5G-MOBIX

Deploying and trialing 5G for CAM

Coen Bresser

5G for CAM @ IoT Week Dublin, 21 June 2022

5GMOBIX

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

5GMOBIX

ABOUT

- EU funded Innovation action (H2020-ICT-18-2018)
- November 2018 – September 2022
- 59 partners from 11 countries in Europe (incl. Linked Third parties)
- 9 non-EU funded partners from China and South Korea

OBJECTIVES

Accelerate deployment of 5G at cross-border areas

- Carry out trials along X-border corridors to assess 5G capabilities for CAM
- Qualify the 5G-infrastructure and evaluate the benefits of 5G within the CAM context
- Identify spectrum allocation gaps, contribute to standardisation and 5G CEF preparation

Technical

Business

Define deployment scenarios & recommendations including x-border context

- Perform cost/benefit analysis and impact assessment
- Identify new business opportunities for 5G-enabled CAM
- Investigate legal, regulatory and security issues

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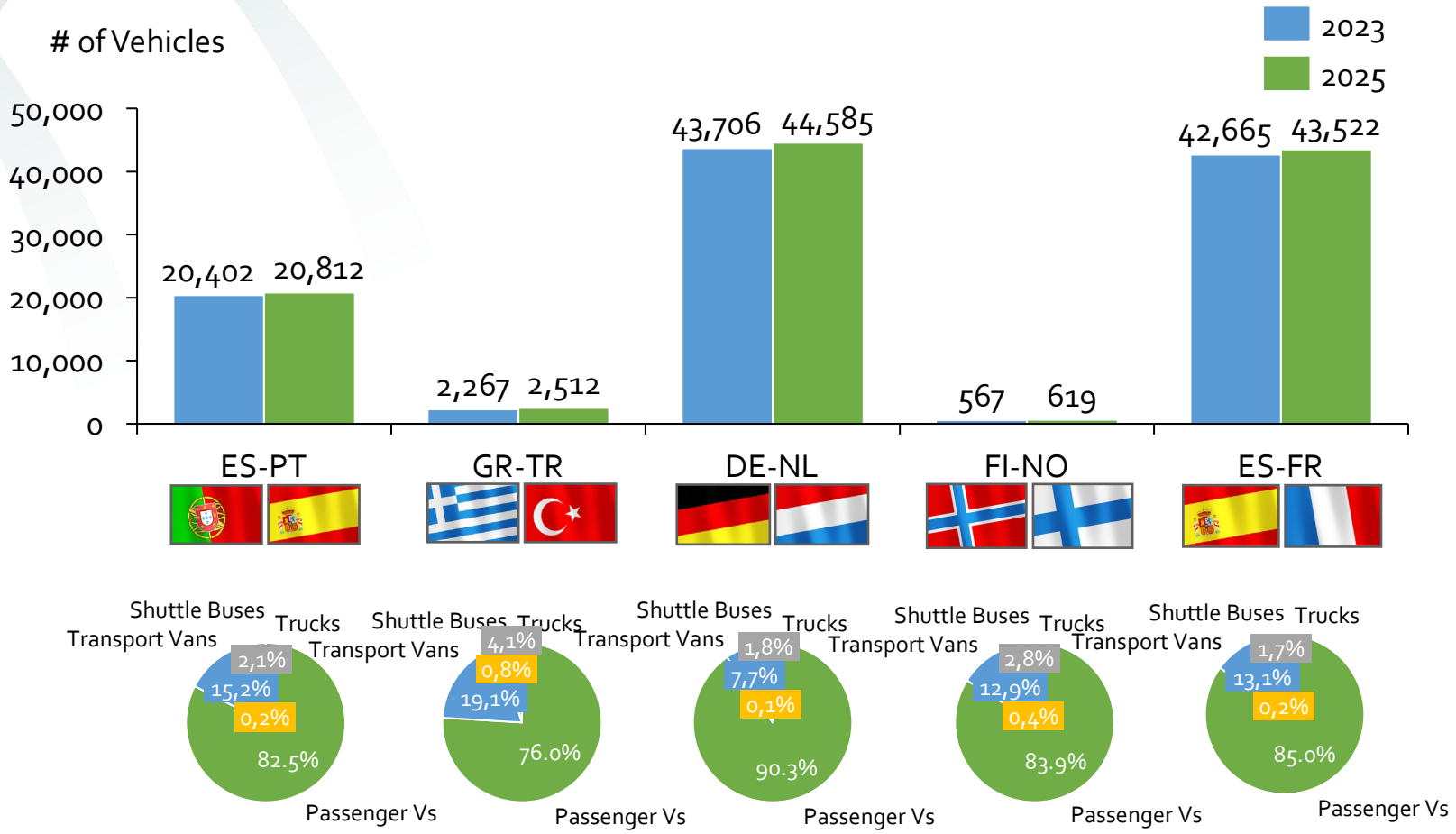
Telecom & Connectivity
ISEL
Telefónica
Choose it all
CATAPULT
Satellite Applications
instituto de telecomunicações
SIEMENS
Ingenuity for life
kpn
Fraunhofer
IAO
ict SNETICT
INTRASOFT
INTERNATIONAL
COSMOTE
GTARC
GERMAN TURKISH
ADVANCED RESEARCH CENTRE FOR ICT
imec
Centro de Computação Gráfica
Investigação & Desenvolvimento Tecnológico
Research & Technological Development
Infraestruturas de Portugal
Ligamos destinos
norte litoral
NOS
DAI-Labor
Distributed Artificial Intelligence Laboratory
WINGS
ICT SOLUTIONS
TIS
MOVIMENTO INTELIGENTE
TURKCELL
TEKNOLOJİ
ERICSSON
uni.lu
UNIVERSITÉ DU
LUXEMBOURG
vicomtech
visual interaction & communication technologies
ETRI
Electronics and Telecommunications
Research Institute
DAZZLEE
NOKIA
R&D
A!
TU/e
Technische Universiteit
Eindhoven
University of Technology
Where innovation starts
ERTICO
Business
VTT
CTAG
AKKA
PASSION FOR
TECHNOLOGIES
TNO
innovation
for life
A-to-Be
Powered by Brisa
ENIZEY
ICCS
DEKRA
POLITÉCNICA
ALSA
DGT
Dirección General de Tráfico
FORD OTOSAN
INSTITUT
VEDECOM
TÜBİTAK
AEVAC
LUXEMBOURG
INSTITUTE OF SCIENCE
AND TECHNOLOGY
LIST
CONCELLO
DE VIGO
CNHTC
Valeo
UNIVERSIDAD DE
MURCIA
sensible 4
SELF-DRIVING EVERYWHERE
IMT
INSTITUTO DA
MOBILIDADE E DOS
TRANSPORTES, I.P.
山东省科学院
SHANDONG ACADEMY OF SCIENCES
KATECH
AVM
5GMOBIX
Automated driving

Who are we doing this for

Cross border traffic

Vehicles per day (all lanes, both directions):



Remarks:

- The German-Dutch corridor and the Spanish-French corridor see the highest daily vehicular road traffic
- The traffic along the Finnish-Norwegian corridor is by far the lowest with less than 700 vehicles per day
- Shuttle buses account for only a maximum of 1% of the traffic. This is including long- and short-distance public transportation buses
- 4 different vehicle types:
  - Passenger vehicles, transport vans, (shuttle) buses and trucks
- We assume that the share of overall vehicles in use is the same as on cross-border highways. Thus, trucks and transport vans may be underrepresented.

