

# GR-TR Cross-Border Corridor

## Overview

Dr. Nazlı GÜNEY - Presenter  
IEEE 5G for CAM Summit, 11 May 2021



**5GMOBIX**



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 825496

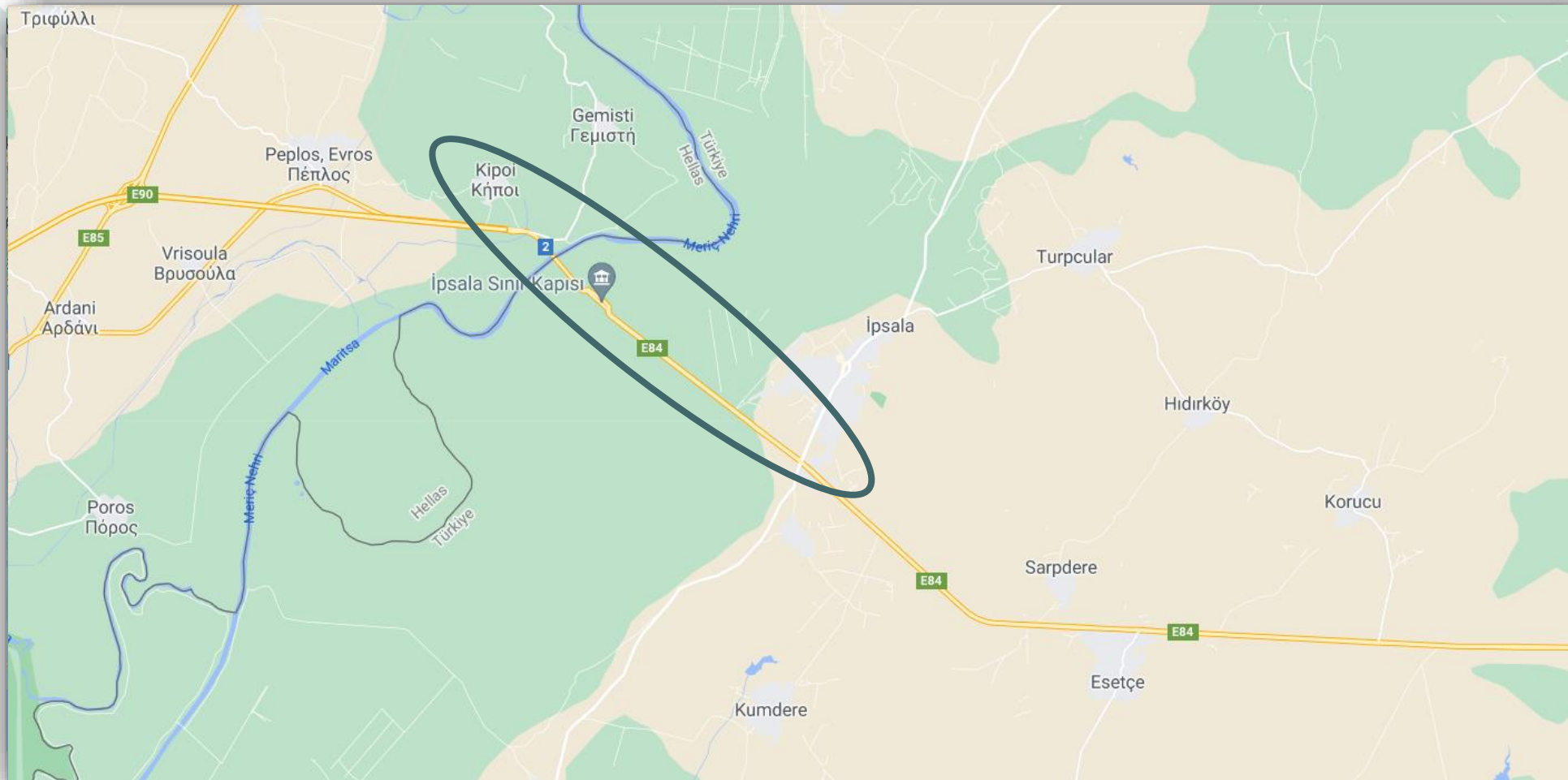
# Agenda

- Trial Location and GR-TR Partners
- User Stories
- 5G Network
- Verification and Integration
- CBC Trial Plan and Next Steps

# Trial Location and GR-TR Partners



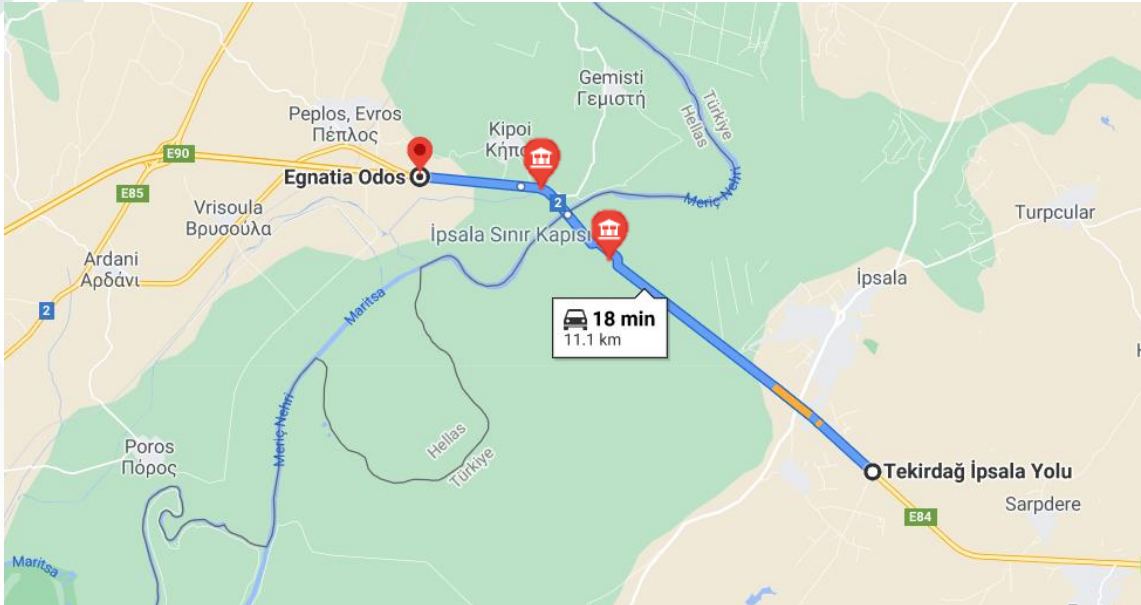
# Where is the GR-TR corridor?



# The GR-TR Border in Pictures



# Test and Trial Locations



Ipsala – Kipoi cross-border site

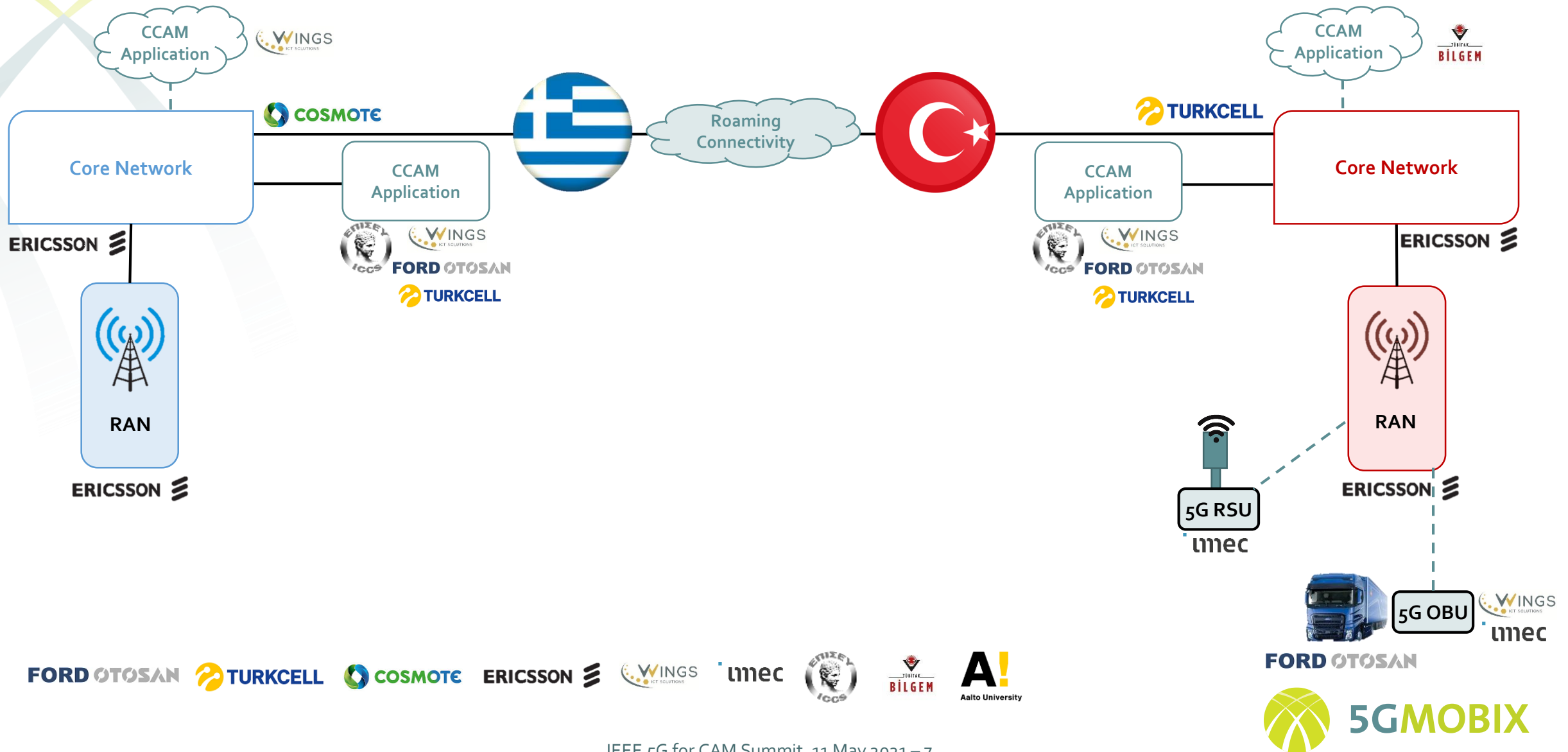
Border crossing  
permissions are needed









Ford Otosan test site to be used for long-term  
functionality development & testing

