

Challenges and Solutions for C-ITS Services over Long-Range C-V2X



24. VDE/ITG Fachtagung Mobilkommunikation

Outline



- Motivation
- C-ITS use cases
- Existing long-range C-V2X
- Selected challenges and solutions for long-range C-V2X
- Summary & conclusion

Motivation



Increased Safety

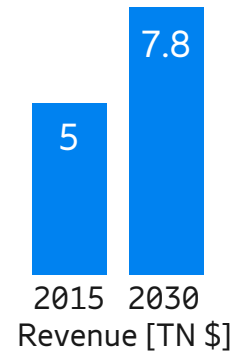


European Union:

Decrease the number of road fatalities by **50%**

European Commission, "Towards a European road safety area: policy orientations on road safety 2011-2020", 2010

Growing market

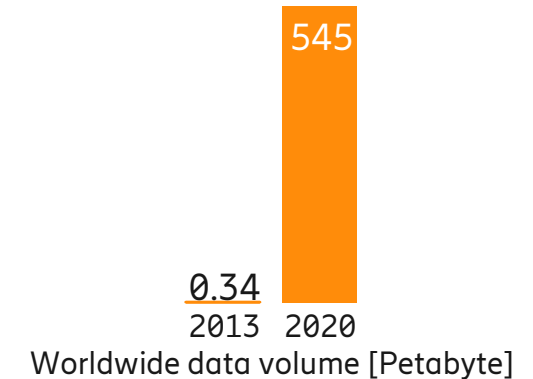


For automotive industry:

Revenue increase from \$5 trillion to **\$7.8 trillion**

PwC Strategy&, "Connected car report 2016: Opportunities, risk, and turmoil on the road to autonomous vehicles", 2016

Data explosion



For telecom industry:

186% CAGR data volume increase

HIS Automotive, "Five Critical Challenges Facing the Automotive Industry", 2015

C-ITS Day 1 use cases



Origin / Kind	Service	Use cases	Facilities Layer Service (ISO, SAE, ETSI-ITS)
C-Roads / V2I, V2N (V2N) Link	Traffic Jam	Dangerous end of queue, Traffic Jam Ahead	DEN
	Stationary vehicle warning	Stopped vehicle, Broken-down vehicle, Post-crash	DEN
	Special vehicle warning	Emergency vehicle in operation, Stationary safeguarding emergency vehicle, Stationary wrecking service warning	DEN
	Exchange of Impact Reduction Containers (IRCs)	Request IRC	DEN
	Exchange of IRCs	Response IRC	DEN
	Dangerous situation	Electric Emergency Brake Light, Automatic Brake Intervention, Occupant restraint system intervention	DEN
	Adverse weather conditions	Fog, Precipitation, Traction Loss	DEN
Car 2 Car Communication Consortium / V2V (V2N2V) Link	In-vehicle signage	Dynamic Speed Limit Information, Embed VMS "Free text", Other Signage Information	IVI
	Other Hazardous Locations Notification	Accident Zone, Traffic Jam Ahead, Stationary vehicle, Weather condition warning, Temporary Slippery Road, Animal or person on the road, Obstacle on the road	DEN
	Road works warning	Lane closure (and other restrictions), Road closure, Road works - mobile	DEN
	Signalized Intersections	Green Light Optimal Speed Advisory, Public Transport Prioritization	SPAT, MAP, SR, SS

DENM: Decentralized Environmental Notification, ETSI EN 102 637-3;
 SPAT: Signal Phase And Timing, ETSI TS 103 301 / CEN ISO/TS 19091;MAP:
 SR: Signal Request, ETSI ITS 103 301 / CEN ISO/TS 19091;

IVI: In-Vehicle Information, ETSI TS 103 301 / ISO/TS 19321;
 MAP: Map (topology), ETSI ITS 103 301 / CEN ISO/TS 19091;
 SS: Signal request Status, ETSI ITS 103 301 / CEN ISO/TS 19091;

C-ITS Day 1 use cases – safety & liability



Day 1 applications being for information purposes only, the driver always remains in control of the vehicle, [...] no changes concerning liability compared to the current situation [1]

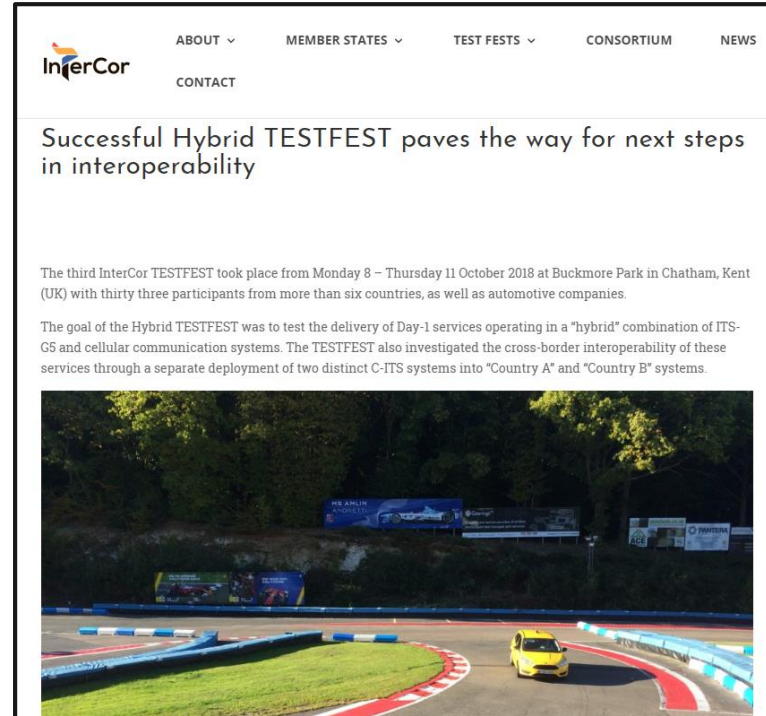
Severity	Exposure	Controllability		
		C1: Simply controllable	C2: Normally controllable	C3: Difficult to control or uncontrollable
S1 Light and moderate injuries	E1: < once / year	QM	QM	QM
	E2: few times / year	QM	QM	QM
	E3: > once / month	QM	QM	A
	E4: almost every drive	QM	A	B
S2 Severe injuries, possibly life-threatening, Survival probable	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3 Life-threatening injuries (survival uncertain) or fatal injuries	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