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Source: Detecon Analysis; ACEA_report-vehicles-in-use-europe-january-2021-1

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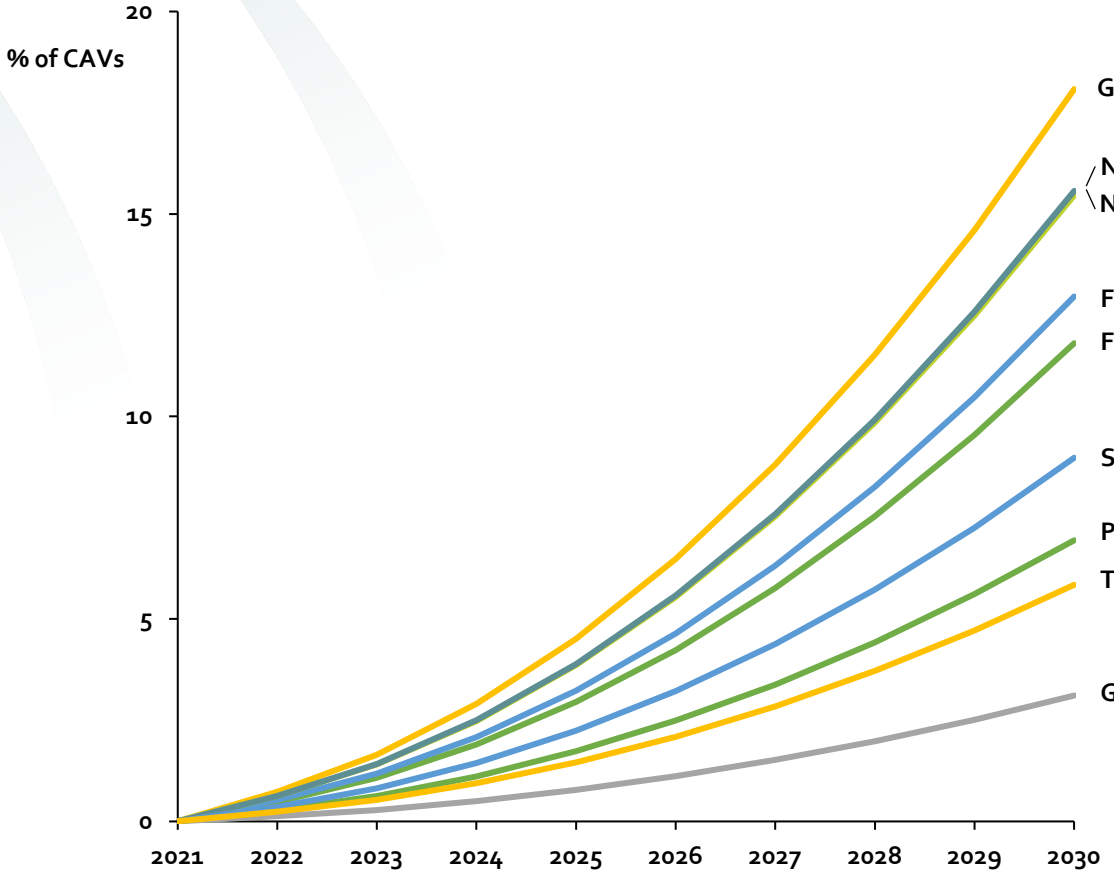
And what is the L3+ expectation

Fleet share of Level 3+* by country with country adj. (all vehicle types):



	2021	2022	**2023**	2024	**2025**	2026	2027	2028	2029	2030
Finland	**0,00%**	**0,48%**	**1,08%**	**1,90%**	**2,95%**	**4,23%**	**5,76%**	**7,53%**	**9,54%**	**11,81%**
France	**0,00%**	**0,53%**	**1,18%**	**2,08%**	**3,23%**	**4,64%**	**6,32%**	**8,26%**	**10,47%**	**12,96%**
Germany	**0,00%**	**0,73%**	**1,65%**	**2,90%**	**4,51%**	**6,48%**	**8,81%**	**11,52%**	**14,60%**	**18,08%**
Greece	**0,00%**	**0,13%**	**0,28%**	**0,50%**	**0,78%**	**1,12%**	**1,52%**	**1,98%**	**2,51%**	**3,11%**
Nether-lands	**0,00%**	**0,63%**	**1,41%**	**2,48%**	**3,86%**	**5,54%**	**7,53%**	**9,85%**	**12,49%**	**15,46%**
Norway	**0,00%**	**0,63%**	**1,42%**	**2,50%**	**3,88%**	**5,58%**	**7,59%**	**9,92%**	**12,58%**	**15,57%**
Portugal	**0,00%**	**0,28%**	**0,63%**	**1,11%**	**1,73%**	**2,49%**	**3,38%**	**4,42%**	**5,61%**	**6,94%**
Spain	**0,00%**	**0,36%**	**0,82%**	**1,44%**	**2,24%**	**3,22%**	**4,38%**	**5,72%**	**7,25%**	**8,98%**
Turkey	**0,00%**	**0,24%**	**0,53%**	**0,94%**	**1,46%**	**2,09%**	**2,84%**	**3,72%**	**4,71%**	**5,84%**

Source: Detecon Analysis; ACEA; OICA; McKinsey; Deloitte
Within this study, CAVs & CAM are defined as level 3-5 as per SAE definitions.

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The project

5G-MOBIX at a glance

LOCATIONS

- **2** Cross-Border Corridors (CBC)
- **4** complementary European Trial Sites (TS)
- **2** complementary Asian Trial Sites (TS)

5G NETWORK

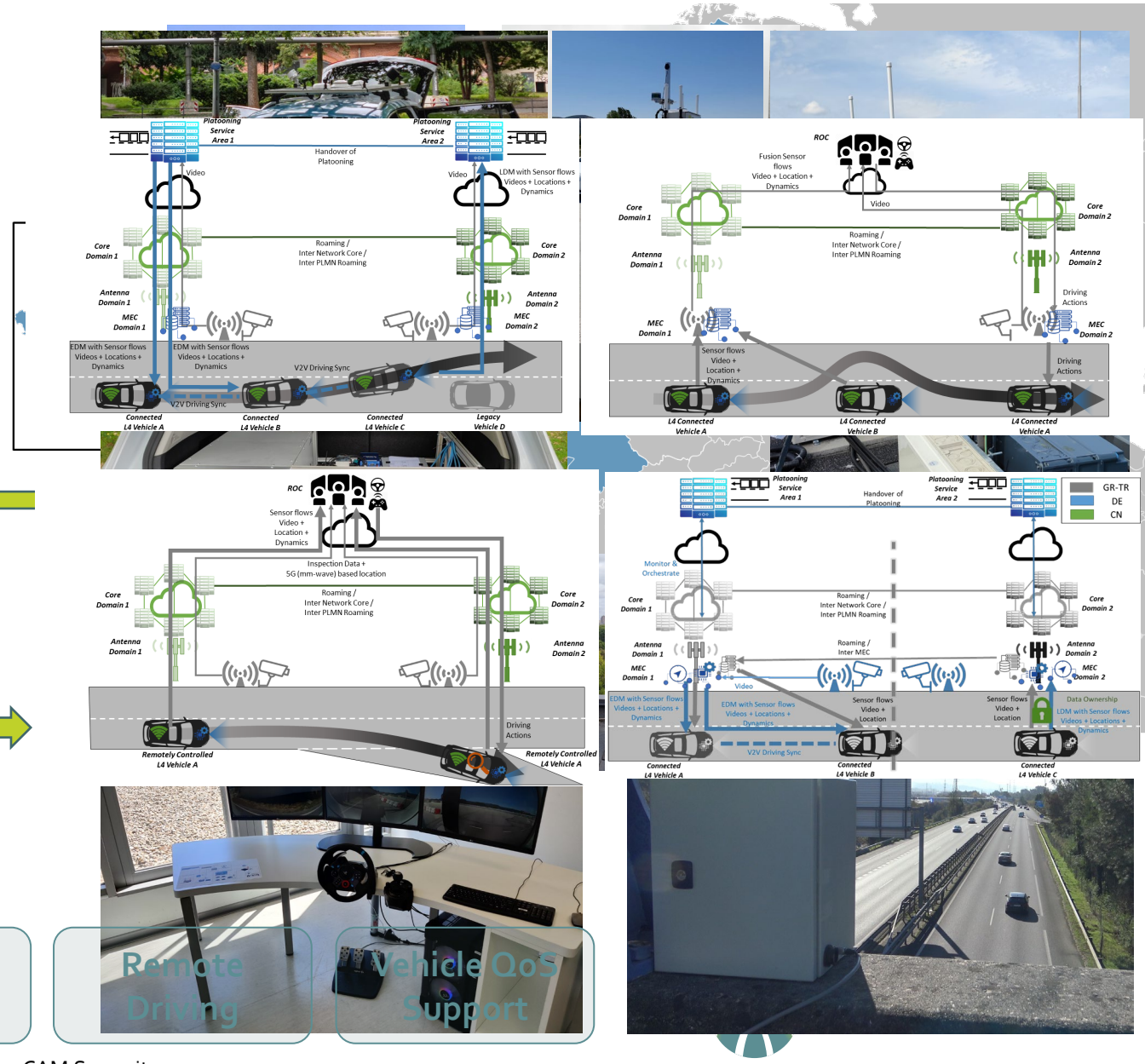
- **8 NSA** 5G networks
- **4 SA** 5G networks
- **29 gNBs** deployed in total

