



MEC IN ACTION: AN OVERVIEW OF EDGE COMPUTING ACTIVITIES

Part 2: Predictive QoS for Edge Computing: Insights from 5GAA

20th March 2020

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(INTEL, Next Generation and Standards, Vice-Chairman of MEC)

Presentation at the



Web & Networks IG

Agenda

- Intro on edge computing
- ETSI MEC standard
 - MEC V2X API and Predictive QoS
- Use cases of interest

- 5GAA
 - Predictive QoS
 - MEC demo

- Conclusions



Part 1 Already presented in a past W3C conf call

(<https://www.w3.org/wiki/Networks>)

Slides here: <https://lists.w3.org/Archives/Public/www-archive/2020Jan/att-0001/01-part>

Part 2



**THIS
presentation**
([https://www.w3.org/
wiki/Networks](https://www.w3.org/wiki/Networks))

Abstract

The talk will be focused on Intel activities on edge computing, ranging from standardization (e.g. ETSI MEC), industry groups (e.g. 5GAA – 5G Automotive Association) and mentioning also some PoCs and experimental activities.

Particular focus will be given to MEC use cases of potential interest for W3C (e.g. application offloading), and on Intel engagement in the automotive domain (mentioning a recent 5GAA Demo on MEC and predictive QoS).

5GAA

(5G Automotive Association)



Driving Connected Mobility Forward

5GAA brings together automotive, technology and telecommunications companies to work closely together to develop end-to-end connectivity solutions for future mobility and transportation services



AUTOMOTIVE INDUSTRY

Vehicle Platform, Hardware
and Software Solutions



TELECOMMUNICATIONS

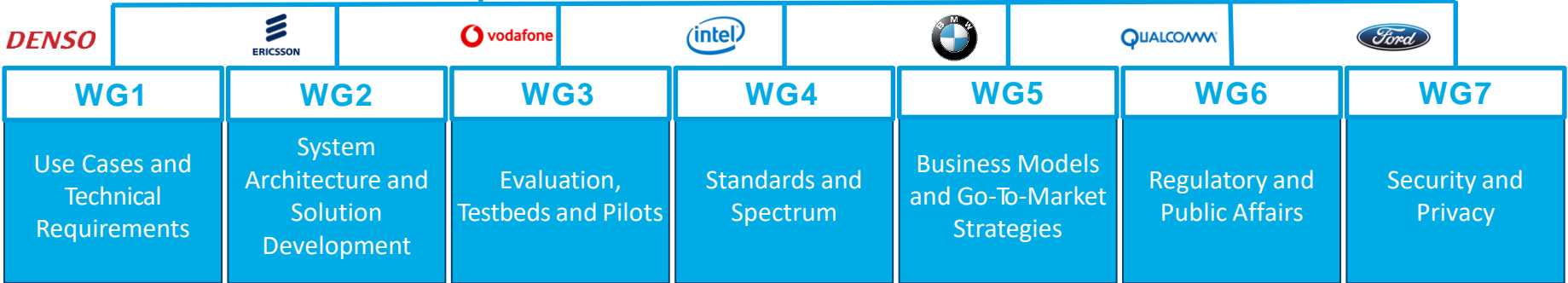
Connectivity and Networking
Systems, Devices and Technologies

5GAA unites today over 130 members from around the world working together on all aspects of C-V2X including technology, standards, spectrum, policy, regulations, testing, business models and go-to-market

