The path from 4G to 5G

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Cranfield, UK , 26-September-2018

Agenda

1. C-V2X overview and 5GAA
2. Why C-V2X
3. Status of C-V2X
4. Evolution to 5G
5. Role of road authorities/operators
6. C-V2X and rail

Vision or reality?

Slink to ource

Link to Source

Vehicles need communication

Traffic safety and automated driving

Traffic efficiency

Infotainment

EUROPEAN COMMISSION

" … the Commission will follow an integrated approach between automation and connectivity in vehicles …"

On the road to automated mobility: An EU strategy for mobility of the future

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5GAA Automotive Association

5G Automotive Association, **pioneering digital transformation** in the **automotive industry**

Learn more at

WWW.5GAA.ORG

Driving Connected Mobility Forward

5GAA brings together the automotive and telecommunications industries to accelerate the global deployment of Cellular Vehicle-To-Everything (C-V2X) as a first step towards a fully integrated intelligent transport system with 5G

AUTOMOTIVE INDUSTRY

Vehicle Platform, Hardware and Software Solutions

TELECOMMUNICATIONS

Connectivity and Networking Systems, Devices and Technologies

5GAA unites 90+ 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

*as of Sept 2018

5GAA: A Global Cross Industry Association

September 2016

- “Audi, BMW Group, Daimler AG are teaming with Ericsson, Huawei, Intel, Nokia, and Qualcomm to create the 5G Automotive Association (5GAA), which will help develop, test, and promote 5G standards”
- “Scope of the alliance is focused on bringing connectivity solutions to market addressing technical, business, and regulatory challenges”

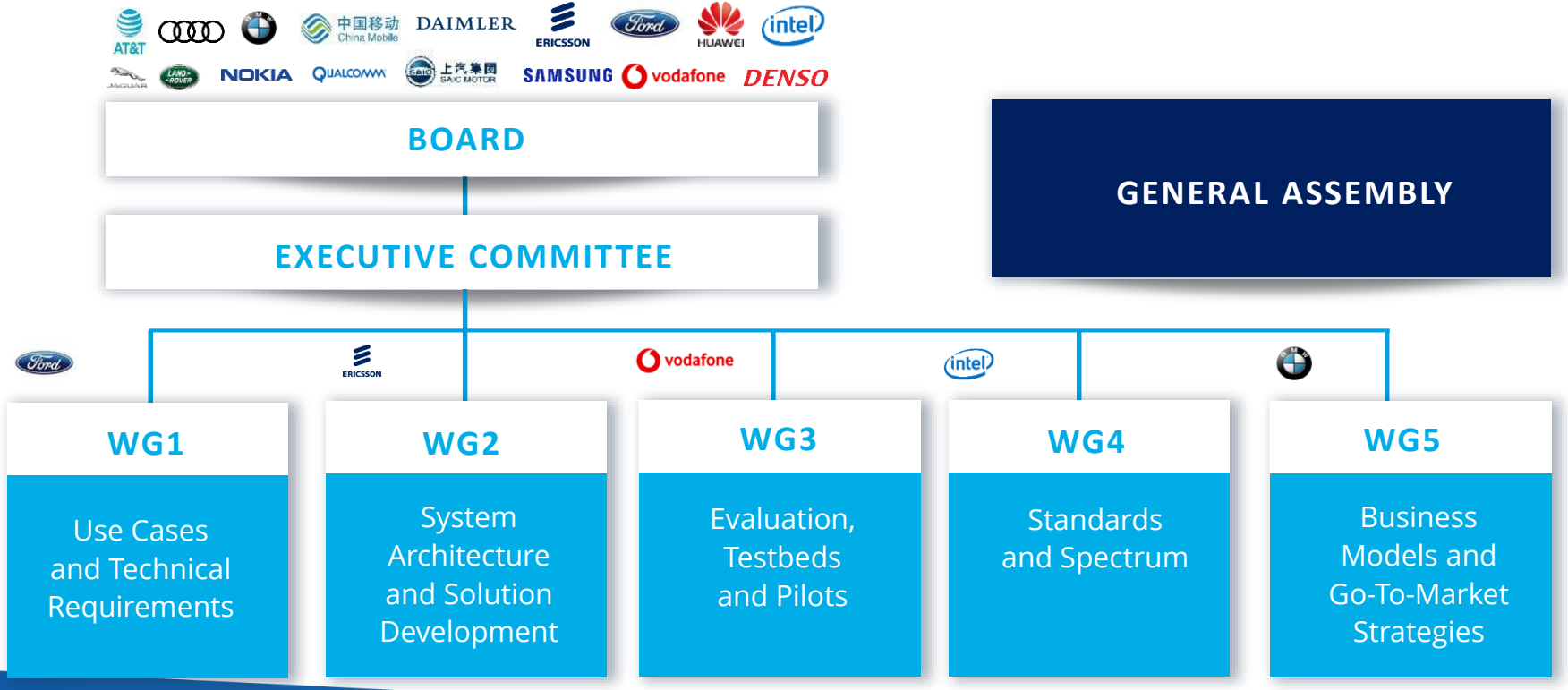
Q3 2018

- 5GAA unites 90+ members working together to:
  - Deliver innovation for road safety, connectivity and sustainability
  - Accelerate cooperative, connected, automated mobility
  - Develop 360º solutions for SMART mobility services
  - Pave the way towards 5G mobility

5GAA Automotive Association


Airgain
ALPINE
ANALOG DEVICES
Anritsu
envision : ensure
AT&T
Audi
北汽集团
BAIC GROUP
Bell
BlackBerry
BMW GROUP
BOSCH
大唐电信科技产业集团
CETECOM
千方科技
CHINA TRANSINFO
China unicom中国联通
中国移动
China Mobile
Continental
The Future in Motion
Cohda Wireless
commsignia
DAIMLER
DANLAW
DEKRA
DENSO
ERICSSON
FEV
Ford
Fraunhofer
GEELY
gemalto
security to be free
Hirschmann Car Communication
TE
HITACHI
Inspire the Next
HUAWEI
HONDA
HYUNDAI
MOTOR GROUP
iDIRECT
Infineon
intel
INTERDIGITAL
JAGUAR
LAND ROVER
JUNIPER NETWORKS
KDDI
KEYSIGHT TECHNOLOGIES
kt
Laird
LG
LEAR CORPORATION
MITSUBISHI ELECTRIC
Changes for the Better
muRata
Neusoft东软
NISSAN
MOTOR CORPORATION
NOKIA
noris network
NTT docomo
OKI
orange
P3
Panasonic
proximus
PSA GROUP
QUALCOMM
ROHDE&SCHWARZ
ROHM
SAMSUNG
SAVARI
SAIC
上汽集团
SAIC MOTOR
SK telecom
安亭·上海国际汽车城
Anting • Shanghai International Automobile City
SKYWORKS
SMART MOBILE LABS
SoftBank
SUMITOMO ELECTRIC
Telefónica
A1 Telekom Austria Group
TELUS
TERRANET
TÜVRheinland
u-blox
Valeo
VENIAM
verizon
VIAVI
vodafone
Volkswagen
VOLVO
WNC
Wistron NeWeb Corp.
ZF

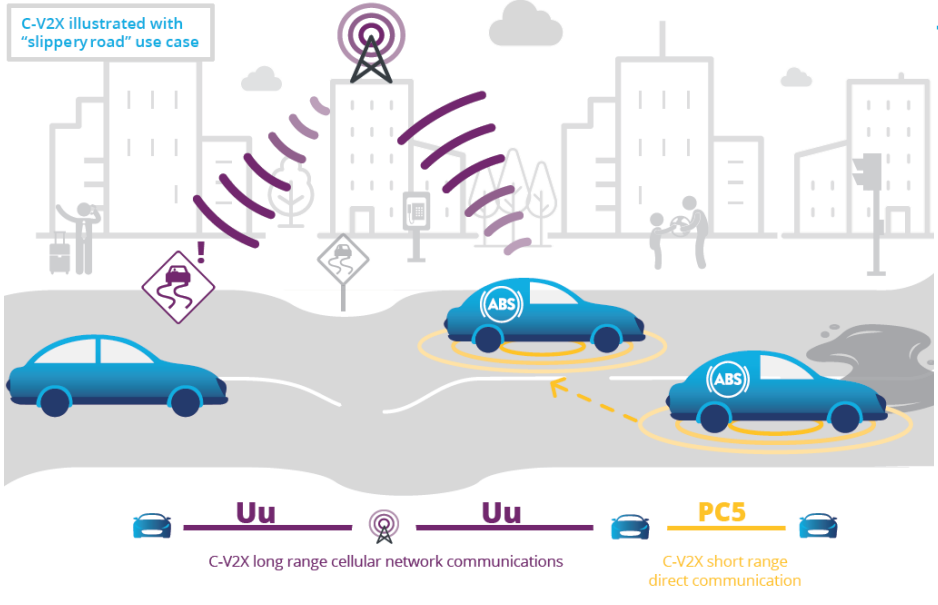
Set up 5GAA - Our Organisational Structure



C-V2X Technology Explained

Why Cellular V2X (C-V2X)?