VEHICLES & Roadside infrastructure

- **21** SAE L3 & L4 automated vehicles
- **32** 5G enabled OBUs
- **24** MEC/Edge nodes
- **22** Road Side Units

USE CASES

- **5** use case categories based on 3GPP TS 22.186, focusing on x-border operation
- **24** Unique User Stories



Advanced Driving | Vehicles Platooning | Extended Sensors | Remote Driving | Vehicle QoS Support

5G-MOBIX – Work areas

Elaborate Evaluation Framework with Central Test Server

Cross-Border Issues

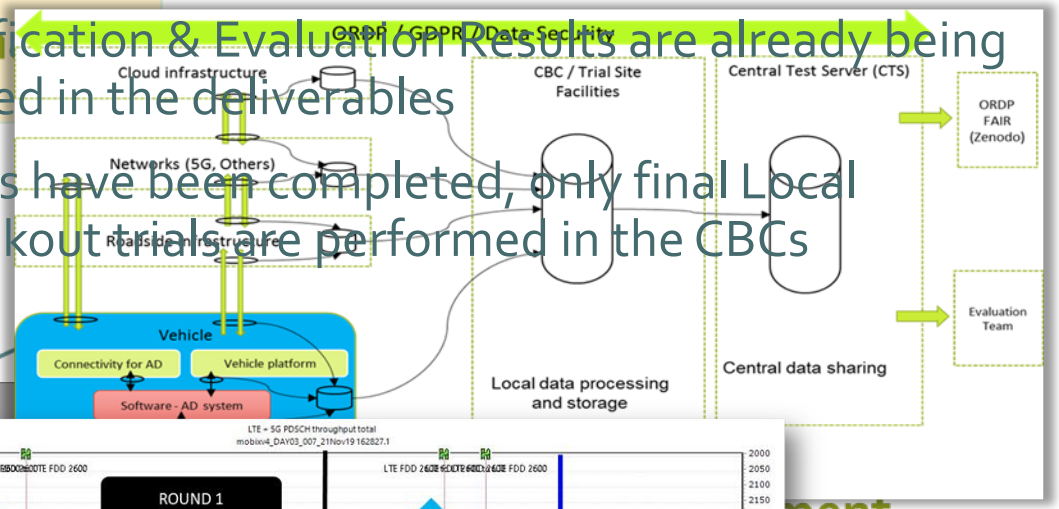
5G Networks

Verification & Evaluation Results are already being placed in the deliverables

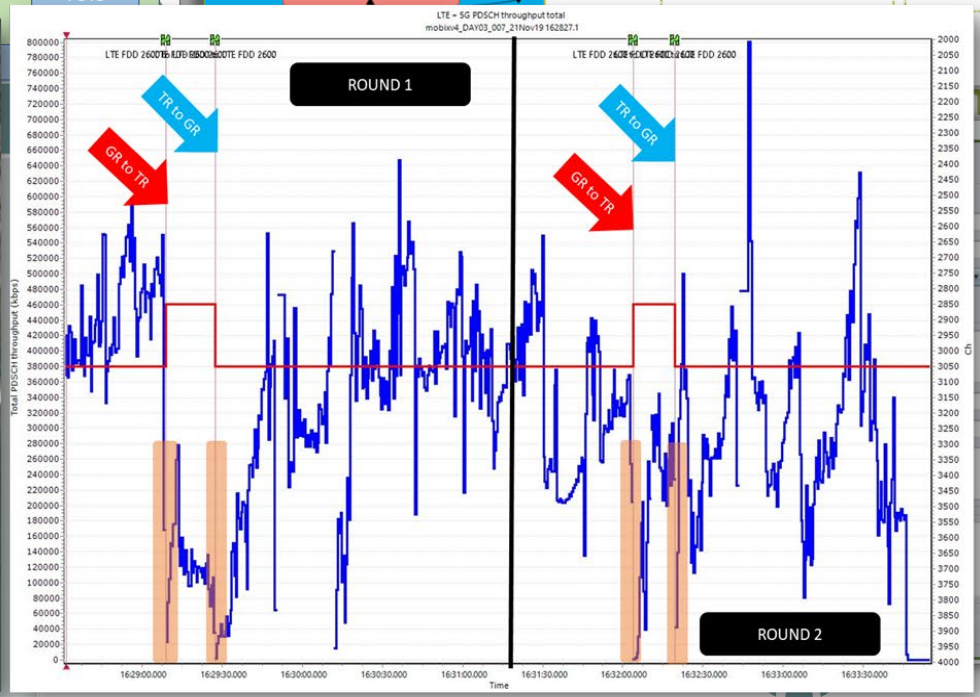
Trials have been completed, only final Local Breakout trials are performed in the CBCs

WP3 – Development & roll-out

T3.5



KPI #	Test Ca
KPI_AG1	DL Data T… stationary
KPI_AG2	UL Data T… stationary
KPI_AG3	DL Data T… stationary
KPI_AG4	UL Data T… stationary
KPI_AG5	DL Data T… mobile
KPI_AG6	UL Data T… mobile
KPI_AG7	User Plane
KPI_AG8	UL Packet
KPI_AG9	DL Packet
KPI_AG10	HO measu…



WP4 Trials

WP5 Evaluation

5G networks

Site	Type	Commercial/Test Components	# gNBs	Freq. Bands	Slicing
ES	NSA	Commercial: Transport network, 1x 4G RAN (MOCN) Test: 1x Core, 5G RAN, MEC	4	800 MHz (LTE B20), 1800 MHz (LTE B3) 2600 MHz (B7), 3.7 Hz (5G NR n78)	No
PT	NSA (SA)	Commercial: IP and Transport Network Test: 1x RAN, 1x Core, MEC	3	1800 MHz (LTE B3), 3700 MHz (5G NR n78)	No
GR	NSA	Commercial: IP and Transport Network Test: 1x RAN, 1x Core	1	LTE B7 (2600) 20MHz, NR n78F (3500-3600)	No
TR	NSA	Commercial: IP and Transport Network Test: 4x RAN, 1x Core	3 (+1)	LTE B7 (2600) 20MHz, NR n78G (3600-3700)	No
DE	NSA/SA	Commercial: 2x NSA Core + 2x RAN, 1x MEC Test: 1x SA Core + 1x RAN, MEC	2	NSA: 2.1 GHz (5G NR n1) + 800 MHz (LTE B20), 900 MHz (LTE B8), 1800 MHz (LTE B3) 3.6 GHz (5G NR n78) + 1800 MHz (LTE B3), 2600 MHz (B7) SA: 3.7 - 3.8 GHz (n78)	No
FI	NSA/SA	Commercial: 2x NSA Core + 2x RAN Test: 2xRAN, 2xCore, MEC	2	2600 MHz (B7), 3.5 GHz (n78)	Yes
FR	NSA	Commercial: 1x Core Test: 3x RAN + 2x Core, 2x MEC	3	700 MHz (4G), 800 MHz (4G), 1800 MHz (4G) 2100 MHz (3G/4G), 2600 MHz (4G) 3500 MHz (5G), 3700-3800 MHz (n77), 26 GHz (n258)	No
NL	SA	Commercial: 1x 4G RAN (MOCN), 1x 4G transmission Test: 3x 5G RAN, 3x Core, 3x MEC	6	3.7 GHz (5G NR n78) 27 GHz (5G NR n258), LTE: 800 MHz (LTE B20), 1800 MHz (LTE B3)	Yes
CN	SA	Commercial: 2x Core (China Mobile, China Unicom) Test: 2x RAN 2x MEC	3	3.5GHz(n78), 4.9 GHz(n79) 2.6GHz(n41)	Yes
KR	NSA	Test	3	22-23.6 GHz	No