5GAA Organisational Structure

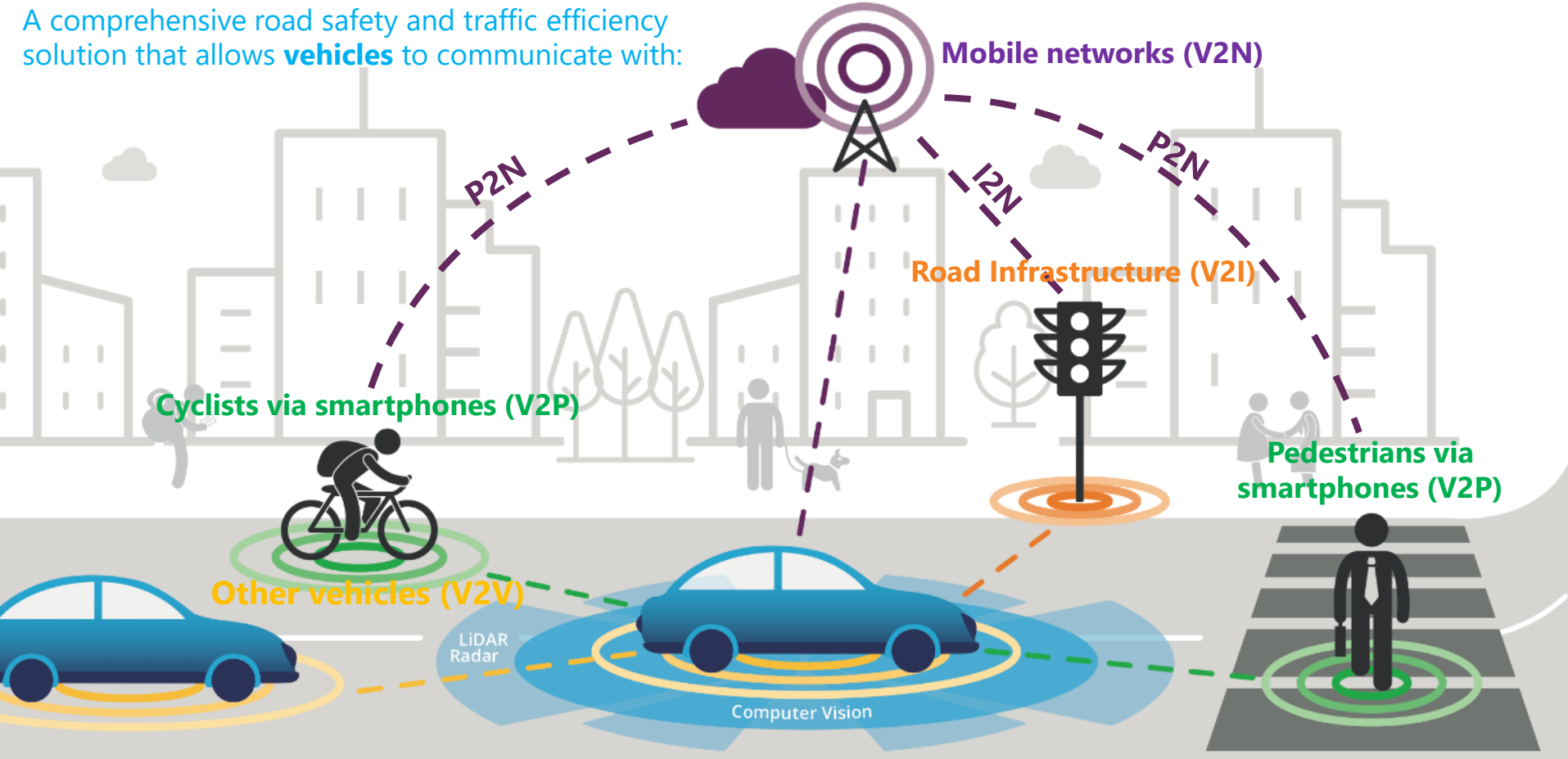


GENERAL ASSEMBLY



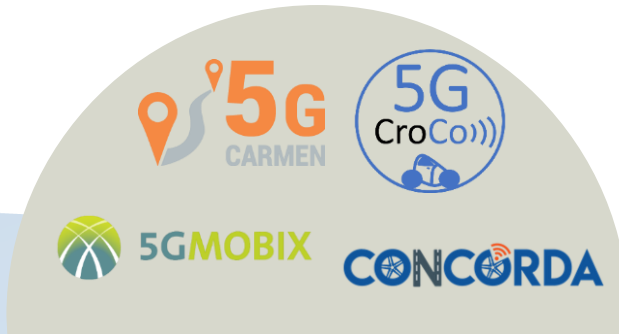
What is C-V2X (Cellular-Vehicle to Everything)?

A comprehensive road safety and traffic efficiency solution that allows **vehicles** to communicate with:



Supporting innovation: Leverage solutions together

- On-going dialogue between 5GAA and leading technology partner organisations to advance innovation in all world regions
- 5GAA to continue strengthen technical cooperation and maximise benefits with existing organisations or projects by reinforcing engagement via common members
- Develop new partnerships with relevant organisations on specific aspects e.g. vulnerable road users or road authorities



5GMOBIX

CONCORDA



OMNIAIR
CONSORTIUM

Automated and Connected cars – key drivers

Connected Car Vision

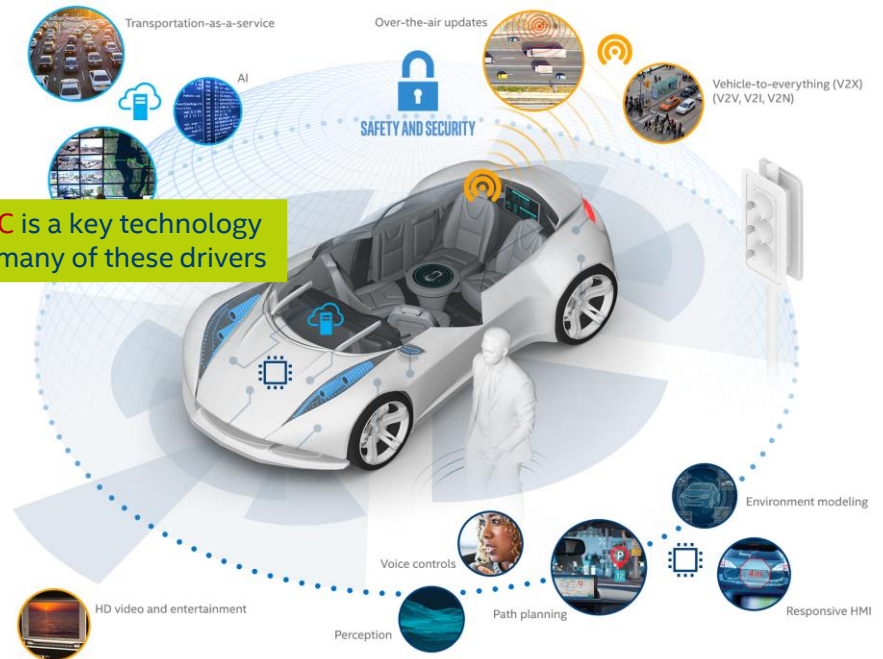
- Cloud V2X services
- Over the air updates
- Infotainment / media delivery
- Intelligent route and path planning
- Tracking / fleet management
- Transportation as a service

Inter-Car Communication

- Cars talk to another cars, pedestrians, road side units
- Road safety
- Telematics information exchange
- Environment perception
- Cooperative & automated driving




MEC is a key technology for many of these drivers



Suggested reading: 5GAA White Paper on Edge Computing

http://5gaa.org/wp-content/uploads/2017/12/5GAA_T-170219-whitepaper-EdgeComputing_5GAA.pdf

Predictive QoS in 5GAA

- 5G Automotive Association (5GAA) has developed the concept of predictive Quality of Service (QoS), which is a mechanism enabling mobile networks to provide advance notifications about predicted QoS changes to interested consumers.
- This makes it possible to adjust application behaviour before the predicted QoS change takes effect, which is important to certain automotive use cases, such as remote and autonomous driving.
- QoS predictions may also be exposed to the V2X Application through a **MEC service API** 

Use Case	QoS KPIs to be Predicted	Examples of Potential Application Reactions
Tele-Operated Driving	Data rate, Latency, Reliability	Change route, Park vehicle, Handover to nearby driver, Change sensor set/properties, Change teleoperation mode (e.g., from manoeuvring to trajectory provision)
High-Density Platooning	Latency, Reliability	Change inter-vehicle distance, Handover to driver, Change platoon speed or length, Terminate platoon
Hazardous Location Warning	Reliability	Inform user about availability of warning service, Change speed, Change route
Lane Merge	Latency, Reliability	Change speed of merging attempt, Abort lane merge
Software Update	Data rate	Reschedule, Stop or resume download
Infotainment	Data rate	Change video quality

- Work Item **MEC 030** introduces new MEC Service, called V2X Information Service (VIS).
- Key requirement for **MEC V2X API** is the support for service exposure and communication ability across participating V2X applications in different MEC systems
- Stable draft available at the MEC Open Area:
<https://docbox.etsi.org/ISG/MEC/Open>

Suggested reading: 5GAA White Paper on “Making 5G Proactive and Predictive for the Automotive Industry”

https://5gaa.org/wp-content/uploads/2020/01/5GAA_White-Paper_Proactive-and-Predictive_v04_8-Jan.-2020-003.pdf



5GAA

Intel Demo on MEC

In-Vehicle Entertainment Utilizing Multi-Access Edge Computing (MEC) over 5G Networks

Intel, Marelli, Terranet, Equinix, UniPisa

Turin, November 14th, 2019
5GAA (5G Automotive Association)

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<https://5gaa.org/news/5gaa-live-demos-show-c-v2x-as-a-market-reality/>