[1] C-ITS Platform, "Final Report", January 2016, [Link](#)

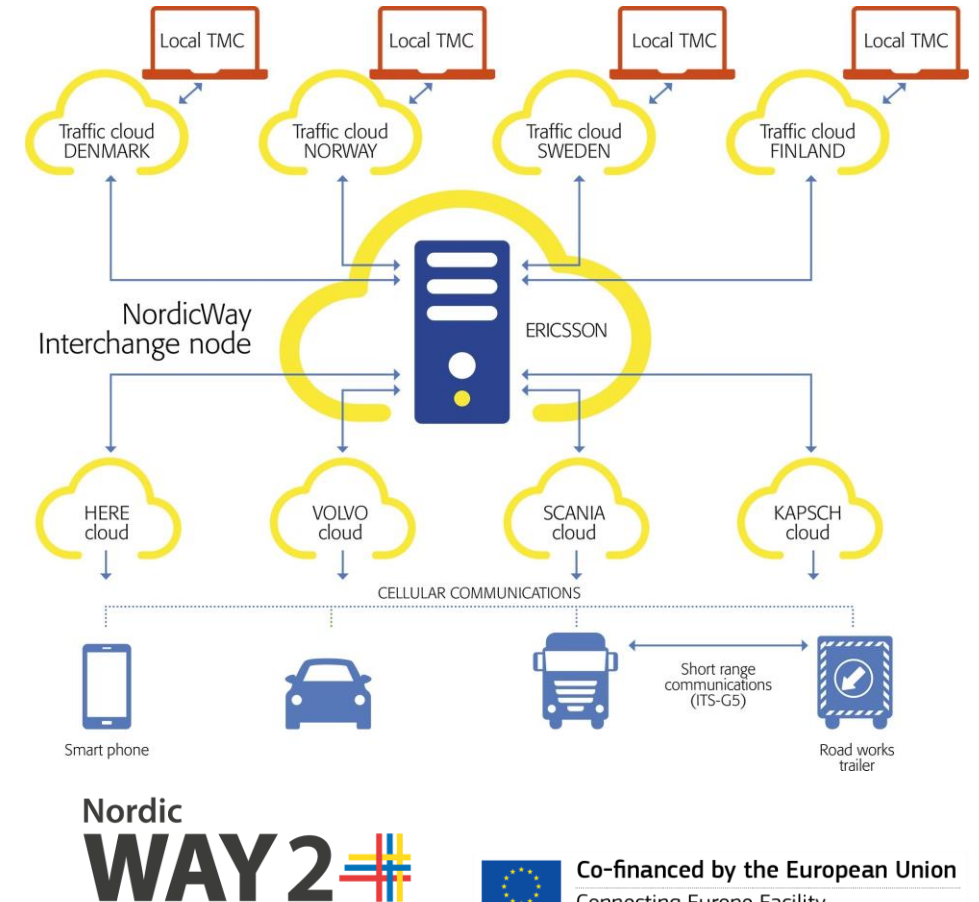
Existing long-range C-V2X



- Similar services:
 - Google Maps, HERE WeGo, ...
 - Automotive OEM clouds
- Projects funded by “Connected Europe Facilities (CEF)” are showing this pre-commercially
 - InterCor
 - NordicWay2
 - CONCORDA (beyond Day 1)
- **Backend interexchange is key for interoperability**



Source: InterCor Project, “Successful Hybrid TESTFEST paves the way for next steps in interoperability, <https://intercor-project.eu/successful-hybrid-testfest-paves-the-way-for-next-steps-in-interoperability/>