10 KPIs (e.g. user experienced data rate) are assessed for on each of the sites

Deployed Advanced 5G technologies overview

Technology / Site	ES-PT	GR-TR	DE	FI	FR	NL	CN	KR
C-V2X	5G-V2X	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X
MEC Deploy-ment	Yes, Nokia solution	Yes, Ericsson solution	Yes, near edge & far edge	Yes, MEC Service Discovery	Yes, Far/ Cloud Edge	Yes, MEC Discovery SSC M3	Yes, China Mobile solution	No
Network Slicing	No	No	No	Yes	No	Yes	Yes	No
Roaming	Cross-border	Cross-border	Multi-SIM in NSA/SA	Multi-SIM in NSA/SA, Lab SA-SA	Multi-SIM in NSA	Virtual cross-border	Multi-SIM in NSA/SA	No
Satellite Deployment	No	No	No	No	Yes	No	No	No

10 KPIs (e.g. user experienced data rate) are assessed for on each of the sites

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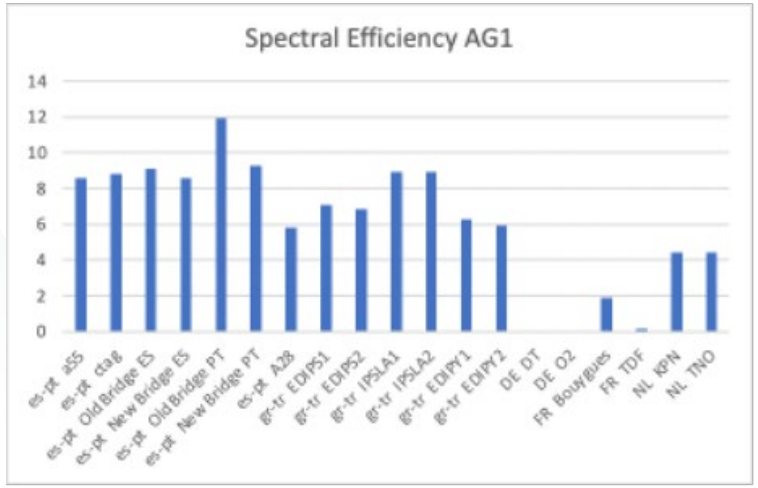
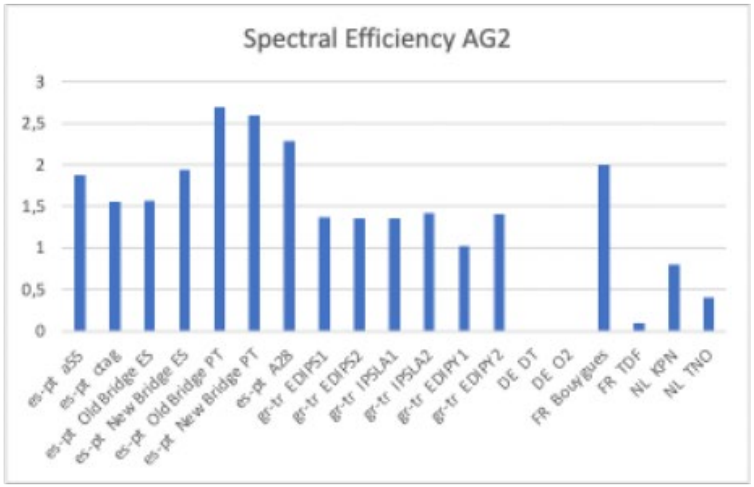
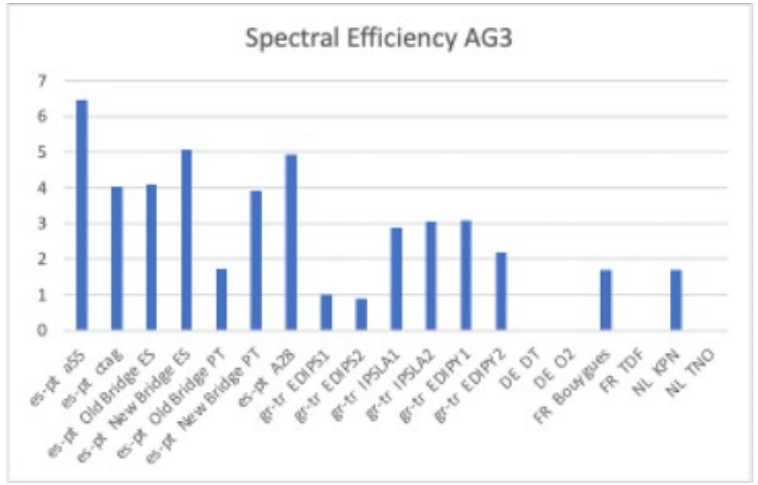
Agnostic: Spectral efficiency at both cell-center and cell-edge

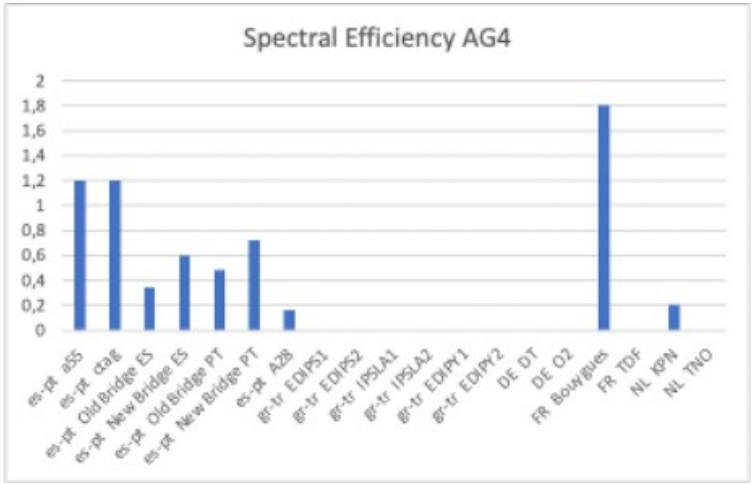
Cell center

Cell edge









DL

UL

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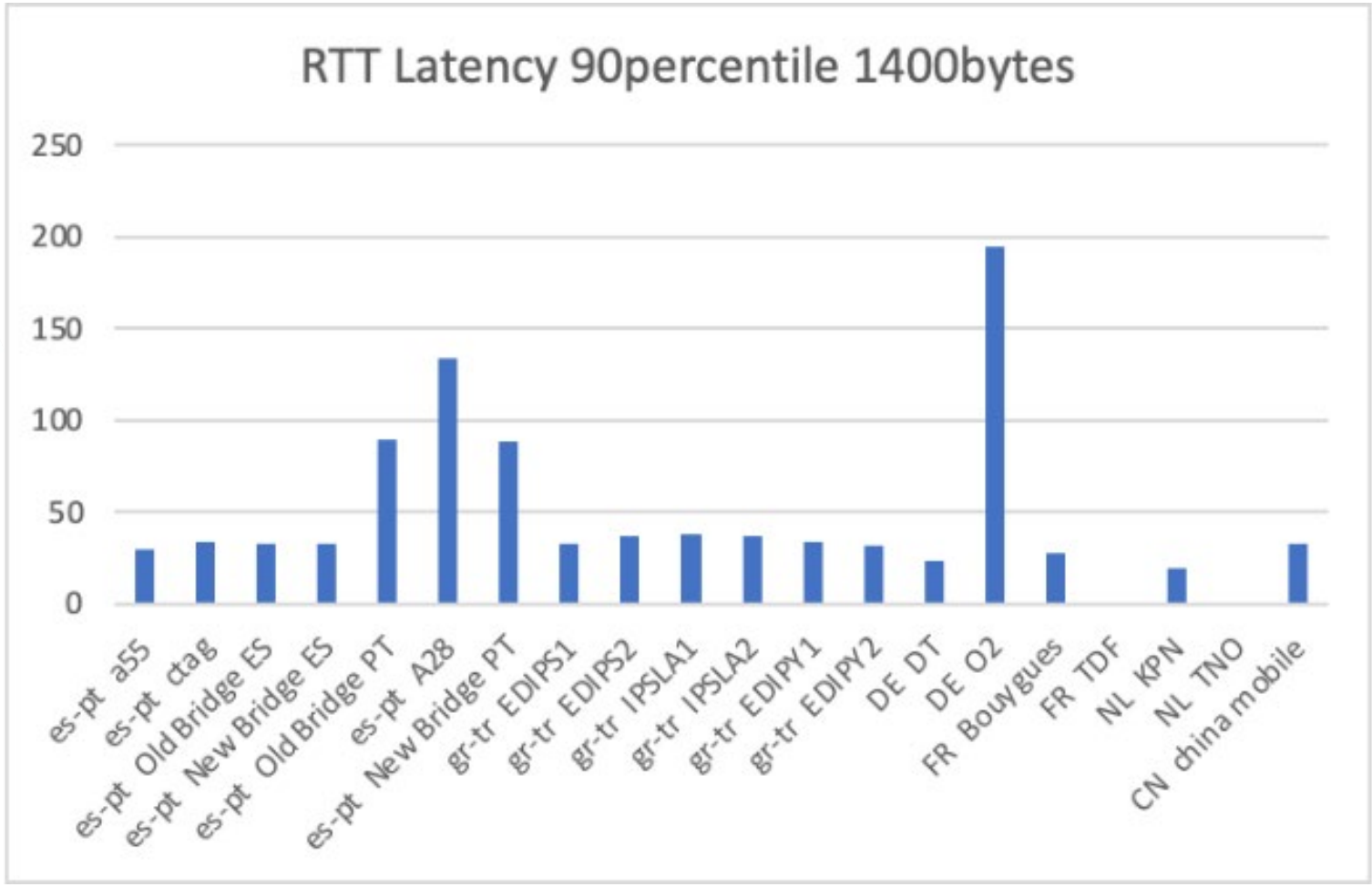
Agnostic: Roundtrip latency