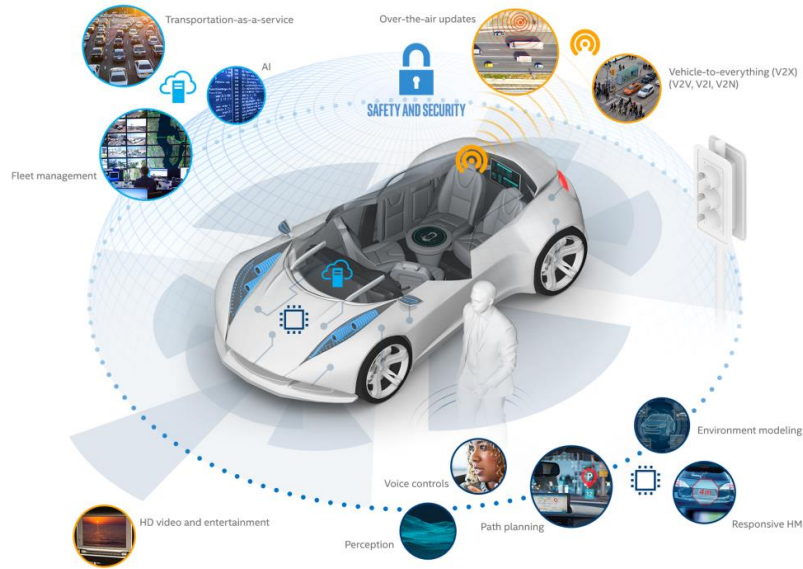
experience
what's inside™

In-Vehicle Entertainment utilizing Multi-Access Edge Computing (MEC) over 5G Networks

- **Multi-Access Edge Computing (MEC)** is a key technology offering cloud computing capabilities and an IT service environment at the edge of 5G mobile networks.
- This demo, realized by Intel, together with Marelli, Terranet and Equinix, shows how MEC can support immersive **high-definition (HD) entertainment** for all occupants of a moving vehicle, including video streaming, gaming, virtual reality (VR), office work, online education, advertisement, etc.



In-Vehicle Entertainment – motivation in 5GAA



Automotive sector is key for **MEC** and for **5G**.
These technologies will open the door to multiple use cases and services that can be monetized by **5GAA** stakeholders.
In addition to traditional use cases on connected and automated cars, **infotainment** is also a promising market.

(Excerpt from Intel 5G Connected Vehicles Webinar):
"Intel predicts a new **\$7 trillion passenger economy** will emerge when passengers become riders." [...]
"We did a study that shows drivers spend **300 hours a year** behind the wheel and 5G offers **entertainment opportunities** to optimize that time as we transition from drivers to riders."

[figure: Intel]

Predictive QoS – reference scenario

- vehicle planning to follow a **trajectory** from location A to location B



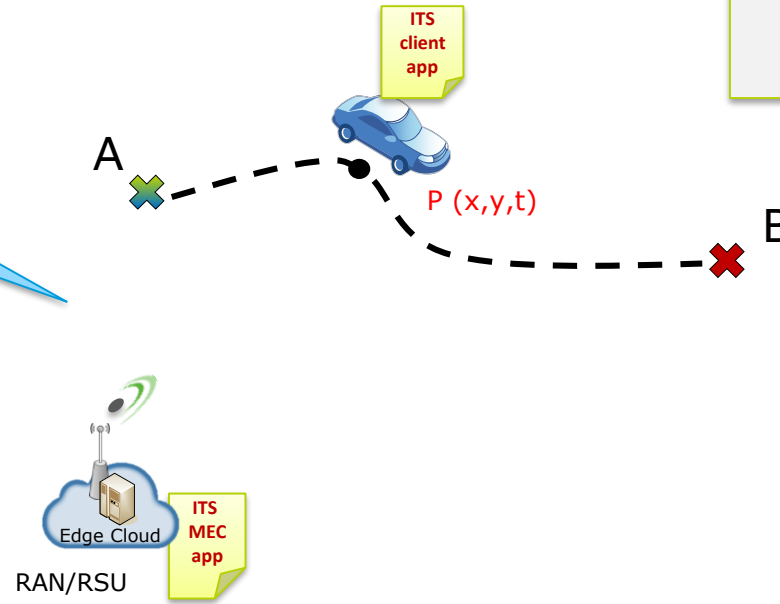
Example of **map** @ Device/car Display

Predictive QoS – reference scenario

predicted QoS info examples:

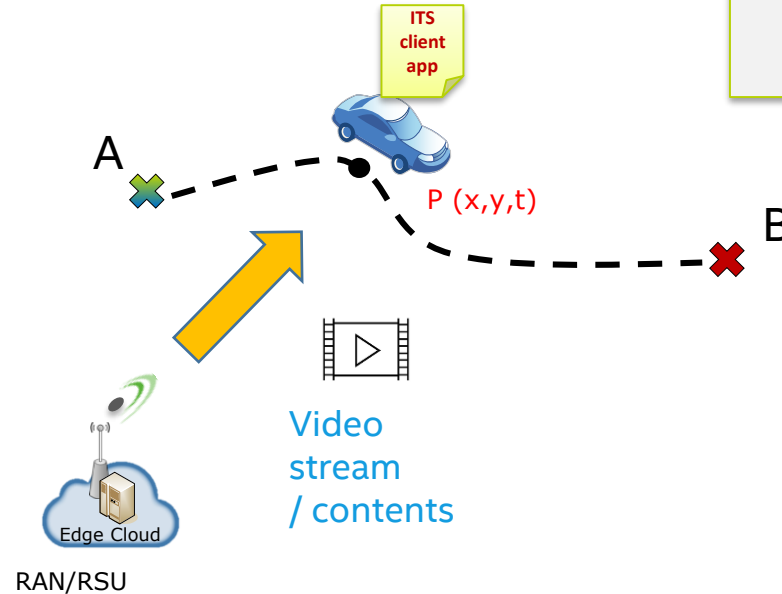
- 1 - Resource Type (GBR, delay critical GBR or Non-GBR);
- 2 - Priority level;
- 3 - Packet Delay Budget;
- 4 - Packet Error Rate.
- 5 - Averaging window.

- vehicle planning to follow a trajectory from location A to location B
- MEC could be used to support info **delivery of radio conditions** "en route", ahead of the vehicle's passing time, before reaching a decision.



