Cooperation models:
CEF2 Digital programme
5G Corridors opportunities

5GAA cooperation models white papers

5GAA is continuously supporting Road Operators with deployment perspectives

1. C-ITS Vehicle to Infrastructure Services: How C-V2X technology completely changes the cost equation for road operators.
   BMAC White paper Mar 2019
2. MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements
   NetExp White paper June 2020
3. Cooperation Models enabling deployment and use of 5G infrastructures for CAM in Europe
   Coop Models White Paper, Mar 2021
4. Network Reselection Improvement (cross-border continuity of service)
   NRI Technical Report, June 2021

C-ITS Vehicle to Infrastructure Services:

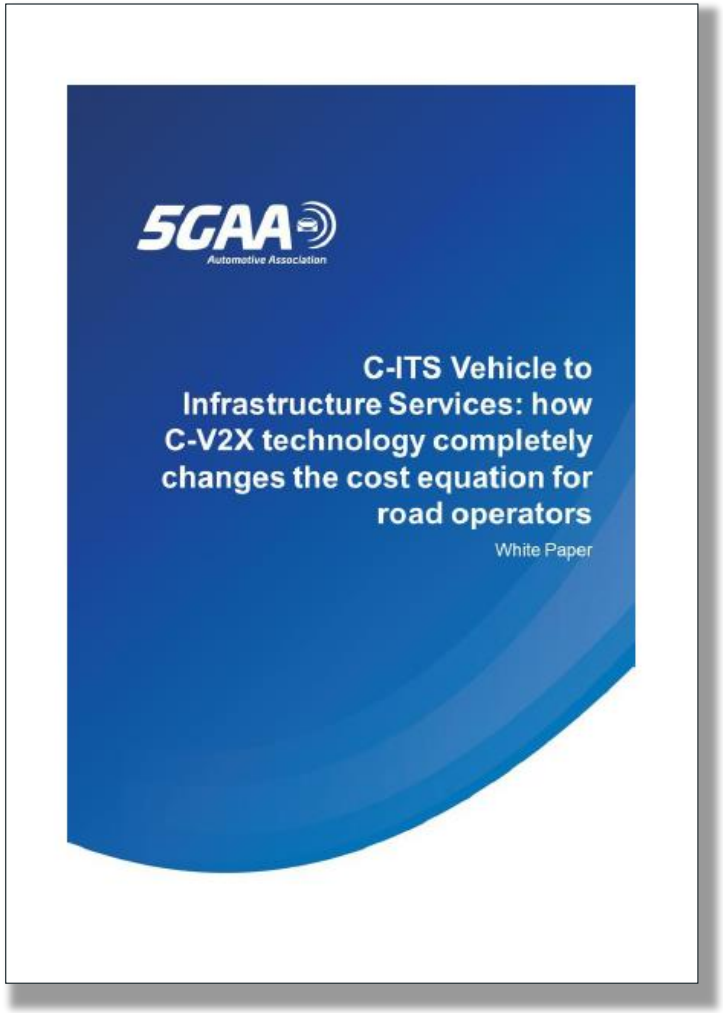
How C-V2X technology completely changes the cost equation for road operators.

Brief overview & conclusions

5GAA position on C-ITS Vehicle to Infrastructure Services

5GAA has published a white paper with deployment recommendations for C-ITS Vehicle to Infrastructure Services:

- https://5gaa.org/news/5gaa-releases-white-paper-on-the-benefits-of-using-existing-cellular-networks-for-the-delivery-of-c-its/
- http://5gaa.org/wp-content/uploads/2019/01/5GAA-BMAC-White-Paper_final2.pdf