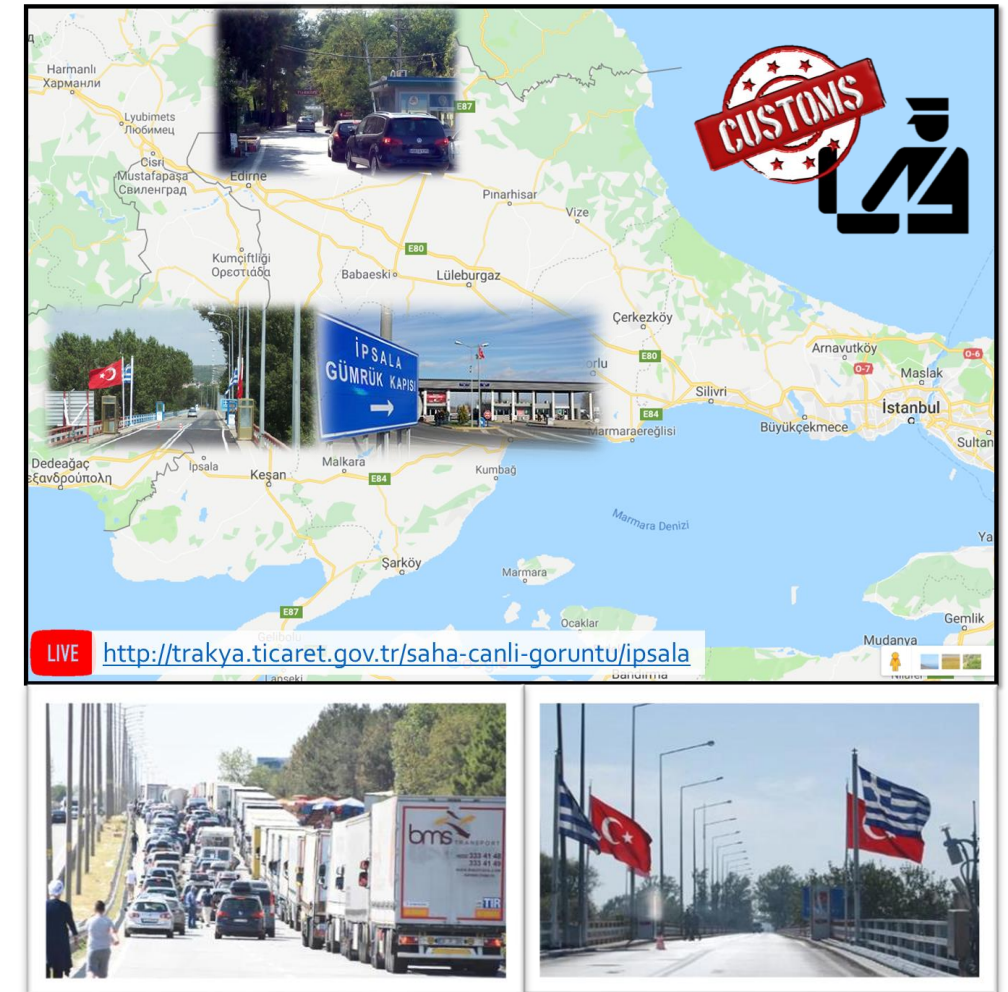
Knowledge & technology

# GR-TR Partners



# GR-TR Corridor in Numbers

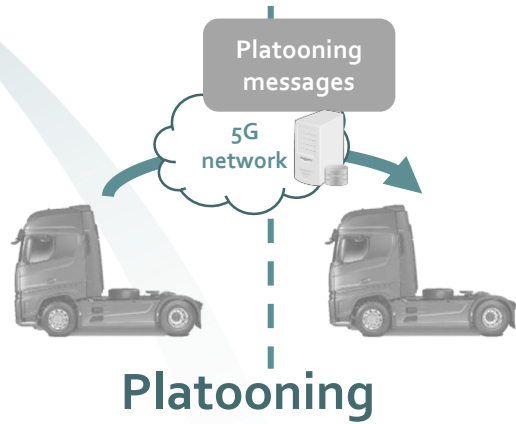
	Greece-Turkey Corridor	
	Location	CBC Ipsala – Kipoi border region
	5G Networks	NSA, 3 (TR) + 1 (GR) gNBs → 5 sites / 6 sectors + 1 additional gNB at the Ford Otosan plant
	Vehicles	2 2 trucks from Ford Otosan
	OBUs	3 2 OBUs from IMEC + 1 OBU from WINGS
	RSU / Edge App / Cloud	3 / 3 / 2 3 RSUs from IMEC + RSI from WINGS 3 edge applications + 2 Cloud applications
	User stories	4 <ul style="list-style-type: none"> <li>• Platooning</li> <li>• See-what-I-see</li> <li>• Truck Routing</li> <li>• Assisted Border-Crossing</li> </ul>



# User Stories

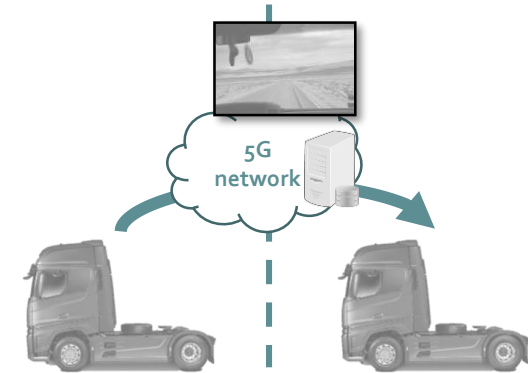


# GR-TR User stories



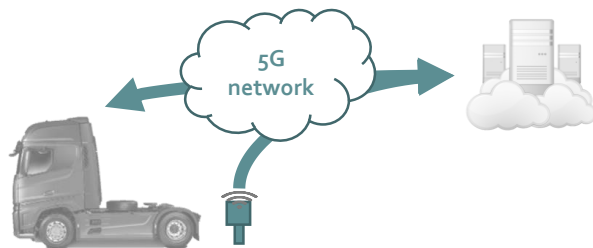
Platooning messages between leading truck and followers to affect their maneuvers

«Platooning»  
Use Case Category



**See what I see**

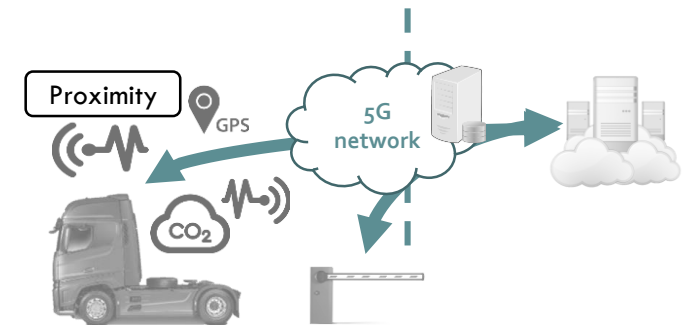
4K video streaming from one vehicle to the others



**Truck routing**

Remote operation of the vehicle at the customs site for X-ray checks

«Extended Sensors»  
Use Case Category



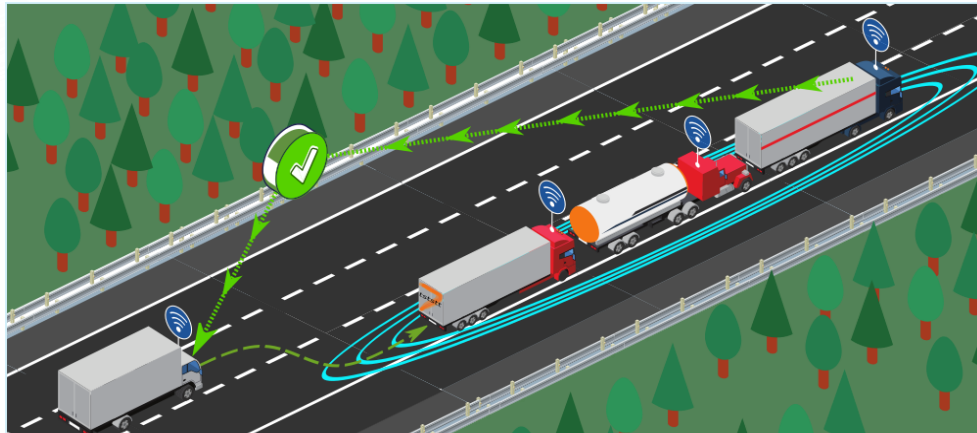
**Assisted Border Crossing**

Zero touch decision making: the vehicle is allowed to pass the border with no stops

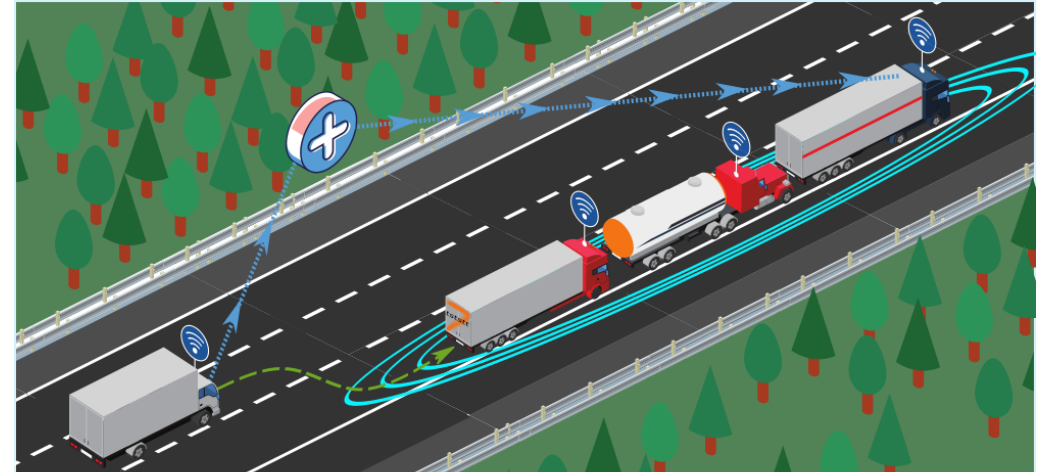
# Platooning with See-What-I-See



In your truck, you have a touchscreen in which you can search for nearby platoons.



The platoon leader will have to approve the request. If she does, you can then approach the platoon



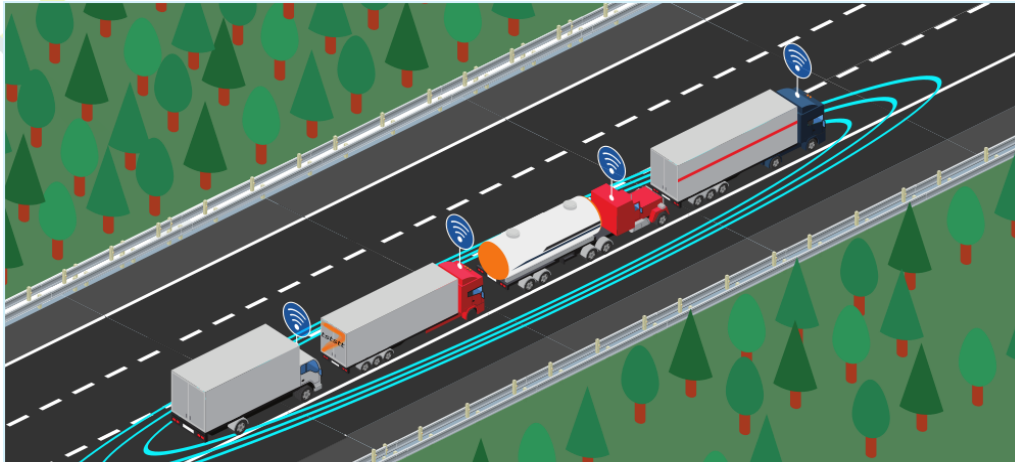
If one is found, then you can send a "join" request.



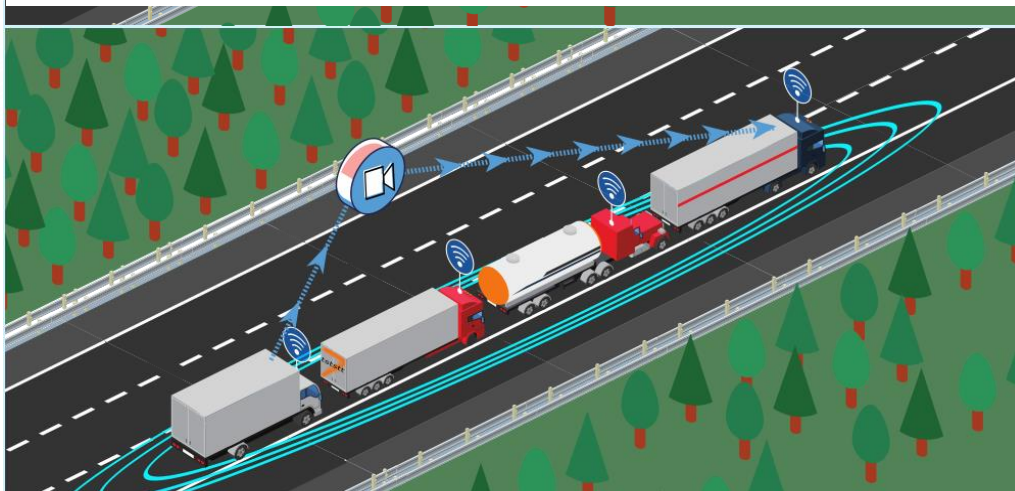
Approval and location is displayed on the touchscreen.



# Platooning with See-What-I-See (2)



At this point, the automatic system will take over and your vehicle will be automatically driven.



Once this integration is complete, you can request access from the leading driver to a "see what I see" application.

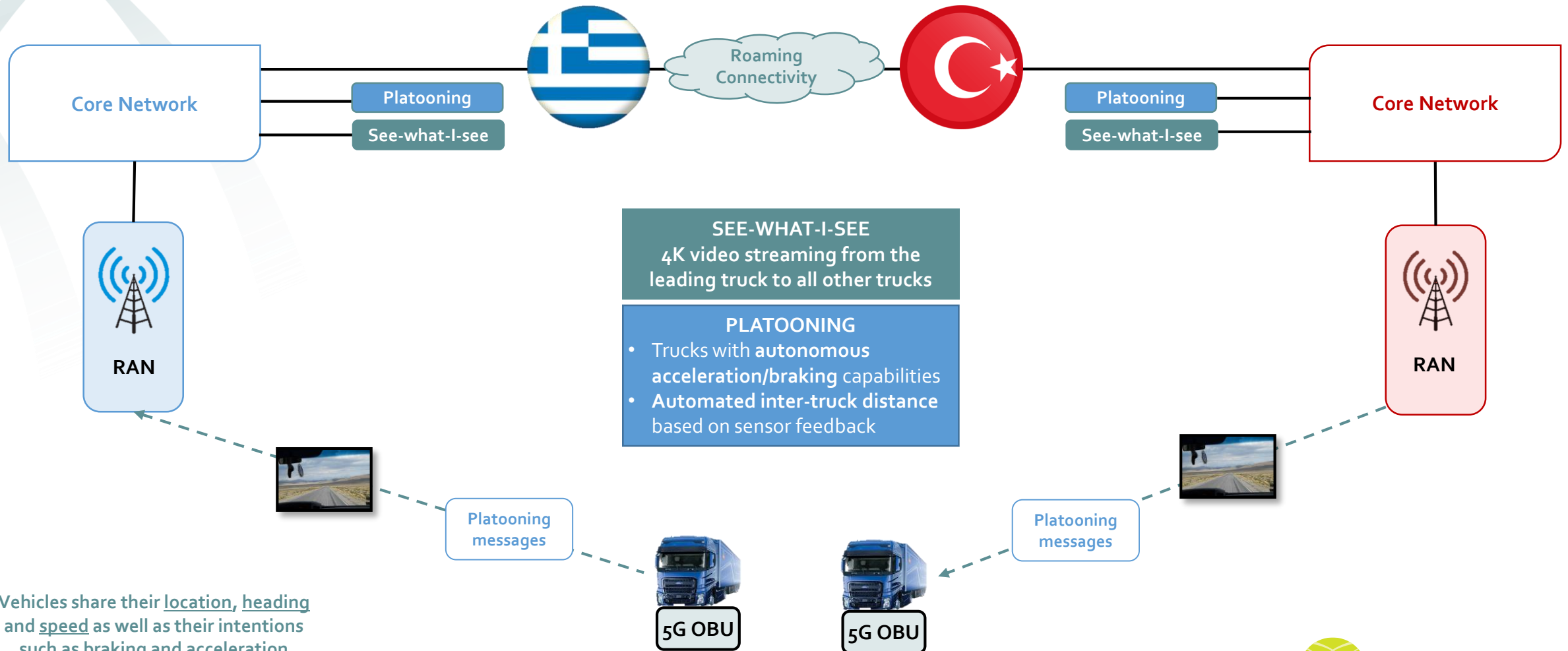


Application allows you to see a continuous stream from a camera positioned on the leader's windshield and pointed forward.