Challenges & solutions – QoS & charging

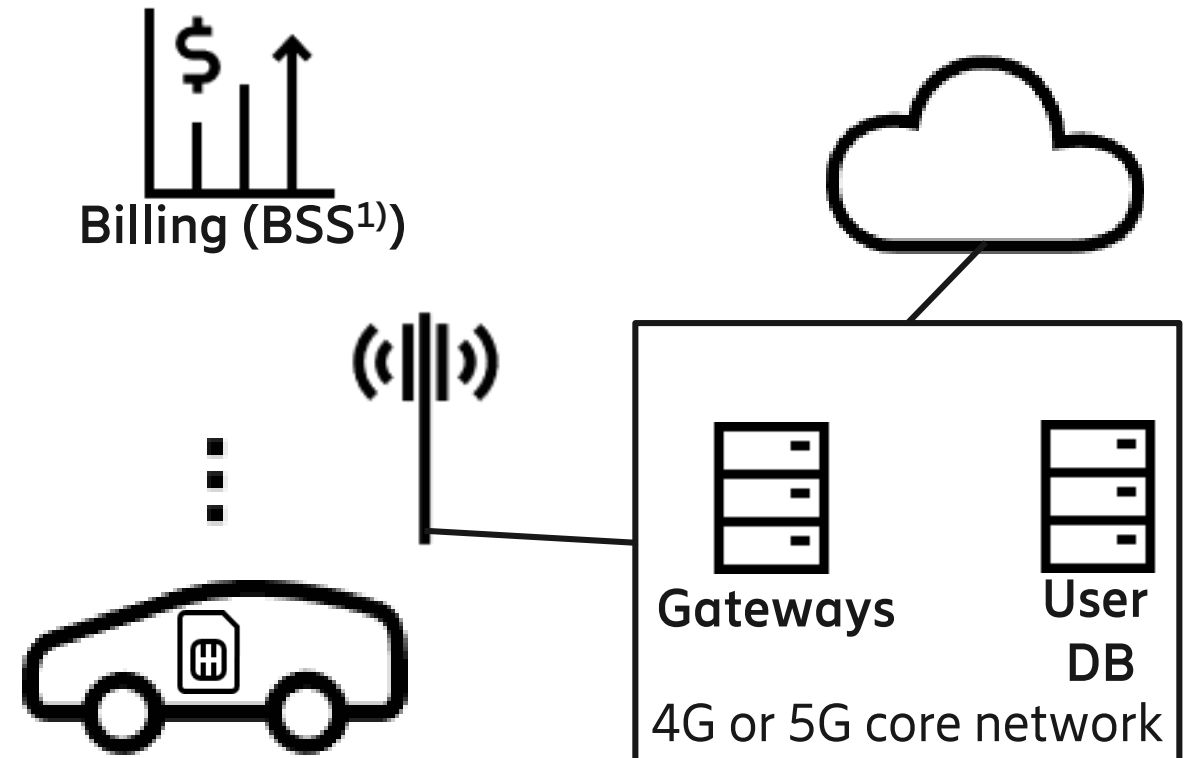


Challenges:

- Serve different classes of applications (e.g. **infotainment / telematics** + **C-ITS**)
- Prioritize QoS data traffic over other data traffic
- Charge separately
- Keep complexity of communication unit / application in vehicle low

Solutions:

- Network Slicing: Needs 5G core; 4G slicing (DECOR¹) only allows one slice per UE
- Multiple APNs²: Results in multiple IP addresses per vehicle making the in-vehicle software complicated
- Dedicated bearers: Fulfill the requirements and put the effort to the MNO³, not the car manufacturer



1) DECOR: Dedicated Core Network (aka DCN)

2) APN: Access Point Name

3) MNO: Mobile Network Operator

4) BSS: Business Support System

Challenges & solutions – QoS & charging



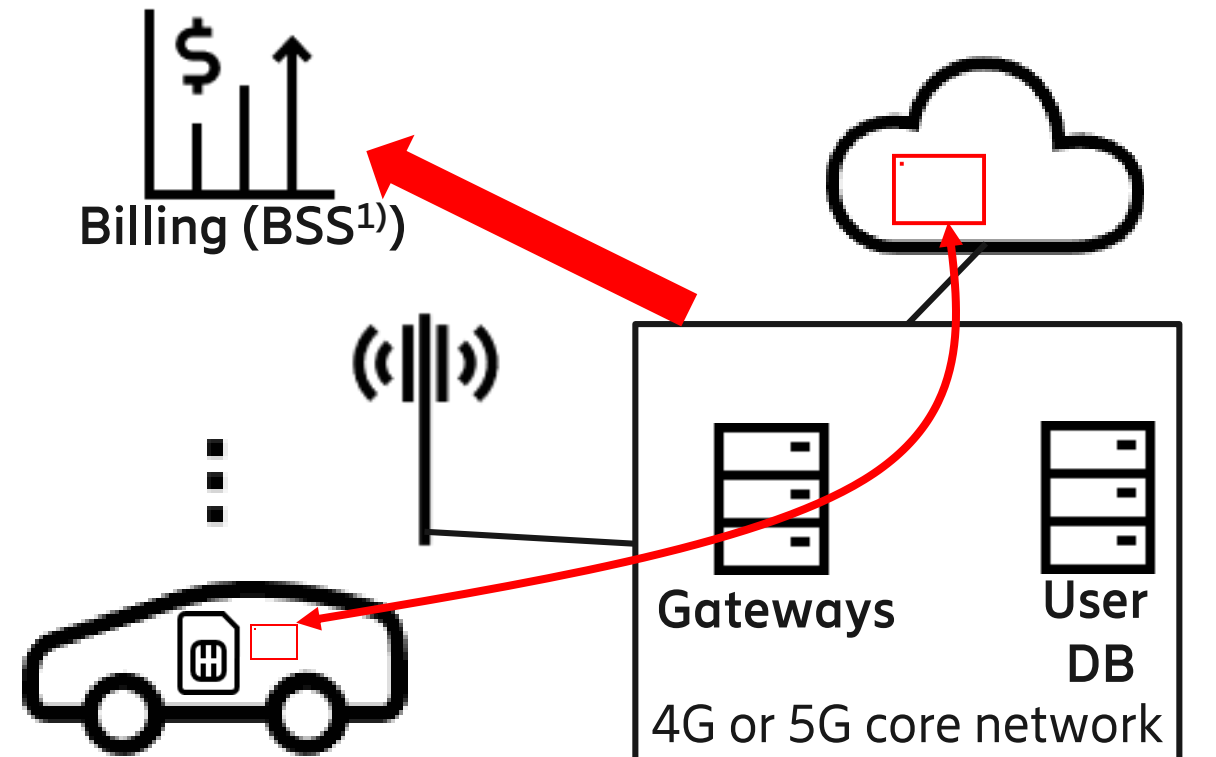
Challenges:

- Serve different classes of applications (e.g. **infotainment / telematics** + C-ITS)
- Prioritize QoS data traffic over other data traffic
- Charge separately
- Keep complexity of communication unit / application in vehicle low

Solutions:

- Network Slicing: Needs 5G core; 4G slicing (DECOR¹) only allows one slice per UE
- Multiple APNs²: Results in multiple IP addresses per vehicle making the in-vehicle software complicated
- Dedicated bearers: Fulfill the requirements and put the effort to the MNO³, not the car manufacturer