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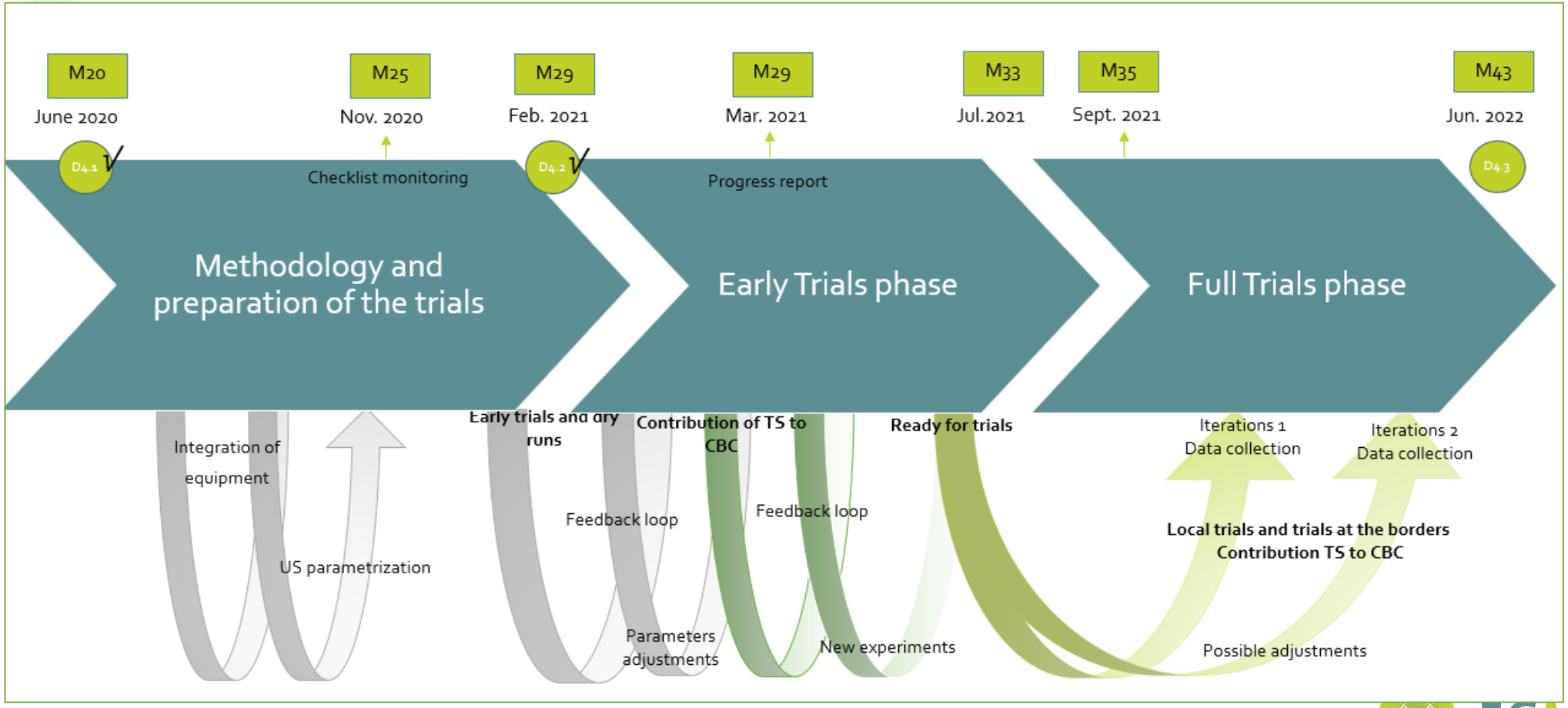
Getting the live CAM data

Execution of the trials



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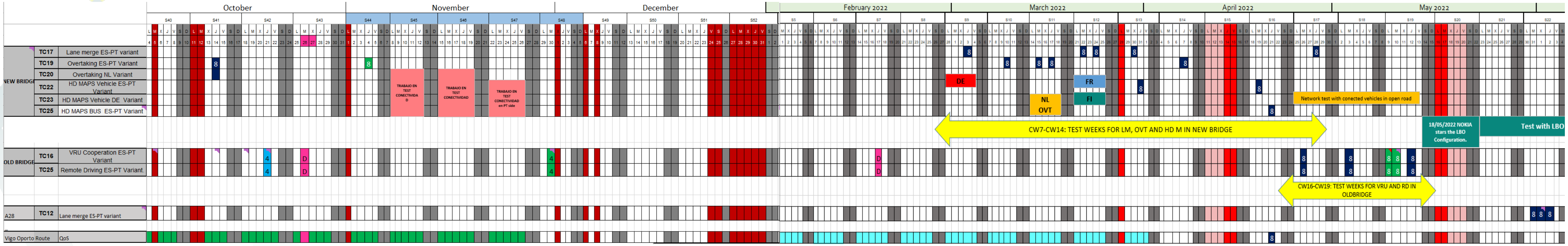
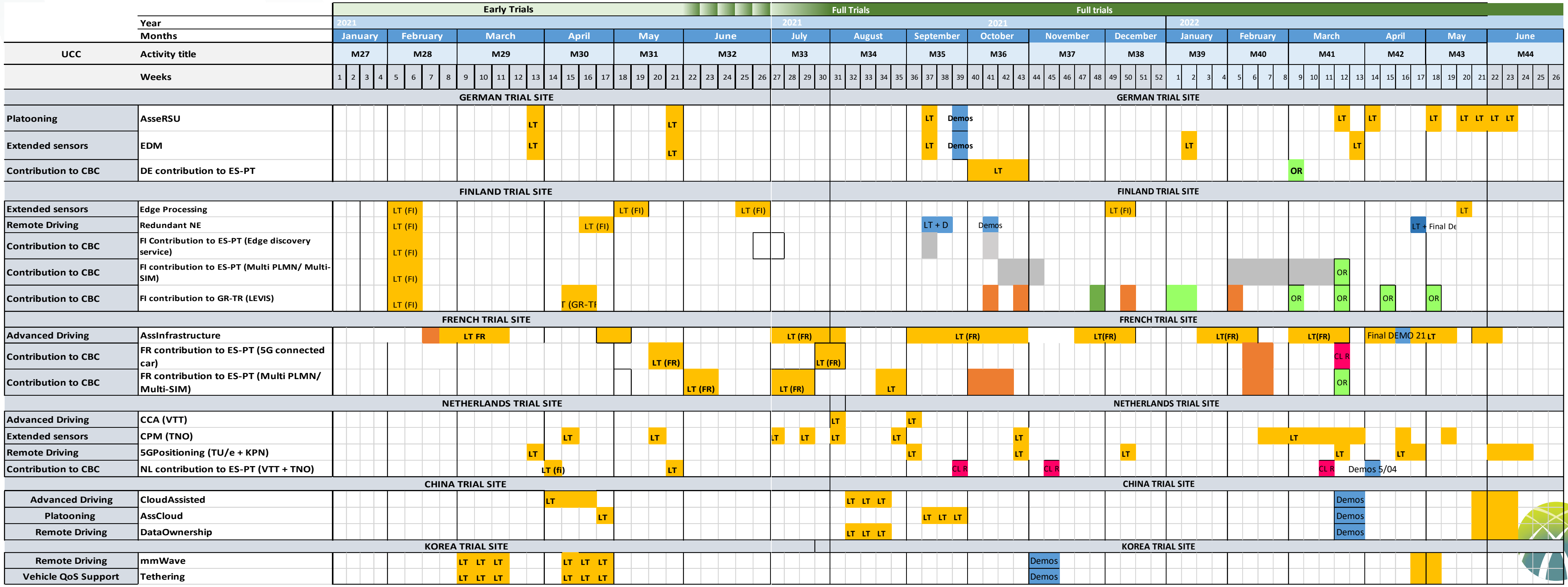
Trials quick view