You can have a continuous vision of the road ahead of the leader and your cruise will be safer and more comfortable.

# Use Case Category: Platooning

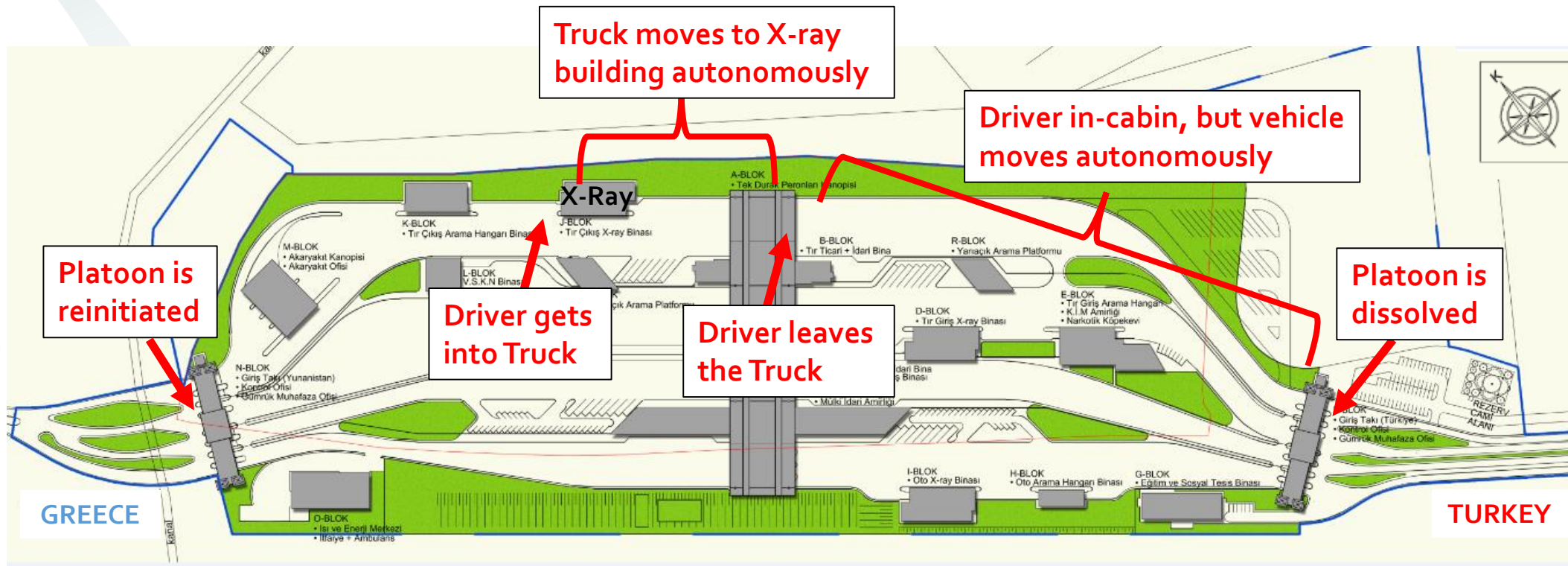


Vehicles share their location, heading and speed as well as their intentions such as braking and acceleration mainly over C-V2X Uu interface. PC5 will be available as redundancy.

# Truck Routing in Customs Site



Transfer platoon members from one end of the customs area the other much faster



SOURCE: Site map received from the customs authorities during the Ipsala visit on August 1st, 2019.

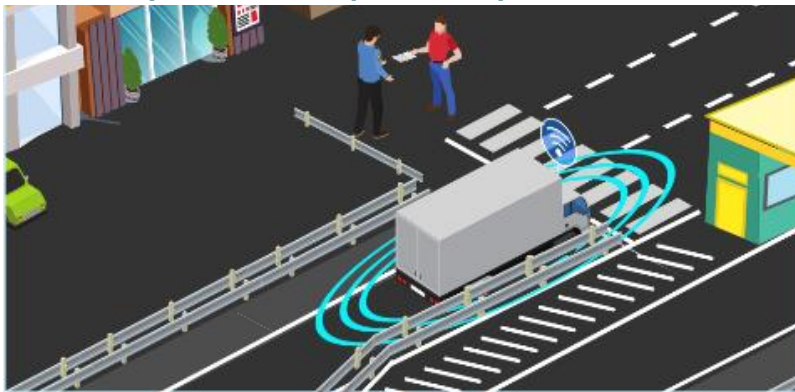
# Truck Routing in Customs Site (2)



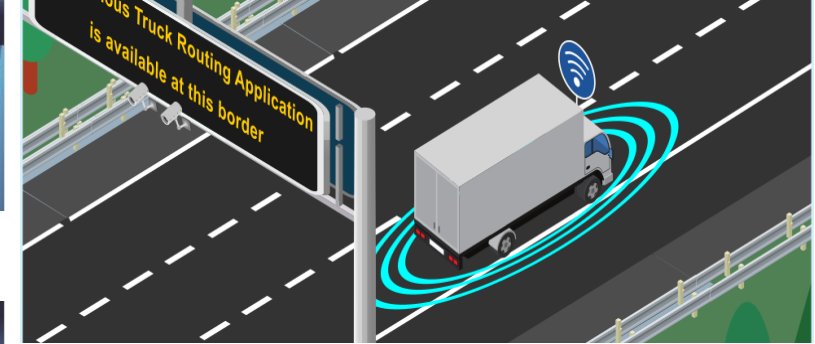
The road sign is seen



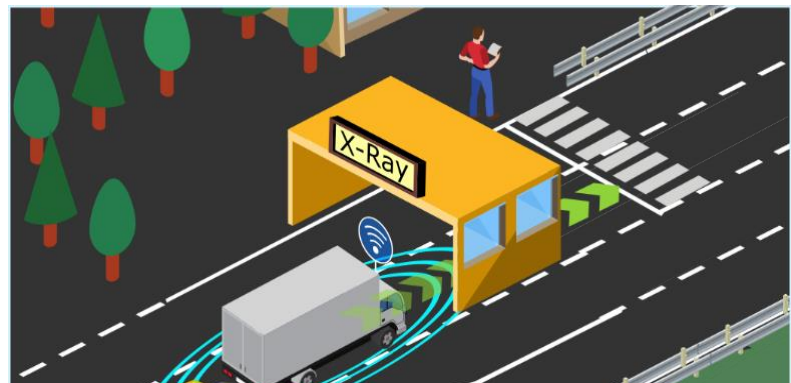
The driver gets off the truck for paper work and an x-ray check is requested by the authorities.



The driver is given the option to use the application. The plate is recognized.



The decision for x-ray inspection is made at the entrance of the customs zone.



The truck will be driven by a centralized control system to the x-ray building.

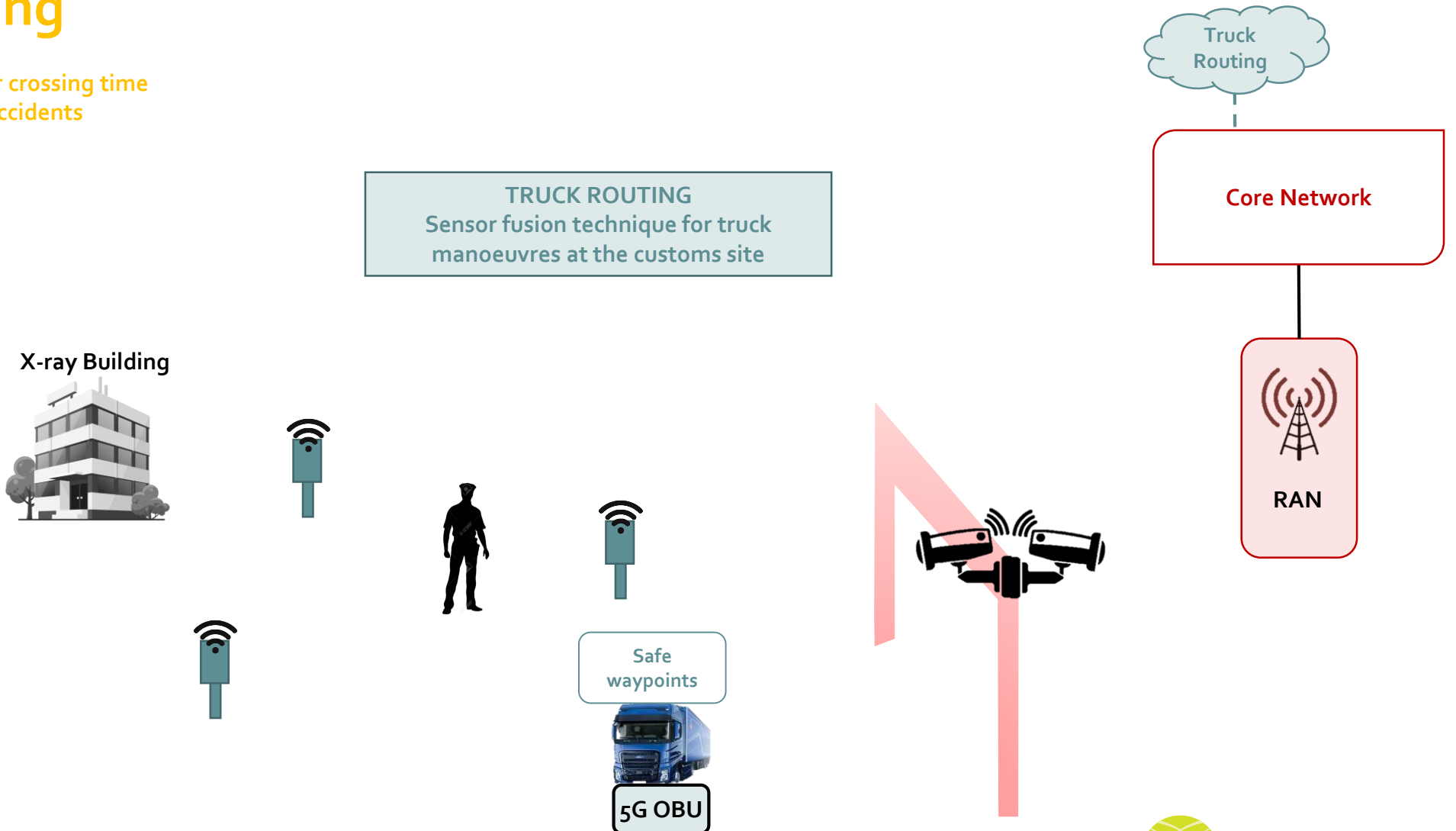


After the x-ray inspection, if everything is ok, the truck will be on its way.

# Use Case Category: Extended Sensors

## Truck Routing

Decreased average border crossing time  
and prevention of accidents



# Truck Routing Application

The diagram illustrates a truck routing application architecture and the types of data it processes.

**Architecture Diagram:**

- RSUs (Road Side Units):** Three RSUs are positioned along a road. Each RSU is equipped with C-V2X Antennas, 5G Antennas, a 4G Modem, and a LIDAR sensor. They are powered by External Power 220V.
- Truck (OBU):** An On-Board Unit (OBU) is mounted on a truck traveling on the road.
- TÜBİTAK Cloud:** A central cloud service that receives and processes data.
- Data Flow:**
  - RSUs send **Raw LiDAR Packages** (labeled 3) to the TÜBİTAK Cloud.
  - The TÜBİTAK Cloud **Listens UDP Port Sync. Messages** and **Calculates Path**.
  - The cloud sends **Truck Information** (labeled 3) to the OBU.
  - The cloud sends a **Path** (labeled 4) to the OBU.
  - RSUs also receive **Raw LiDAR Packages** (labeled 3) from the cloud.
- Environment:** The road scene includes an **X-Ray Building**.