0) Baseline: **Infotainment / telematics** over 4G/5G network



1) DECOR: Dedicated Core Network (aka DCN)

2) APN: Access Point Name

3) MNO: Mobile Network Operator

4) BSS: Business Support System

Challenges & solutions – QoS & charging



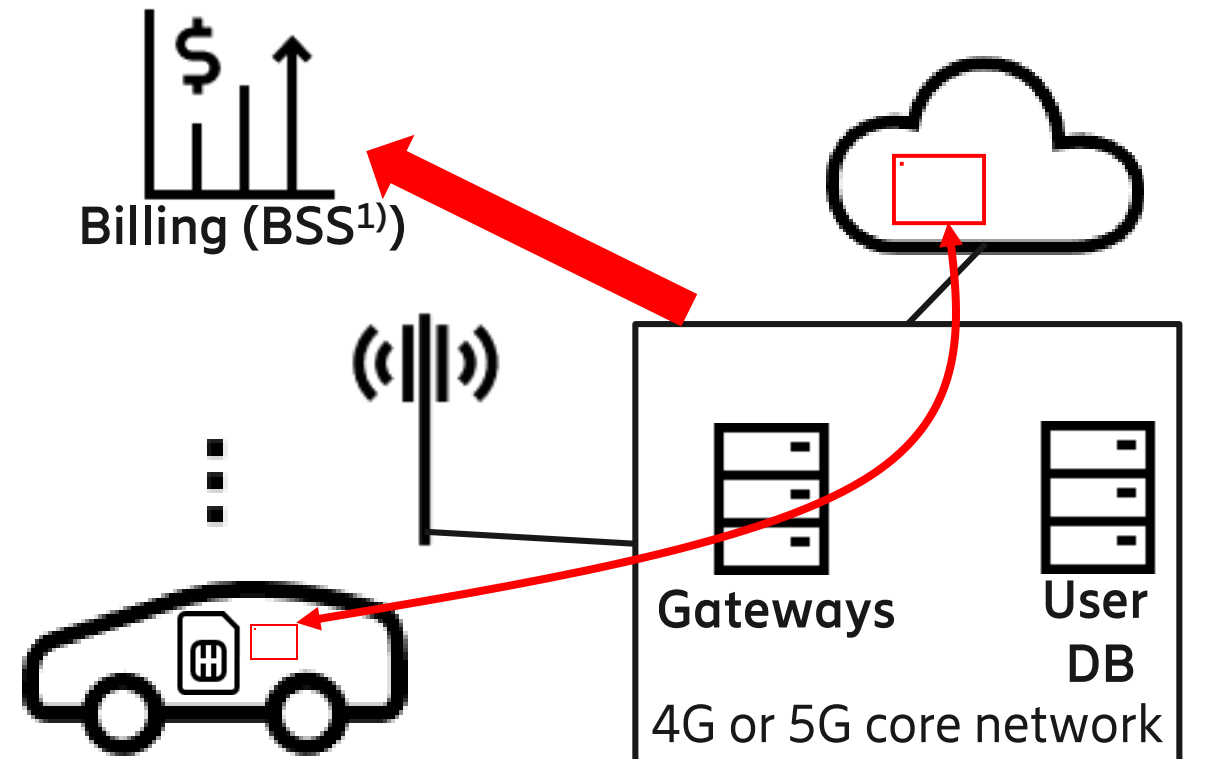
Challenges:

- Serve different classes of applications (e.g. **infotainment / telematics** + **C-ITS**)
- Prioritize QoS data traffic over other data traffic
- Charge separately
- Keep complexity of communication unit / application in vehicle low

Solutions:

- Network Slicing: Needs 5G core; 4G slicing (DECOR¹) only allows one slice per UE
- Multiple APNs²: Results in multiple IP addresses per vehicle making the in-vehicle software complicated
- Dedicated bearers: Fulfill the requirements and put the effort to the MNO³, not the car manufacturer

- 1) Contract: MNO, C-ITS provider, and vehicle OEM / owner agree on **C-ITS service** delivery



1) DECOR: Dedicated Core Network (aka DCN)