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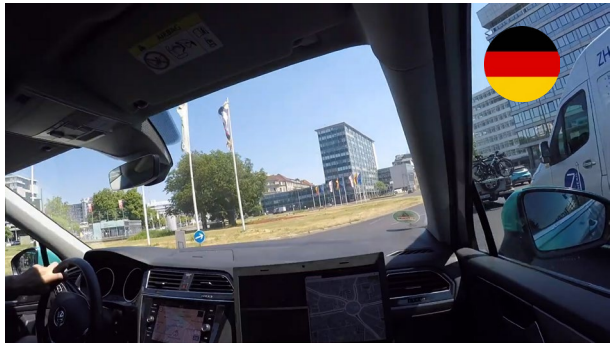
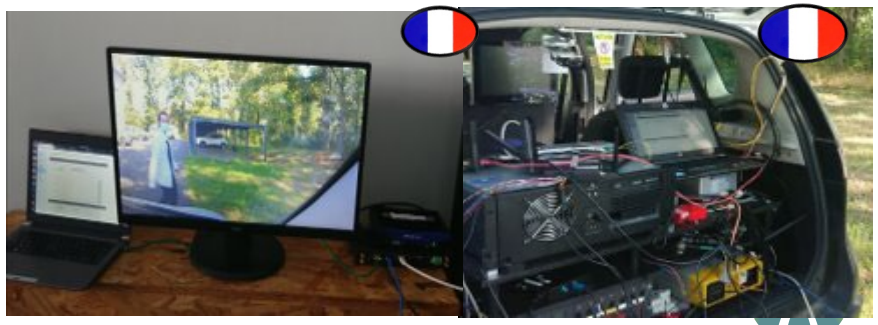
Trials impressions



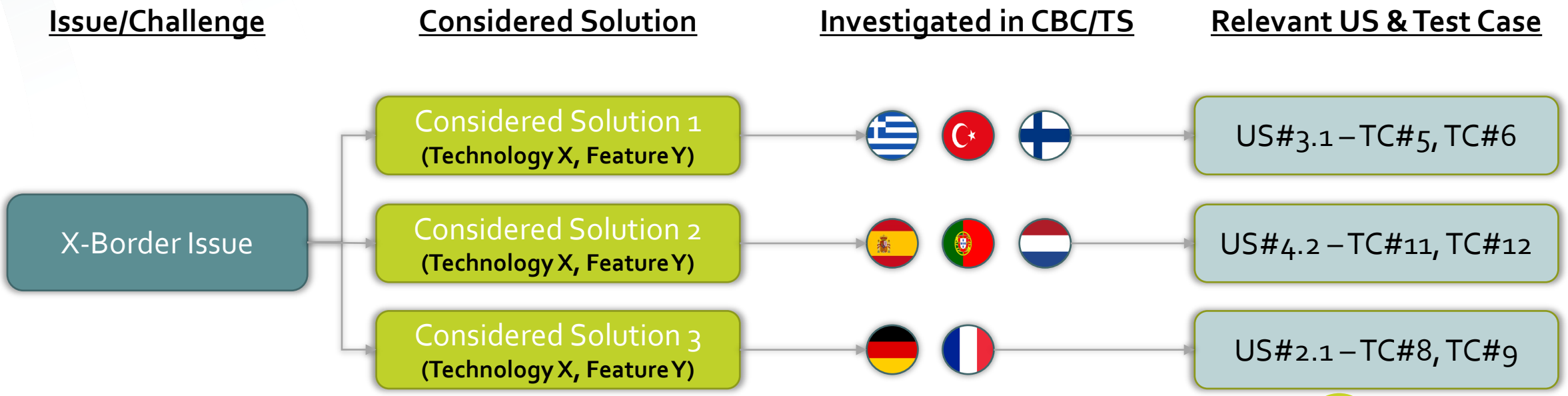


5GMOBIX

Creating the learnings

Cross-Border Issues (XBIs) & Considered Solutions (CSs)

- **Cross-Border Issues (XBIs):** identified set of technical challenges towards seamless cross-border CAM functionality over 5G → **11 XBIs** addressed in 5G-MOBIX
- **Considered Solutions (CS):** identified set of the most promising technical approaches to address the identified XBIs → **27 CSs** will be evaluated in 5G-MOBIX



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XBI versus CS

XBI ID	Cat.	Title	CS_0 - Feature OFF	CS_1 - S1 handover with S10 interface using an NSA network	CS_2 - Release and redirect using an NSA network	CS_3 - Release and redirect with S10 interface using an NSA network	CS_4 - Multi-modem / multi-SIM connectivity - Passive Mode	CS_5 - Multi-modem / multi-SIM connectivity-Link Aggregation	CS_6 - Release and redirect using an SA network	CS_7 - Internet-based interconnection	CS_8 - Direct Interconnection	CS_9 - Satellite connectivity	CS_10 - MEC service discovery and migration using enhanced DNS support	CS_11 - Imminent HO detection & Proactive IP change alert	CS_12 - Inter-PLMN HO, AF make-before-break, SA	CS_13 - Double MQTT client	CS_14 - Inter-MEC exchange of data	CS_15 - Inter-server exchange of data	CS_16 - LBO NSA	CS_17 - HR NSA	CS_18 - LBO SA	CS_19 - HR SA	CS_20 - Compressed sensing positioning	CS_21 - Adaptive Video Streaming	CS_22 - Predictive QoS	CS_23 - Uu geobroadcast	CS_24 - PC5 geobroacast	CS_25 - mmWave 5G	CS_26 - Network slicing
XBI_0	T	Baseline	■																										
XBI_1	T	NSA Roaming interruption		■	■	■																							
XBI_2	T	SA Roaming interruption							■							■													
XBI_3	T	Inter-PLMN interconnection latency								■	■																		
XBI_4	T	Low coverage Areas					■					■	■																
XBI_5	T&A	Session & Service Continuity					■	■	■					■	■	■	■	■	■	■	■	■	■						
XBI_6	T	Data routing																	■	■	■	■							
XBI_7	T&A	Insufficient Accuracy of GPS Positioning																					■						
XBI_8	A	Dynamic QoS Continuity																						■	■				■
XBI_9	A	Geo-Constrained Information Dissemination																								■	■	■	
XBI_10	T	mmWave applicability																										■	
XBI_11	T	Network slicing applicability																											■