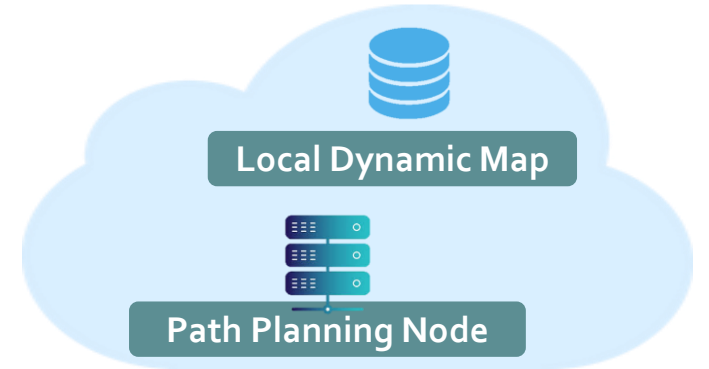
**Data Types Diagram:**

- Type 1: permanent static data (map)**
- Type 2: transient static data (traffic sign, landmarks, subways)**
- Type 3: transient dynamic data (weather situation, traffic information, signal phase)**
- Type 4: highly dynamic data (motor bikes, vehicles, pedestrians)**

**System Components:**

- Local Dynamic Map:** Represented by a database icon.
- Path Planning Node:** Represented by a server rack icon.

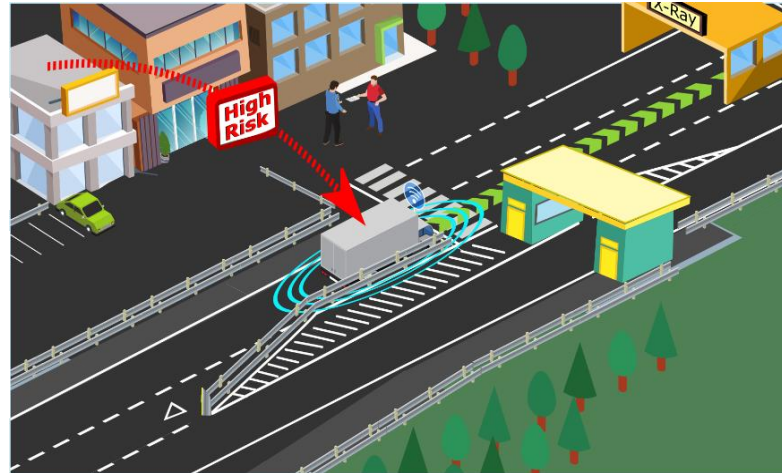
**5GMOBIX Logo:** A green circular logo with a stylized 'X' shape inside, followed by the text **5GMOBIX**.



# Assisted Border Crossing

Perform Risk / Threat assessment based on input from CO<sub>2</sub> sensor and truck manifest

All cargo in a vehicle is identified based on a wireless technology (e.g. NFC). Identified cargo inventory *cross-checked with the vehicle's documentation / manifest*



If NO human / livestock / unauthorized cargo, issue "Low Risk" and instruct a –zero touch– border crossing


Customs agents location monitored via Proximity & GPS readings



Autonomous vehicles are instructed to stop or change course

Once the vehicle's trajectory is determined to potentially lead to a collision or an accident with customs agents an alert is issued.

# Assisted Border Crossing (2)





## Login Form

username

password

**Log In**

Don't have an account? Register now!

## Registration Form

firstname

lastname


email

username


password

Pick your role:

**Register**




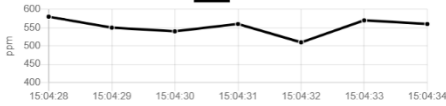
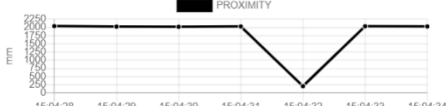
Sensor	Last Value	Last Timestamp	Status
CO <sub>2</sub>	560	15:04:34	●
Proximity	2030	15:04:34	●
License Plate	AIN 323212	15:04:34	●
NFC #ID	<input type="text" value=""/>	15:04:34	●



## Driver GUI

[Log Out](#)




Message / Alert Board	
Access Granted	15:04:30
Access Granted	15:04:31
Attention! You are coming to an object	15:04:32
Access Granted	15:04:33
Access Granted	15:04:34


ECU Information	
Speed:	2.0
RPM:	34.0
Temp:	900.0
Fuel:	0.0

Cargo Information	
Temperature:	33.5
Humidity:	88.2
Luminosity:	
Vibration:	



## Customs Agent GUI


[Log Out](#)



☐ Manually Open Barrier

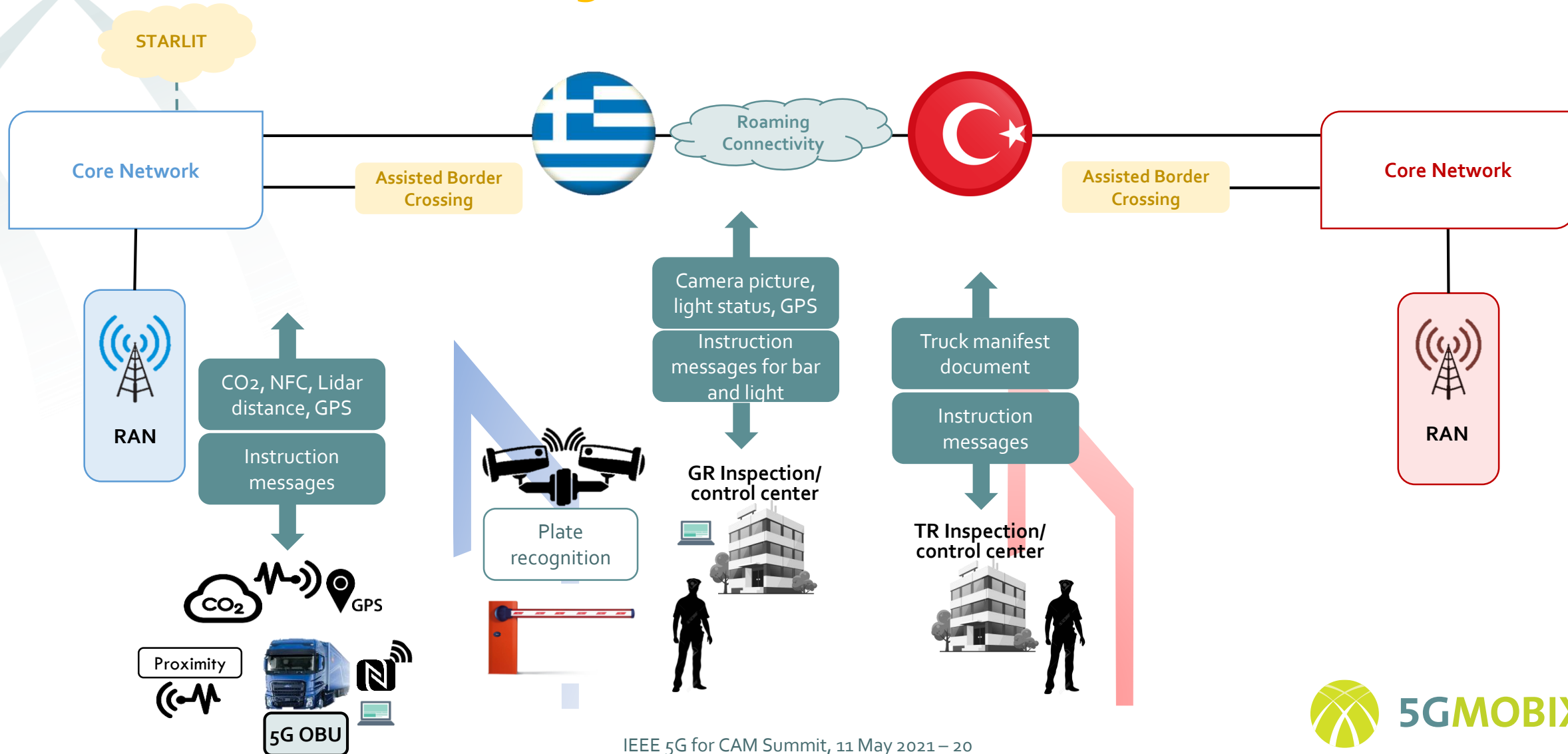
Truck ID	Date	Time	Status
Truck: AIN 323212	13 / 10 / 2020	14:49:03	Cleared

Message / Alert Board	
Access Granted	14:48:59
Increased Co2 level	14:49:00
Access Granted	14:49:01
Access Granted	14:49:02
Access Granted	14:49:03



# Use Case Category: Extended Sensors

## Assisted Border Crossing

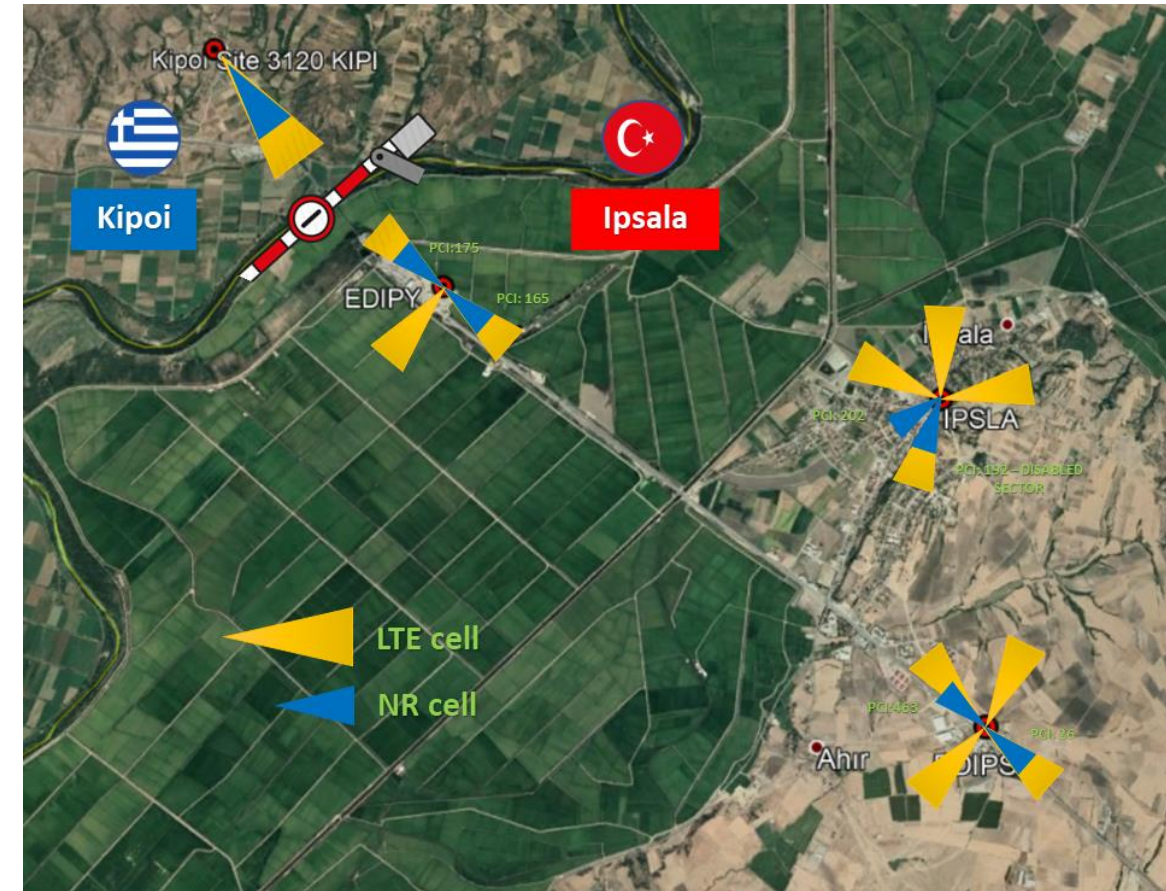
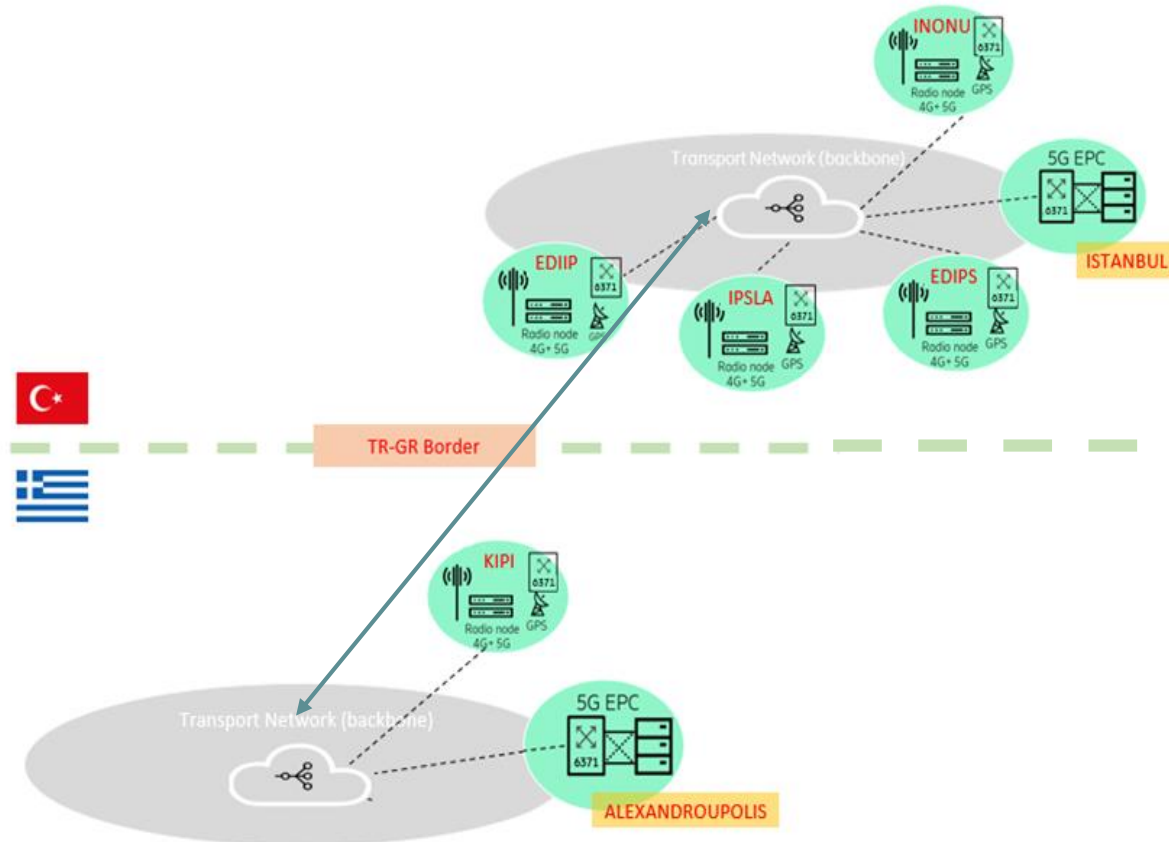