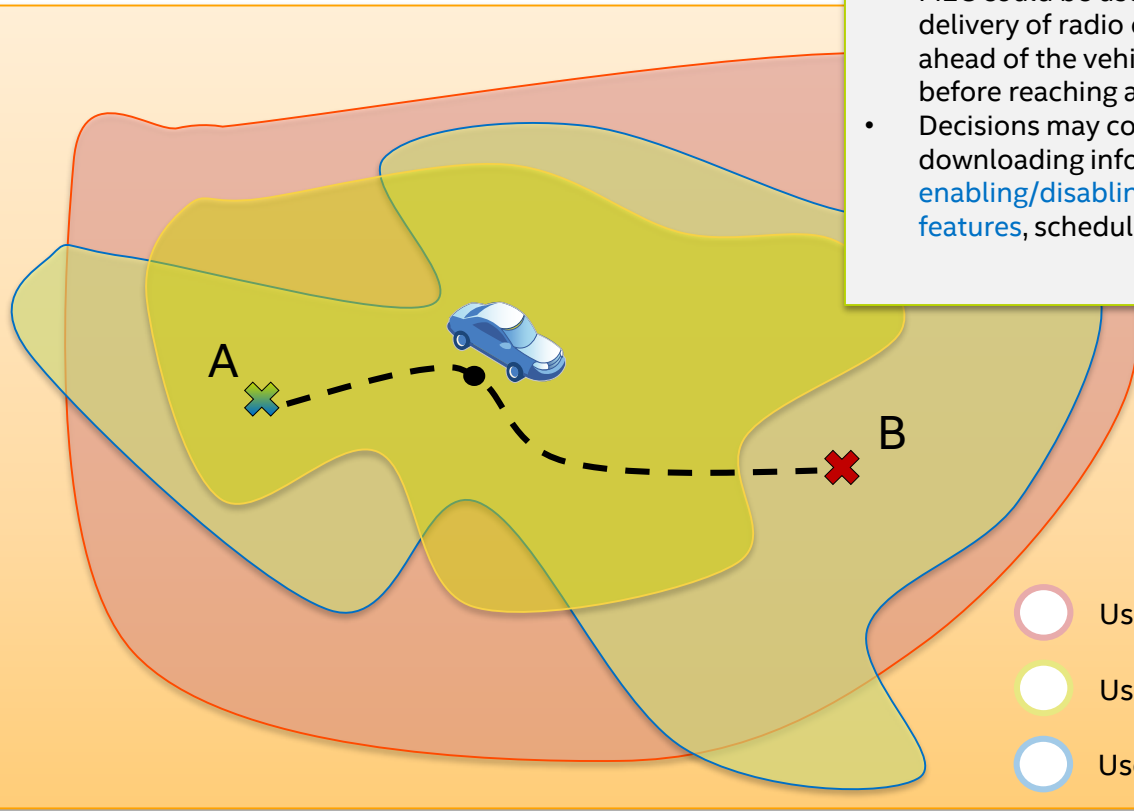
Predictive QoS – reference scenario

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- Decisions may consist in e.g., [downloading infotainment content](#), enabling/disabling autonomous driving features, scheduling SW updates, etc.



Predictive QoS – reference scenario

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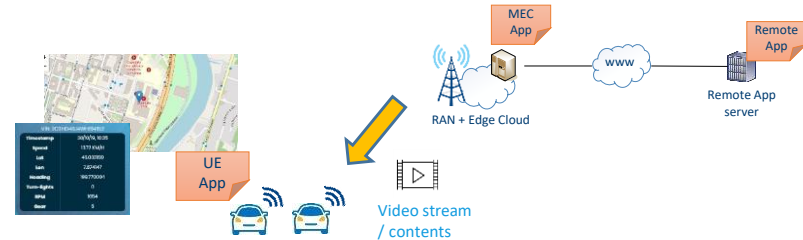
- Use Case 1 “coverage”
- Use Case 2 “coverage”
- Use case 3 “coverage”

In-Vehicle Entertainment – demos

This demo (based on IVE use case) aims at demonstrating two main concepts:

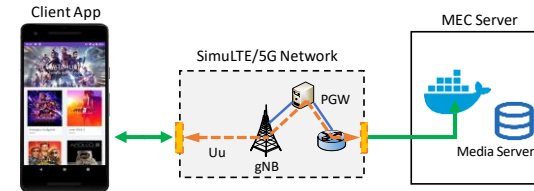
- The benefits of **edge computing**, by comparing different **deployment options**

[Realized by Marelli/Intel/Equinix]



- The **multimedia delivery adaptation**, thanks to **Predictive QoS** through realtime simulation and live data from drive tests

[Realized by Terranet/Intel/UniPisa]

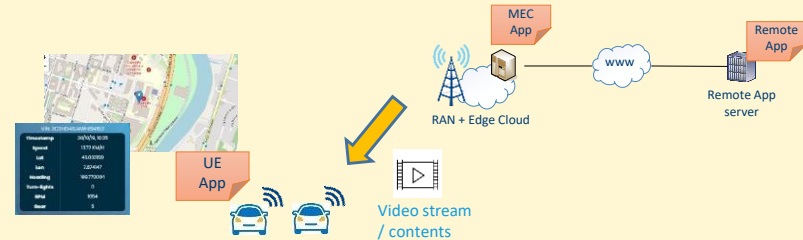


In-Vehicle Entertainment – demos

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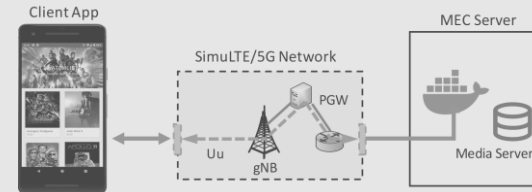
- The benefits of **edge computing**, by comparing different **deployment options**

[Realized by Marelli/Intel/Equinix]

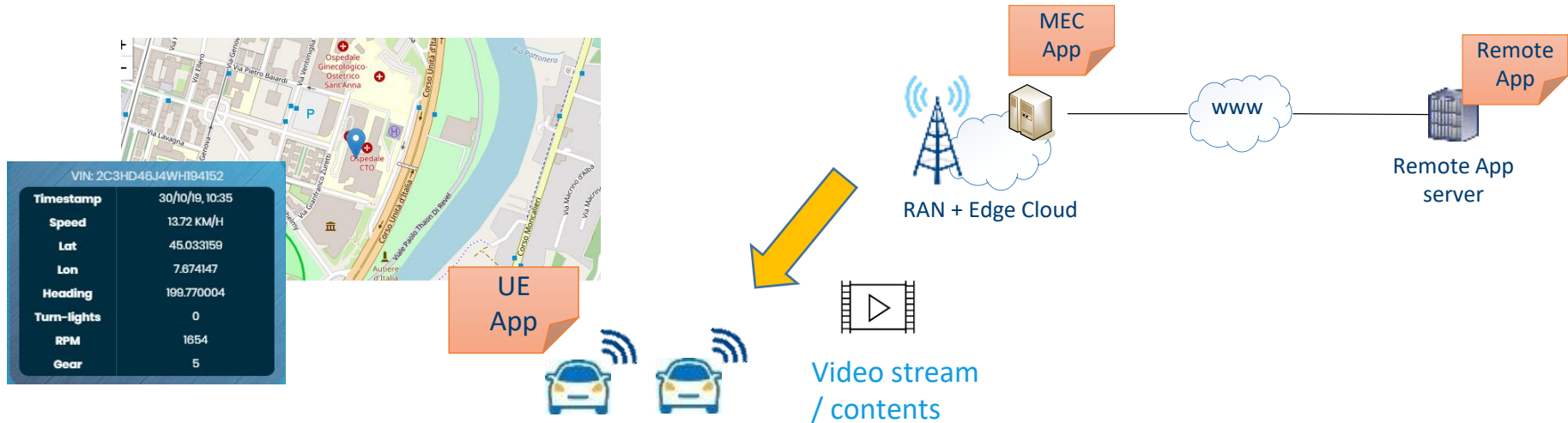


- The multimedia delivery adaptation, thanks to Predictive QoS through realtime simulation and live data from drive tests