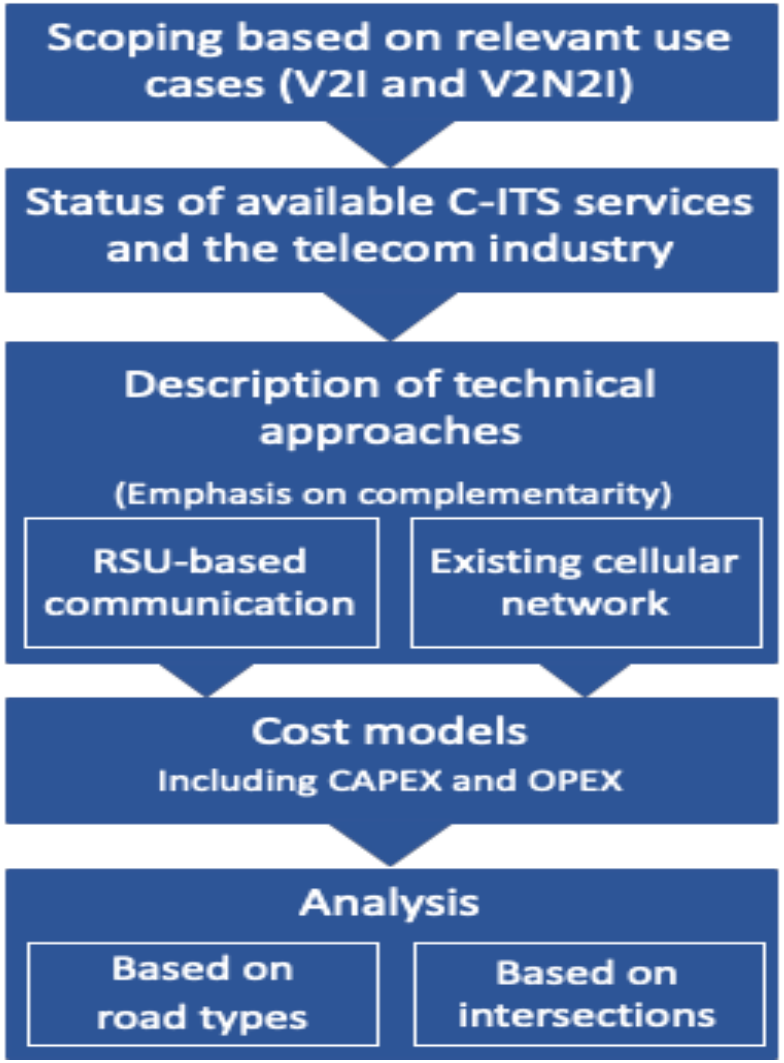


Contributors:

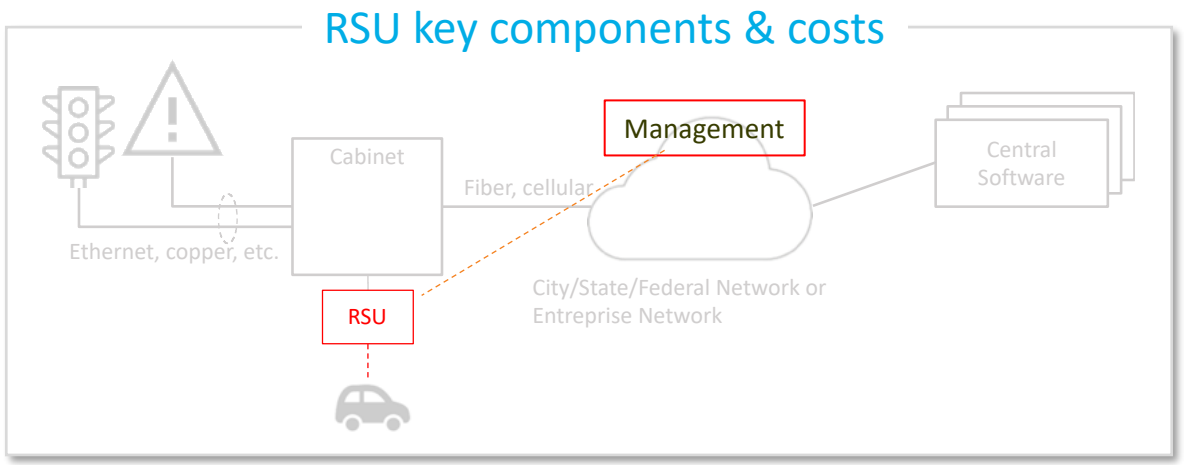
- BMW, Deutsche Telekom, Ericsson, Huawei, Intel, LG, Mitsubishi, Nokia, NTT Docomo, Orange, Qualcomm, Samsung, Sumitomo, Telstra, Vodafone