# 5G Network

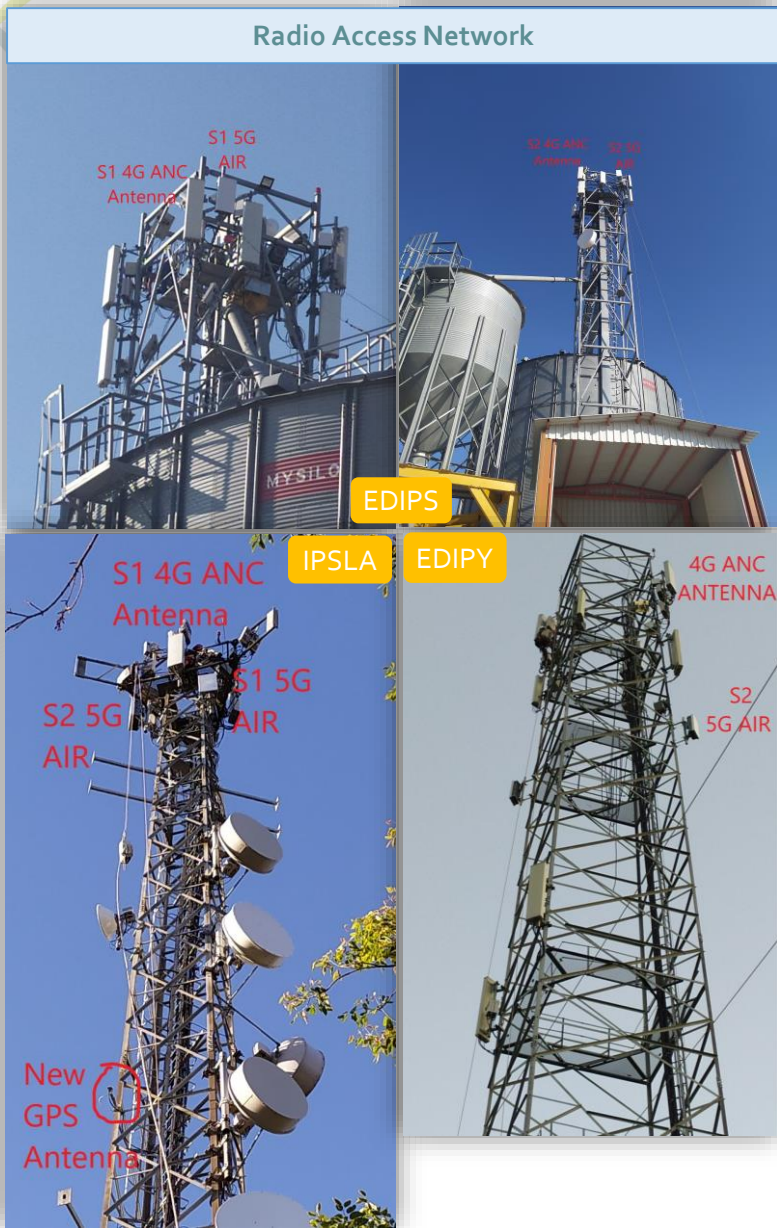


# 5G Network - Architecture

Network type	Frequency bands	Sites
NSA Option 3X	LTE: 2600 MHz band NR: 3600-3800 MHz (B78G – B43)	EDIPIY, IPSLA, EDIPS, INONU
NSA Option 3X	LTE: 2600 MHz band NR: 3420-3600 MHz (B78F – B42F)	KIPOI



# 5G Network - Pictures



NETWORK ENGINEERING STEPS	
	Network Design
	Radio Access Network Deployment
	Integration
	Transport Network Upgrades
	Core Network Installation
	Configuration
	End-to-end Network Testing
	IP Network Implementation
	Inter-operator Testing



ENM@Psalidi  
(Management Servers at  
COSMOTE Athens)