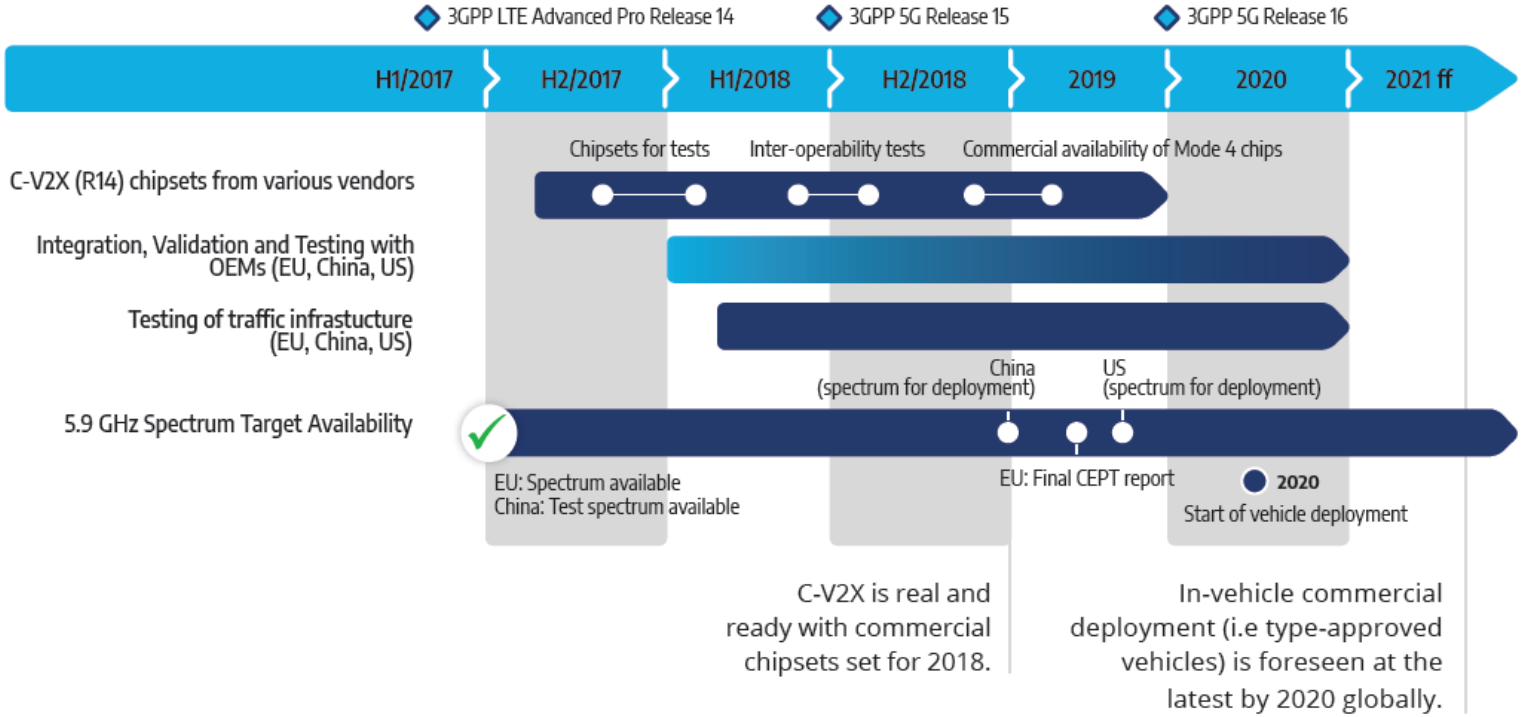
C-V2X is a future proof, comprehensive unified platform for connected vehicles, safety and transportation. C-V2X includes **both short-range direct communication through PC5**, and **long-range cellular network communication through Uu** – that are together paving the way to 5G.



C-V2X

- ALLOWS FOR LOW-LATENCY, DIRECT SAFETY, COMMUNICATION TO WORK WITHOUT NETWORK COVERAGE
- CAN OPERATE WITHOUT A SIM OR NETWORK ASSISTANCE
- ALLOWS LARGER SIGNAL PROPAGATION RANGE AND EARLIER WARNING
- IMPROVED LOCATION TRACKING WITH GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)
- CAN USE THE NETWORK TO ACQUIRE TIMING INFORMATION IF GNSS IS UNAVAILABLE
- CAN RELY ON OTHER CARS FOR SYNCHRONIZATION

Timeline for deployment of LTE-V2X (V2V/V2I)



Why does it matter?

Road fatalities in the EU #2

Source: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2017.pdf

Figure 12: Share of fatalities by area type in the EU, 2015

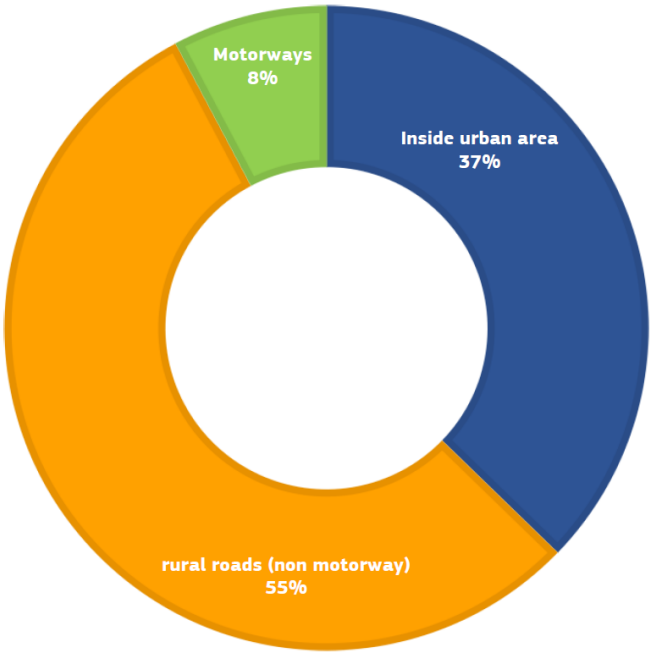
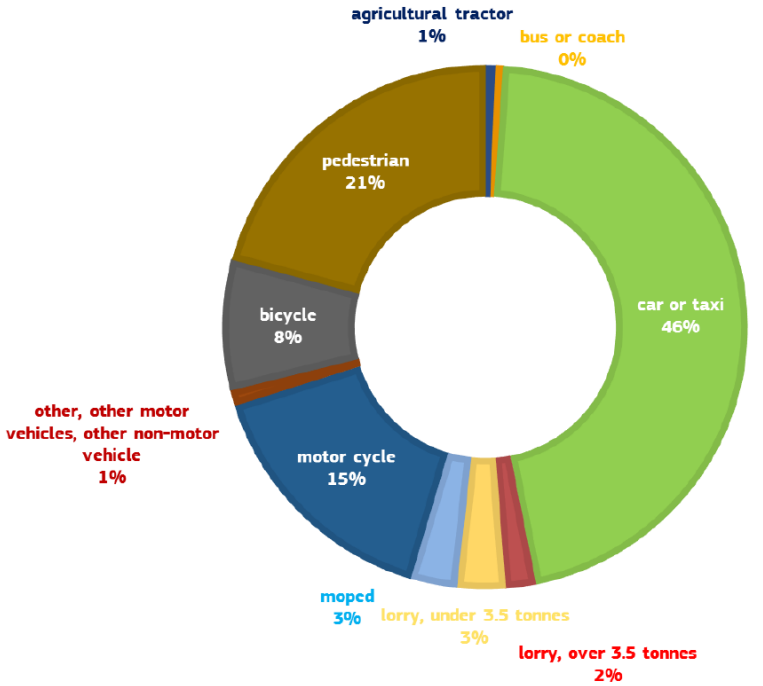


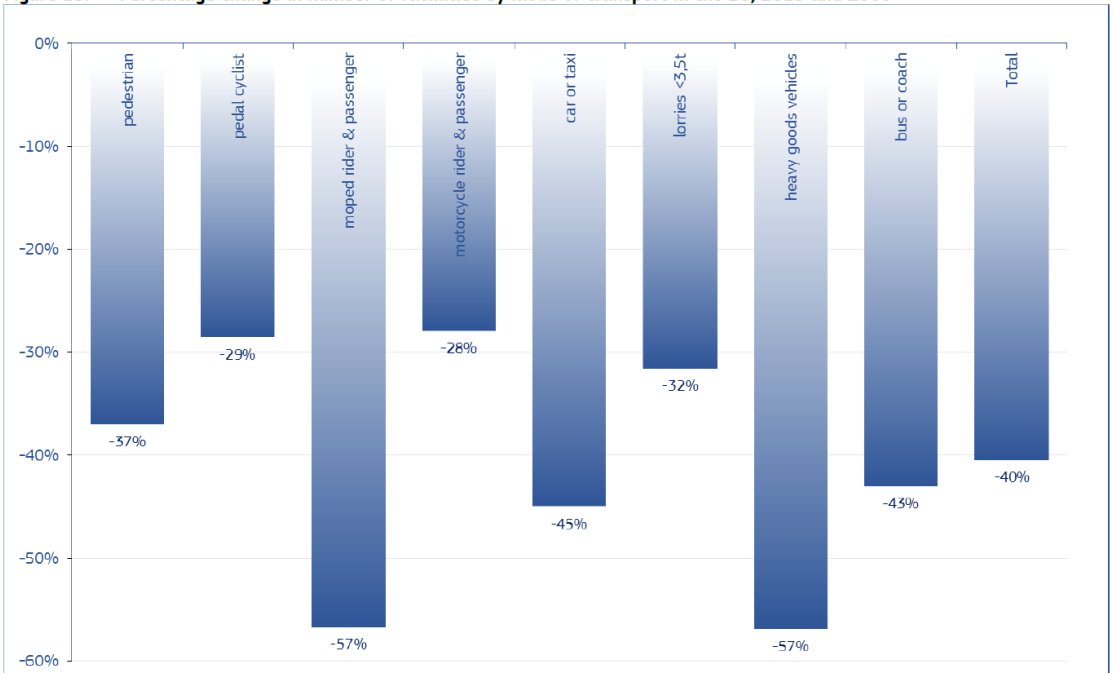
Figure 14: Distribution of fatalities by mode of transport in the EU, 2015



Road fatalities in the EU #3

Source: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2017.pdf

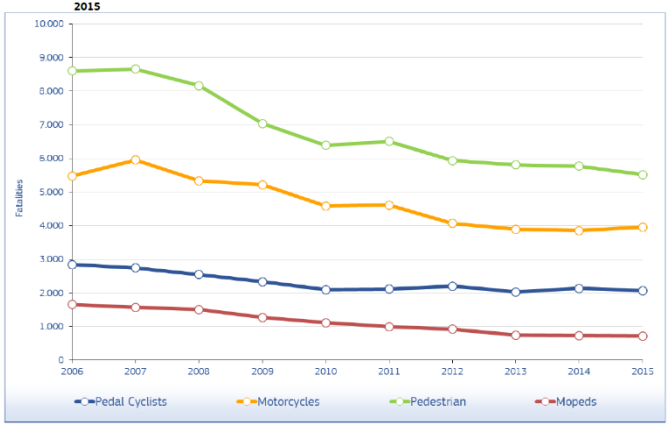
Figure 15: Percentage change in number of fatalities by mode of transport in the EU, 2015 and 2006



Summary:

1. New technologies have reduced car related fatalities
2. Motorways cause only 8 % of fatalities
3. Huge share of VRU fatalities close to 50%
4. Reduction of VRU fatalities has been much smaller than in-car fatalities and have not substantially changed in more recent years

Figure 16: Annual number of fatalities by mode of transport (drivers and passengers, vulnerable modes) in the EU, 2006-2015



Why C-V2X?