2) APN: Access Point Name

3) MNO: Mobile Network Operator

4) BSS: Business Support System

Challenges & solutions – QoS & charging



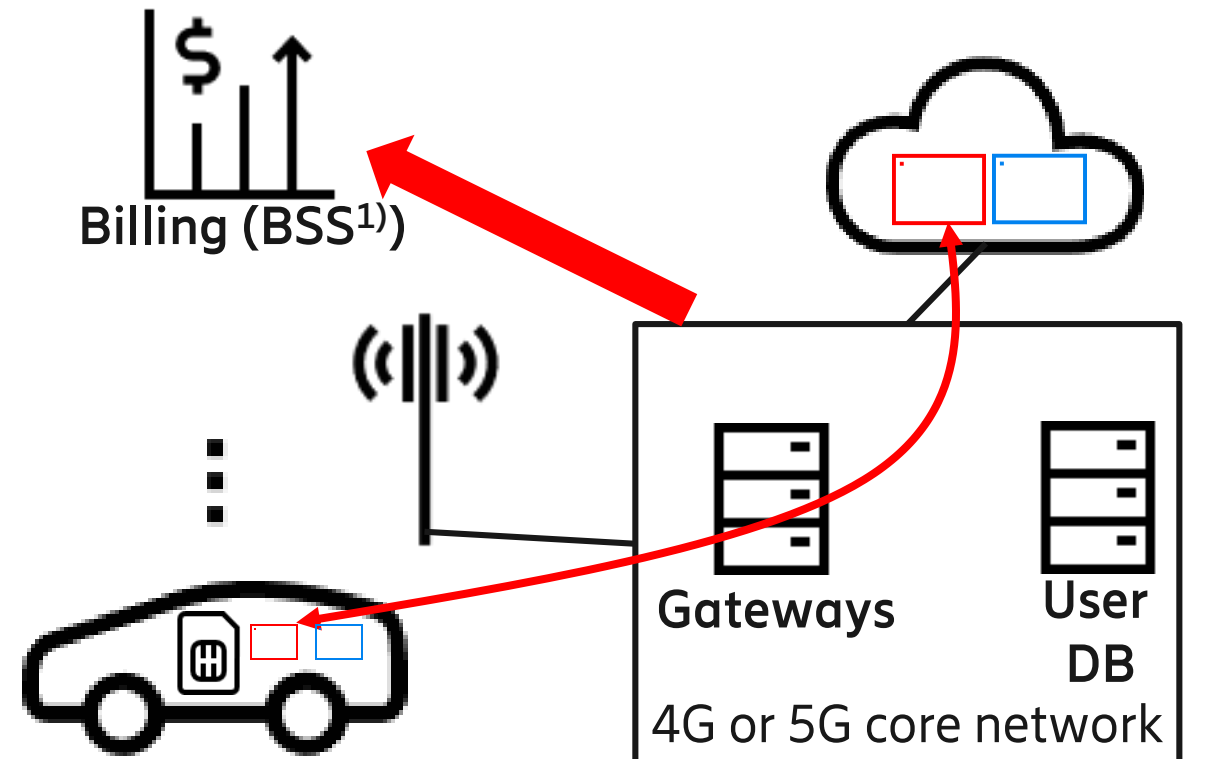
Challenges:

- Serve different classes of applications (e.g. **infotainment / telematics** + **C-ITS**)
- Prioritize QoS data traffic over other data traffic
- Charge separately
- Keep complexity of communication unit / application in vehicle low

Solutions:

- Network Slicing: Needs 5G core; 4G slicing (DECOR¹) only allows one slice per UE
- Multiple APNs²: Results in multiple IP addresses per vehicle making the in-vehicle software complicated
- Dedicated bearers: Fulfill the requirements and put the effort to the MNO³, not the car manufacturer

- 2) **C-ITS service** deployed in cloud and vehicles
→ IP addresses and port numbers



1) DECOR: Dedicated Core Network (aka DCN)

2) APN: Access Point Name

3) MNO: Mobile Network Operator

4) BSS: Business Support System

Challenges & solutions – QoS & charging



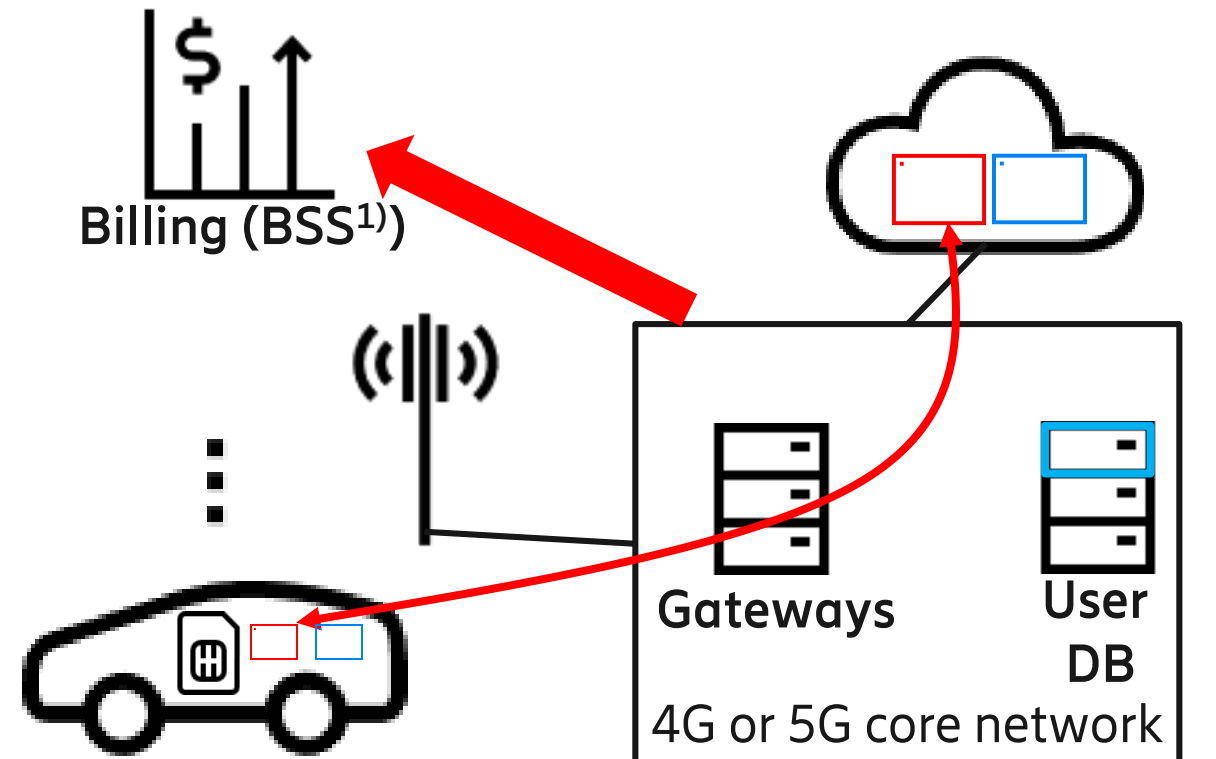
Challenges:

- Serve different classes of applications (e.g. **infotainment / telematics** + C-ITS)
- Prioritize QoS data traffic over other data traffic
- Charge separately
- Keep complexity of communication unit / application in vehicle low

Solutions:

- Network Slicing: Needs 5G core; 4G slicing (DECOR¹) only allows one slice per UE
- Multiple APNs²: Results in multiple IP addresses per vehicle making the in-vehicle software complicated
- Dedicated bearers: Fulfill the requirements and put the effort to the MNO³, not the car manufacturer

3) Dedicated bearers for these IP addresses / ports configured for specific SIMs by MNO



1) DECOR: Dedicated Core Network (aka DCN)

2) APN: Access Point Name

3) MNO: Mobile Network Operator

4) BSS: Business Support System

Challenges & solutions – QoS & charging



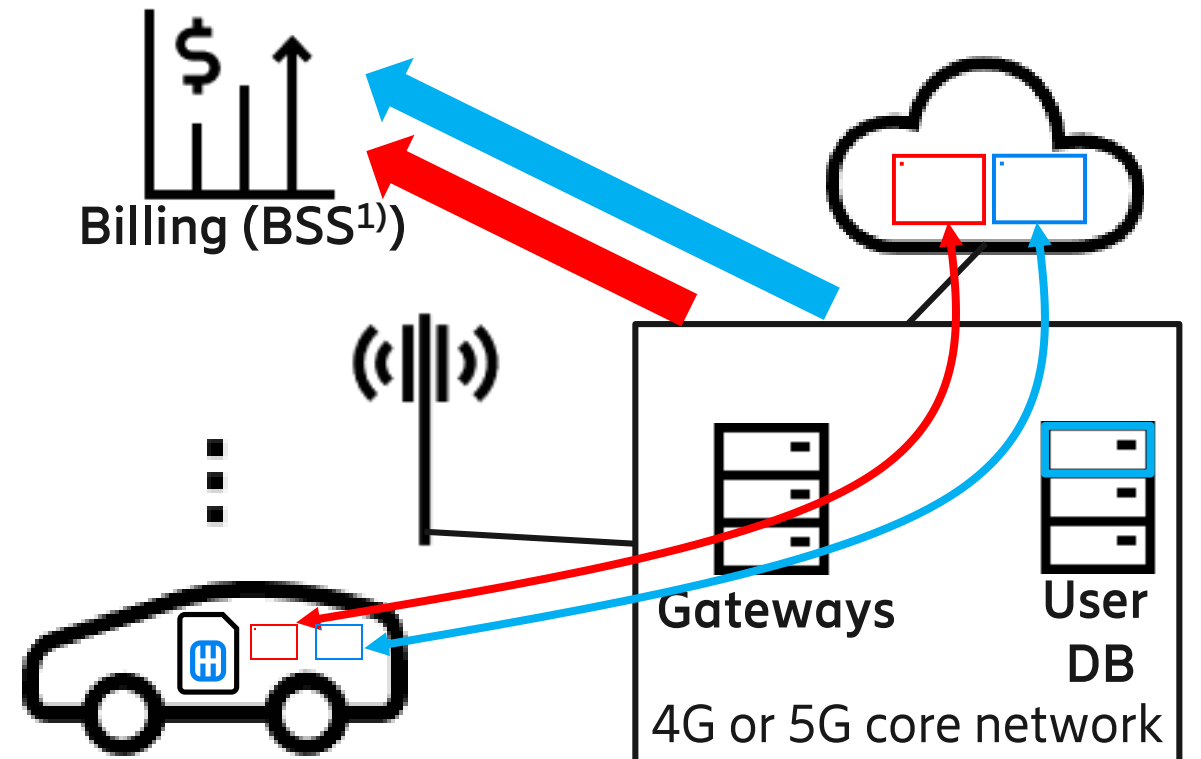
Challenges:

- Serve different classes of applications (e.g. **infotainment / telematics** + **C-ITS**)
- Prioritize QoS data traffic over other data traffic
- Charge separately
- Keep complexity of communication unit / application in vehicle low

Solutions:

- Network Slicing: Needs 5G core; 4G slicing (DECOR¹) only allows one slice per UE
- Multiple APNs²: Results in multiple IP addresses per vehicle making the in-vehicle software complicated
- Dedicated bearers: Fulfill the requirements and put the effort to the MNO³, not the car manufacturer

- 4) Dedicated bearer for **C-ITS services** established automatically; charged separately



1) DECOR: Dedicated Core Network (aka DCN)

2) APN: Access Point Name

3) MNO: Mobile Network Operator

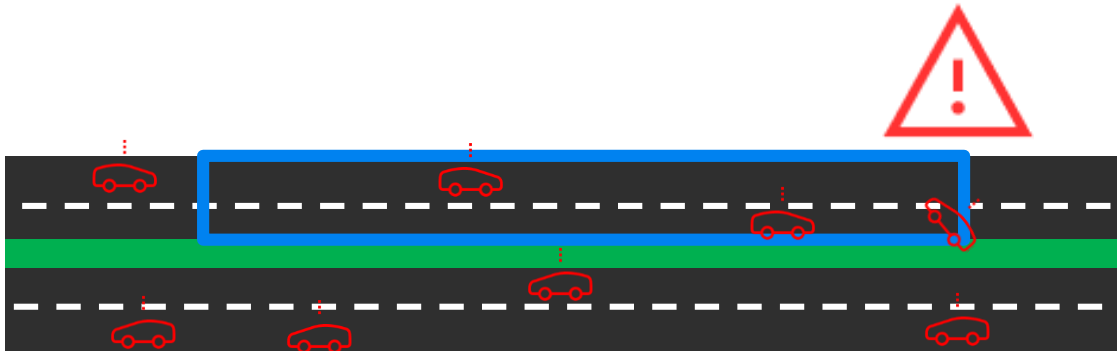
4) BSS: Business Support System

Challenges & solutions - geocasting



Challenge:

- Message must be received by vehicles in “destination area” (service dependent)
 - must be **at least** sent to destination area (larger area OK)