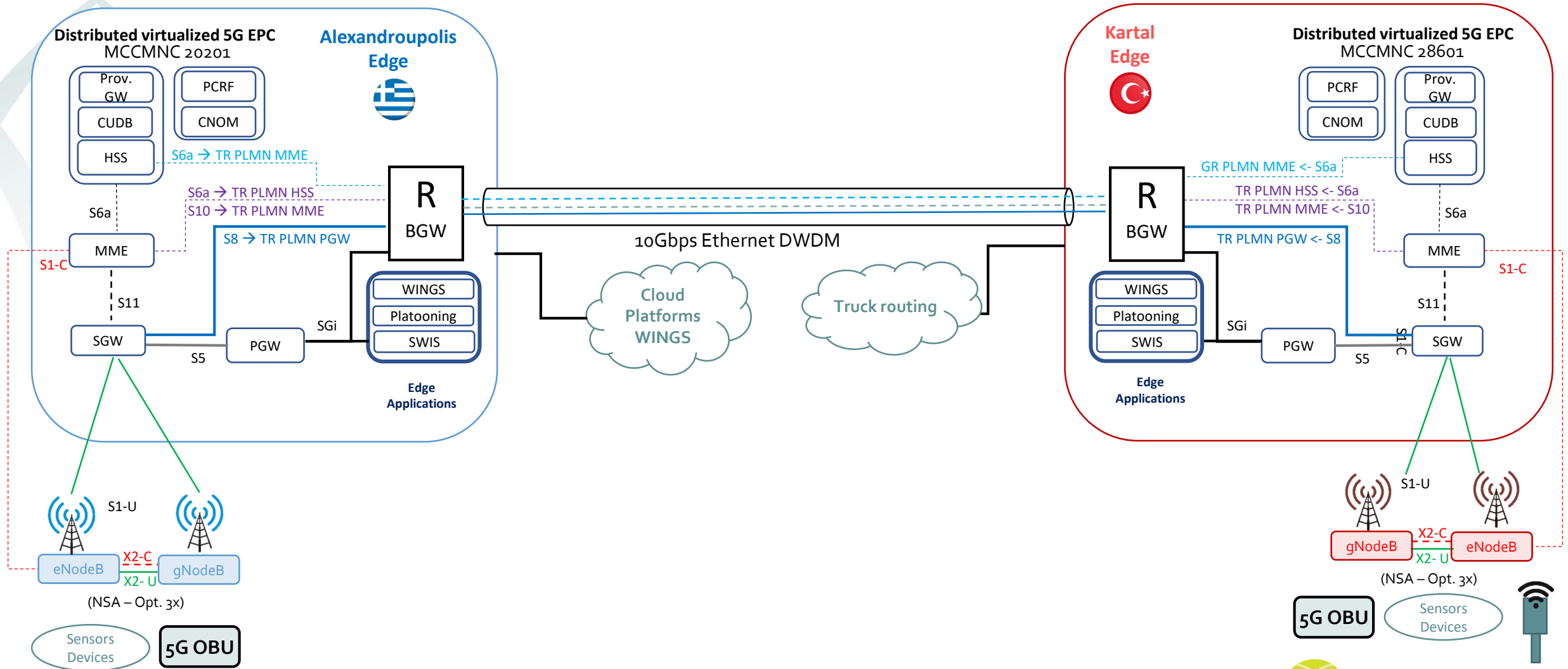
Core at the Edge of  
@Alexandroupoli



KIPOI



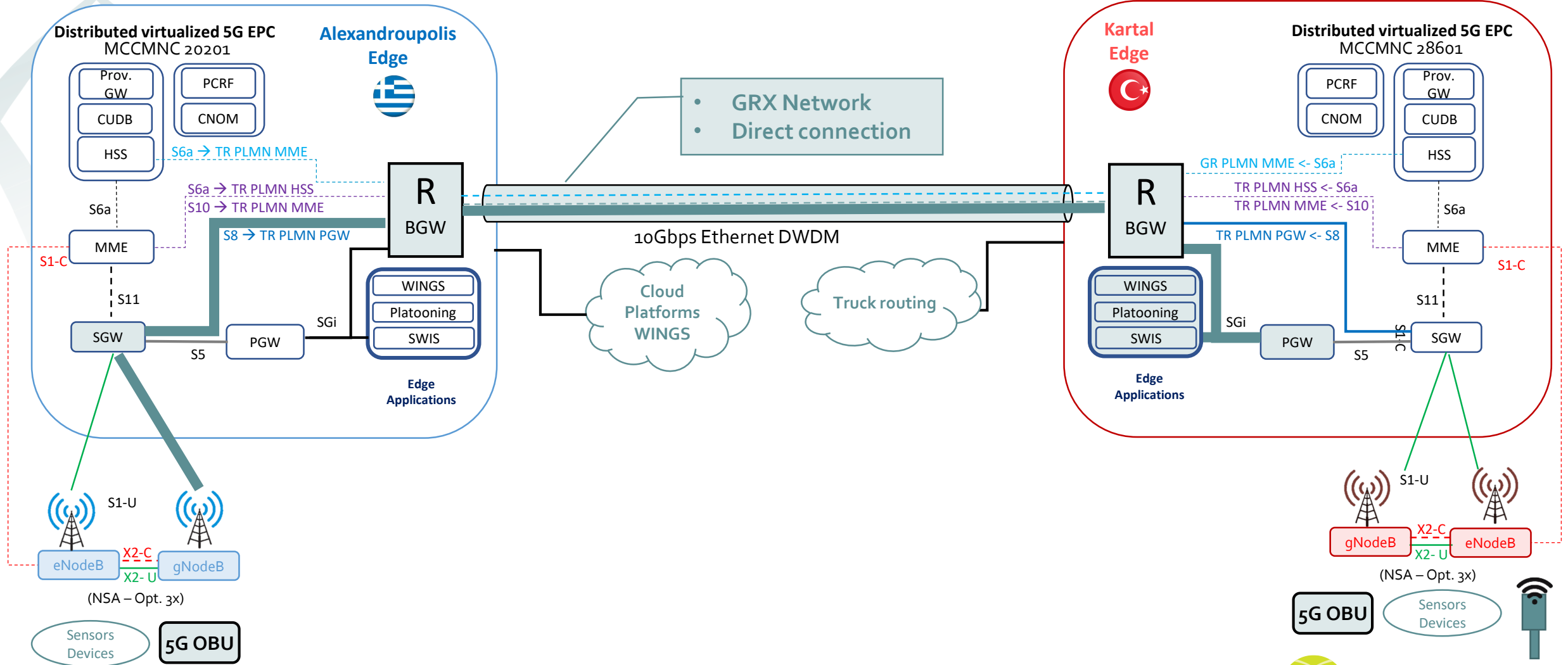
# 5G Network - Interfaces



# 5G Network - Roaming

## Home Routed

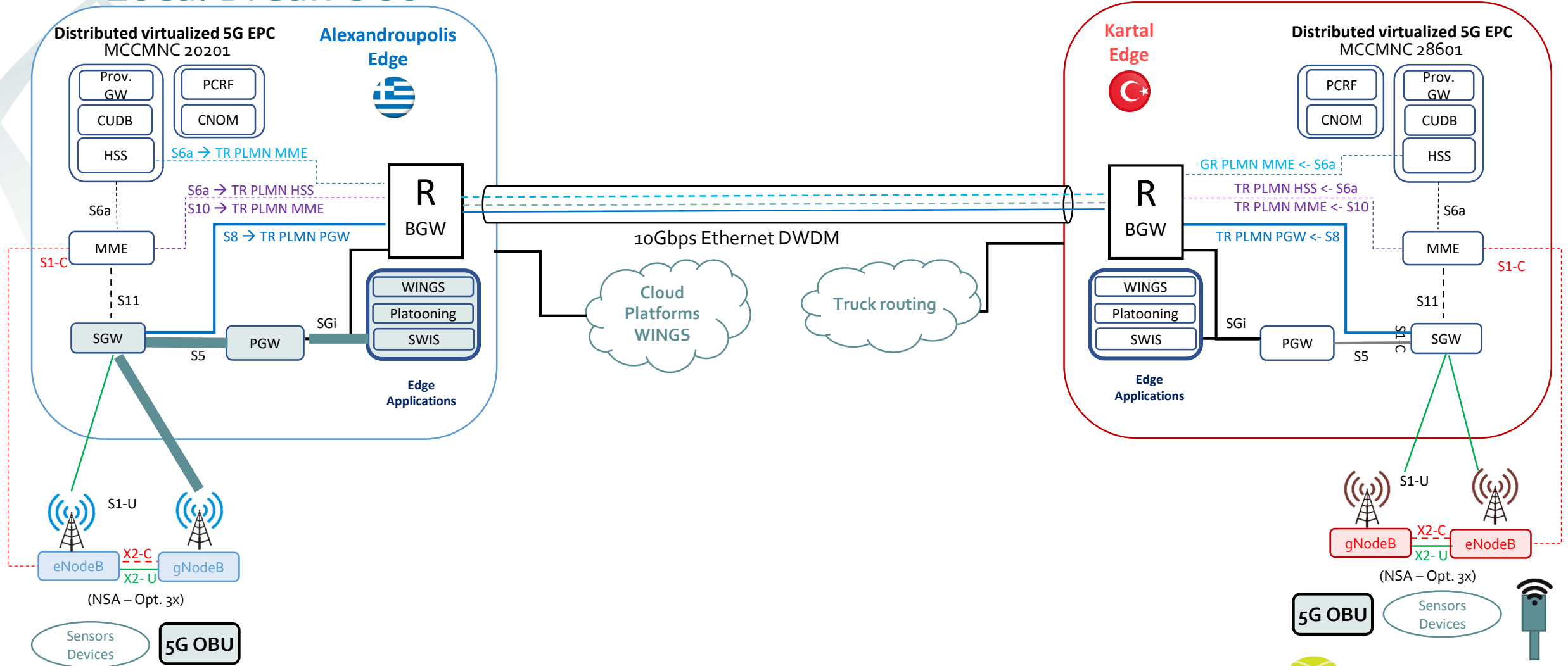
✓ Service continuity  
✗ Large latency



# 5G Network - Roaming

## Local Break Out

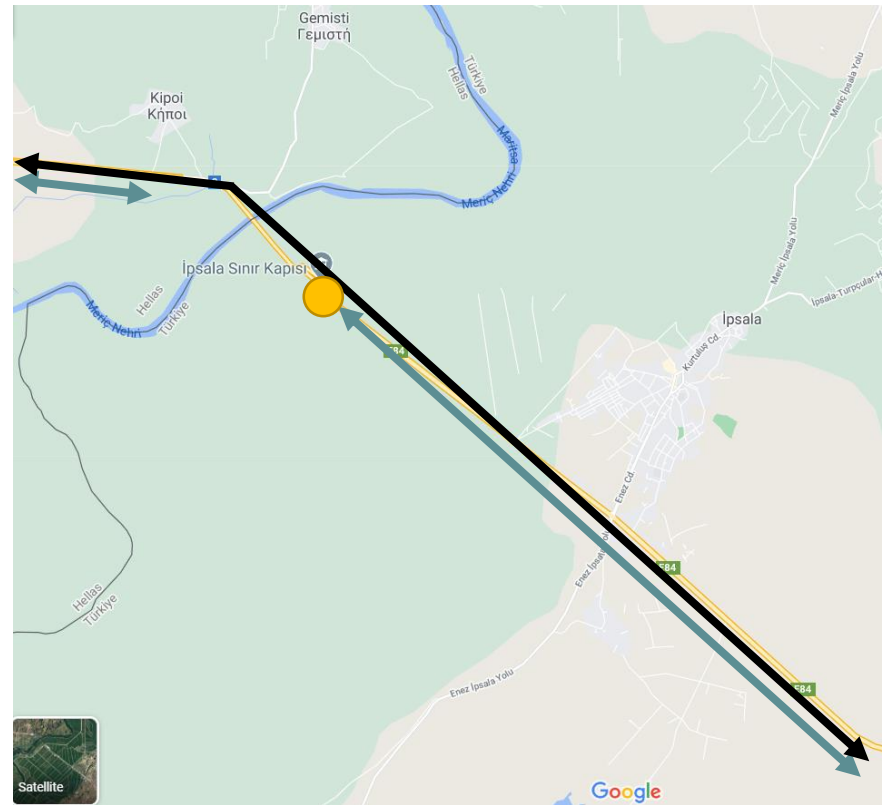
✗ Service disruption  
✓ Short latency



# 5G Network - Inter-PLMN Handover



GR-TR inter-PLMN handover area



Platooning



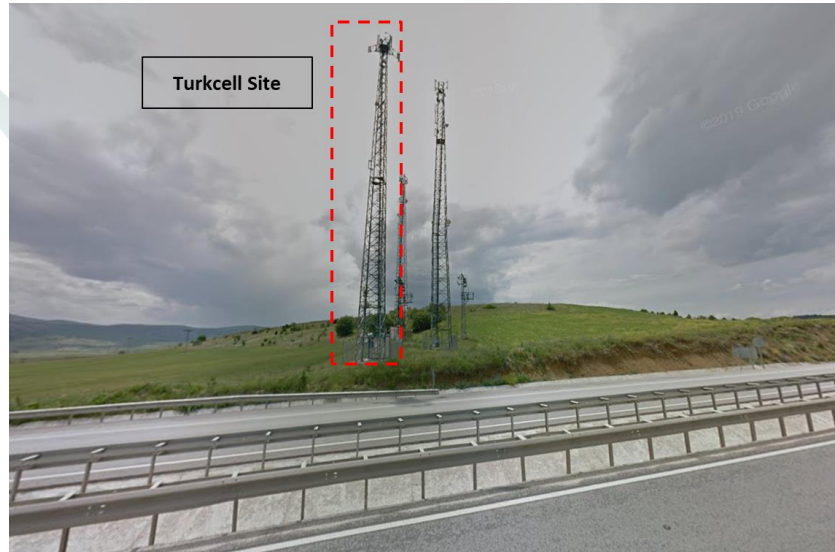
Truck Routing



See-what-I-see /  
Assisted Border  
Crossing



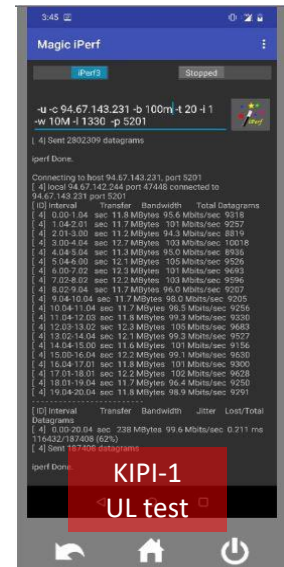
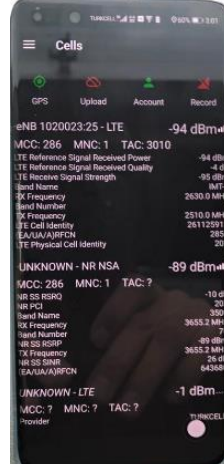
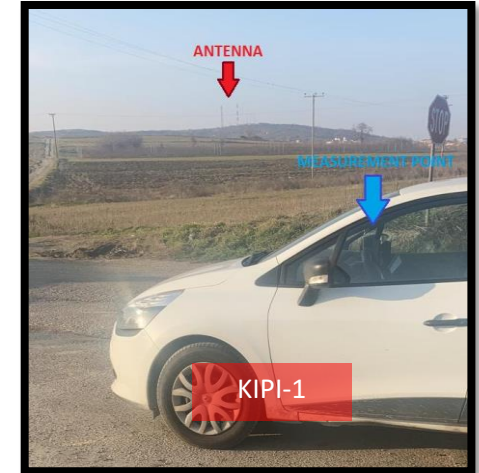
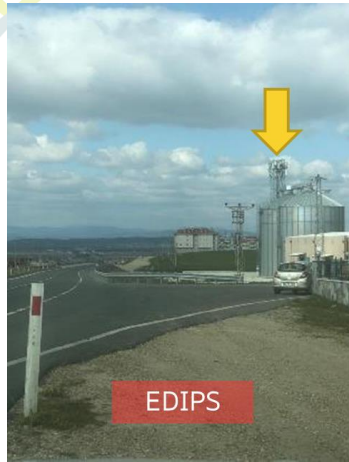
# 5G Network - Test @Eskişehir



TEST TYPE	Test Run 1	Test Scenario	COMMENTS
TCP_UL Cell Capacity	✓		Successfully Completed

- L2600MHz [5MHzBW] was the anchor cell and NR3500 [100MHz BW] is used for the 5G service.
- IPERF server is used for **synthetic** traffic. The server wasn't directly connected to the PGW.
- Transmission backbone supports 900Mbps and also carries live traffic.

# Stationary Tests



All sectors were tested individually close to the site location. Their UL/DL performances were checked. TDD:424 (SSC:383) was used and UL&DL Carrier aggregation was activated at Turkcell's cells.



Legend:

- 500 Gbps Backbone Total (8bps)
- 100,000 (1.34%)
- 300,000 (3.85%)
- 1,000,000 (12.7%)
- 2,000,000 (25.4%)
- 3,000,000 (38.1%)
- 4,000,000 (50.8%)
- 5,000,000 (63.5%)
- 6,000,000 (76.2%)
- 7,000,000 (88.9%)
- 8,000,000 (101.6%)
- 9,000,000 (114.3%)
- 10,000,000 (127.0%)
- 11,000,000 (139.7%)
- 12,000,000 (152.4%)
- 13,000,000 (165.1%)
- 14,000,000 (177.8%)
- 15,000,000 (190.5%)
- 16,000,000 (203.2%)
- 17,000,000 (215.9%)
- 18,000,000 (228.6%)
- 19,000,000 (241.3%)
- 20,000,000 (254.0%)
- 21,000,000 (266.7%)
- 22,000,000 (279.4%)
- 23,000,000 (292.1%)
- 24,000,000 (304.8%)
- 25,000,000 (317.5%)
- 26,000,000 (330.2%)
- 27,000,000 (342.9%)
- 28,000,000 (355.6%)
- 29,000,000 (368.3%)
- 30,000,000 (381.0%)
- 31,000,000 (393.7%)
- 32,000,000 (406.4%)
- 33,000,000 (419.1%)
- 34,000,000 (431.8%)
- 35,000,000 (444.5%)
- 36,000,000 (457.2%)
- 37,000,000 (469.9%)
- 38,000,000 (482.6%)
- 39,000,000 (495.3%)
- 40,000,000 (508.0%)
- 41,000,000 (520.7%)
- 42,000,000 (533.4%)
- 43,000,000 (546.1%)
- 44,000,000 (558.8%)
- 45,000,000 (571.5%)
- 46,000,000 (584.2%)
- 47,000,000 (596.9%)
- 48,000,000 (609.6%)
- 49,000,000 (622.3%)
- 50,000,000 (635.0%)
- 51,000,000 (647.7%)
- 52,000,000 (660.4%)
- 53,000,000 (673.1%)
- 54,000,000 (685.8%)
- 55,000,000 (698.5%)
- 56,000,000 (711.2%)
- 57,000,000 (723.9%)
- 58,000,000 (736.6%)
- 59,000,000 (749.3%)
- 60,000,000 (762.0%)
- 61,000,000 (774.7%)
- 62,000,000 (787.4%)
- 63,000,000 (800.1%)
- 64,000,000 (812.8%)
- 65,000,000 (825.5%)
- 66,000,000 (838.2%)
- 67,000,000 (850.9%)
- 68,000,000 (863.6%)
- 69,000,000 (876.3%)
- 70,000,000 (889.0%)
- 71,000,000 (901.7%)
- 72,000,000 (914.4%)
- 73,000,000 (927.1%)
- 74,000,000 (939.8%)
- 75,000,000 (952.5%)
- 76,000,000 (965.2%)
- 77,000,000 (977.9%)
- 78,000,000 (990.6%)
- 79,000,000 (1003.3%)
- 80,000,000 (1016.0%)
- 81,000,000 (1028.7%)
- 82,000,000 (1041.4%)
- 83,000,000 (1054.1%)
- 84,000,000 (1066.8%)
- 85,000,000 (1079.5%)
- 86,000,000 (1092.2%)
- 87,000,000 (1104.9%)
- 88,000,000 (1117.6%)
- 89,000,000 (1130.3%)
- 90,000,000 (1143.0%)
- 91,000,000 (1155.7%)
- 92,000,000 (1168.4%)
- 93,000,000 (1181.1%)
- 94,000,000 (1193.8%)
- 95,000,000 (1206.5%)
- 96,000,000 (1219.2%)
- 97,000,000 (1231.9%)
- 98,000,000 (1244.6%)
- 99,000,000 (1257.3%)
- 100,000,000 (1270.0%)

[illegible]

The chart displays the MAC Layer Downlink Throughput in kbps. The Y-axis ranges from 0 to 1,200,000 kbps. The X-axis shows time slots from 16:21:40 to 12:41:20. The legend indicates three data series: NR-MAC-DL-THR (red), NR-MAC-DL-SCH-THR (orange), and TOTAL-MAC-DL-THR (purple). The orange series represents the majority of the throughput, with peaks reaching over 1,000,000 kbps. The red series shows lower throughput, generally below 200,000 kbps. The purple series represents the total throughput, which is the sum of the red and orange series.