C-V2X versus DSRC: there are two competing eco-systems for car connectivity

	Cellular-V2X eco-system	ITS G5/DSRC eco-system
Underlying Technology	Based on standard 3GPP LTE and 5G; LTE V2V/V2I supports unlicensed 5,9GHz band complemented by Edge Cloud	Based on IEEE WiFi standard 802.11p in unlicensed 5,9GHz band Technology disadvantages: unlicensed band, weak QoS, lower reach, limited bandwidth
Deployment Models	Leverage existing mobile network infrastructure; deploy edge cloud	Completely new deployment along all relevant roads and streets (only few km covered so far)
Eco-System Supporters	5G Automotive Association; all mobile carriers, many OEMs (Audi, BAIC, BMW, Ford, Mercedes, PSA, SAIC)	Many Road Operators; most truck manufacturers; selected OEMs (GM, Hyundai, Toyota, VW)
Regional Implications	NAM: DSRC process of rulemaking delayed; 5GAA, Ford, Qualcomm, … promoting C-V2X CHN: Full focus on C-V2X; Spectrum for LTE-V2X testing already allocated EUR: Undecided JPN/KOR: Small DSRC deployments (moving slowly), DSRC based field trials	

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Why is C-V2X the preference ? #1

5GAA study on cost-benefit analysis on C-V2X technology

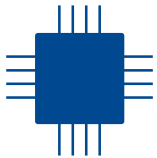
Future-proof, providing a progression to 5G

C-V2X will evolve to facilitate new capability in the 5G era. In the meantime, the dual modes of LTE C-V2X meet all the requirements of the automotive industry

Economies of scale will develop more rapidly

Many automotive OEMs believe C-V2X will be less expensive to implement than IEEE 802.11p (and cheaper than a combination of IEEE 802.11p for V2V, plus cellular for V2N)

V2V and V2N modules **can be combined in a single C-V2X chipset**



This same integration between V2V and cellular is not expected for DSRC/
ITS-G5, which will need dual/multiple chipsets in vehicles compared to potential for a single C-V2X chipset

Source: Analysys Mason and SBD Automotive: „Socio-economic benefits of Cellular V2X", December 2017, Study commissioned by 5GAA, http://5gaa.org/news/5gaa-study-the-cost-benefit-analysis-on-cellular-vehicle-to-everything-c-v2x-technology-and-its-evolution-to-5g-v2x/

An OEMs view – Ford about Key Cellular-V2X Technical Characteristics

A. **Low-latency**: C-V2X is designed for reliable, predictable, low-latency direct communications
B. **Network independence:** "Direct" C-V2X is designed to operate without network assistance (does not require SIM cards to function) *but can use the deployed mobile networks to enhance functionality*
C. **High-speed use cases**: C-V2X is designed for high-speed vehicular use cases. By design and following extensive analyses R14 C-V2X works up to 500 km/h relative Doppler in 5.9 GHz band
D. **ITS spectrum** : C-V2X is designed to operate in the ITS spectrum
E. **Security**: Benefits from established security protocols defined by the automotive standards communities, including SAE, IEEE and ETSI.

Source: 26.4.2018, 5GAA C-V2X Workshop for North American Transportation Planning and North American Road Operators
http://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf

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An OEMs view – Ford about the importance of C-V2X #1

A. **Performance**: C-V2X delivers superior performance and reliability by leveraging the latest advances in radio technology

B. **Implementation Efficiency**: C-V2X can be implemented by utilizing the cellular technology platforms that automakers are already deploying
   - Analysts expect that 90% of new US vehicles will have cellular modems by 2025
   - In the US, by 2019 100% of new Ford vehicles will have cellular modems
   - Integration with existing in-vehicle cellular platforms and services will results in fewer things-gone-wrong at a lower expected cost

C. **Readiness**: Commercial C-V2X products are available for deployment as early as 2019
   - supported by a broad ecosystem reflected in the diversity of 5GAA membership

Source: 26.4.2018, 5GAA C-V2X Workshop for North American Transportation Planning and North American Road Operators
http://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf

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An OEMs view – Ford about the importance of C-V2X #2

D. **Reuse**: C-V2X leverages a very significant portion of the V2X work already done
   - Benefits from existing V2X transport layers and application protocols: safety Apps developed for DSRC will work unchanged with CV2X radios
   - Learnings from past V2X research are reusable

E. **Global Footprint**: C-V2X will be deployed consistently and predictably across the world in the same way that other cellular technologies such as LTE have been

F. **Evolution**: C-V2X is the first step towards 5G that will leverage future improvements in cellular radio technology while remaining backward compatible

Source: 26.4.2018, 5GAA C-V2X Workshop for North American Transportation Planning and North American Road Operators
http://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf

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Status of C-V2X

Road fatalities - Impact of latest safety technology in the UK

Source: https://www.autovistagroup.com/news-and-insights/road-deaths-europe-decrease-manufacturers-add-more-technology

… data from the Society of Motor Manufacturers and Traders (SMMT) and JATO Dynamics shows that around **66.8% of new cars** are offered with at least one self-activating safety system, either as standard or as an optional extra. Nearly **1.8 million new vehicles** a year are now available **with collision warning systems** alone, up 20% on the previous year.

Thanks to these innovations and more, road accidents in the UK have fallen by nearly **10% since 2012**,…

Hazard warnings: C-V2N support for safety related applications

More „safety potential“ in V2N:
- Sharing of warnings between OEMs e.g. via HERE
- Interface to city and regional traffic managment

Mercedes-Benz

Mercedes-Benz offers **communication between cars** since new E-Class in 2016 – „Car-to-X communication **via backend**“

Source: 5GAA – Policy Debate: Cellular-V2X Technology: Paving the Road to 5G, Delivering Today for Connected and Automated Vehicles in Europe, 5.12.2017, Brussels: „Daimler's Perspective on Car-to-X Technologies“

25.-27. April, TEN-T Days, Ljubljana... Today, BMW drivers receive a wide variety of traffic information, such as **hazard warnings**, speed limits, **accident warnings, wrong-way driver alerts**, on- and off-street parking information and far more besides...

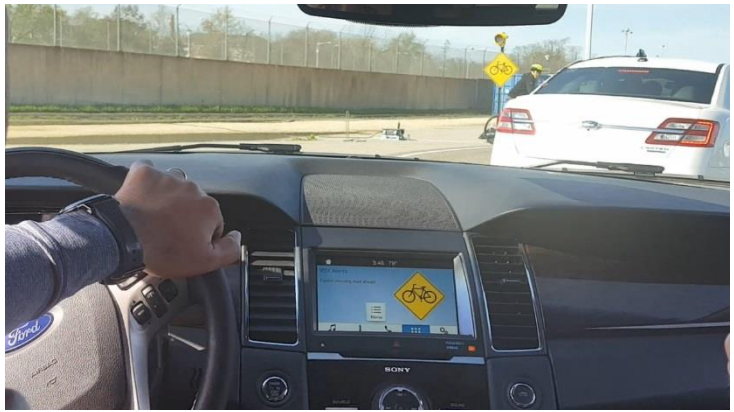
Link to Source

When a Volvo switches on hazards, nearby Volvos will know“
From 2018 Volvo Cars' **Hazard Light Alert** will connect Swedish and Norwegian Volvo passenger cars and trucks **via a cloud-based system**.