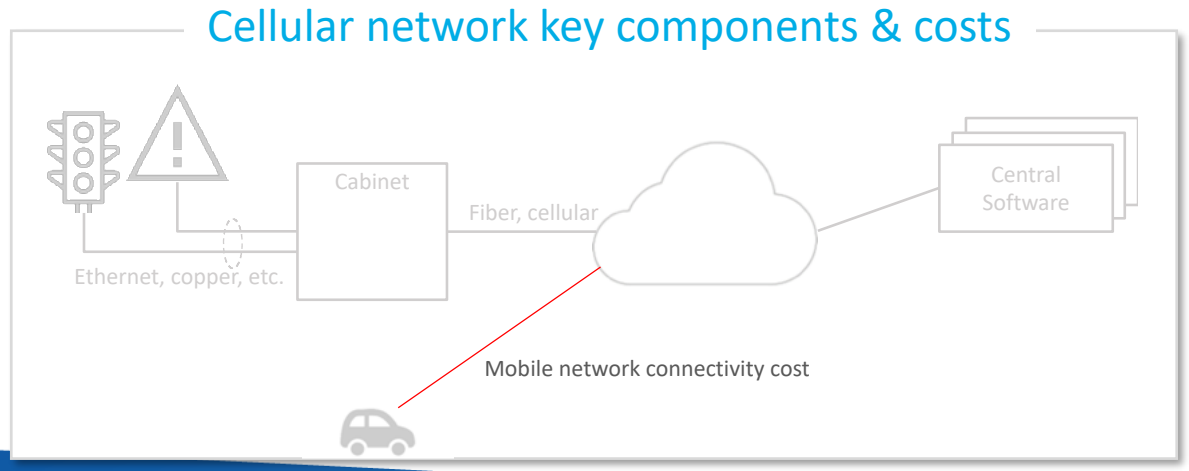
Scope and structure of the white paper

- Analysis on the benefits of using existing cellular networks for the delivery of C-ITS services in comparison with RSU deployments.
- Deployment options in terms of expenditures over a ten-year timeframe for the deployment of V2I and V2N2I C-ITS services for vehicles communicating with infrastructure.
- For each option, the deployment costs, operation and maintenance cost, and connectivity costs are evaluated.
- Highlights complementarity between mobile communications networks (Uu) and sidelink (PC5) technologies.



Considered deployment options and cost structures





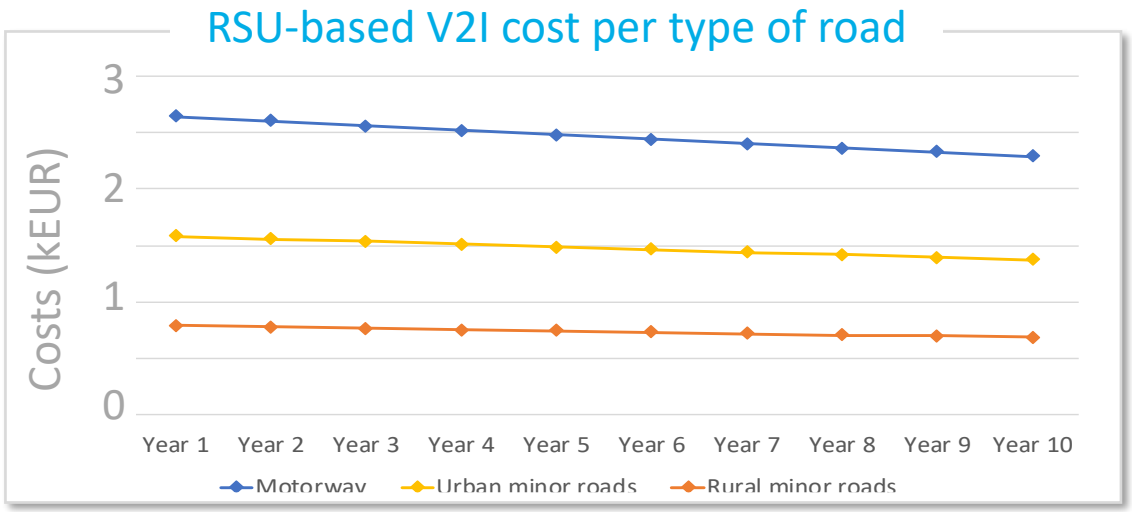
These costs were analyzed:

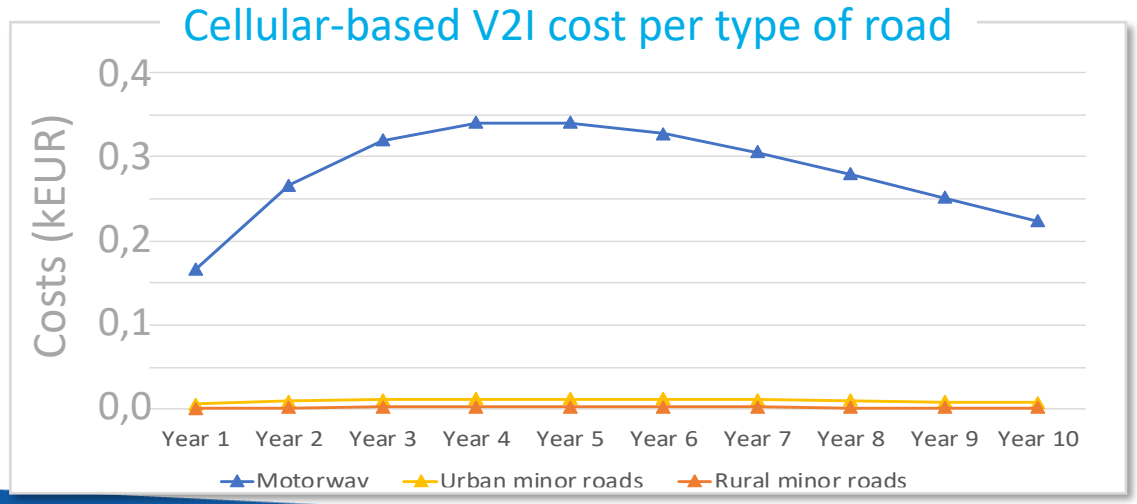
- Deployment costs: CAPEX for network assets and infrastructure.
- Operation and maintenance costs: OPEX to operate and maintain the network infrastructure.
- Connectivity costs: OPEX related to connectivity services

Costs were split per road type:

- Motorway, Urban roads, Urban minor roads, Rural A roads, Rural minor roads

Comparing cellular-based V2I with RSU-based V2I costs





Observations:

- Cost of delivering ITS services with existing cellular networks is significantly lower compared to widespread RSU rollout.
- Cost gap between RSU and cellular is larger for rural and minor urban areas and lower for motorways and major urban roads.
- Cumulative connectivity cost is not offset even within 10 years
- The portion of data transmitted in relation to road operator services represent a small fraction, compared to other V2N services.

Key take-aways

Cost of delivering ITS services with existing cellular networks is significantly lower compared to widespread RSU rollout: in best cases it could be even more than a hundred times lower than with only dedicated RSUs.

Infrastructure C-ITS services can be delivered as V2I with short range radio, V2N2I with cellular networks, or a mix of both.

Mobile communication networks have advanced significantly since V2I services were defined by ETSI – some of the architectural principles date from a time when smartphones were still a new concept.

Making traffic light information available on Internet is a good way to manage road operator investments and offer road efficiency services. This is already common in many parts of the world.

It is expected that cellular connectivity will be available in 55% of new vehicles globally by 2020. 5GAA estimates more than 100 million cellular connected vehicles today that could be updated for several ITS-services.

Spectrum licensing can be a mechanism to foster mobile network coverage expansion for rural or other underserved areas. This could be used to accelerate coverage of roads and highways too.

MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements

Brief overview & conclusions

NetExp White Paper abstract

This paper describes how cellular coverage of roads, to support automotive, road operation and consumer services, can be extended and expedited through cooperation between mobile network operators, road operators, national and regional governments as well as national road and communications regulators/ authorities.

It is primarily a strategy playbook with recommendations on cooperation between mobile network operators (MNO) and road operators/governments.

The paper should facilitate discussion between road operators, governments and MNO's, to expedite the deployment of mobile networks alongside roads.

NetExp White Paper structure

1 Situational overview
1.1 Background on government needs
1.2 Background on the connected vehicle evolution
1.3 Road and road infrastructure requirements – on the way to ‘digital roads’
2 Cost-benefit considerations regarding cellular road coverage
2.1 Socio-economic connected vehicle use cases that drive network requirements
2.2 Connected vehicle requirements that drive network investments
2.3 Cost drivers for mobile network setup
3 Regulatory framework mechanisms to incentivise network expansion
3.1 Clear road coverage obligations
3.2 Spectrum auctions without strict road obligations
3.3 Expand rural coverage
3.4 Cross-border coverage improvement
3.5 Public co-funding for critical corridors
3.6 Reuse of existing public infrastructure
3.7 Neutral host infrastructure model
3.8 5G spectrum considerations
4 Recommended 5GAA positions

Situational overview: Road and road infrastructure requirements – on the way to 'digital roads'

Maximize information dissemination to/between road users by establishing a Digital Road:

1. A reliable digital representation of the static road parameters, such as geometry, speed limits, traffic regulations, etc., and consistent with ISAD level D. Using connected vehicles to monitor and report issues on roads, bridges, tunnels, etc.
2. Getting access to information/data from/to roadside infrastructure (e.g. traffic lights, road works warnings, variable speed limit signs, etc.), and dynamic road parameters (such as traffic jams, road hazards, etc.). The latter can be collected via in-car sensors, providing the necessary data, qualified and consolidated by service providers, and consumed as services by traffic participants (ISAD level C). This information needs to be provided through highly available and 'low' latency IT interfaces.
3. Providing sufficient mobile network coverage alongside the road network, including sufficient network capacity according to the quality-of-service needs described in use cases, and for distributing traffic-related services, as mentioned above.

