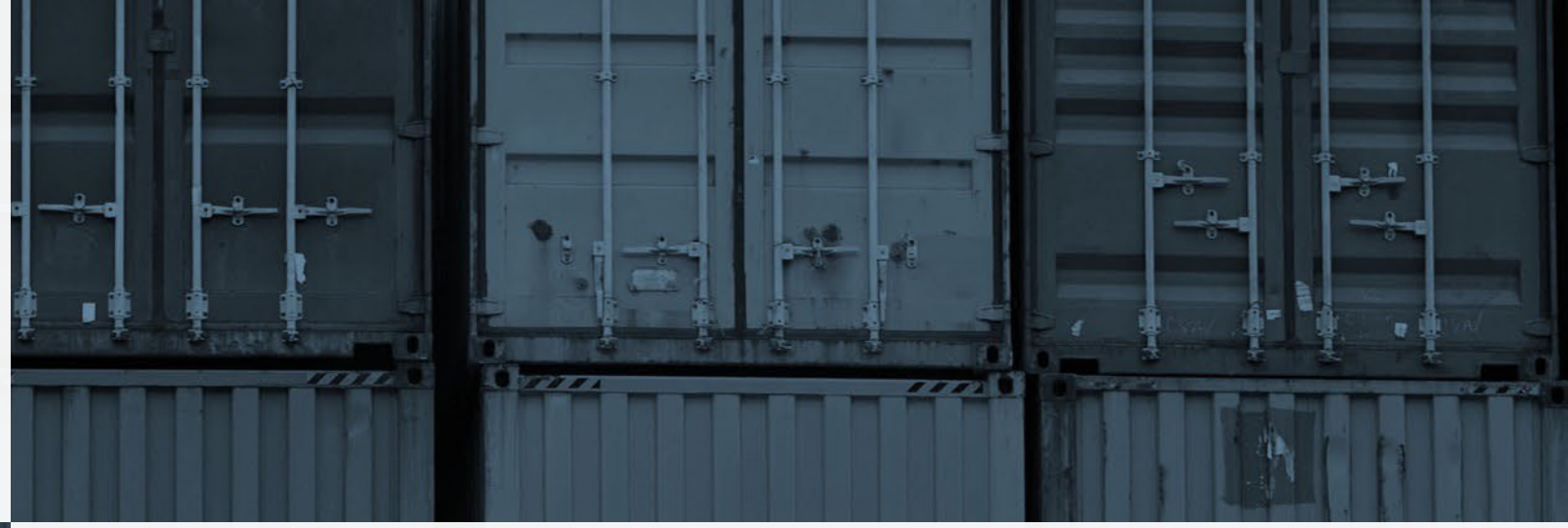


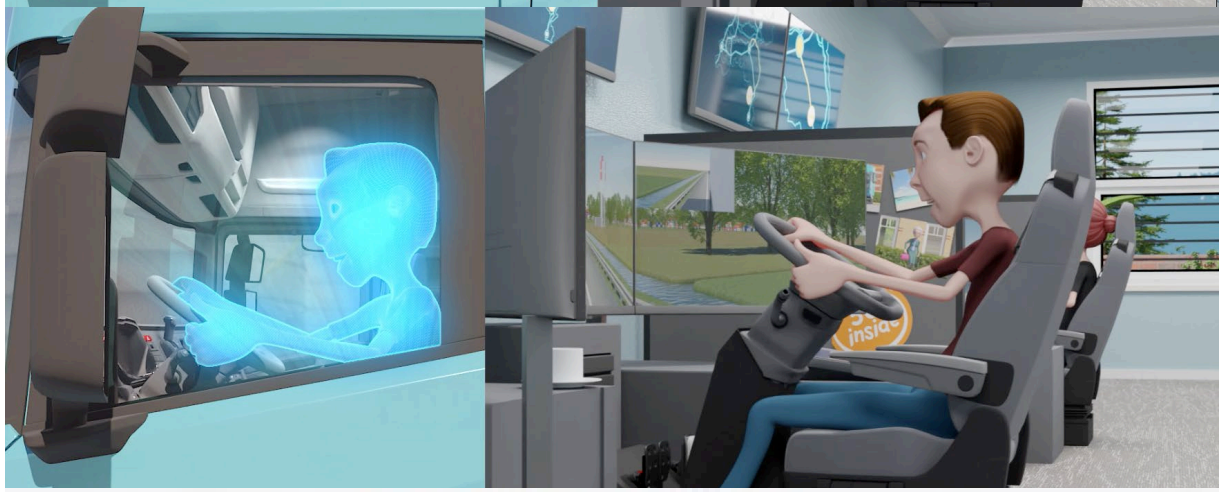
5G BLUEPRINT – NEXT GENERATION CONNECTIVITY FOR ENHANCED, SAFE AND EFFICIENT TRANSPORT & LOGISTICS

Johann Marquez-Barja, imec & University of Antwerp

Global IoT 5G CAM Session, 21/06/22, Dublin, Ireland

European Commission

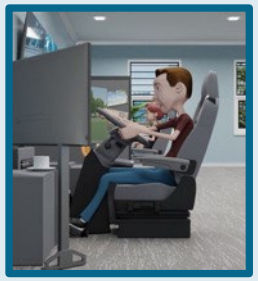
5G-Blueprint designs and validates a **technical architecture, business** and **governance model** for uninterrupted **cross-border Tele-Operated** transport based on **5G connectivity**



5G BLUEPRINT

5G-BLUEPRINT IN A NUTSHELL

TELE-OPERATED TRANSPORT



TECHNOLOGY – 5G NETWORK & ENABLING FUNCTIONS

Fast | **Reliable** | **Secure** | **Guaranteed** | **Cross-border**

C H A L L E N G E S

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

Technical challenges

5G Network requirement

- Low latency
- High throughput
- High availability at cross-borders
- Security and Reliability
- Radio RF - Spectrum

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

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 Vandenberghe, *Ministerie van Infrastructuur en Waterstaat*

Technical Coordinator: Prof. Johann Marquez-Barja, *Interuniversitair Micro-Electronica Centrum (IMEC)*