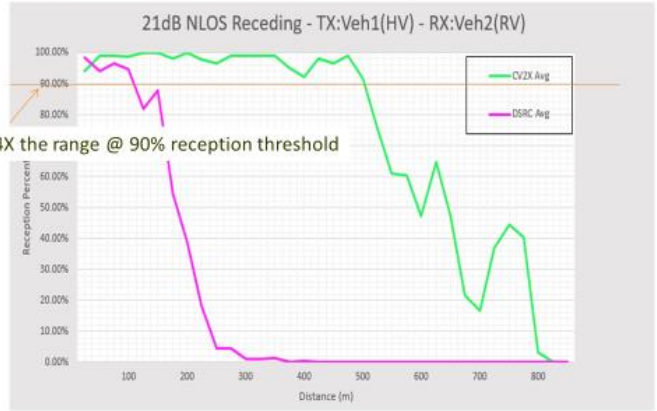
Link to Source

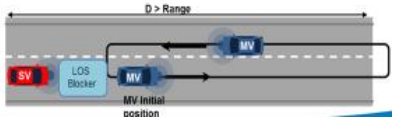
Impressions from C-V2X Demonstrations in Washington DC, April 26th , 2018

See also: http://www.traffictechnologytoday.com/news.php?NewsID=90735



Obstructed Non-Line-of-Sight (NLOS) Range/Reliability Road Test in Miramar, San Diego





Ford presented field test measurements comparing LTE V2X and DSRC

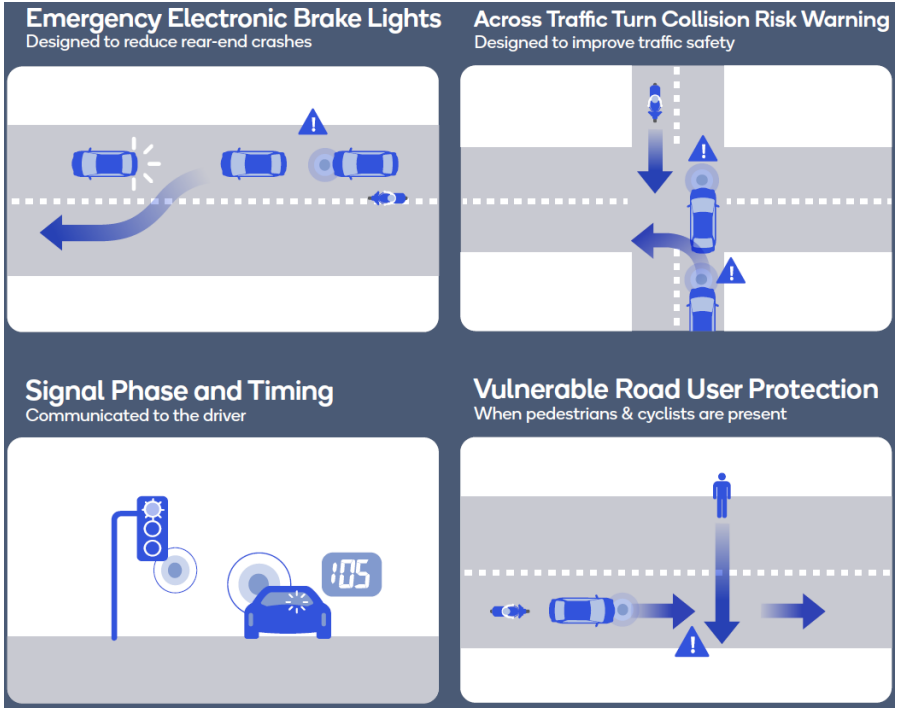
Source: 26.4.2018, 5GAA C-V2X Workshop for North American Transportation Planning and North American Road Operators
http://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf

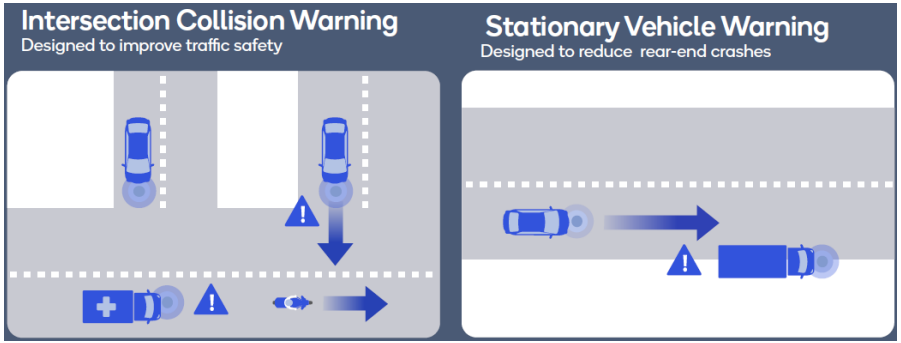
Impressions from C-V2X Demonstrations in Paris, July 11th , 2018

See also: http://5gaa.org/news/5gaa-bmw-group-ford-and-groupe-psa-exhibit-first-european-demonstration-of-c-v2x-direct-communication-interoperability-between-multiple-automakers/

Source: 5GAA.org

Use Cases





Status of C-V2X - Gaining Momentum Worldwide #1

- "AT&T, Ford, Nokia and Qualcomm Launch Cellular-V2X Connected Car Technology Trials Planned for the San Diego Regional Proving Ground with Support From McCain" (Qualcomm Press Release, 31 October 2017)
- "Continental successfully conducts Cellular V2X: Field Trials in Shanghai, China: initial C-V2X trials in Shanghai with Huawei have successfully reached an average latency of 11 ms for direct communication between vehicles" (Continental Press Release, 18 December 2017)
- "Groupe PSA and Qualcomm Technologies … announced advancements in Cellular Vehicle-to-Everything (C-V2X) communication technology testing …C-V2X technology trial will lead to a commercial deployment from 2020 " (PSA Press Release, 21 February 2018)
- "BMW Group is working on the implementation of the LTE-based, wireless C-V2X technology offering unrivalled benefits for the development of the 5G ecosystem. The BMW Group already leads the way in implementing traffic safety messages based on backend-supported mobile technology (LTE) […]. These will be complemented within the next few months by the rollout of C-V2X direct communication technology in the allotted frequency range, enabling time-sensitive traffic messages." (BMW Press Release @MWC, 26 February 2018)
- "Rohde & Schwarz demonstrates test capability of 3GPP C-V2X technology in preparation for GCF certification in preparation of commercialization" (Rohde & Schwarz Press Release @MWC, 27 February 2018)
- "Groupe PSA and Qualcomm Technologies testing vehicle-to-vehicle communication featuring C-V2X technology: France's first C-V2X demonstration at In&Out Digital Mobility event in Rennes" (PSA Press Release & Demonstration video, 14 March 2018)

Status of C-V2X - Gaining Momentum Worldwide #2

- "The 5G Automotive Association (5GAA), Audi, Ford, and Qualcomm Technologies Inc. have completed the world's first demonstration of cellular vehicle-to-everything (C-V2X) direct communications technology operating across vehicles from different manufacturers" (Qualcomm Press Release, 26 April 2018)
- Panasonic, Qualcomm and Ford "announced … to deploy … C-V2X technologies in Colorado. This is the first U.S. deployment of C-V2X technology and is an extension of a previously announced partnership between the Colorado Department of Transportation (CDOT) and Panasonic to integrate connected vehicle technology in the state of Colorado …Panasonic will work with Kapsch TrafficCom … Kapsch TrafficCom will provide roadside units (RSUs), as well as with Ficosa to provide C-V2X onboard units (OBUs). " (Qualcomm Press Release, 1 June 2018)
- ConVeX Consortium Hosts Europe's First Live C-V2X Direct Communication Interoperability Demonstration Between Motorcycles, Vehicles, and Infrastructure (Qualcomm Press Release, 4 July 2018)
- 5GAA …"the BMW Group, Ford … and … PSA — in association with Qualcomm …and Savari, Inc. — announced today Europe's first live demonstration of C-V2X direct communication technology operating across vehicles from multiple auto manufacturers. The live demonstration also featured …C-V2X direct communication technology operating between passenger cars, motorcycles, and roadside infrastructure". (5GAA Press Release, 11 July 2018)
- Qualcomm and Datang Demonstrate World's First Multi-Chipset Vendor C-V2X Direct Communication Interoperability (Qualcomm Press Release, 22 August 2018)
- The demonstrations will feature Groupe PSA's popular sport utility vehicle (SUV) models: DS 7 CROSSBACK, PEUGEOT 4008 and CITROËN C5 AIRCROSS. The DS cars will be equipped with Huawei's solution based on C-V2Xand the PEUGEOT and CITROEN cars will be equipped with the Qualcomm® 9150 C-V2X chipset solution (PSA Press Release, 14 September 2018)

Evolution to 5G

Evolution towards 5G

Support the deployment of connected automated vehicles with reliable and enhanced Cellular-V2X (C-V2X) communication technology. Establish 5G as communication technology of choice, starting with advanced LTE capabilities

Full support for 5GAA strategy

Link to source

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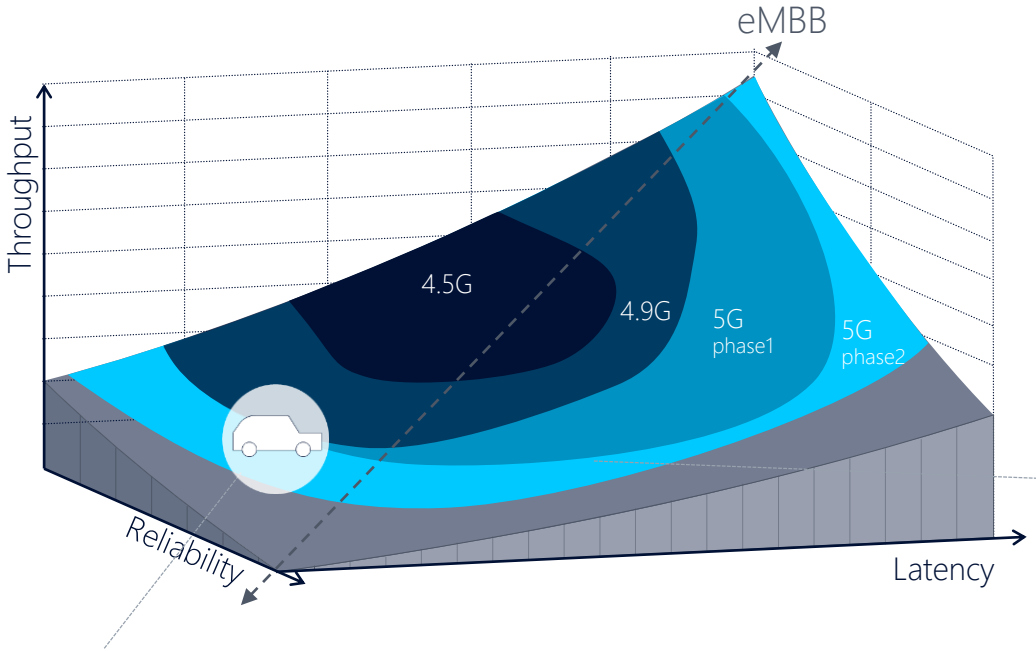
5G - Transform to meet individual use case requirements