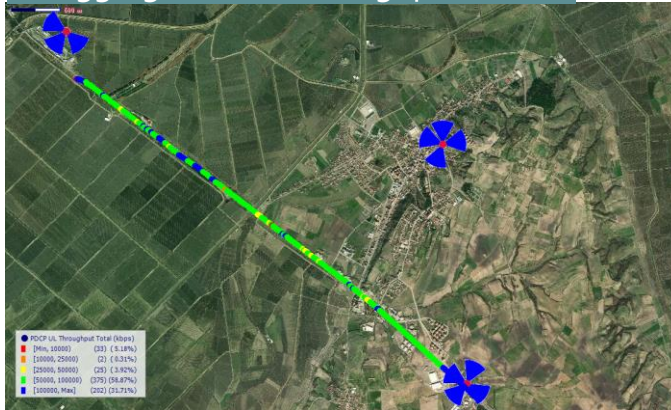
- ! Transmission backbone capacity is important for reaching peak rates. Transmission links are shared with the live network.

LOCATION	Peak DL	Average DL
Ipsala	862 Mbps	88% of total samples >100Mbps for DL
Kipoi	716 Mbps/	100% of total samples >100Mbps for DL

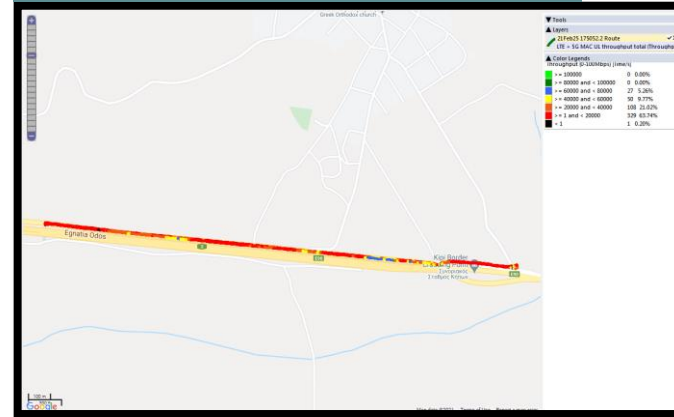
# Mobility Test results - Upload



Aggregated UL Throughput (TR)

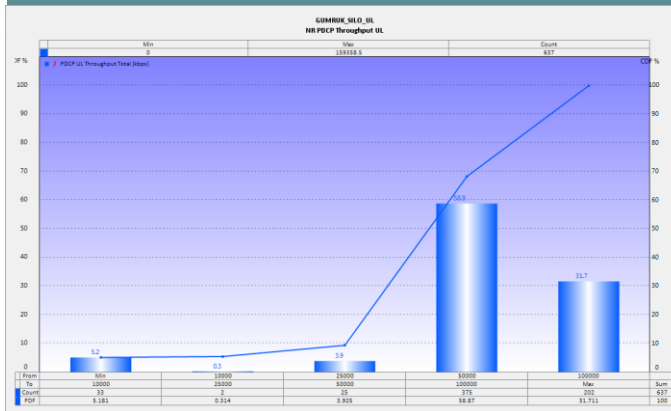


Aggregated UL Throughput (GR)

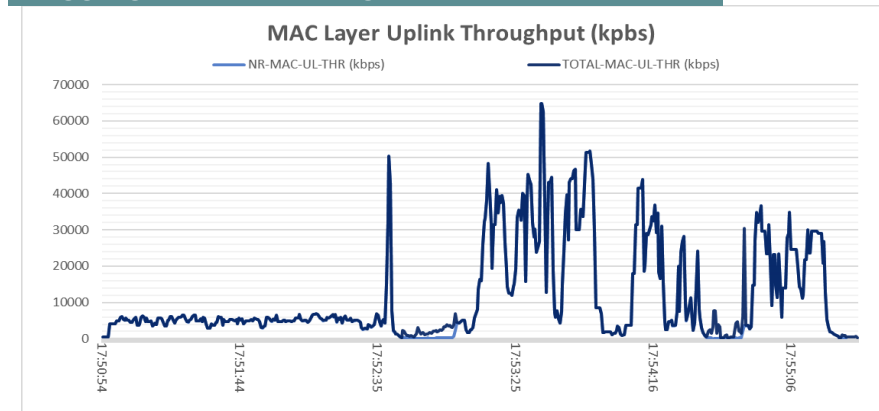


! LTE-NR Uplink Carrier aggregation feature was not activated on the GR site.

Aggregated UL Throughput distribution (TR)

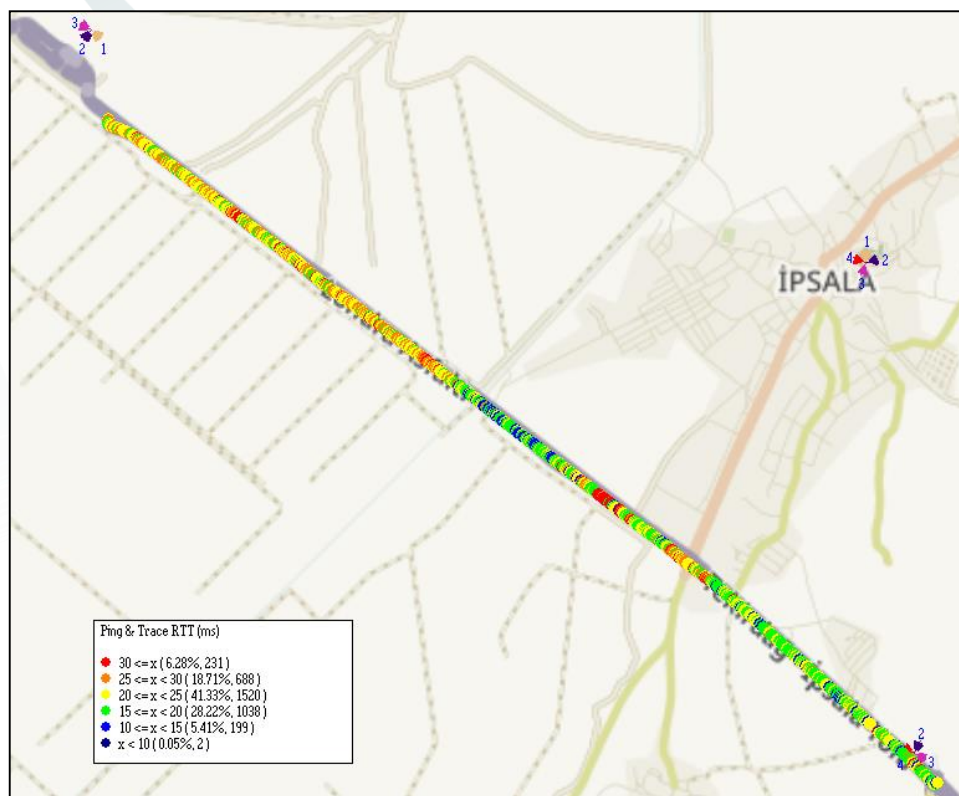


Aggregated UL Throughput distribution (GR)



LOCATION	Peak DL	Average DL
Ipsala	159 Mbps	94% of total samples >100Mbps for DL
Kipoi	65 Mbps	80% of total samples >100Mbps for DL

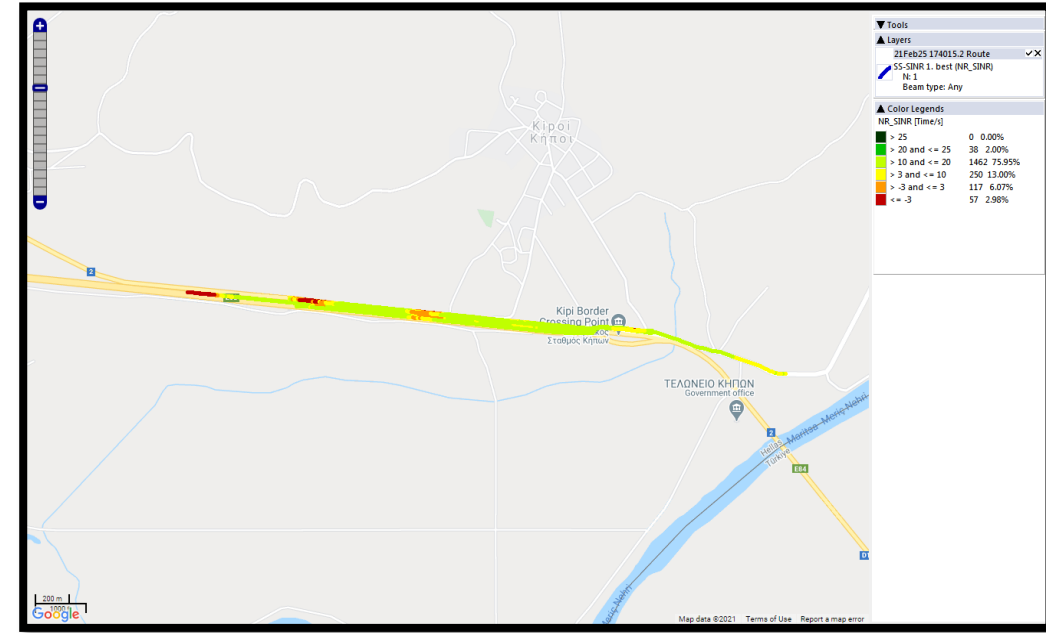
# Mobility Test results - Latency



LOCATION	Latency
Ipsala	Min 12msec
	Avg 21msec
Kipoi*	Min 15msec
	Avg 21 msec

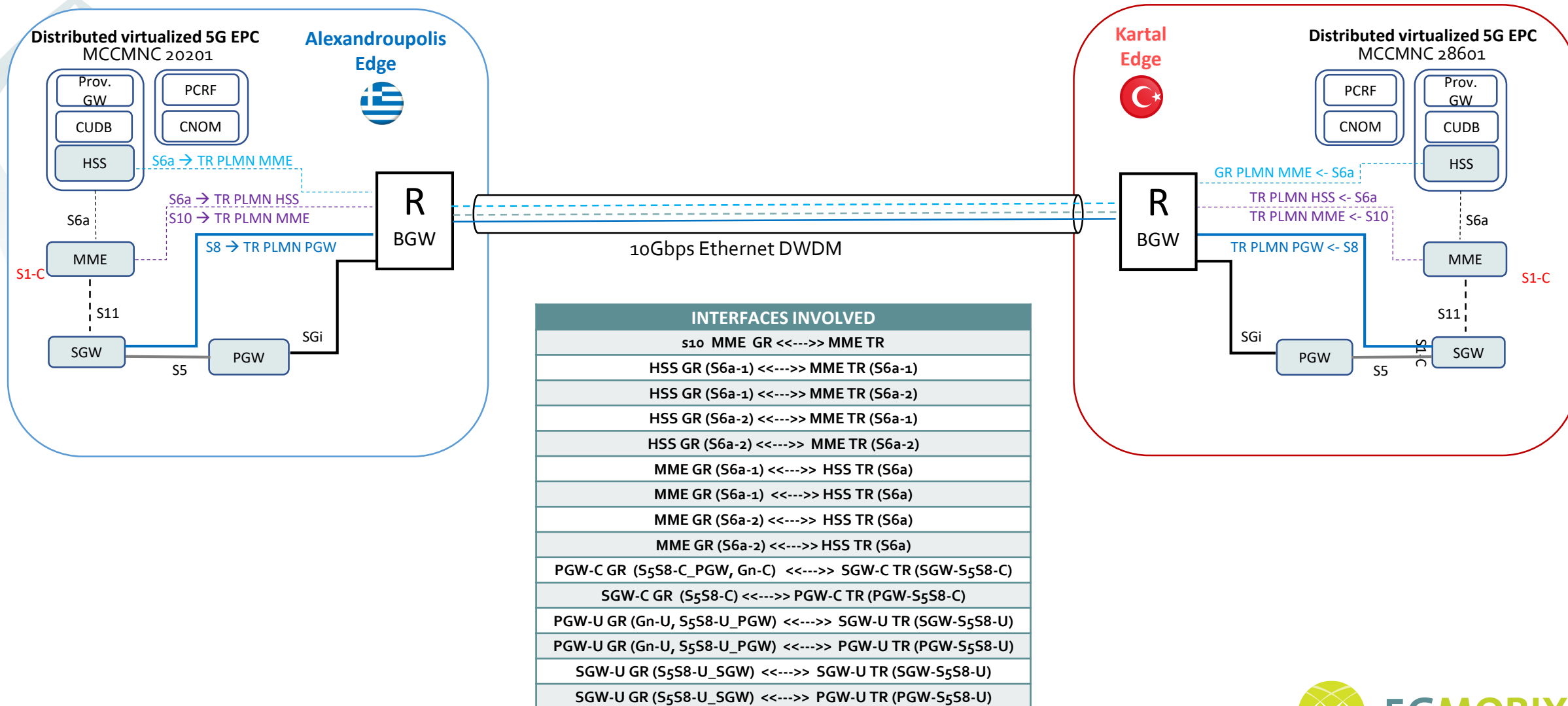
\* Latency measurement plot is not available for the Greece test.