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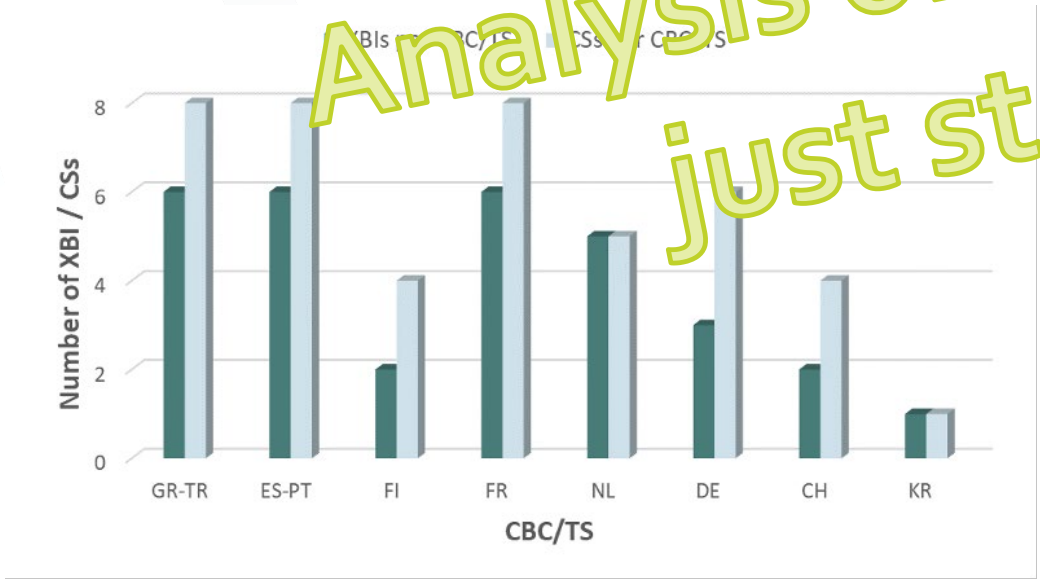
XBI and CS coverage

Nr of XBIs/CSs per site



Nr of sites addressing XBIs

Analysis of the results just started

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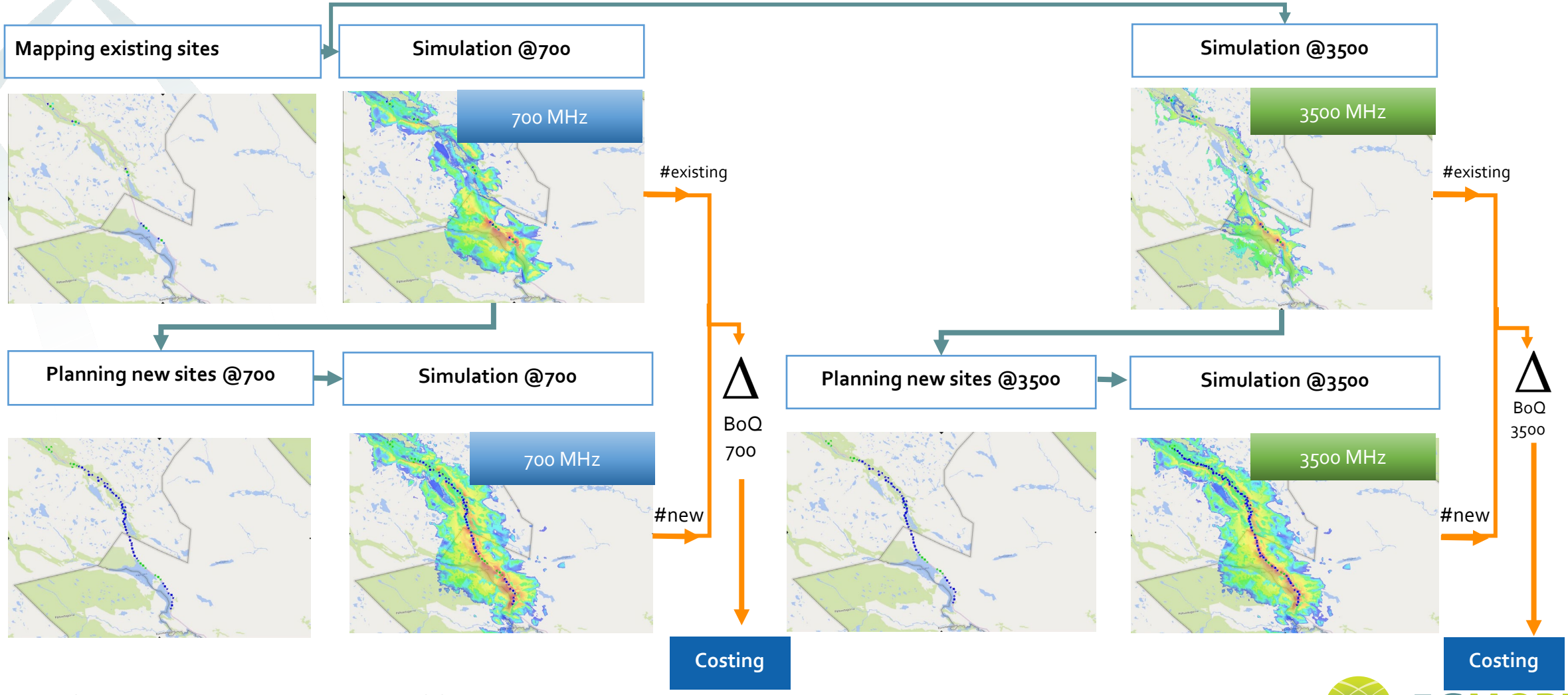
To wider deployment

Cost expectations



Source of sites: cellmaper.net, antenasgsm.com, data.anfr.fr, keraies.eett.gr, publications

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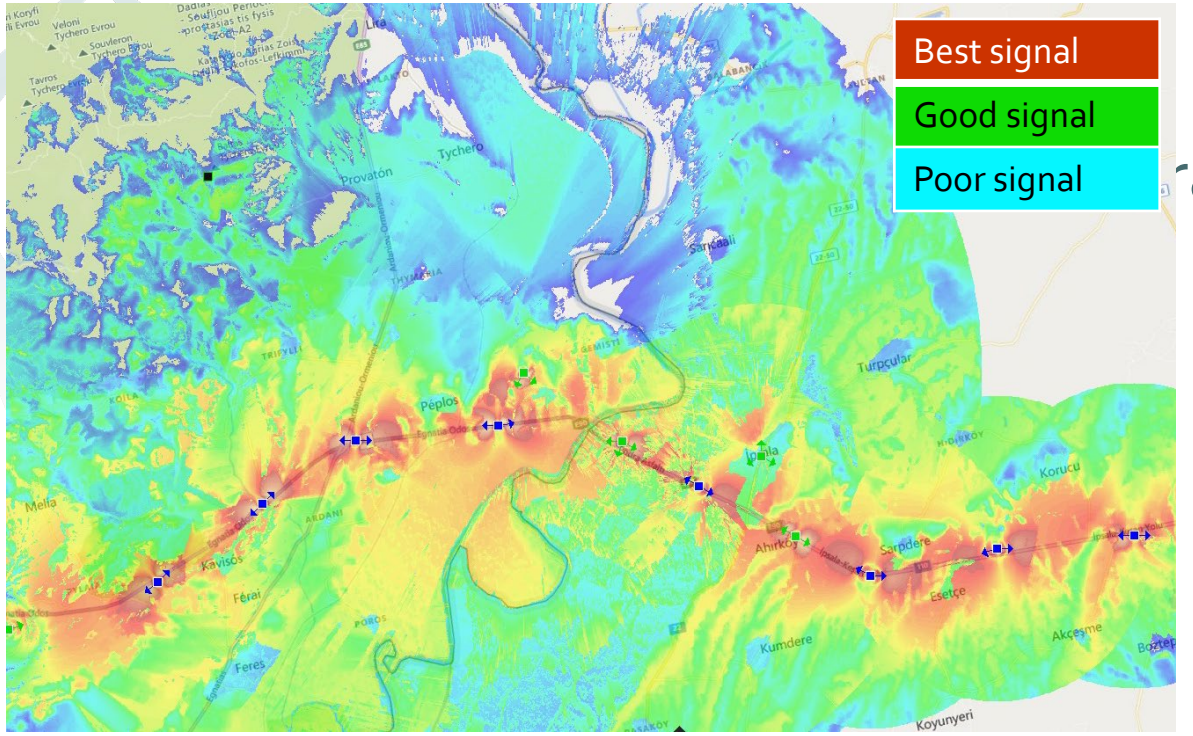
Example Radio Planning GR-TR