Important functionalities for Automotive



- New radio with low latency
- Edge computing (MEC)
- Network slicing
- Ultra-reliable low latency communication

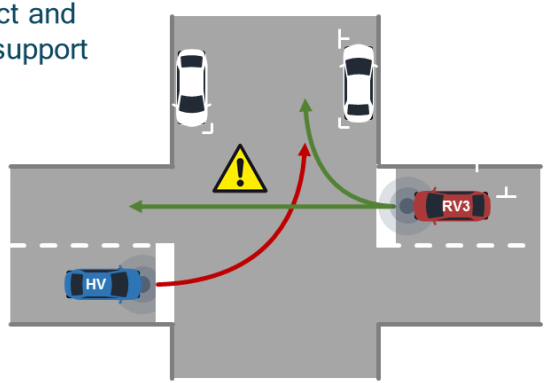
Support of automated driving

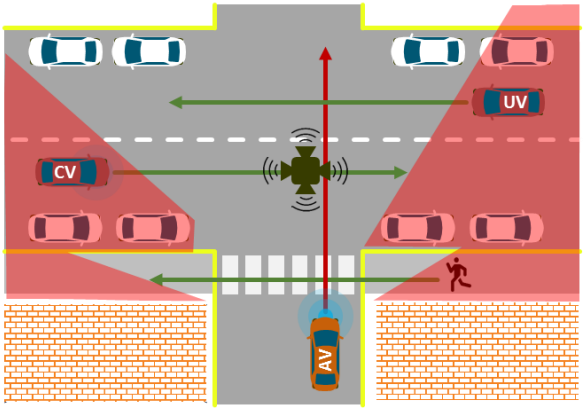
Throughput	Latency B.	Reliability
!0-300 Mbit/s	5ms-1s	Very high

C-V2X: Evolution from LTE V2X to 5G V2X

See also: http://www.traffictechnologytoday.com/news.php?NewsID=90735

- Basic safety messaging
- Dual (direct and network) support





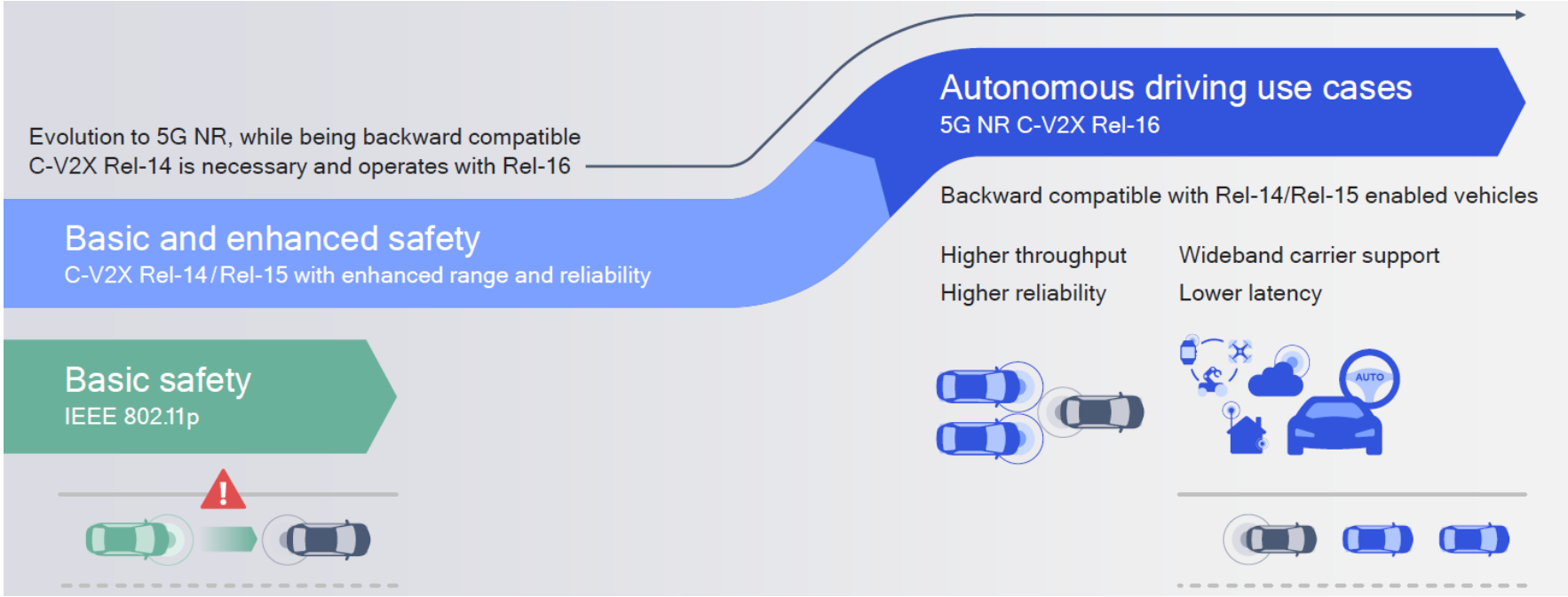
- Backward compatible
- HD sensor and intent sharing

Presented by Ford at: 5GAA C-V2X Workshop and Demonstration for North American Transportation Planning and Road Operator Communities, April 26th, 2018, Washington DC

5G automotive use cases - examples

- Software Update (including vehicle-to-vehicle)
- Real-Time Situational Awareness & High-Definition Map
- Object-based Sensor Sharing
- Vulnerable Road User (VRU)
- Group Start in Cities (variant of Platooning Use Case)
- Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations
- Teleoperated driving
- Automated Intersection Crossing

Chip vendors: 5G NR will be backward compatible



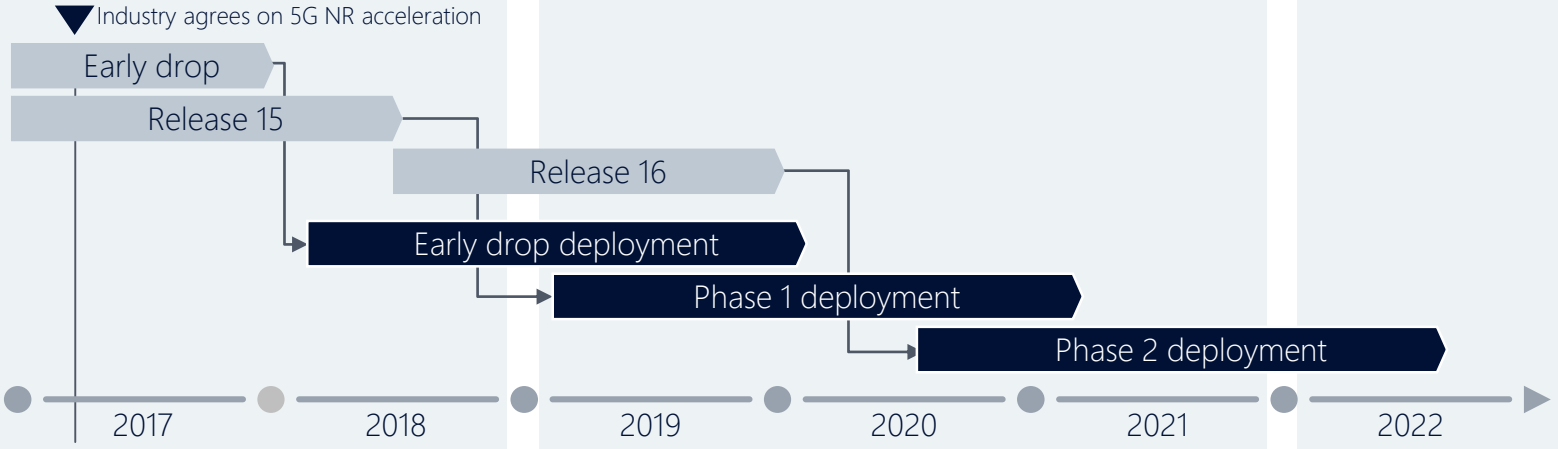
Source: Qualcomm webinar, Feb. 12th 2018: 5G NR basd C-V2X,
https://d3v6gwebjc7bm7.cloudfront.net/event/15/87/87/1/rt/1/documents/resourceList1518453045031/5gnrbasedcv2xwebinardeckfinal1518453060732.pdf