# Mobility tests - Crossing the border!



- Various tests have been carried out to check the performance of existing sites on the approximately 7 km road in Turkey and 3km in Greece.
- Due to the COVID-19 restrictions, the physical border crossing tests cannot be performed.

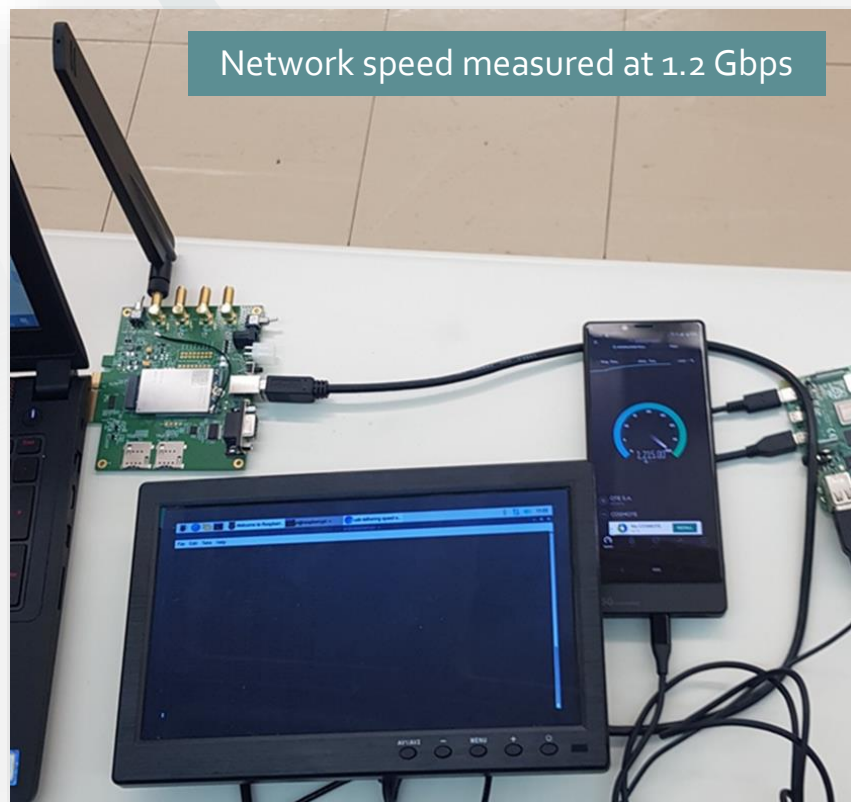
# Core-to-Core Connectivity Testing



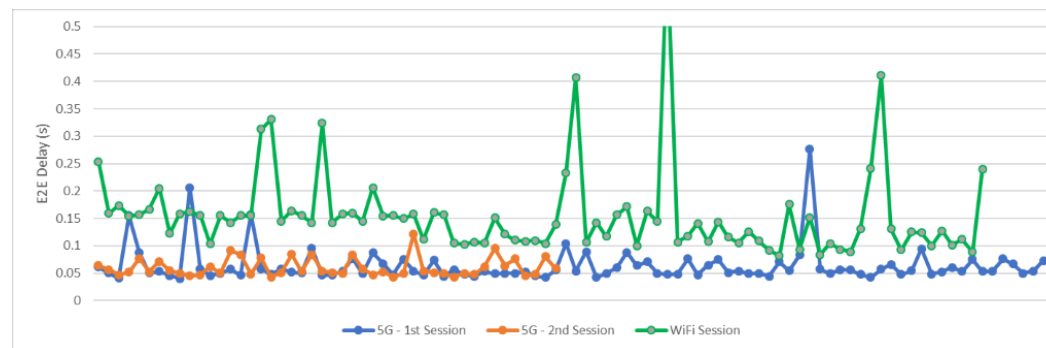
# Verification and Integration



# WINGS OBU



WINGS OBU & testing board under test in COSMOTE premises, Athens



```
pi@raspberrypi: ~  
$ speedtest-cli  
Retrieving speedtest.net configuration...  
Testing from Cosmote (62.103.102.2)...  
Retrieving speedtest.net server list...  
Selecting best server based on ping...  
Hosted by Cosmote S.A. (Athens) [1.57 km]: 37.875 ms  
Testing download speed...  
Download: 244.99 Mbit/s  
Testing upload speed...  
Upload: 86.81 Mbit/s  
pi@raspberrypi: ~  
$ speedtest-cli  
Retrieving speedtest.net configuration...  
Testing from Cosmote (62.103.102.2)...  
Retrieving speedtest.net server list...  
Selecting best server based on ping...  
Hosted by Cosmote S.A. (Athens) [1.57 km]: 36.556 ms  
Testing download speed...  
Download: 370.42 Mbit/s  
Testing upload speed...  
Upload: 87.20 Mbit/s  
pi@raspberrypi: ~  
$ speedtest-cli  
Retrieving speedtest.net configuration...  
Testing from Cosmote (62.103.102.2)...  
Retrieving speedtest.net server list...  
Selecting best server based on ping...  
Hosted by OTE S.A. (Athens) [1.57 km]: 34.44 ms  
Testing download speed...  
Download: 335.56 Mbit/s  
Testing upload speed...  
Upload: 91.25 Mbit/s  
pi@raspberrypi: ~  
$
```

WINGS OBU processing Unit (HW) cap at 400 Mbps  
Throughput measured up to 370 Mbps is very good  
(more than enough for the UC)

Throughput test via the WINGS OBU ~370 Mbps

# IMEC OBU/RSU

```
graph LR; A[IMEC Belgium] --> B[Ford Otosan Turkey]; B --> C[Turkcell Kartal Plaza]; C --> D[Turkcell Maltepe Plaza]
```

Peak Downlink Throughput: 587 Mbps (2x2 MIMO)  
Uplink Throughput ~ 80-85 Mbps  
Latency ~10-15 ms



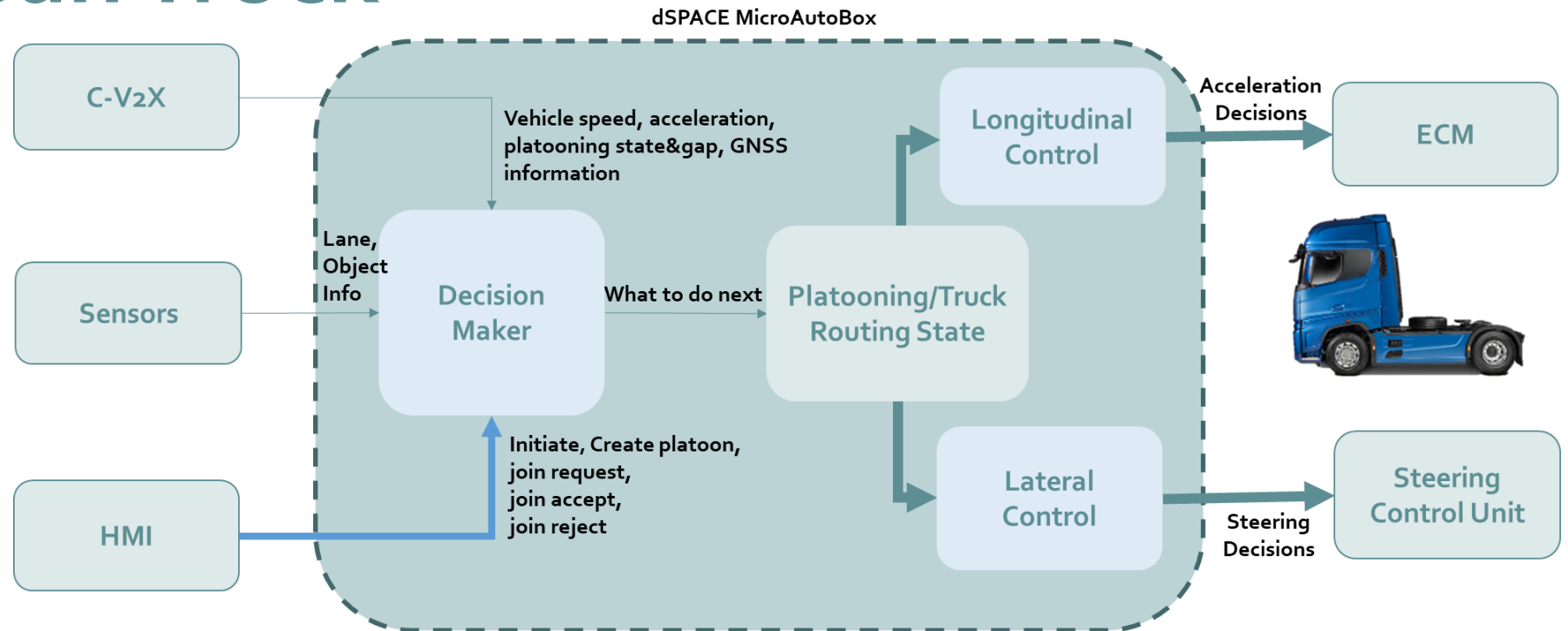
# IMEC OBU/RSU

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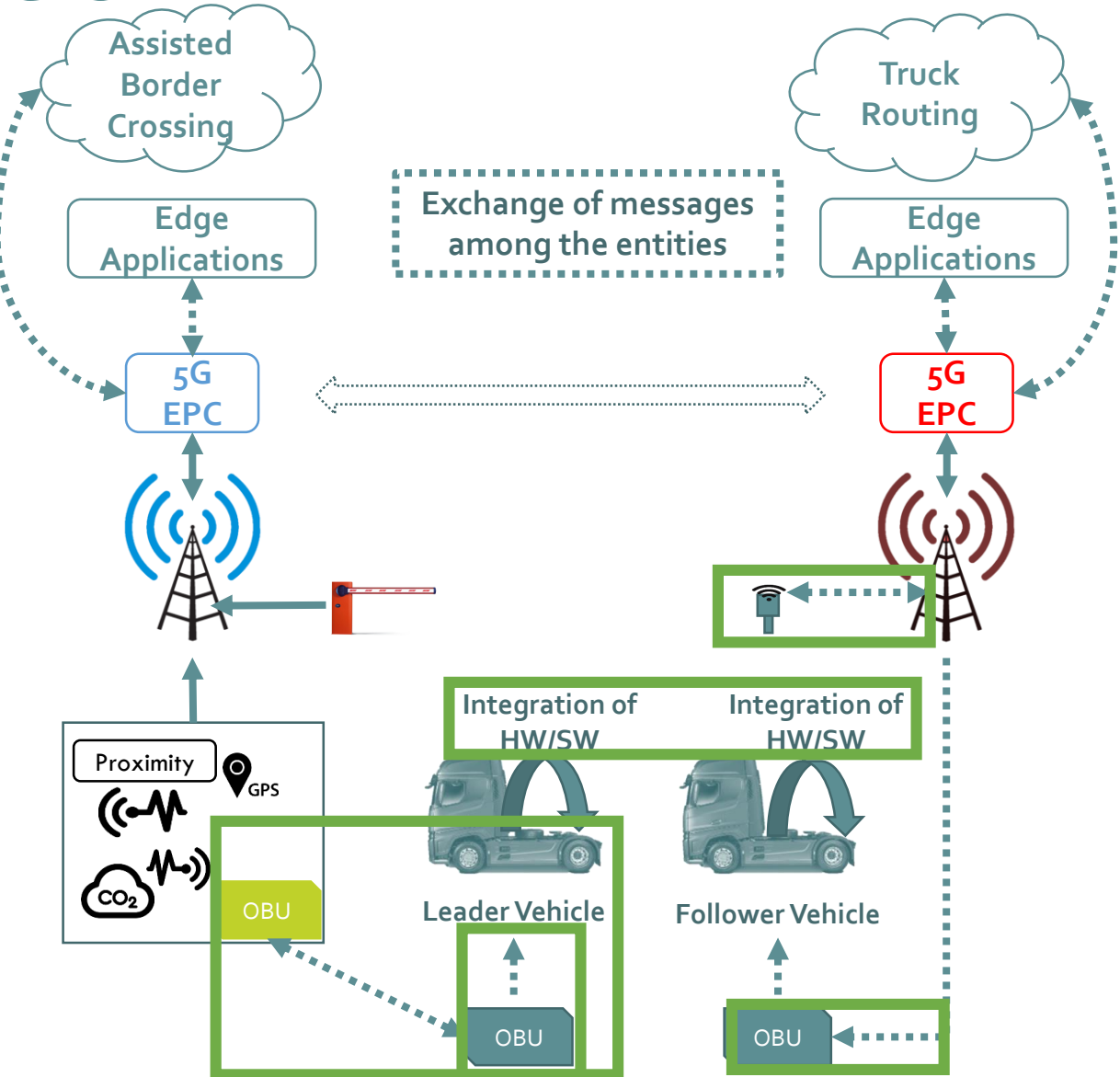


# Ford Otosan Truck





# Integra



# CBC Trial plan & next steps



# Final Demo March 2022



# Thank you



[www.5g-mobix.com](http://www.5g-mobix.com)



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