Cost-benefit considerations regarding cellular road coverage - Cost drivers for mobile networks setup

Passive infrastructure	Active infrastructure	Access & permissions	Spectrum licences	Build costs	Operating costs
Fixed ducts & poles	Commercial wholesale access	**Planning/ construction permits**	Mobile spectrum supply	Mobile roll out obligations	Site rental
Utility ducts & poles	Regulated nNGN access	Rooftop access	Upfront fees	**Cost sharing**	Local authority rates
Dark fibre	NGN sharing agreements	Access to in-building cabling	Ease of renewal	State subsidies	Power
Publicly funded infrastructure				Tower height limits	Annual spectrum fees
Power				EMF limits	Government taxes
				Labour costs	Import tariffs

Use of existing fibre/ducts

Simplify permissions

Shared use of infrastructure: lamp poles, traffic lights, noise barriers, advertising screens, public transport information screens

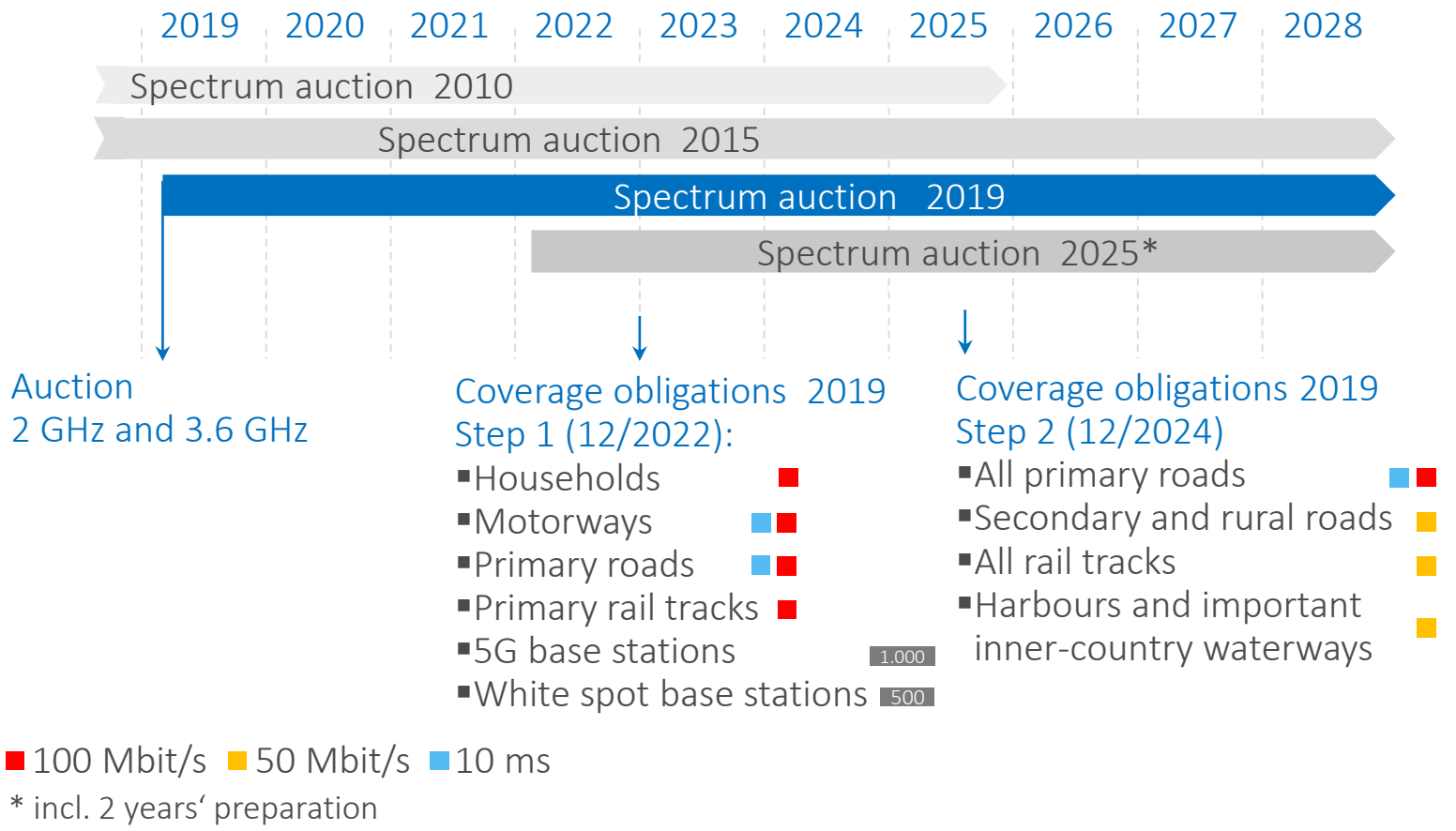
Use of existing power

Source: Vodafone Group PLC

Key take away:

Road Operators can provide key elements that improve the network expansion business case !

Regulatory framework mechanisms to incentivise network expansion - Example: Clear road coverage obligations



Source: Bundesnetzagentur, Germany

Best practice from German 5G auction to provide road coverage requirements, e.g.:

- Coverage with a transmission rate of at least 100 Mbit/s and a maximum latency of 10 milliseconds for all German motorways and all federal roads.
- Coverage with a transmission rate of at least 50 Mbit/s for all state roads.

5GAA Recommendations (1/2)
- Stepwise approach to identify needs and suited mechanisms

1. What drives the need for road coverage for the specific stakeholders?
   a. What are the governmental priorities (safety, efficiency, CO2 emissions, operational cost savings, economic stimuli, etc.)?
   b. What are the key stakeholders and use cases for these priorities?

2. What is the current road coverage situation?
   a. Identify/measure road coverage across the complete road network and broken down by:
      i. Motorways
      ii. Federal roads
      iii. Secondary road network (state roads/local roads/municipal roads)
   b. Who are the relevant stakeholders (regions, municipalities, countries in border areas, owners of public infrastructure, etc.)?

5GAA Recommendations (2/2)
- Stepwise approach to identify needs and suited mechanisms