5G NR – arriving much faster than expected

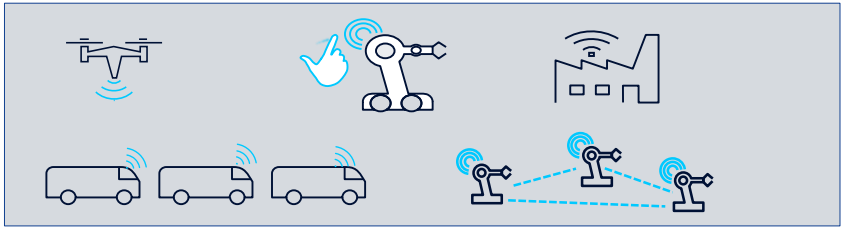
Enhanced mobile broadband

Ultra reliable low latency communications
Massive machine-type communications

Full 5G architecture



- 4G and 5G together
- Differences between global regions



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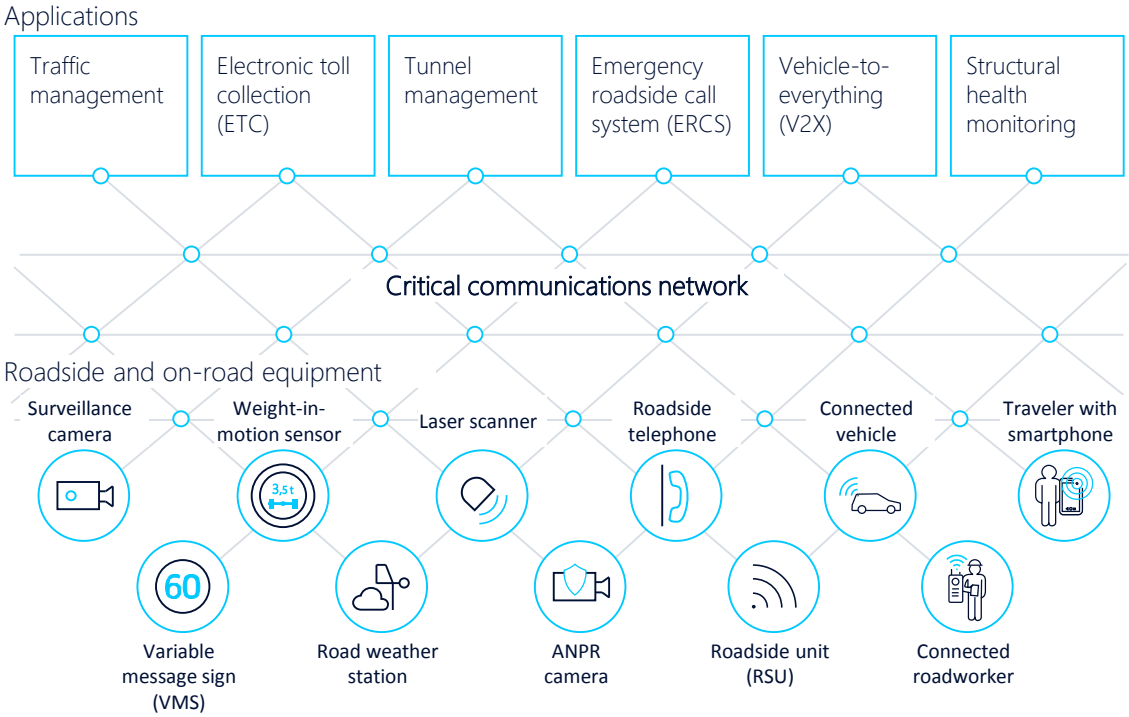
Role of road authorities/operators

Road operators are turning to new ITS to solve traffic issues



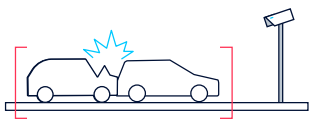
ANPR: Automated Number Plate Recognition

Keep traffic safe. Reduce accidents, reduce fatalities and increase safety for road workers and travelers

Keep traffic on-time. Improve traffic flow, reduce travel time, make operations more efficient and lower pollution

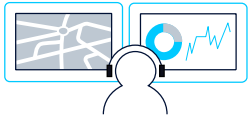
Keep traffic connected. Support automated driving, integrate connected vehicle in roadside system and offer new connected services

Unique characteristics of ITS make it challenging to build an optimized critical communications network

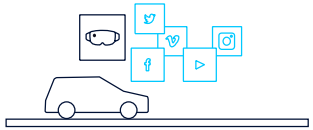


Surveillance camera
Video traffic I IP-service
Medium latency I High bandwidth I Medium reliability I Medium criticality

Variable message sign, Weight-in-motion sensor, Road weather station
Data traffic I TDM-service I Legacy interfaces, e.g. serial
Medium latency I Low bandwidth I High reliability I High criticality



Roadside telephone
Voice traffic I Legacy interfaces, e.g. E&M
Low latency I Low bandwidth I High reliability I High criticality



Future ITS applications, incl. vehicle-to-everything (V2X)
Low latency I High bandwidth I High reliability I High criticality

Business implications

- Road operators need to connect much more equipment, sensors, …. to manage safe traffic
- Mobile operators will need to deploy many more base stations and small cells to provide 5G coverage

→ New opportunities for business relationships and business models

C-V2X and rail

C-V2X technology opens a wide range of applications in the rail domain

SNCF and Qualcomm – Joint tests conducted on SNCF rail route in France

Train-to-Infrastructure
Communications
(e.g. Level crossings)

Train-to-Train
Communications
(e.g. virtual coupling/platooning)

Train-to-Maintenance Operators
Communications

Train-to-Ground
Communications
(e.g. signaling systems)

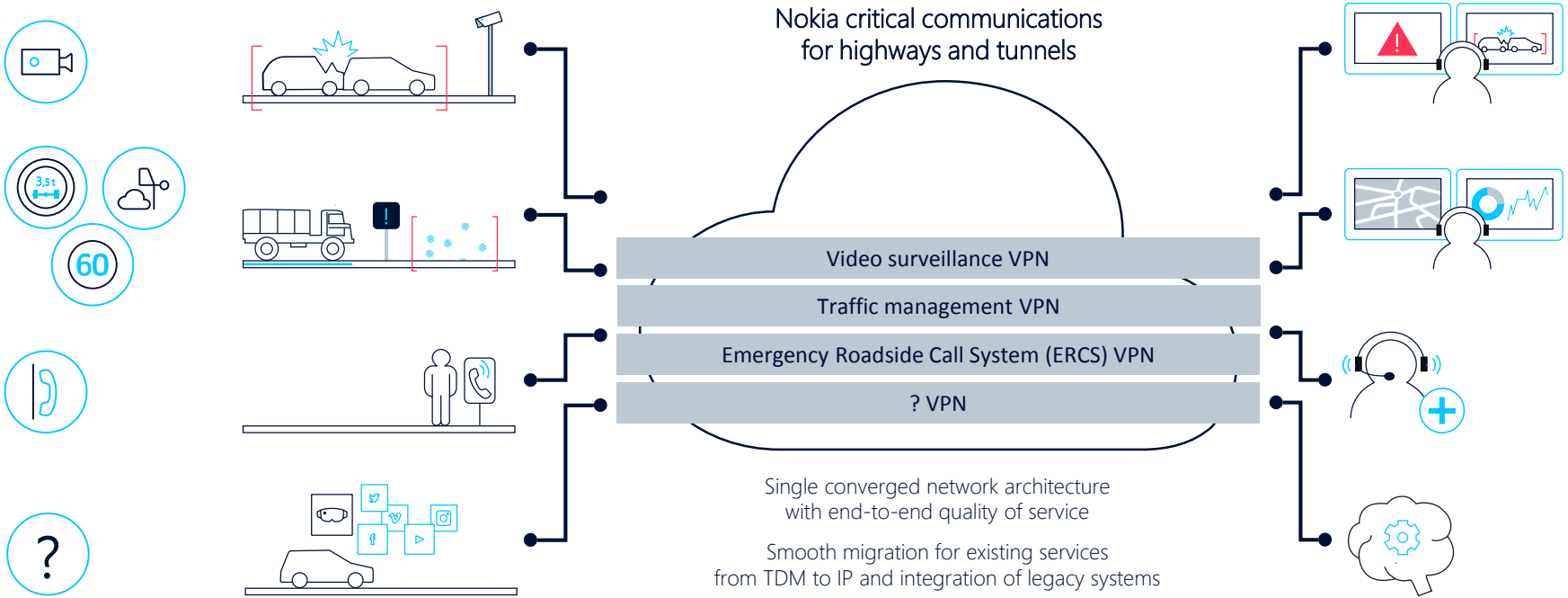
Source: SNCF, Synergies in Connected Mobility of Tomorrow: C-V2X & Railways Case Study, 10.7.2018 Paris, 5GAA C-V2X Workshop and Demonstration , http://5gaa.org/wp-content/uploads/2018/07/5GAA_180710_Paris-Workshop_SNCF.pdf

Summary

- 5G is the technology of choice – a single technology meeting the needs of the automotive segment
- Cellular-V2X and in particular LTE V2N delivers early benefits also for traffic safety
- Europe needs to support a technology neutral approach on direct communications to speed up 5G introduction for automotive

Efficiency today, with Nokia solutions for highways and tunnels

Optimized critical communications networks for ITS

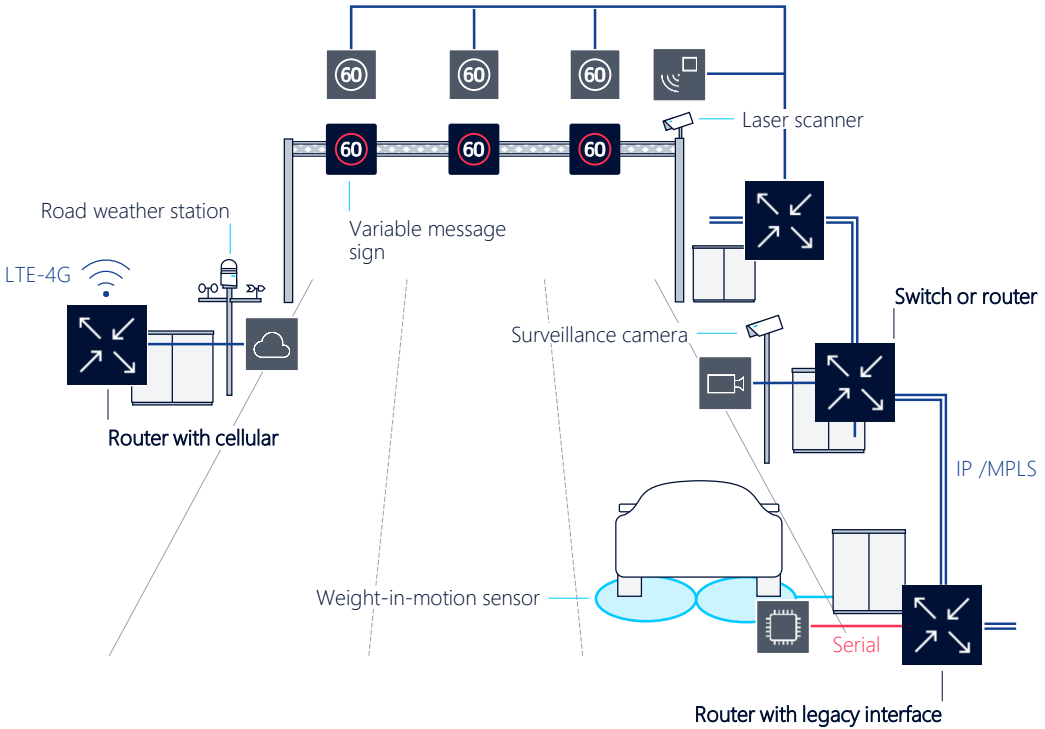


Solution for wired access, Ethernet / IP roadside network

Nokia solutions for highways and tunnels

Roadside networks for ITS equipment with hardened, compact critical Ethernet / IP communications equipment