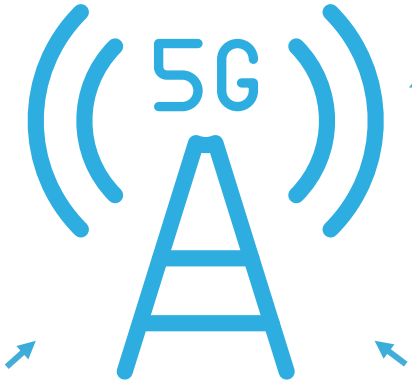
USE CASES

UC1: Automated barge control

Vlissingen

UC4: Remote take over

NL – BE Cross-border



UC2: Automated docking

Vlissingen and Antwerp

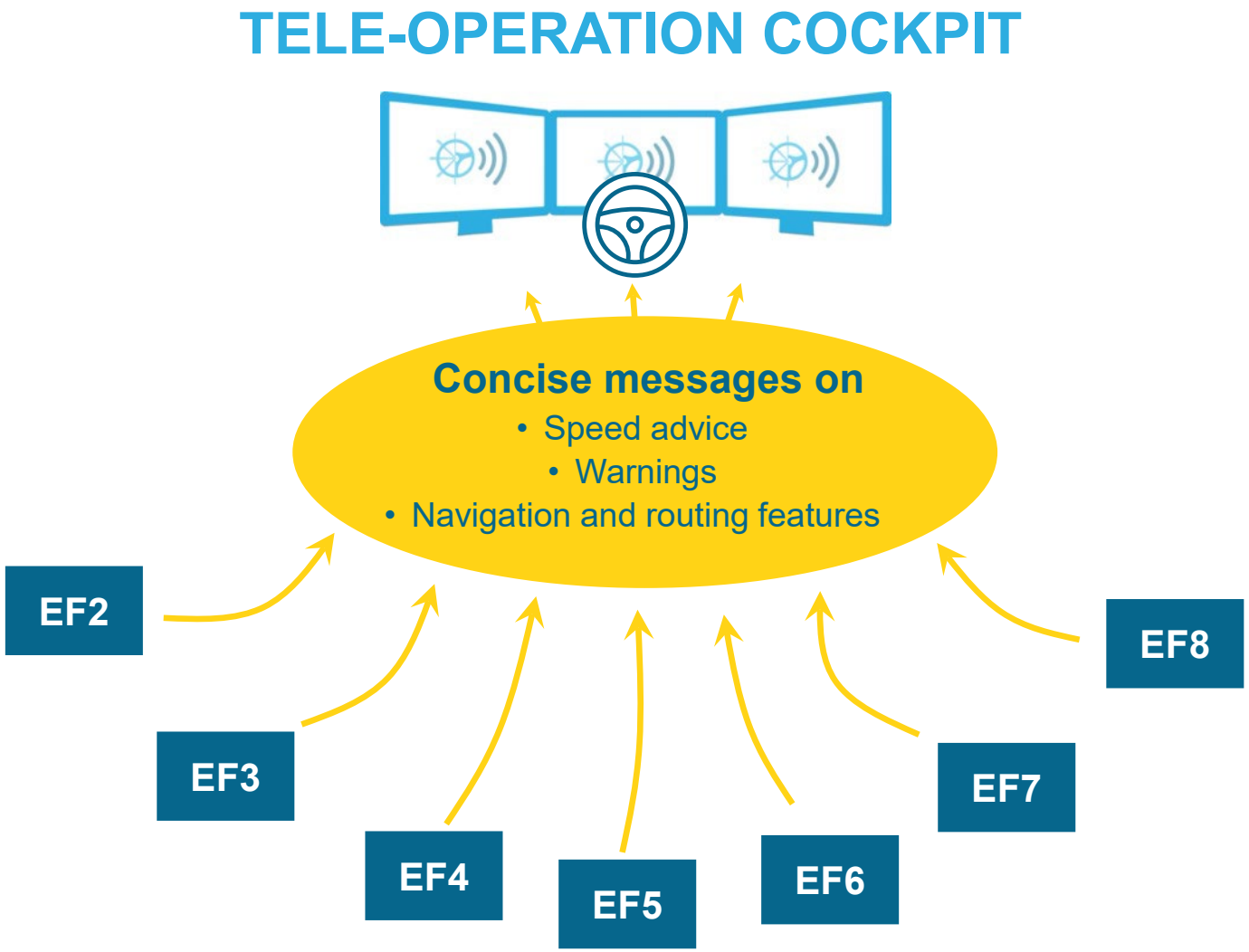
Teleoperated crane

UC3: CACC-based platooning

NL – BE Cross-border

ENABLING FUNCTIONS

EF1	Enhanced awareness dashboard
EF2	Vulnerable Road User (VRU) interaction
EF3	Timeslot reservation at intersections
EF4	Distributed perception
EF5	Active collision avoidance
EF6	Container ID recognition
EF7	ETA sharing
EF8	Scene analytics



PILOT AREA

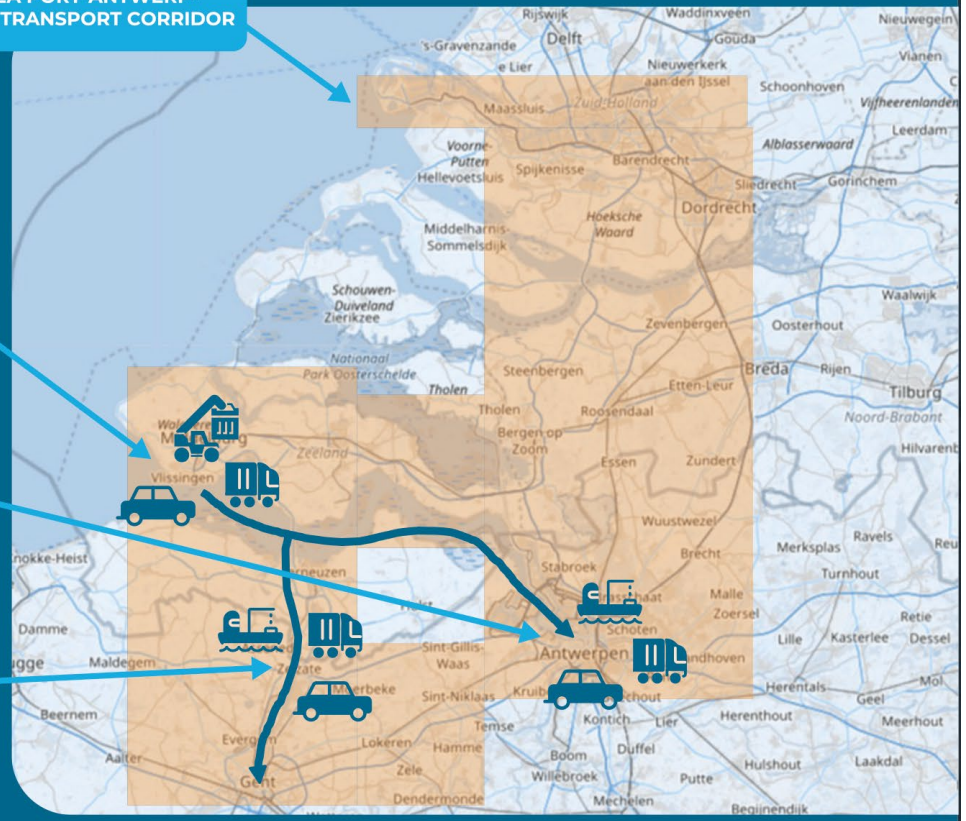
5G PILOT SITES

NORTH SEA PORT-ANTWERP-ROTTERDAM TRANSPORT CORRIDOR

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



CONSORTIUM AS A WHOLE

5G BLUEPRINT

Network operators

kpn

eurofiber

Vehicle OEMs

TOYOTA

Teleoperation OEMs

v-tron

roboauto

MWLC
More work less carbon

SEAFAR

Logistics

Transport

Kloosterboer

VERBRUGGE INTERNATIONAL n.v.