[Realized by Terranet/Intel/UniPisa]

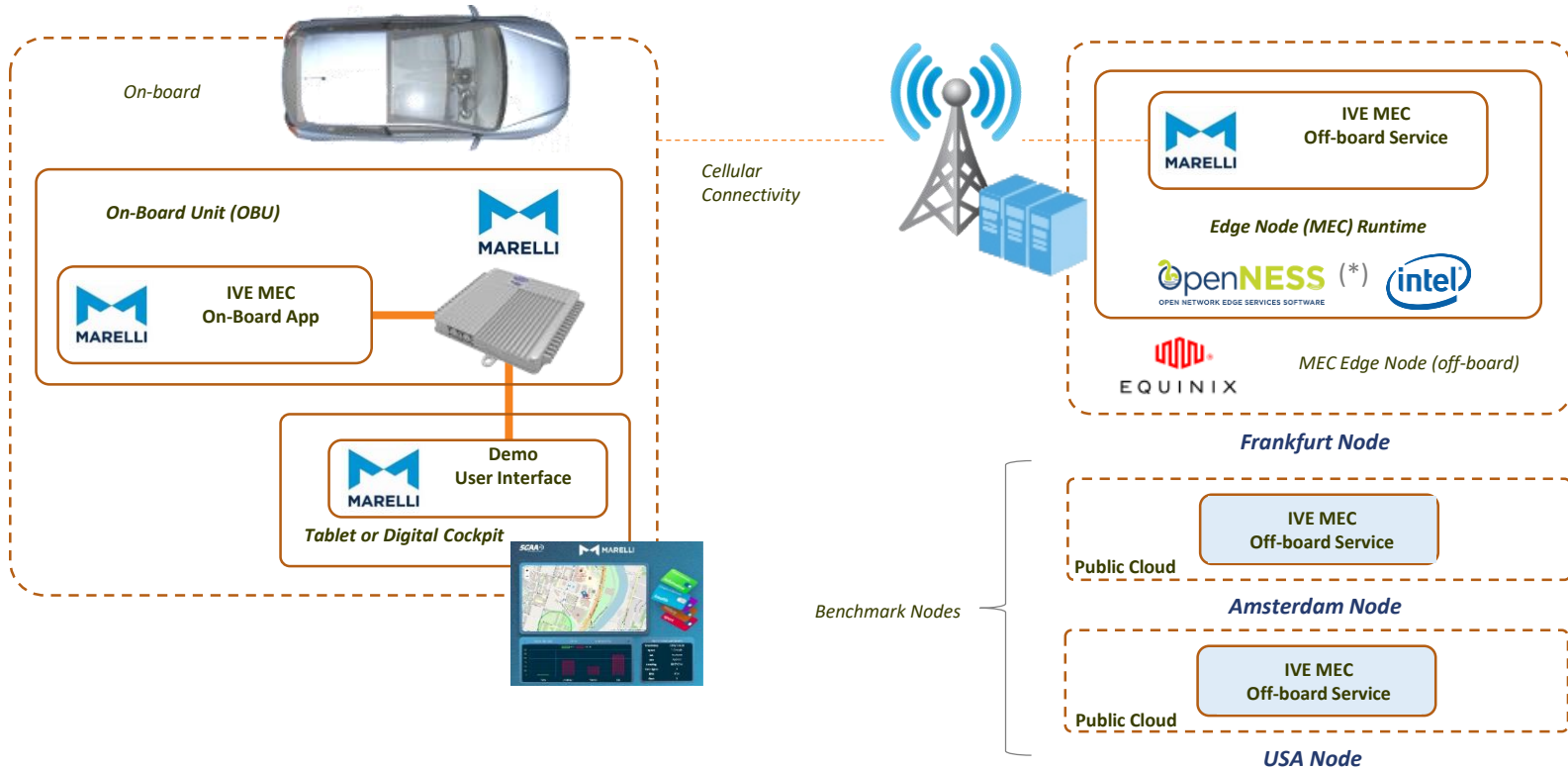


Benefits of Edge Deployments



- The IVE **client App** running on the **On-Board Unit (OBU)** displays high-definition video contents to passengers based both on their interests and car context (e.g. position, heading, speed, etc.).
- Video contents are retrieved from off-board services in the **Cloud** or at the **Edge**.
- The demo shows how a media server instantiated at the edge can provide **lower communication latencies**, faster service response times, **higher bandwidth** and more dynamic and fine-grained geographical provisioning.

Reference Architecture used for IVE App Tests



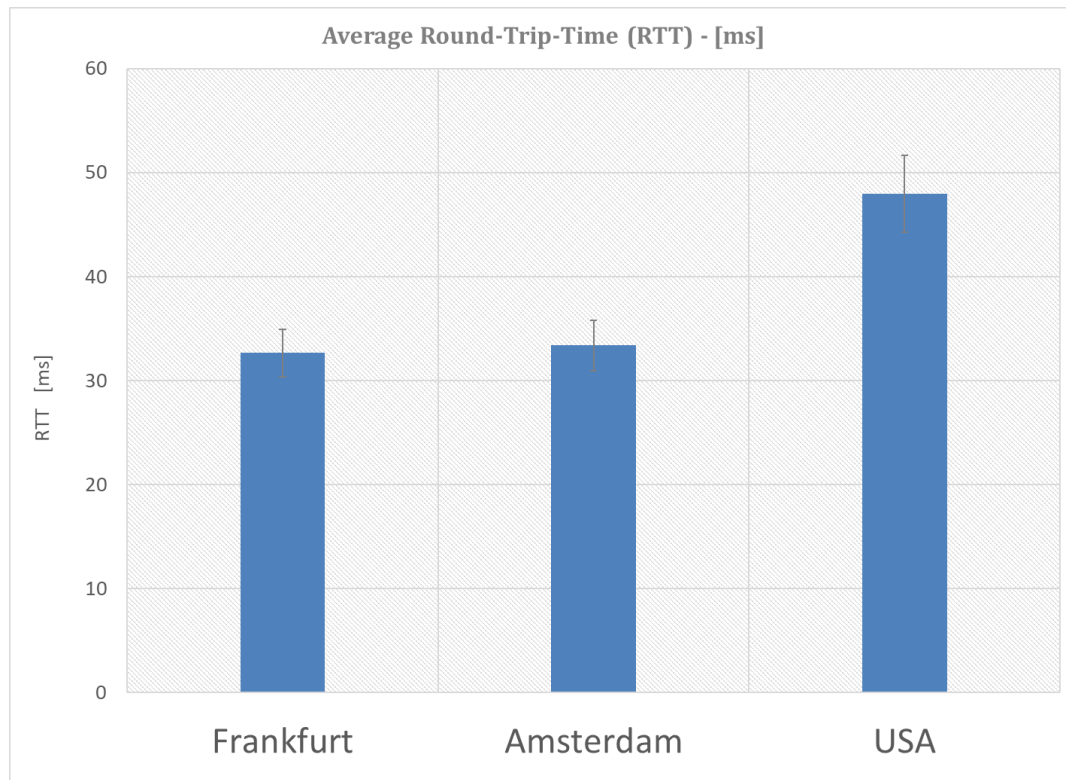
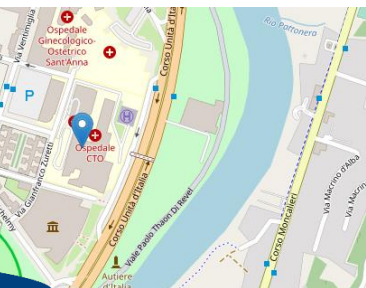
MEC performance evaluation – preliminary comparative results