- Deterministic Quality of Service (QoS) to the roadside for high availability and high resiliency
- High bandwidth for video surveillance
- Support of legacy interfaces, e.g. serial
- Integration of microwave and cellular for backhauling
- Compact form factors for deployment in roadside cabinets
- Hardened equipment to support harsh roadside environments

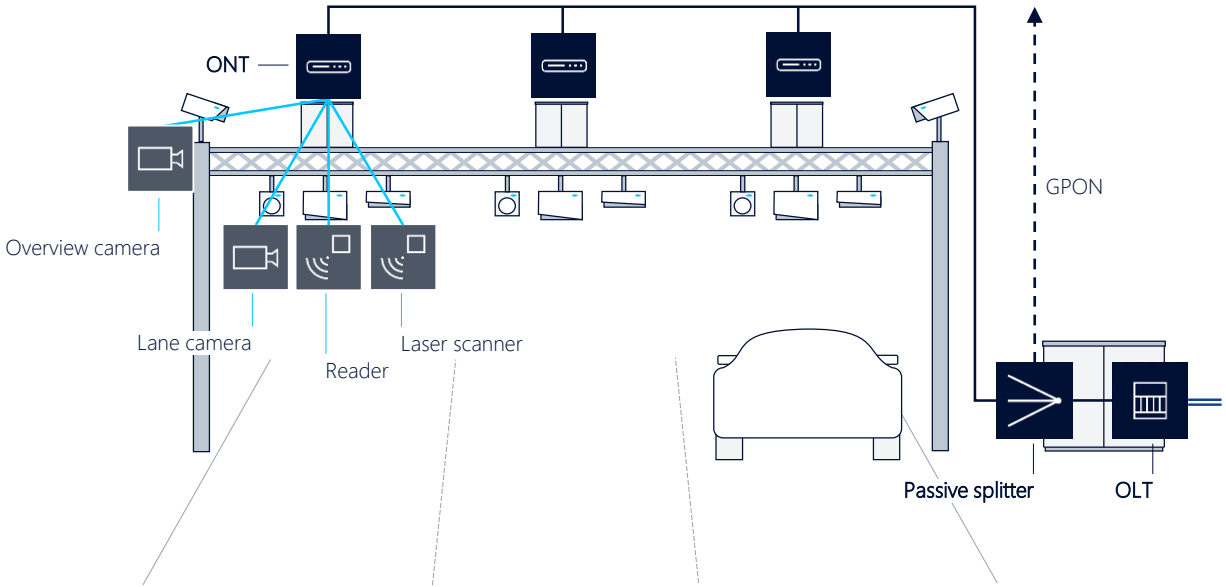


Solution for wired access, Optical LAN roadside network

Nokia solutions for highways and tunnels

Passive optical roadside networks for ITS equipment with hardened and compact platforms

- High availability and high resiliency
- Low latency to process thousands of vehicles travelling at high speed
- Less active equipment in the field reducing power consumption and maintenance efforts
- Compact form factors for deployment on gantry and in roadside cabinets
- Hardened equipment to support harsh roadside environments

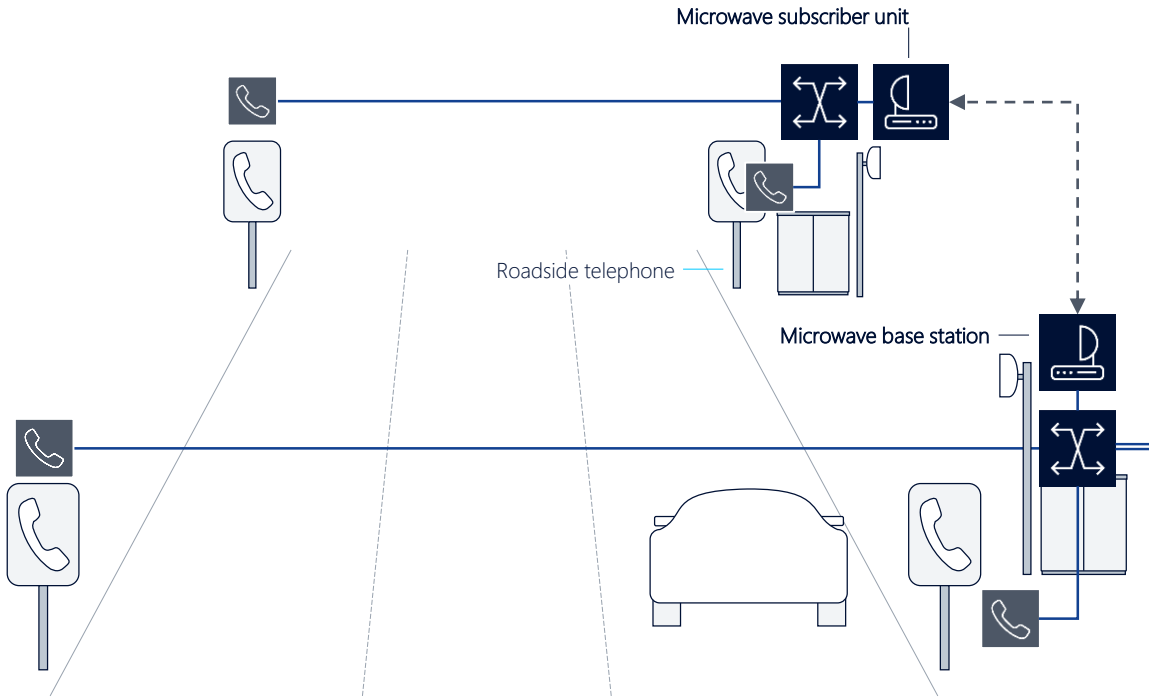


Solution for wired access, Microwave backhauling

Nokia solutions for highways and tunnels

Microwave backhauling for remote locations where no fiber or coper is available or expensive to trench with small formfactor microwave units

- High bandwidth microwave links
- Point-to-multipoint connection over up to 10km of distance
- Integrated with Ethernet / IP roadside network equipment
- Hardened equipment to support harsh roadside environments

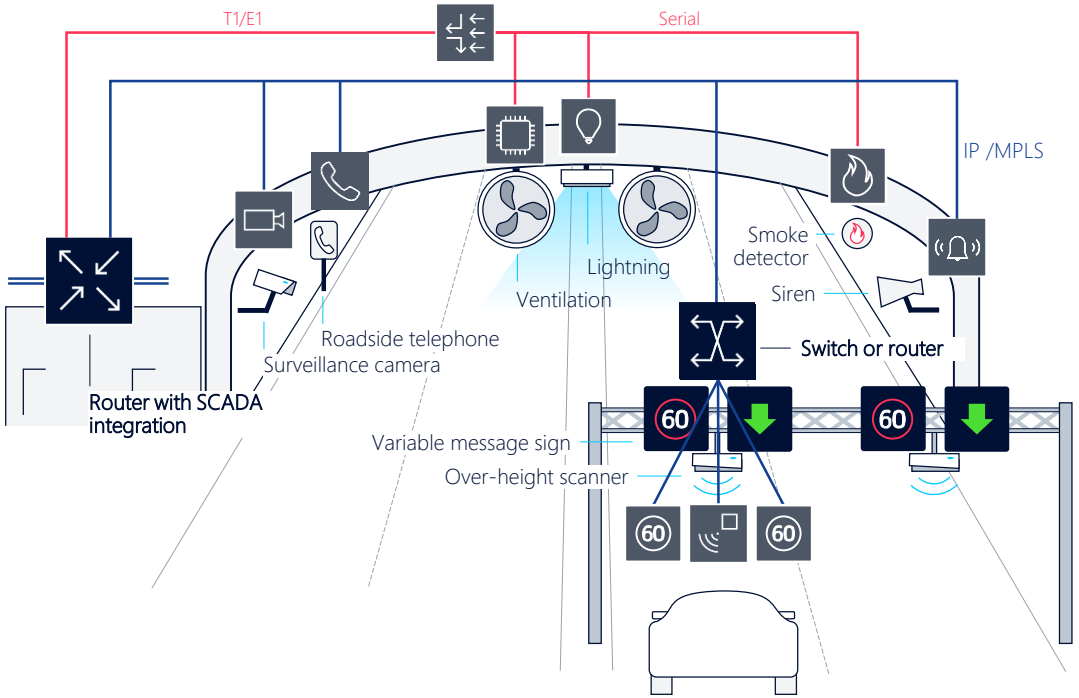


Solution for wired access, IP tunnel network

Nokia solutions for highways and tunnels

Tunnel networks for traffic management and building management equipment with highly available IP/MPLS communications equipment