TRANSPORT Roosens

Ports

Port of Antwerp

North Sea Port

Software

[sentors]

room 40

NxtPort

Connected Mobility sector

BEMOBILE
a revolution in traffic

swarco
The Better Way. Every Day.

locatienet

Research institutes

imec

HAN_UNIVERSITY OF APPLIED SCIENCES

UNIVERSITY OF APPLIED SCIENCES

Business accelerator

MARTEL innovate

Impuls Zeeland

Governments

Ministry of Infrastructure and Water Management

Flanders
State of the Art

ADVISORY BOARD

5G BLUEPRINT

Regional government

Provincie Zeeland

STAD ANTWERPEN

Agentschap Telecom
Ministerie van Economische Zaken en Klimaat

Vehicle OEMs

FORD OTOSAN

DAF

Logistics sector

TTN

Port of Amsterdam International

ICBO
INTERNATIONAL CONTAINER BARGE OPERATORS

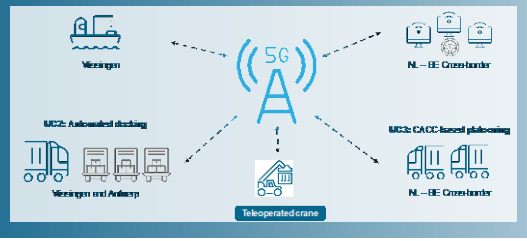
Port of Rotterdam

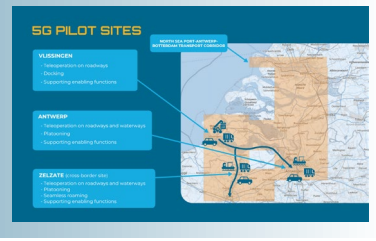
Associations

here

USE CASES & PILOT SITES – CONNECTIVITY REQUIREMENTS

USE CASES AND SITES



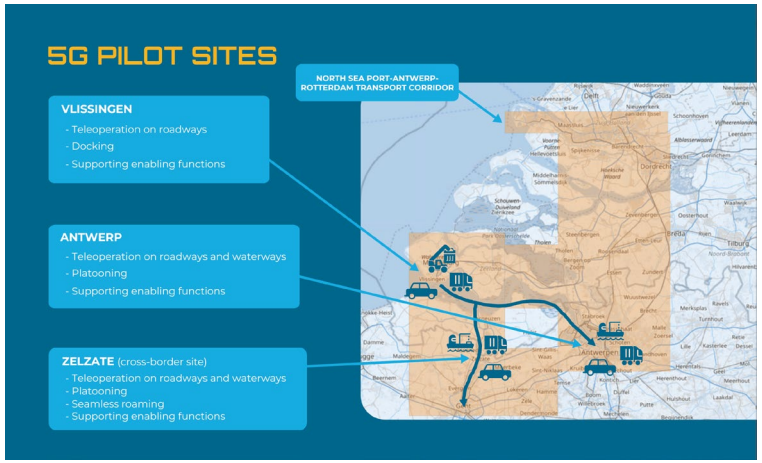


5G BLUEPRINT

Use-case	Vlissingen	Zelzate	Antwerp
UC1 Automated Barge Control		**Cross-border** *passive* 7 • Navigating canal with obstacle (bridge) at the border location	**"Hard" conditions** 4 7 • Navigating busy port
UC2 Automated driver-in-loop docking	**Full use case** 2 4 5 6 7 • Truck docking • Crane operation		*no test/demo only deployment* 1 2 4 5 7
UC3 CACC based Platooning	**Milk run** • Between terminal and MSP factory (same trajectory as UC4) 1 2 3 4 5 7	***Cross-border (tentative)*** • *PC5 Mode 3 or UU CACC handover (tentative)* 1 2 3 4 5 7	**Full use case** • Platooning on different road types • Co-existence with ITS-G5 signals
UC4 Remote Takeover Operation	**Terminal traffic & basic milk runs** • Confined area (terminal) • Short route over 50 km/h public roads and with limited traffic between terminal and MSP factory 1 3 4 5 7	**Cross-border, high speed, urban** • Crossing the border on 50 km/h public road, 90 km/h in Flanders • Urban environment with presence of iTLCs 1 2 3 4 5 7	**Milk runs** • Short route over 50 km/h public roads, including 2 parallel locks, between terminal and Transport Roosens 1 2 4 5 7 8

Enabling functions:

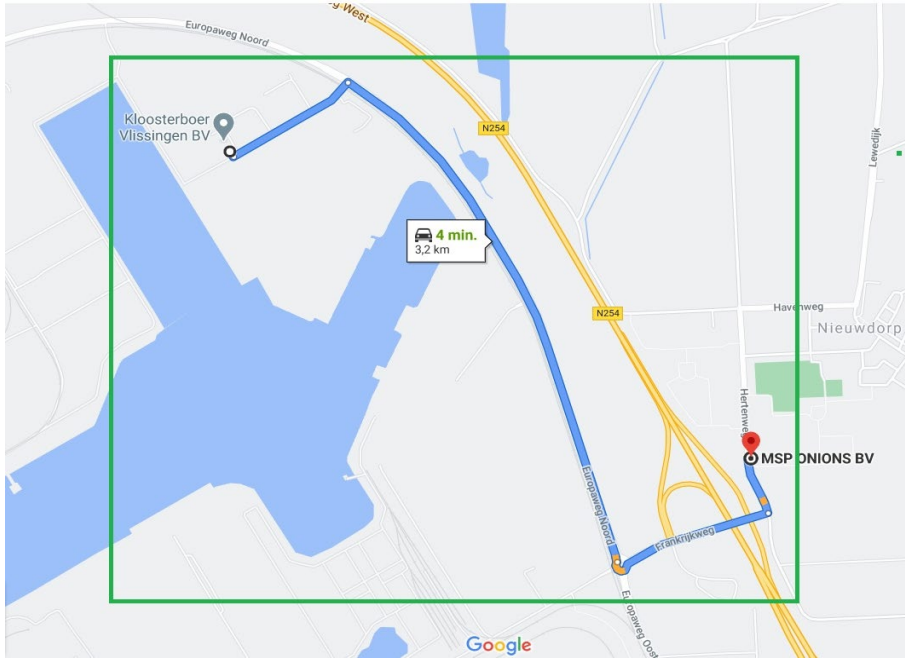
1 Enhanced awareness HMI
2 VRU interaction
3 Time slot reservation intersection
4 Distributed perception
5 Active collision avoidance
6 Container ID recognition
7 ETA sharing
8 Scene analytics