700 MHz



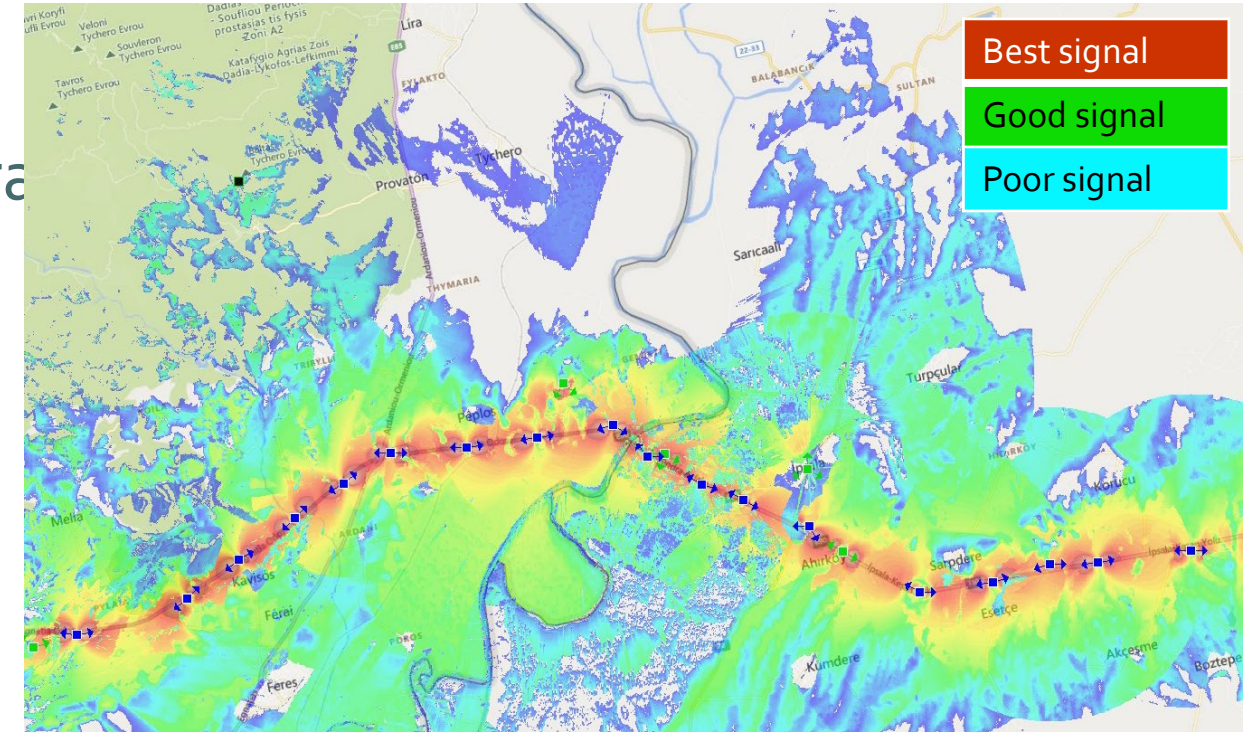
700MHz FDD radio coverage simulation: Existing + New Sites

Remarks:

Existing site

New site. GR: Δ +4, TR: Δ +4

3500 MHz



3500MHz TDD radio coverage simulation: Existing + New Sites

Remarks:

Existing site

New site. GR: Δ +9, TR: Δ +9

Level (on average)	Interpretation	Color code
- 60 dBm	Excellent	Brown-orange
- 72 dBm	Very good	Orange
- 90 dBm	Good	Green
- 111dBm	Low	Light blue
- 122 dBm	Poor	Dark blue

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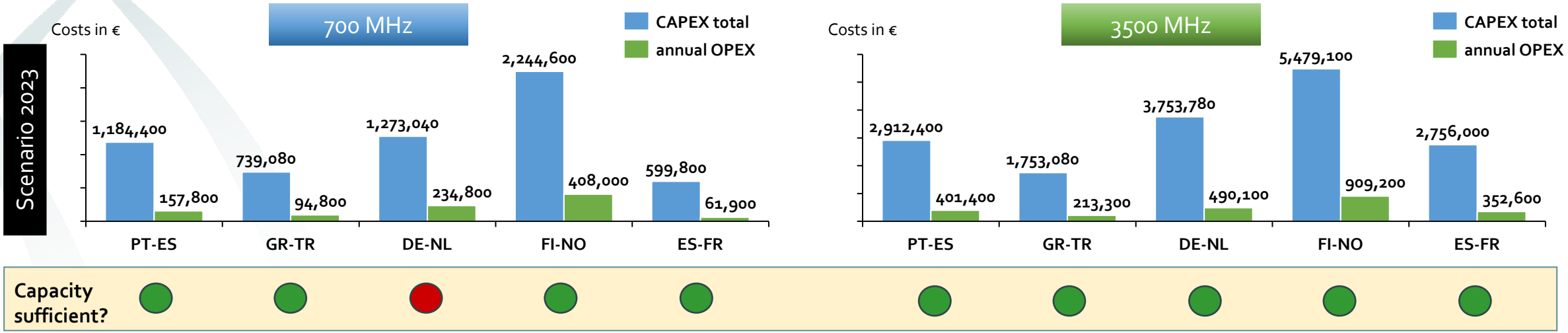
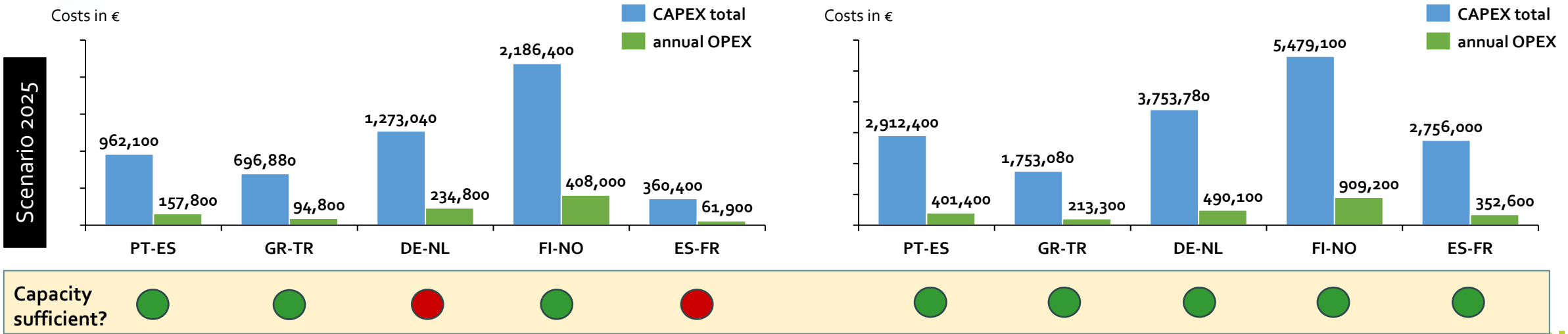
Costs expectations -> key influencing factors





Important disclaimer: The cost results are **estimates**. We assume that these costs may vary **+/- 20%** within one country from operator to operator.

5GMOBIX

Ongoing Work & Next Steps

- Troubleshooting LBO deployments & executing related final tests
- Local evaluations & results (almost done)
- Combined results analysis
  - TS contributions to Cross-Border Issues (XBI) & Considered Solutions (CS)
  - Which CSs have a relevant impact on XBIs
  - Cross-comparison of results
  - Lessons learned
- Development & Deployment lessons learned already available

Development & Deployment lessons learned

- *Compatibility of early/pre-commercial equipment not guaranteed and feature sets not necessarily complete*
- *Accurate synchronization of connectivity equipment is essential for measuring the performance of a 5G network.*
- *The HW and SW used for the OBU (chipset, OS, antennae, etc.) plays a critical role in the observed performance. More stable versions of 5G chipsets in the future should help boost performance*
- *Testing MEC applications requires elaborate E2E integration testing to account for the diverse set of potential errors in any of the infrastructure elements and software implementations*

Thank you
And enjoy the demo

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www.5g-mobix.com

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