- Converged IP/MPLS network for traffic management and building management systems
- Deterministic QoS across the whole tunnel infrastructure for highest availability and resiliency
- TDM and SCADA integration for building management
- High bandwidth for video surveillance
- Support of legacy interfaces, e.g. serial
- Compact form factors for deployment in tunnel cabinets
- Hardened equipment to support harsh tunnel environments

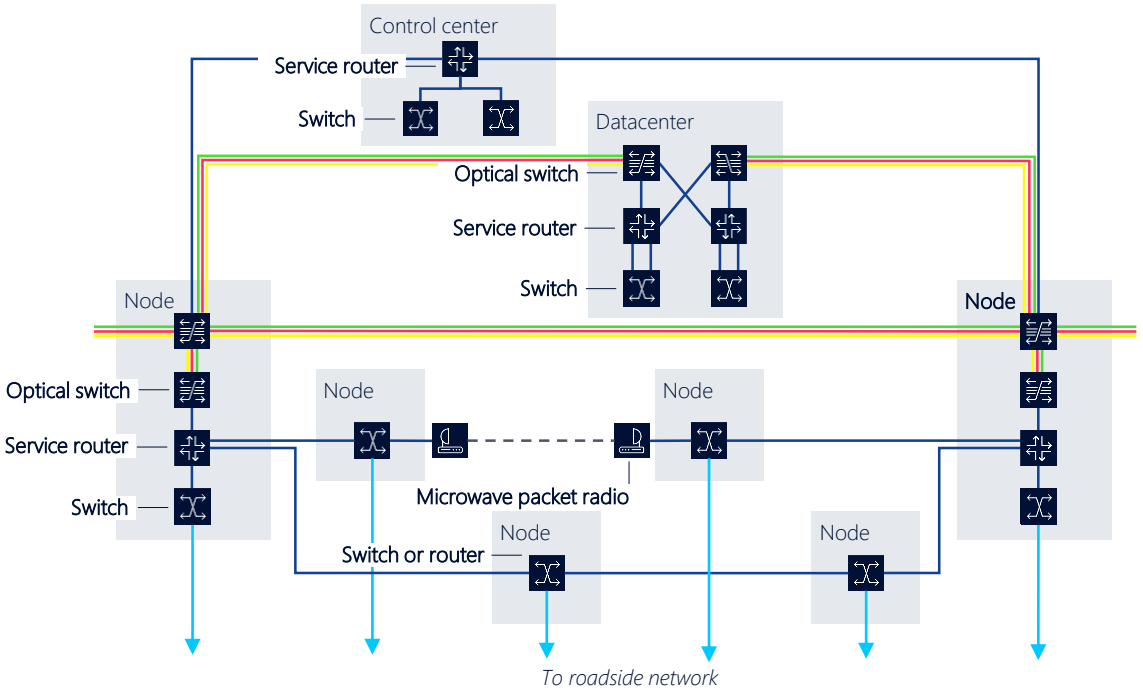


Solution for IP backbone

Nokia solutions for highways and tunnels

Converged backbone architecture for all ITS applications with IP/MPLS technology and a unified network management platform

- Single converged network architecture with separate VPNs for different services and traffic types with deterministic level of security, QoS, etc.
- High availability through protection design with meshed or multi-ring architectures
- Scalable network architecture with a layered modular approach
- Transport of legacy TDM traffic
- Optical transport for high-bandwidth packet transport between major locations
- Microwave transport providing connectivity where fiber is not available or expensive to trench
- Unified service, network and element management tool for the end-to-end communications infrastructure

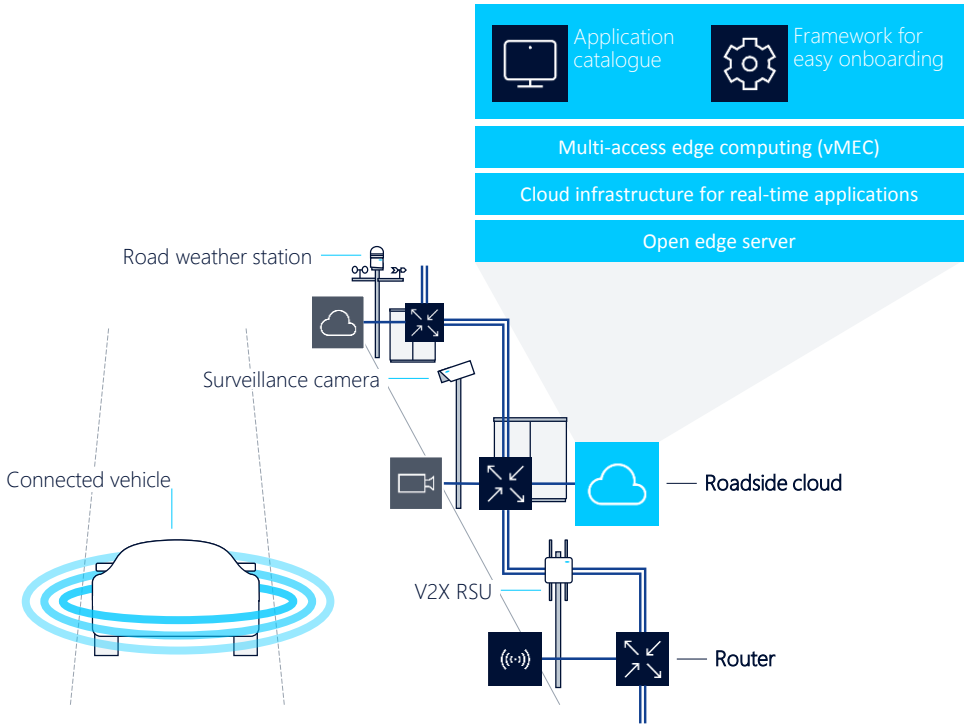


Solution for roadside cloud

Nokia solutions for highways and tunnels

Edge computing platform for secure and agile deployment of new, advanced roadside services

- Distributed processing and storage at the point of action along the roadside for most demanding roadside services (e.g. video analytics, real-time traffic analytics, etc.)
- Fully integrated element of critical communications infrastructure of road operator
- Access technology agnostic integrating wired and wirelessly connected roadside equipment and V2X communications
- Nokia AppFactory, a framework for easy onboarding of roadside services
- Nokia virtual Multi-access Edge Computing, a software layer with micro services
- Nokia AirFrame Cloud Infrastructure for Real-time applications (NCIR)
- Nokia AirFrame open edge server, a edge computing server for harsh environments

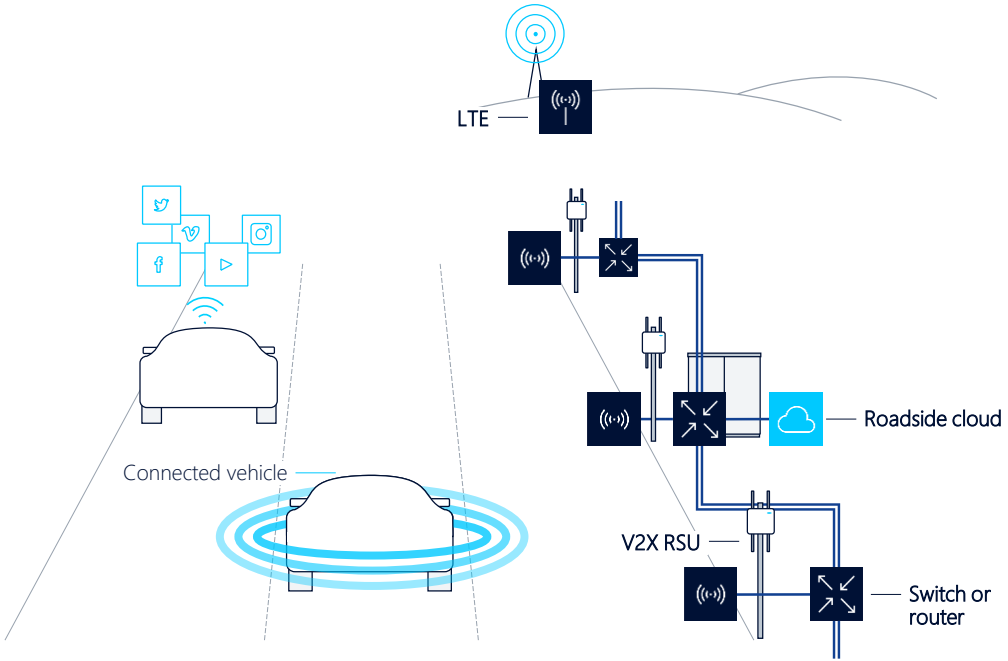


Solution for wired access, V2X and LTE

Nokia solutions for highways and tunnels

V2X communications and broadband internet access to meet the increasing connectivity need of vehicles and their passengers

- Low latency V2X communications for improved traffic safety and traffic flow
- Smart integration of connected vehicles into the roadside systems via V2X RSUs
- Support of C-V2X technology
- Advanced V2X applications with pre-integration to Nokia roadside cloud
- Broadband internet connectivity demanded for traveler convenience on the road, only to be met with LTE technology
- Monetization opportunity for road operators network capacity wholesale to mobile network operators



Solution for wired access, Wi-Fi

Nokia solutions for highways and tunnels

Advanced Wi-Fi portfolio to improve traveler experience, e.g. at rest areas

- Broadband internet connectivity demanded for traveler convenience at the rest areas
- Supporting traveler information in real time on traffic conditions and offering new connected services
- Advanced performance with 2.4 GHz and 5GHz for peak rates up to 1733 Mb/s and 800 Mb/s and latest 802.11ac wave 2 and 4x4 MIMO technology
- Pay-as-you-go subscription model reducing OPEX
- Wi-Fi Controller as-a-service reducing CAPEX
- Plug-and-play and auto-configuration for fast deployment and pain-free scaling