Drive tests in Turin with 3 server locations:

- Frankfurt
- Amsterdam
- USA

VIN: 2C3HD46J4WH194162

Timestamp	30/10/18, 10:35
Speed	13.72 KM/H
Lat	45.033169
Lon	7.674147
Heading	199.770004
Turn-lights	0
RPM	1654
Gear	5

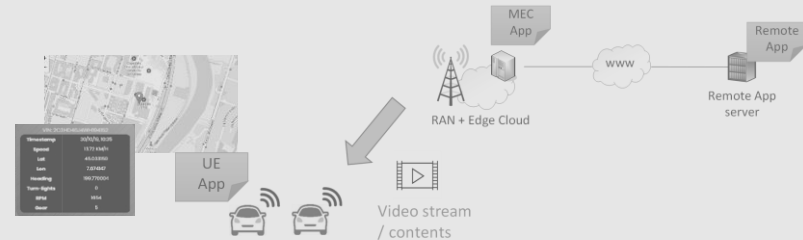


In-Vehicle Entertainment – demos

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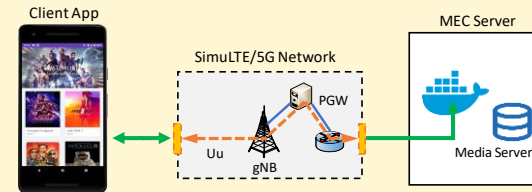
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[Realized by Marelli/Intel/Equinix]



- The **multimedia delivery adaptation**, thanks to **Predictive QoS** through realtime simulation and live data from drive tests

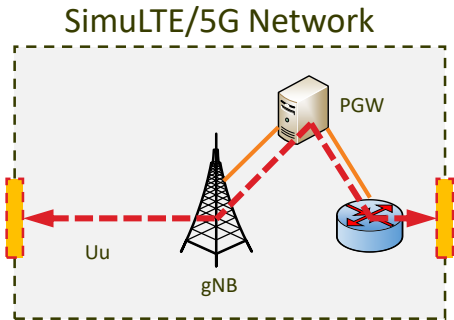
[Realized by Terranet/Intel/UniPisa]



Collecting Data from Live Measurements in Turin

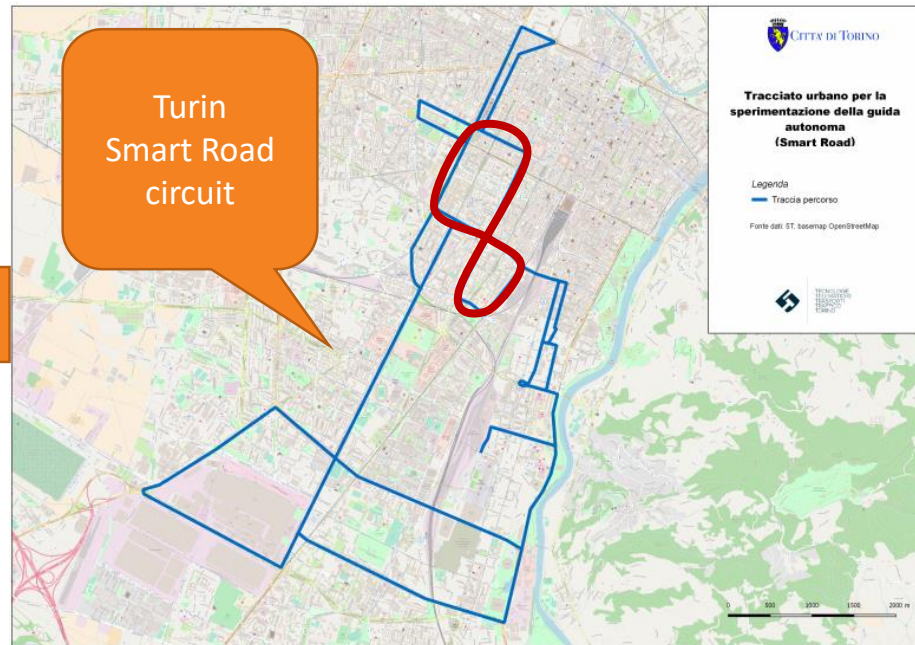
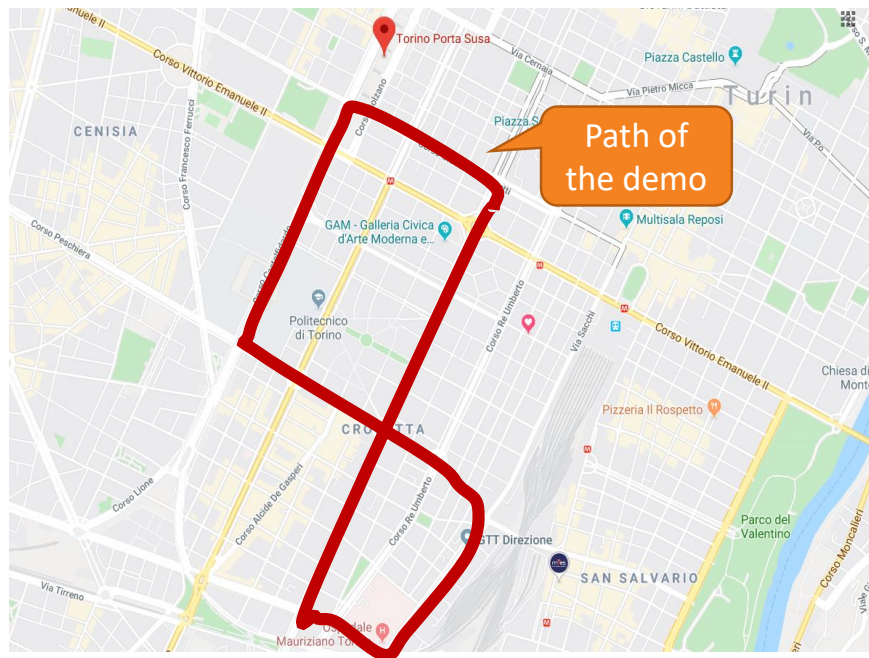