3. Which of mechanisms can improve the situation?
   a. Clear road coverage obligations
   b. Provision of public roadside infrastructure
   c. Spectrum auctions without strict road obligations for competitive MNO markets with high customer demands
   d. Incentives to expand rural coverage
   e. Cross-border coverage improvement
   f. Public co-funding for critical corridors
   g. Neutral host model for infrastructure sharing
   h. Ensure sufficient 5G spectrum
4. What steps need to be taken and which key stakeholders need to support this?

Cooperation Models enabling deployment and use of 5G infrastructures for CCAM in Europe

Brief overview & conclusions

Main MNO cost drivers for deployment of 5G

- 1. Optimising location of antennas
- 2. Finding new sites and erecting masts
- 3. Access to power
- 4. Access to fibre connection or similar

"20 to 50% motorways benefit from an existing fibre backhaul infrastructure suitable to support 5G deployment"

- Simplified site permits
- Provide access to passive infrastructure
- Shared use of roadside furniture

Four cooperation models identified

1. Investment by MNO in full active 5G network (along the roads)
2. Investment by road/rail operator in passive infrastructure
3. Investment by single Neutral Host infrastructure Provider (“NHP”) in passive infrastructure
4. Co-investment by consortium of interested parties (NHPs, MNOs, road/rail operators) in active combined mobile network and RSU infrastructure

Cooperation model option 1/4:
Investment by MNO in full active 5G network (along the roads)

- Delivery of Day 1 or Day 1.5 C-ITS services by CSP via MNO
- OEM-MNO-CSP contractual relationship
- Requires continuous mobile network coverage alongside roads
- Requires Cross-MNO cross-OEM interoperability
- Virtual RSU opportunities to Road Operators

Possible market failures:

- Role and cooperation of Road Operators
- Cross-border continuity, out-of-coverage areas, Edge computing interop

Cooperation model option 2/4:
Investment by road/rail operator in passive infrastructure

- Broker role of the national government (e.g. NL)
- Access to road operator fibre and utilities (e.g., electricity)
- Base stations sharing via public infrastructure or between MNO
- Requires MNO-RO willingness to cooperate
- Need for potentially heavy long-term cooperation negotiations

Possible market failures:

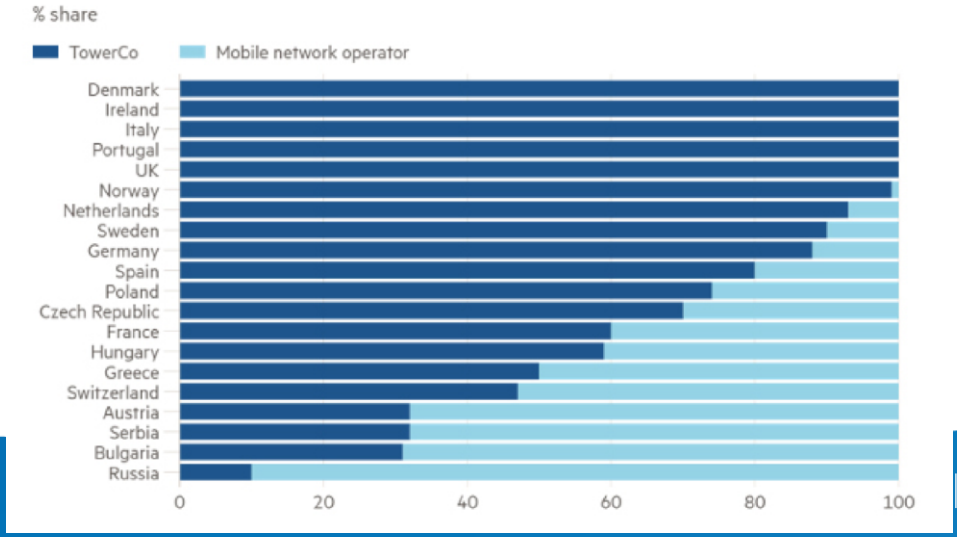
- Access to shared infrastructure: practical/implementation challenges
- legal implications, financial models, the future scalability of the model
- may lead to anti-competitive situations if MNOs are not treated fairly

Cooperation model option 3/4: Investment by single Neutral Host infrastructure Provider (“NHP”) in passive infrastructure

- National government assigns a neutral body to manage road infrastructure assets and make further investments e.g. “tower companies”
- Spread cost across many interested investors along road side
- Potential combination of base stations and RSUs deployment
- Fair treatment of all MNOs in a competitive environment

Possible market failures:

- reinforcement of tower companies market position may represent competition issues
- Model may not work in every MS



Cooperation model option 4/4: Co-investment by consortium of interested parties (NHPs, MNOs, road/rail operators) in active combined mobile network and RSU infrastructure

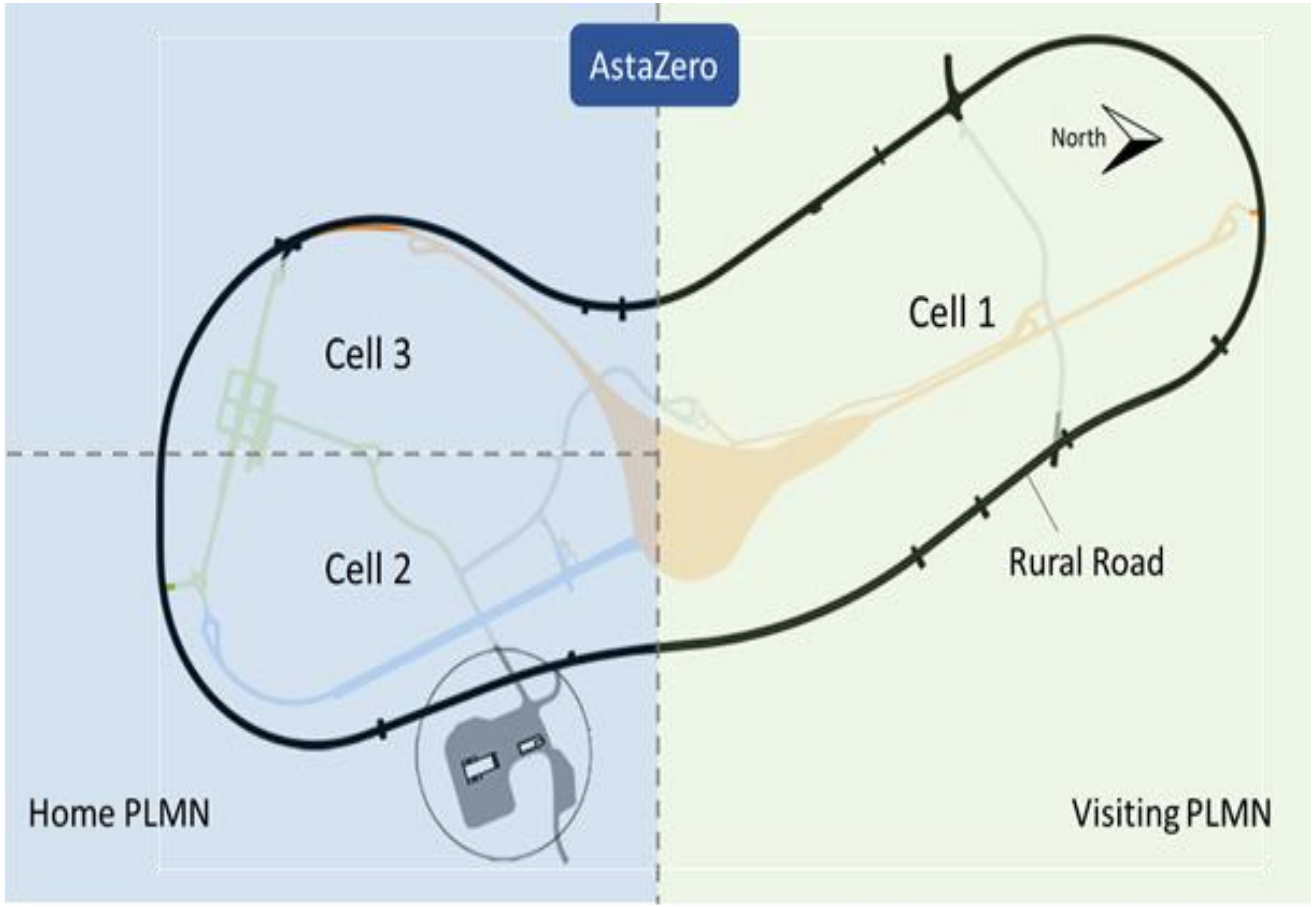
- Joint deployment of cellular small cells possibly combined with RSUs on the 5.9 GHz band on targeted areas
- Mainly relevant in urban areas i.e. densification with small cells
- Upfront cost savings for both the RSU (i.e., RO) and small cell owners (i.e., MNO)
- Joint maintenance, economies of scale