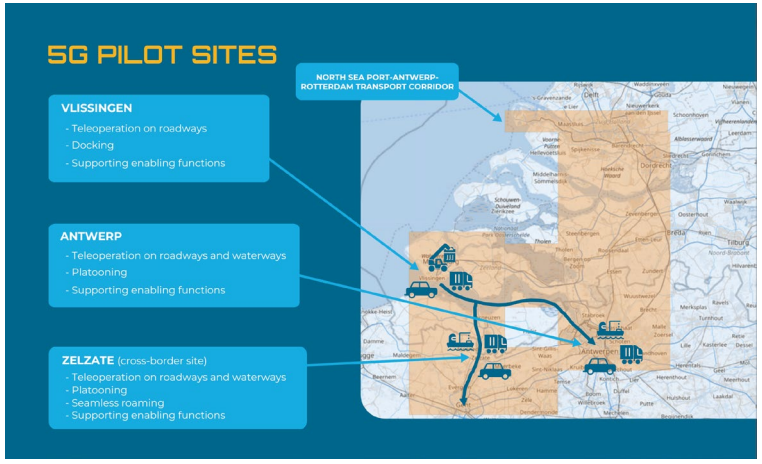


VLISSINGEN SITE DETAILS

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

VLISSINGEN SITE





ZELZATE SITE DETAILS

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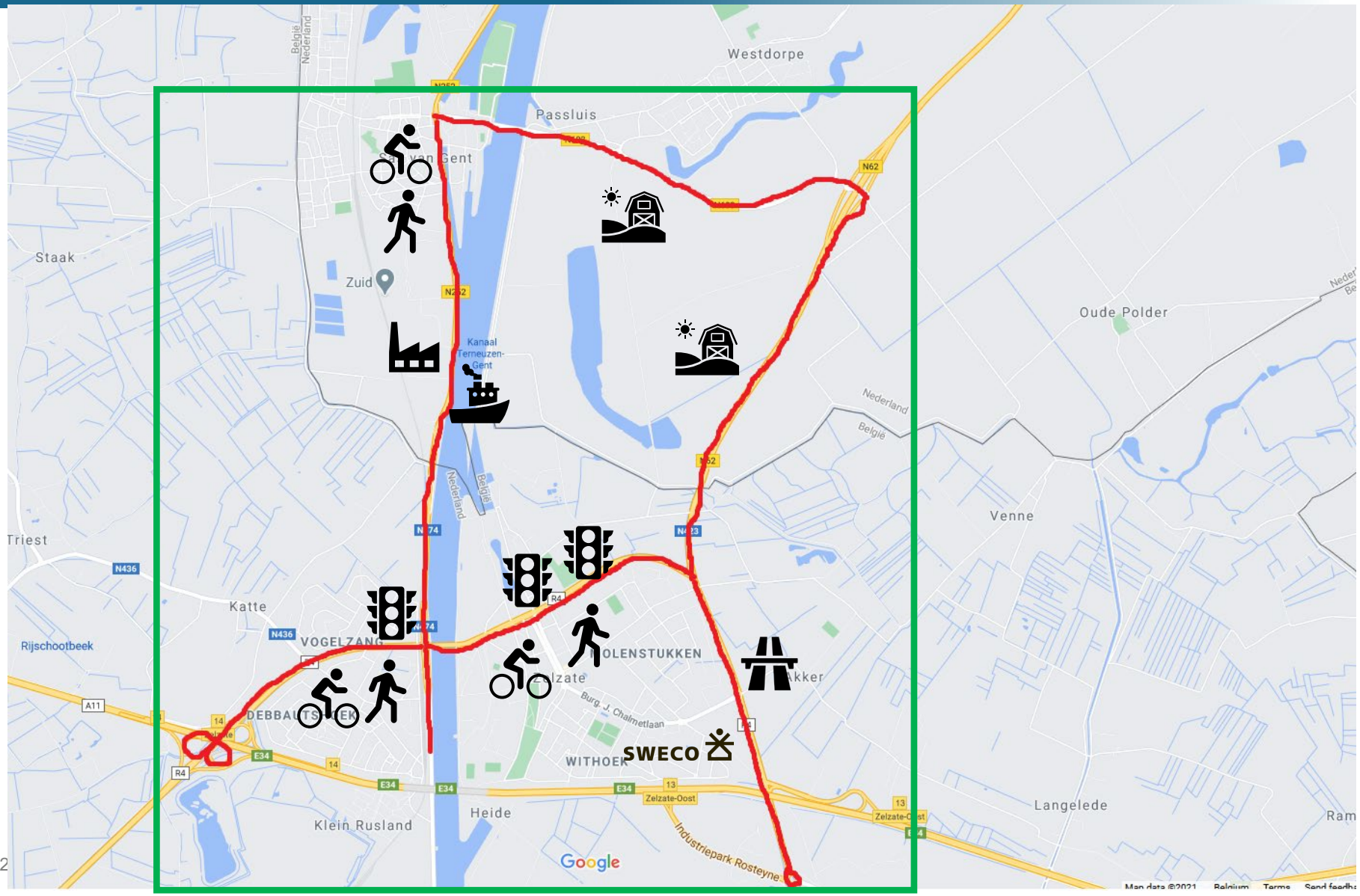
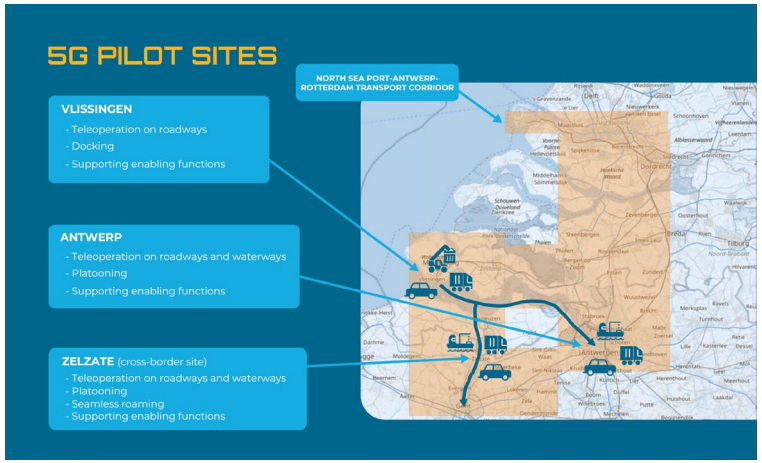
ZELZATE DETAILS