- Cellular network quality LOG file was captured during **drive test** in Turin with Terranet software
- Terranet provided client application, media server backend and cellular network visualization



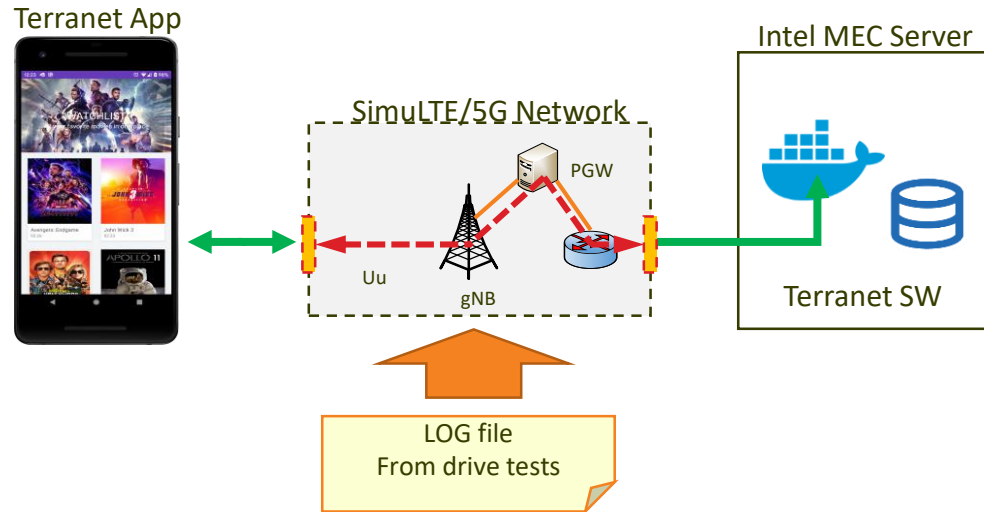
- **Realtime emulation** recreates network quality from actual test drive

Test Drive Routes in Turin



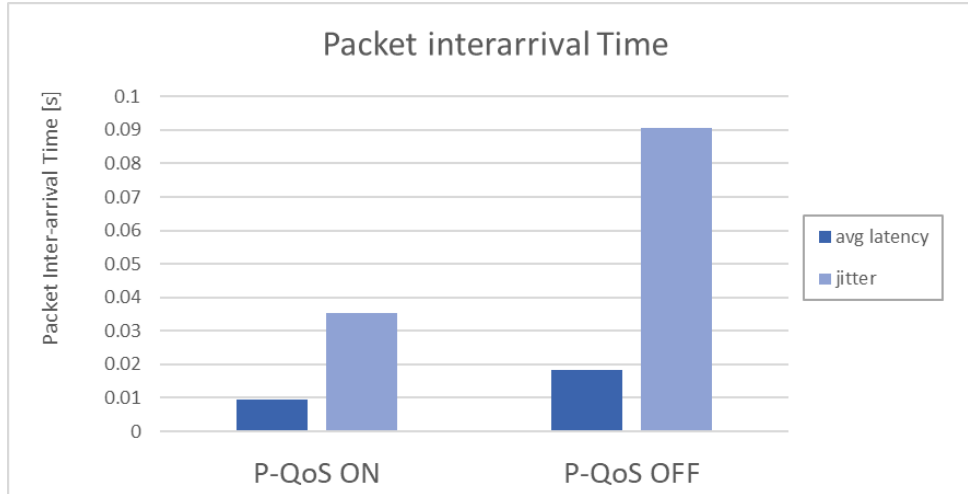
Smart Road circuit

Predictive QoS - Demonstration Diagram



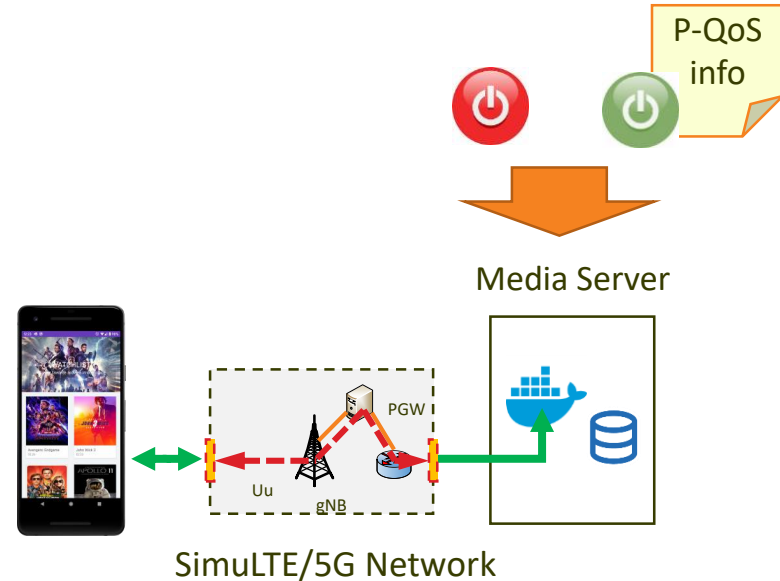
- **Realtime 5G emulated environment** connected with commercial terminal and a MEC server.
- The availability of information about **Predictive Quality of Service (QoS)** can be delivered by MEC to better support immersive high-definition (HD) entertainment for all occupants of a moving vehicle, including video streaming, gaming, virtual reality (VR), office work, online education, advertisement, etc.
- The benefits for passengers will be sustained **high quality entertainment** over 5G networks utilizing predictive QoS and MEC.

Predictive-QoS impact on performance – preliminary results



Test repeated in 2 conditions:

- Predictive-QoS **activated**
- Predictive-QoS **deactivated**

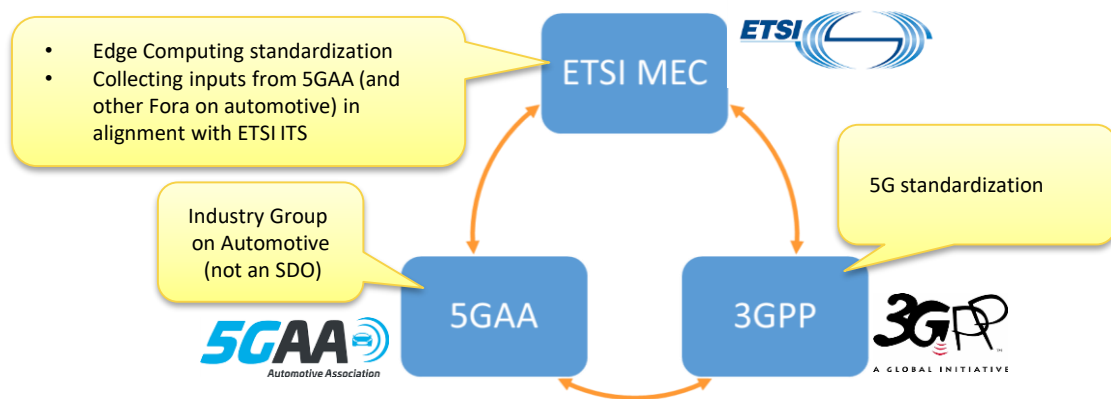


Conclusions



Conclusions 😊

- **Edge computing** is commonly recognized as an important technology for **5G**
- ETSI **MEC** (Multi-access Edge Computing) is leading international **standard** for Edge Computing (more recently also 3GPP started a work on edge computing for supporting 5G communication networks).
- Edge Computing (/MEC) is **access agnostic** (applicable to 5G, WiFi, fixed networks, ...) and also covering **many verticals** like automotive, as well as other industrial use cases.
- **Example** below: synergy between standards and 5GAA (5G Automotive Association)



Examples of **industry groups** relevant for ETSI MEC:

- 5G-ACIA (Alliance for Connected Industries and Automation)
- 5GAA (5G Automotive Association)
- AECC (Automotive Edge Computing Consortium)
- VR-IF (Virtual Reality Industry Forum)
- OFC (Open Fog Consortium)
- SCF (Small Cell Forum)
- GSMA (MEC working group)
- BBF (BroadBand Forum)

INTEL is board member in 5GAA and 5G-ACIA, also in VR-IF and present in many other industry groups



Thank you!

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REFERENCES

- [1] ETSI White Paper: “Mobile Edge Computing: A key technology towards 5G”, September 2015; Link: https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp11_mec_a_key_technology_towards_5g.pdf
- [2] 3GPP TS 23.501: System Architecture for the 5G System, June 2018, http://www.3gpp.org/ftp/Specs/archive/23_series/23.501/23501-f20.zip
- [3] 5GPPP, “5G Vision: The 5G Infrastructure Public Private Partnership: The Next Generation of Communication Networks and Services”, 2015. <https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>
- [4] ETSI GS MEC 003 V1.1.1 (2016-03) Mobile Edge Computing (MEC); Framework and Reference Architecture - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/003/01.01.01_60/gs_MEC003v010101p.pdf
- [5] 5GAA white paper: “Toward fully connected vehicles: Edge computing for advanced automotive Communications”, Dec. 2017, http://5gaa.org/wp-content/uploads/2017/12/5GAA_T-170219-whitepaper-EdgeComputing_5GAA.pdf
- [6] 5G-ACIA White Paper: “5G for Connected Industries and Automation”, April 2018, <https://www.5g-acia.org/publications/5g-for-connected-industries-and-automation-white-paper/>
- [7] ETSI MEC presentation at 5G-ACIA meeting, Frankfurt, October 2018
- [8] ETSI White Paper: “MEC in an Enterprise Setting: A Solution Outline”, September 2018, Link: https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp30_MEC_Enterprise_FINAL.pdf
- [9] ETSI press release on first MEC hackathons, October 2018, <https://www.etsi.org/news-events/news/1345-2018-10-news-etsi-mec-hackathons-bring-developers-together-in-china-germany-and-italy-to-trial-edge-computing-solutions>
- [10] Emara, Filippou, Sabella: “MEC-assisted End-to-End Latency Evaluations for C-V2X Communications”, EUCNC 2018, <https://arxiv.org/pdf/1802.08027.pdf>

MEC SPECS

- [MEC001] ETSI GS MEC 001 V1.1.1 (2016-03) Mobile Edge Computing (MEC) Terminology - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/001/01.01.01_60/gs_MEC001v010101p.pdf
- [MEC002] ETSI GS MEC 002 V1.1.1 (2016-03) Mobile Edge Computing (MEC); Technical Requirements - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/002/01.01.01_60/gs_MEC002v010101p.pdf
- [MEC003] ETSI GS MEC 003 V1.1.1 (2016-03) Mobile Edge Computing (MEC); Framework and Reference Architecture - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/003/01.01.01_60/gs_MEC003v010101p.pdf
- [IEG004] ETSI GS MEC-IEG 004 V1.1.1 (2015-11) Mobile-Edge Computing (MEC); Service Scenarios - http://www.etsi.org/deliver/etsi_gs/MEC-IEG/001_099/004/01.01.01_60/gs_MEC-IEG004v010101p.pdf
- [IEG005] ETSI GS MEC-IEG 005 V1.1.1 (2015-08) Mobile-Edge Computing (MEC); Proof of Concept Framework - http://www.etsi.org/deliver/etsi_gs/MEC-IEG/001_099/005/01.01.01_60/gs_MEC-IEG005v010101p.pdf
- [IEG006] ETSI GS MEC-IEG 006 V1.1.1 (2017-01) Mobile Edge Computing; Market Acceleration; MEC Metrics Best Practice and Guidelines - http://www.etsi.org/deliver/etsi_gs/MEC-IEG/001_099/006/01.01.01_60/gs_MEC-IEG006v010101p.pdf
- [MEC009] ETSI MEC 009 "General principles for Mobile Edge Service APIs" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/009/01.01.01_60/gs_MEC009v010101p.pdf
- [MEC010-1] ETSI MEC 010-1 V1.1.1 (2017-10) "Mobile Edge Management; Part 1: System, host and platform management" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/01002/01.01.01_60/gs_MEC01002v010101p.pdf
- [MEC010-2] ETSI MEC 010-2 V1.1.1 (2017-07) "Mobile Edge Management; Part 2: Application lifecycle, rules and requirements management" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/01002/01.01.01_60/gs_MEC01002v010101p.pdf
- [MEC011] ETSI MEC 011 V1.1.1 (2017-07) "Mobile Edge Platform Application Enablement" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/011/01.01.01_60/gs_MEC011v010101p.pdf
- [MEC012] ETSI MEC 012 "Radio Network Information API" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/012/01.01.01_60/gs_MEC012v010101p.pdf
- [MEC013] ETSI MEC 013 "Location API" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/013/01.01.01_60/gs_MEC013v010101p.pdf
- [MEC014] ETSI MEC 014 "EU identity API" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/013/01.01.01_60/gs_MEC013v010101p.pdf
- [MEC015] ETSI MEC 015 "Bandwidth management API" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/015/01.01.01_60/gs_MEC015v010101p.pdf
- [MEC016] ETSI MEC 016 "UE application interface" - http://www.etsi.org/deliver/etsi_gs/MEC/001_099/016/01.01.01_60/gs_MEC016v010101p.pdf
- [MEC018] ETSI MEC 018 "End to End Mobility Aspects" - http://www.etsi.org/deliver/etsi_gr/MEC/001_099/018/01.01.01_60/gr_MEC018v010101p.pdf

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