<td>1 per vehicle</td>
<td>1 per vehicle</td>
</tr>
</tbody>
</table>
## CONNECTIVITY REQUIREMENTS USE CASE 3 AND 4

**TABLE III**

**USE CASE 3 REQUIREMENTS**

<table>
<thead>
<tr>
<th>Description</th>
<th>HD Camera stream</th>
<th>HD Video screens</th>
<th>Vehicle control interface</th>
<th>Telemetry sources</th>
<th>LiDAR data stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>From/To</td>
<td>TOV→TOC</td>
<td>TOV→TOC</td>
<td>TOC→TOV</td>
<td>TOV→TOC</td>
<td>TOV→TOC</td>
</tr>
<tr>
<td>Service Type</td>
<td>Uplink</td>
<td>Downlink</td>
<td>E2E</td>
<td>Uplink</td>
<td>V2V</td>
</tr>
<tr>
<td>Ideal latency</td>
<td>&lt;50ms</td>
<td>&lt;50ms</td>
<td>&lt;35ms</td>
<td>&lt;100ms</td>
<td>&lt;100ms</td>
</tr>
<tr>
<td>Service Interruption</td>
<td>&lt;150ms</td>
<td>&lt;150ms</td>
<td>&lt;150ms</td>
<td>&lt;1s</td>
<td>&lt;1s</td>
</tr>
<tr>
<td>Bandwidth Requirement</td>
<td>&gt;5Mbps</td>
<td>&gt;5Mbps</td>
<td>&lt;2Mbps</td>
<td>&lt;1Mbps</td>
<td>&gt;20Mbps</td>
</tr>
<tr>
<td></td>
<td>&lt;25Mbps</td>
<td>&lt;25Mbps</td>
<td></td>
<td></td>
<td>&lt;100Mbps</td>
</tr>
<tr>
<td>UE Scenario</td>
<td>Outdoor mobile</td>
<td>Outdoor stationary</td>
<td>Outdoor mobile</td>
<td>Outdoor mobile</td>
<td>Outdoor mobile</td>
</tr>
<tr>
<td>Slice Type</td>
<td>eMBB</td>
<td>eMBB</td>
<td>URLLC/ hMTC</td>
<td>V2N</td>
<td>V2V sidetlink</td>
</tr>
<tr>
<td>No. Flow</td>
<td>3 per vehicle</td>
<td>3 per vehicle</td>
<td>1 per vehicle</td>
<td>1 per vehicle</td>
<td>2 per vehicle</td>
</tr>
</tbody>
</table>
IMPLEMENTING USE CASES
INITIAL RESULTS

Automated driver in loop docking
Vlissingen and Antwerp ports

Forward motion
INITIAL RESULTS
INITIAL RESULTS

CACC based platooning

Cross border on public road
REMOTE TELEOPERATION USING 5G

CACC based platooning
Cross border on public road

Teleoperator + 5G

Remote take over
Cross border on public road

© 5GBlueprint.eu
LESSONS LEARNT SO FAR
5G PERFORMANCE

- 4G testing - Arnhem
  
  Max speed – 30 Kmph

- 5G testing – Helmond – SA/NSA
  
  Max speed – 70 Kmph
UNDERSTANDING LATENCIES (SA)
Initial test results using different modems and two 5QI settings (5QI-8 = basic MBB, 5QI-80 = Low Latency) shown are the 95% percentiles in ms (95% of the samples had lower latency).

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Requirement</th>
<th>Fibocom SA 5QI-80</th>
<th>Digi NSA QCI-8</th>
<th>Digi SA 5QI-8</th>
<th>Sierra* SA 5QI-8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UL</td>
<td>DL</td>
<td>UL</td>
<td>DL</td>
<td>UL</td>
</tr>
<tr>
<td>UC 1: Barge Control</td>
<td>22</td>
<td>35</td>
<td>8.9</td>
<td>5.6</td>
<td>35.8</td>
</tr>
<tr>
<td>UC 2: TeleOperations</td>
<td>50</td>
<td>35</td>
<td>8.9</td>
<td>5.6</td>
<td>35.8</td>
</tr>
<tr>
<td>UC 3: Platooning</td>
<td>50</td>
<td>35</td>
<td>8.9</td>
<td>5.6</td>
<td>35.8</td>
</tr>
<tr>
<td>UC 4: Take Over</td>
<td>50</td>
<td>35</td>
<td>8.9</td>
<td>5.6</td>
<td>35.8</td>
</tr>
</tbody>
</table>

*The Sierra Wireless modem performed poorly in the uplink tests; this is probably an issue in this individual device which can be solved.*
TEST RESULTS – UC 4.4

- Vehicle control message latency
- Calculated as a mean from values calculated from 200 sample batches

<table>
<thead>
<tr>
<th></th>
<th>n = 500 (batches)</th>
<th>LTE</th>
<th>5G production network</th>
<th>5G test network</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>21.23</td>
<td>14.34</td>
<td>7.86</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>26.4</td>
<td>18.4</td>
<td>11.38</td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>45.6</td>
<td>31.4</td>
<td>19.8</td>
<td></td>
</tr>
</tbody>
</table>
WHAT HAVE WE LEARNED SO FAR?

5G and Tele-Operation

- **eMBB and URLLC**
- **Uplink is the main bottle neck**
  - Computing closer to the UE
- **Cross-border roaming**
  - Not properly standardized
  - N14 interface
LESSONS LEARNED SO FAR…

• Benefits and Risks for Tele-operation. (Survey outcome)
  
  **Benefits:**
  
  • **Cost decrease**
    • Reduction of the waiting times and resting hours
    • Less fuel consumption as the smart dashboard will optimize speed (eco-driving)
    • Payload may increase, as the driver cabin may decrease
  
  • **Safety increase**
    • Extended sensing in vehicles and roads will increase safety
    • Drivers/Shippers safety increased (e.g. hazard material, remote locations)
    • Fewer people on site decreases the risk of accidents
  
  • **Job Marker compatibility**
    • Solving the shortage of drivers and shippers
    • Work-life balance improved
LESSONS LEARNT SO FAR…

• Benefits and Risks for Tele-Operation

  - Risks:
    • Lack of legal framework
      • Teleoperation on public roads and water ways is not yet allowed (commercially)
      • Who is liable for what? Payload, transport, security, vandalism
    • For T&L teleoperation is more complex than for RoboTaxis in Cities
      • Manual processes for checking and assuring loads still present
    • Technology readiness
      • 5G coverage
      • 5G R16/R17 vendor equipment availability
      • Cross-border / Cross-operator agreements. (SLAs)
THANK YOU FOR YOUR ATTENTION

5GBlueprint.eu