ANTWERP SITE DETAILS

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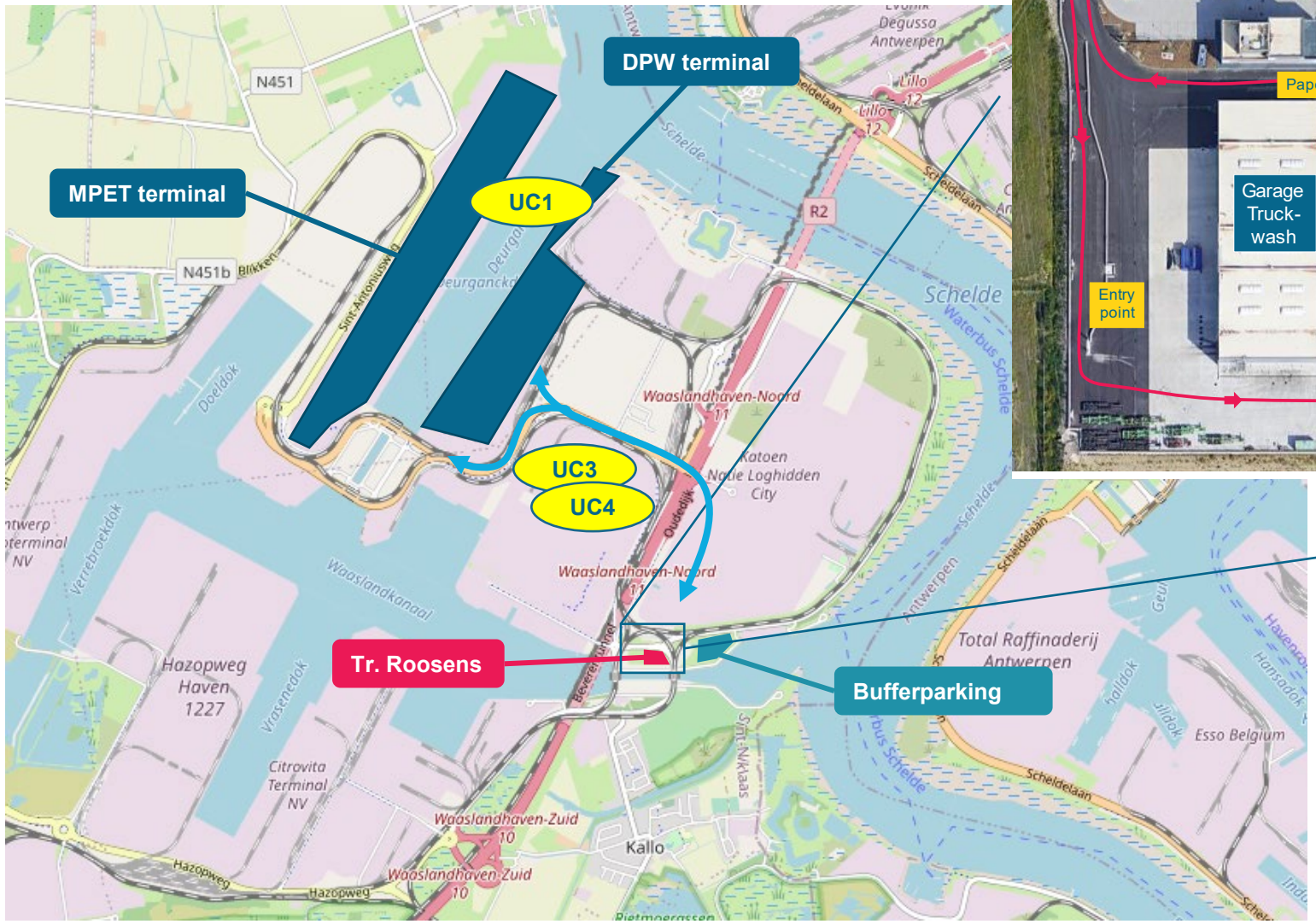
ANTWERP SITE DETAILS



CONNECTIVITY REQUIREMENTS IDENTIFIED

CONNECTIVITY REQUIREMENTS USE CASE 1

TABLE I
USE CASE 1 REQUIREMENTS

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

CONNECTIVITY REQUIREMENTS USE CASE 2

TABLE II
USE CASE 2 REQUIREMENTS

Description	HD Camera stream	HD Video screens (as fallback)	Vehicle control interface	Telemetry sources
From/To	TOV→TOC	TOV→TOC	TOC→TOV	TOV→TOC
Service Type	Uplink	Downlink	E2E	Uplink
Ideal Latency	<50ms	<50ms	<35ms	<100ms
Service Interruption	<150ms	<150ms	<150ms	<1s
Bandwidth Requirement	>5Mbps <25Mbps	>5Mbps <25Mbps	<2Mbps	<1Mbps
Device Scenario	Indoor mobile	Outdoor stationary	Indoor mobile + Outdoor stationary	Indoor mobile
Slice Type	eMBB	eMBB	URLLC/ hMTC	V2X
No. Flow	3 per vehicle	3 per vehicle	1 per vehicle	1 per vehicle

CONNECTIVITY REQUIREMENTS USE CASE 3 AND 4

TABLE III
USE CASE 3 REQUIREMENTS

Description	HD Camera stream	HD Video screens	Vehicle control interface	Telemetry sources	LiDAR data stream
From/To	TOV→TOC	TOV→TOC	TOC→TOV	TOV→TOC	TOV→TOV
Service Type	Uplink	Downlink	E2E	Uplink	V2V
Ideal latency	<50ms	<50ms	<35ms	<100ms	<100ms
Service Interruption	<150ms	<150ms	<150ms	<1s	<1s
Bandwidth Requirement	>5Mbps <25Mbps	>5Mbps <25Mbps	<2Mbps	<1Mbps	>20Mbps <100Mbps
UE Scenario	Outdoor mobile	Outdoor stationary	Outdoor mobile	Outdoor mobile	Outdoor mobile
Slice Type	eMBB	eMBB	URLLC/ hMTC	V2N	V2V sidelink
No. Flow	3 per vehicle	3 per vehicle	1 per vehicle	1 per vehicle	2 per vehicle