Possible market failures:

- Requires heavy consortium negotiations
- Multi-MNO with single Road operator cooperation reduces competition

Seamless customer experience at cross-borders (Network reselection improvement)

AstaZero test track



Description:

- 5G network at AstaZero (using ”Flight rack”) configured with two virtual Core networks PLMNs (H-PLMN and V-PLMN)
- The network configured with 3 cells operating in TDD band 40.
- For the cross-border testing the network is configured with:
  - 1 cell in the north in V-PLMN
  - 2 cells in the south as H-PLMN
  - V-PLMN and H-PLMN on different frequencies
- The test is performed using the ”Rural Road” part of the track which is 5,7 km long.
  - Two handover occations per lap

Cross border tests using existing mobility procedures

Increasing Effort

Scenarios tested:

- Scenario 1 – "Baseline"
  - Same roaming set-up as used in most/all of today's cellular networks

➔ ~30 sec user plane interruption time (best case, often 2-3mins in practice)

➔ IP connections get lost, services broken, new IP address allocated afterwards

- Scenario 2 – "Idle mode mobility" (Equivalent PLMN + Release with Redirect)
  - Introducing MME<->MME (S10) as a roaming interface
  - Requiring some extension of roaming agreements between operators

➔ ~1 sec user plane interruption time, IP adr. kept

Sufficent for most UCs

- Scenario 3 – "S1 Handover"
  - Gives better performance than scenario 2 but more complex
  - Requires more extensions to the roaming agreement than in scenario 2 + more configurations

➔ ~0.1 sec user plane interruption time, IP adr. Kept

Cross-border seamless user experience

Objective: Address cross-border seamless experience in EU

- 70 borders with Min 3 MNO on each side of the borders
- Requires implementation of standardized interfaces
- Put in place processes to answer organizational and contractual issues

Recent discussions at Digital Innovation Forum: cross-border topic was brought to attention of the highest levels among MNOs

Target: use CEF2 Digital to answer the cross-border challenge

Conclusions

- 5GAA is in constant contact with Road Operators who express interest to capitalize on the Mobile Networks to deliver their public mission
- Simple set of MNO-RO cooperation points have been identified to guarantee the right level of service on road networks
- Best cooperation consists of contractual arrangements between the interested stakeholders; regulations should only be considered if market fails to deliver
- Solving the seamless user experience at cross-borders is becoming a major focus of the MNOs in Europe

5GAA Automotive Association

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