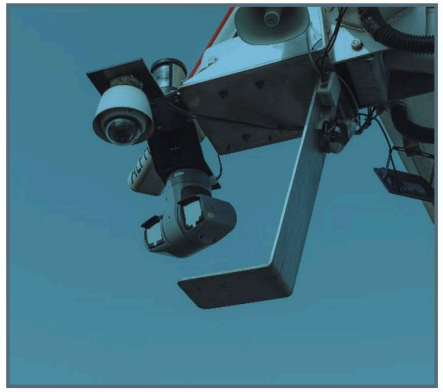
IMPLEMENTING USE CASES

USE CASE 1

Automated barge control

Vlissingen and Antwerp ports

5G BLUEPRINT



INITIAL RESULTS

Automated driver in loop docking

Vlissingen and Antwerp ports

5G BLUEPRINT

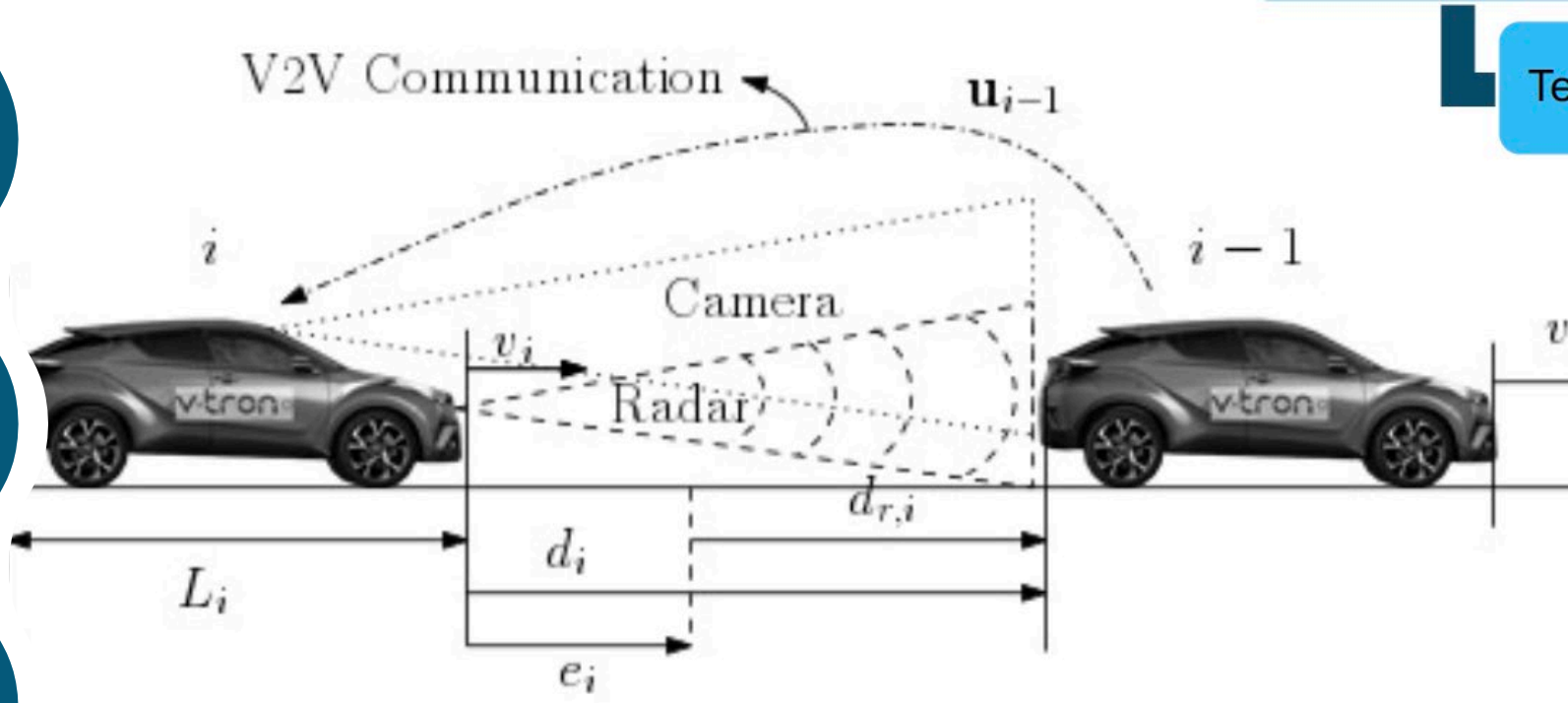
INITIAL RESULTS

Automated driver in loop docking

Vlissingen and Antwerp ports

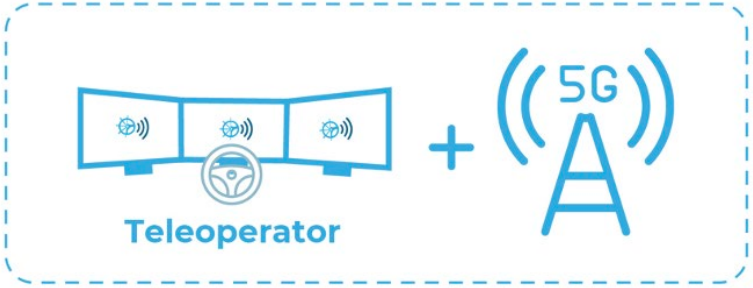
5G BLUEPRINT

INITIAL RESULTS



REMOTE TELEOPERATION USING 5G

CACC based platooning

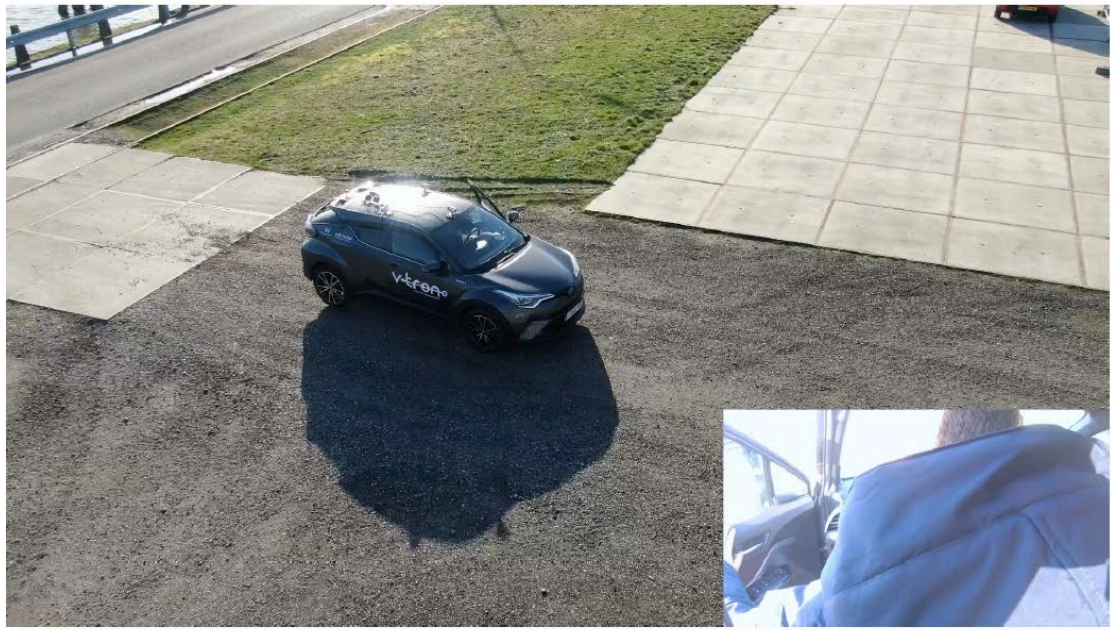


Remote take over

LESSONS LEARNT SO FAR

5G PERFORMANCE

- 4G testing - Arnhem

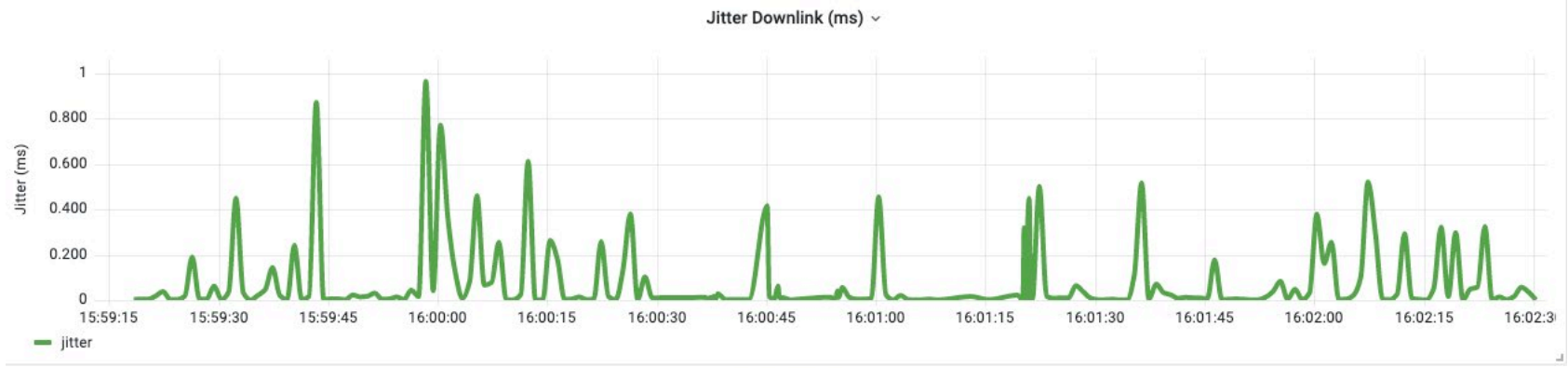


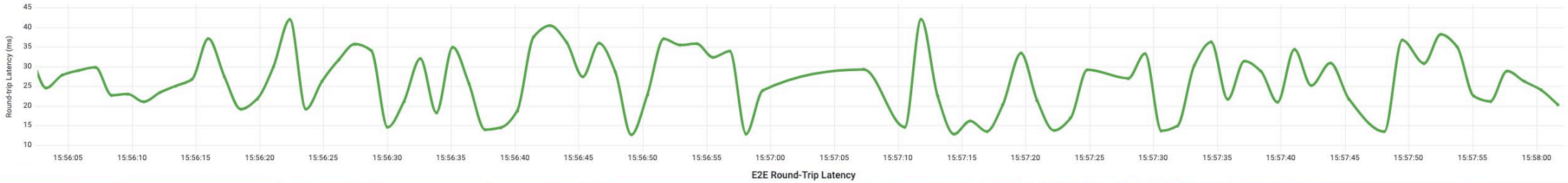
Max speed – 30 Kmph

- 5G testing – Helmond – SA/NSA

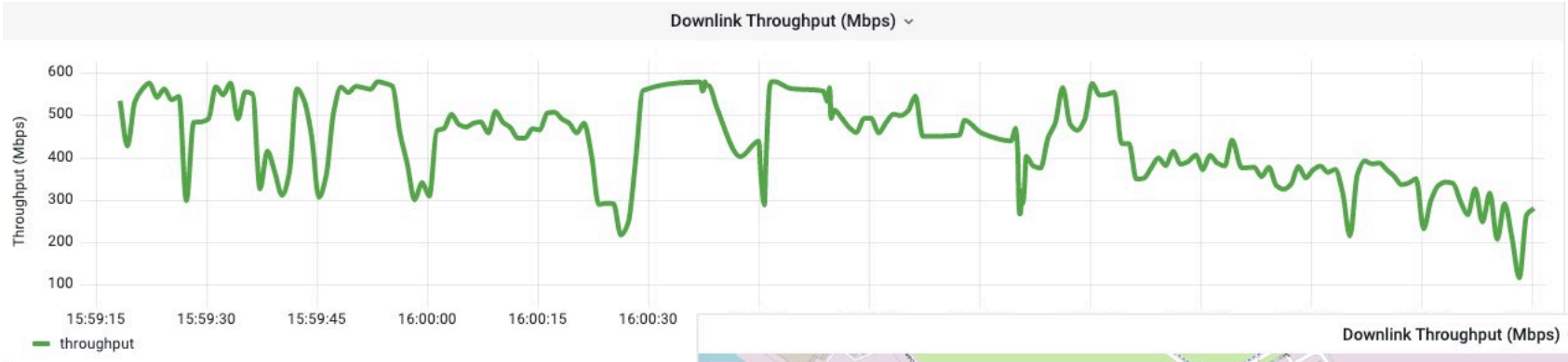
Max speed – 70 Kmph

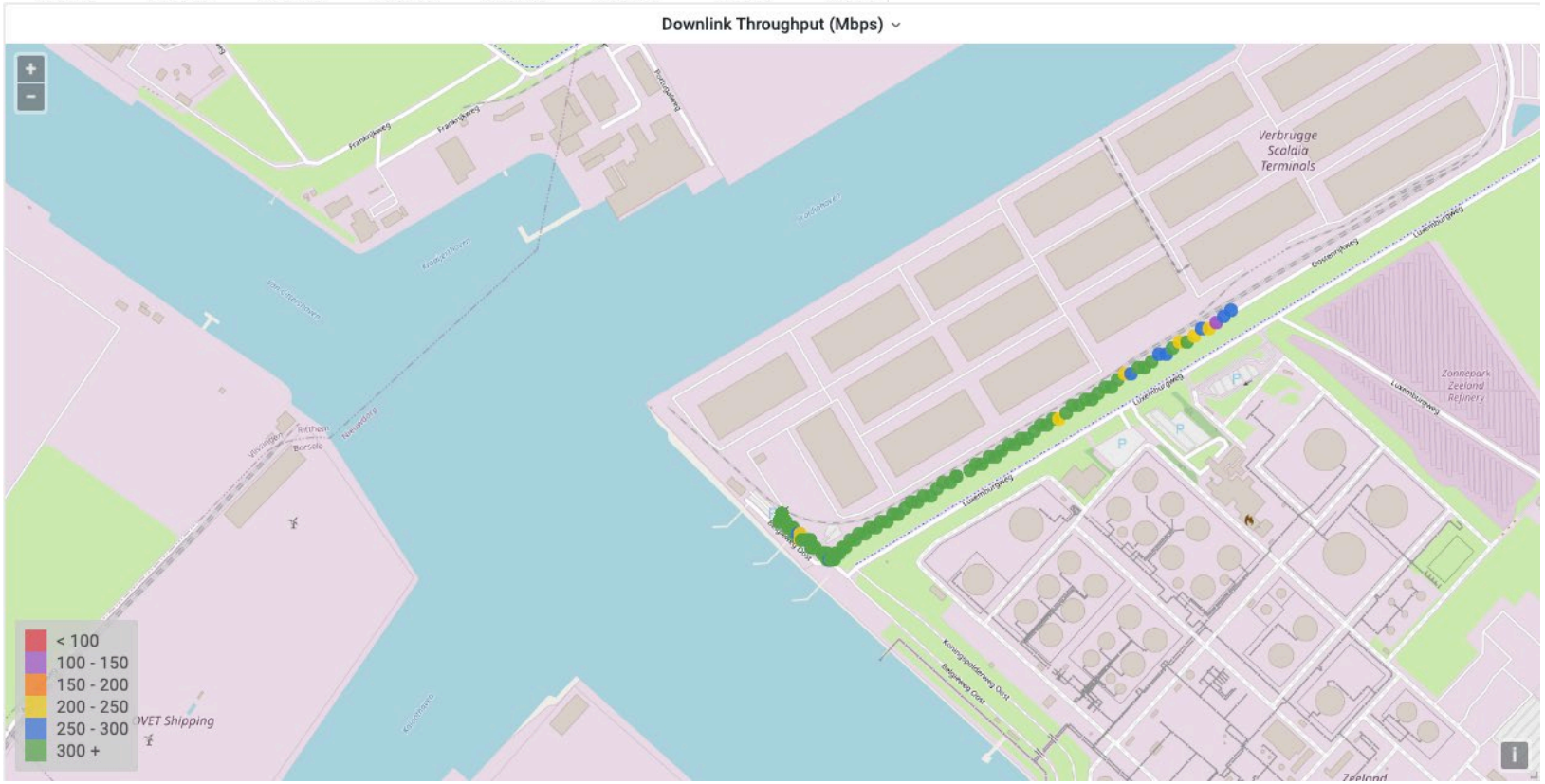
UNDERSTANDING LATENCIES (SA)





UNDERSTANDING BANDWIDTH CAPACITY (SA)





NSA will fulfill most UC Latency Requirements

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)

Use Case	Requirement		Fibocom SA 5QI-80		Digi NSA QCI-8		Digi SA 5QI-8		Sierra* SA 5QI-8	
	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL
UC 1: Barge Control	22	35	8.9	5.6	35.8	22.3	18,9	13,8	173	12.8
UC 2: TeleOperations	50	35	8.9	5.6	35.8	22.3	18,9	13,8	173	12.8
UC 3: Platooning	50	35	8.9	5.6	35.8	22.3	18,9	13,8	173	12.8
UC 4: Take Over	50	35	8.9	5.6	35.8	22.3	18,9	13,8	173	12.8

*) 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

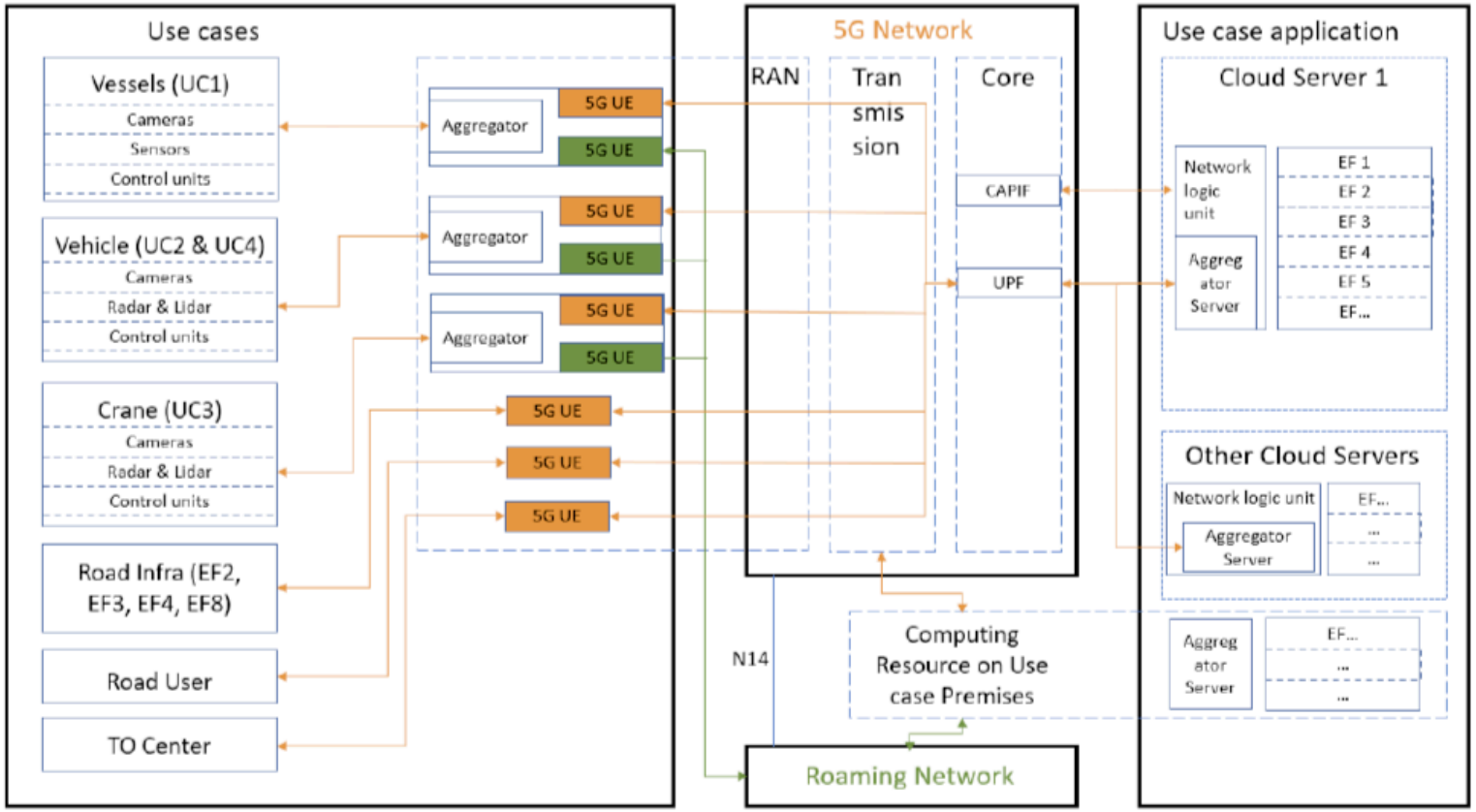
- Vehicle control message latency
- Calculated as a mean from values calculated from 200 sample batches

n = 500 (batches)	LTE	5G production network	5G test network
min	21.23	14.34	7.86
mean	26.4	18.4	11.38
max	45.6	31.4	19.8

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

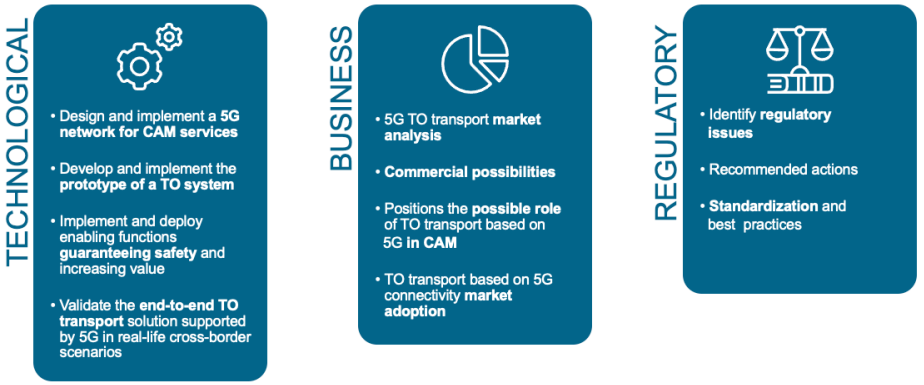


LESSONS LEARNT SO FAR…

- 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 sensoring 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)



5G BLUEPRINT

THANK YOU FOR YOUR ATTENTION

5GBlueprint.eu

THIS PROJECT IS PART OF THE 5G PUBLIC AND PRIVATE PARTNERSHIP

5G PPP WWW.5G-PPP.EU

5GBlueprint project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 952189