 Warning area specified in DENM²⁾ message

Short-range solution:

- Radio communication range assures geographically limited dissemination (~100 – 1000 m)
- The challenge is often to reach an area larger than that → multi-hop communication handled by GeoNetworking layer
 - Geographically Scoped Broadcast: elliptic or rectangular destination area
 - Topology Scoped Broadcast: max. number of rebroadcasts (zero for CAMs¹⁾)

Long-range solutions:

- Multimedia Broadcast Multicast Service (MBMS)
- IoT message queuing protocol handling it, e.g.:
 - Message Queuing Telemetry Transport (MQTT)
 - Advanced Message Queuing Protocol (AMQP)
- Mobile Edge Cloud (MEC) tightly coupled with set of cells and area they serve

1) CAM: Cooperative Awareness Message

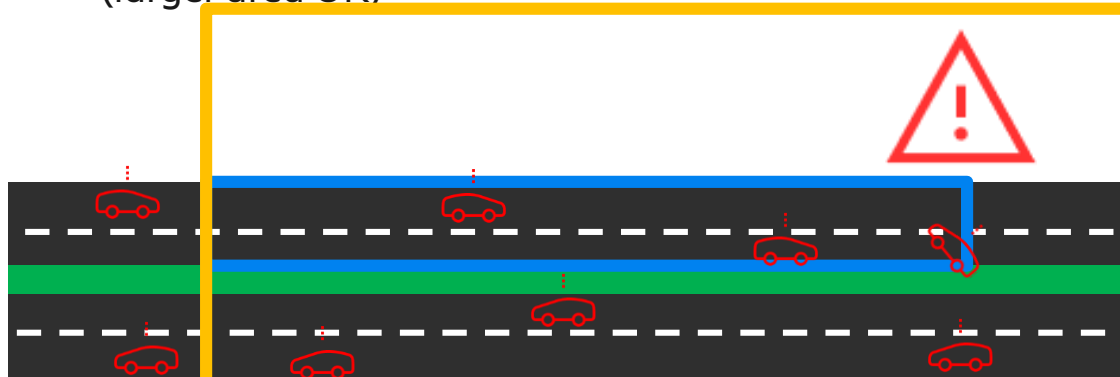
2) DENM: Decentralised Environmental Notification Message



Challenges & solutions - geocasting



Challenge:

- Message must be received by vehicles in “destination area” (service dependent)
- must be **at least** sent to destination area (larger area OK)



-  Warning area specified in DENM²⁾ message
-  Destination area according to GeoNetworking header

Short-range solution:

- Radio communication range assures geographically limited dissemination (~100 – 1000 m)
- The challenge is often to reach an area larger than that → multi-hop communication handled by GeoNetworking layer
 - Geographically Scoped Broadcast: elliptic or rectangular destination area
 - Topology Scoped Broadcast: max. number of rebroadcasts (zero for CAMs¹⁾)

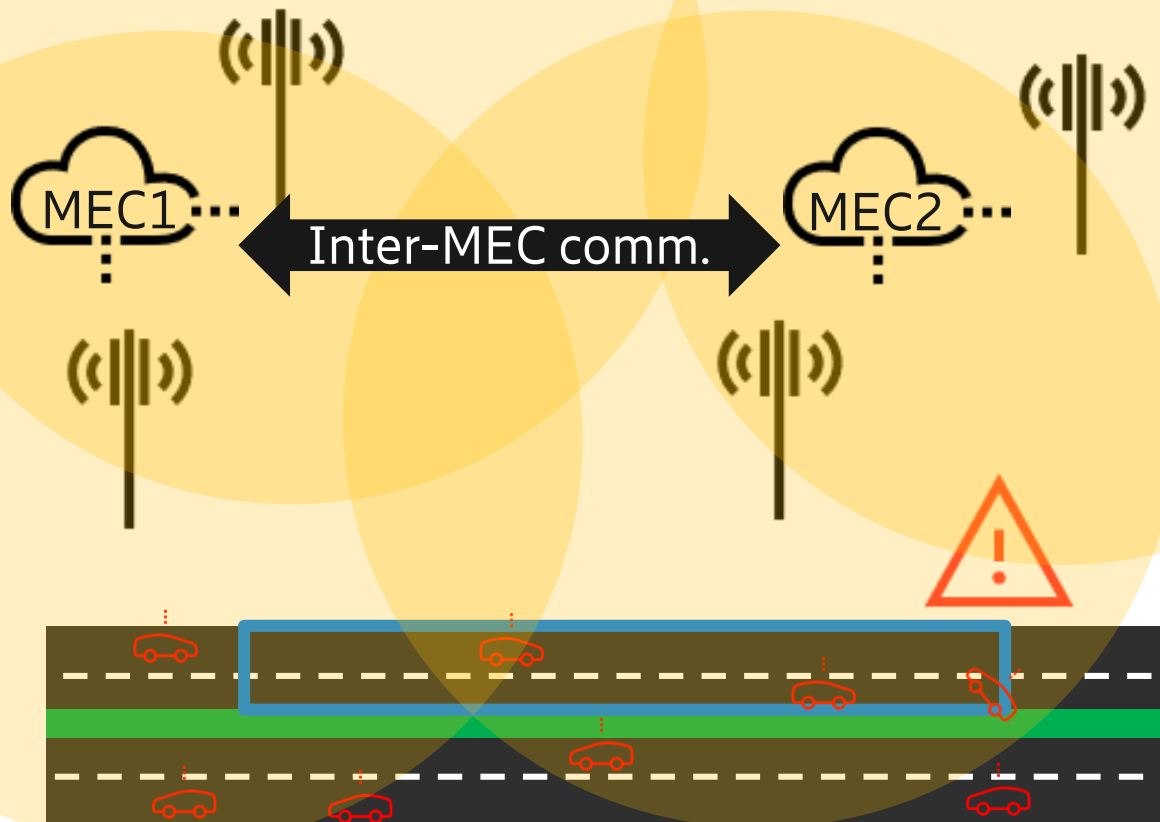
Long-range solutions:

- IoT message queueing protocol handling it, e.g.:
 - Message Queuing Telemetry Transport (MQTT)
 - Advanced Message Queuing Protocol (AMQP)
- Mobile Edge Cloud (MEC) tightly coupled with set of cells and area they serve
- Multimedia Broadcast Multicast Service (MBMS)

1) CAM: Cooperative Awareness Message

2) DENM: Decentralised Environmental Notification Message

Challenges & solutions – geocasting: MEC



Long-range solutions:

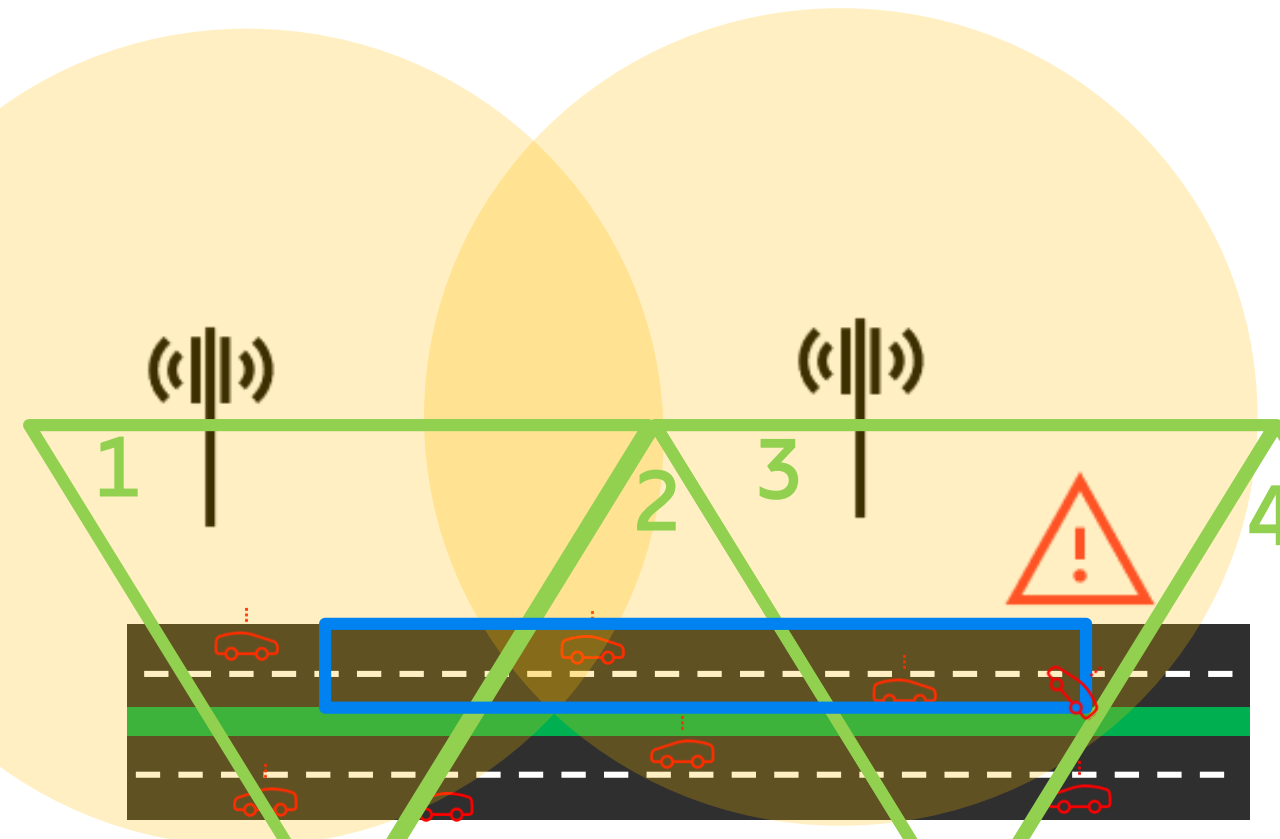
- Mobile Edge Cloud (MEC) tightly coupled with set of cells and area they serve
 - Not a default RAN feature, needs e.g. Selective IP Traffic Offload (SIPTO) to work
 - Fallback to central server possible
- Inter-MEC communication needed when destination area "served" by multiple MEC
- Unicast: must track which vehicle is served by which MEC (e.g. by listening to CAMs)
- Same mechanisms used to "learn" the area served by a MEC according to the cell coverage
- Protocol stack can remain almost unchanged but UDP/IP must be used (encapsulation)

 Warning area specified in DENM² message

1) CAM: Cooperative Awareness Message

2) DENM: Decentralised Environmental Notification Message

Challenges & solutions – geocasting: IoT msg. queueing [≡]



 Warning area specified in DENM²⁾ message

 Areas used for subscription

Long-range solutions:

- IoT message queueing protocol handling it, e.g.:
 - Decouple application from mobile radio network geometries
 - Vehicle subscribes to the “topic” associated to its current area (“shapes” will be discussed in next slide)
 - Can subscribe to more areas to disguise position
- Solution 1: Message sent to all vehicles in subscription areas overlapping with destination area according to message content: **1, 2, 3**
- Solution 2: vehicles subscribe to areas and receive event **originating** from there (e.g. in front of them): **3**
- Additional protocol, e.g. MQTT must be implemented, also in the vehicles
- TCP with connection established in uplink allows to easily overcome firewalls and NAT³⁾

1) CAM: Cooperative Awareness Message

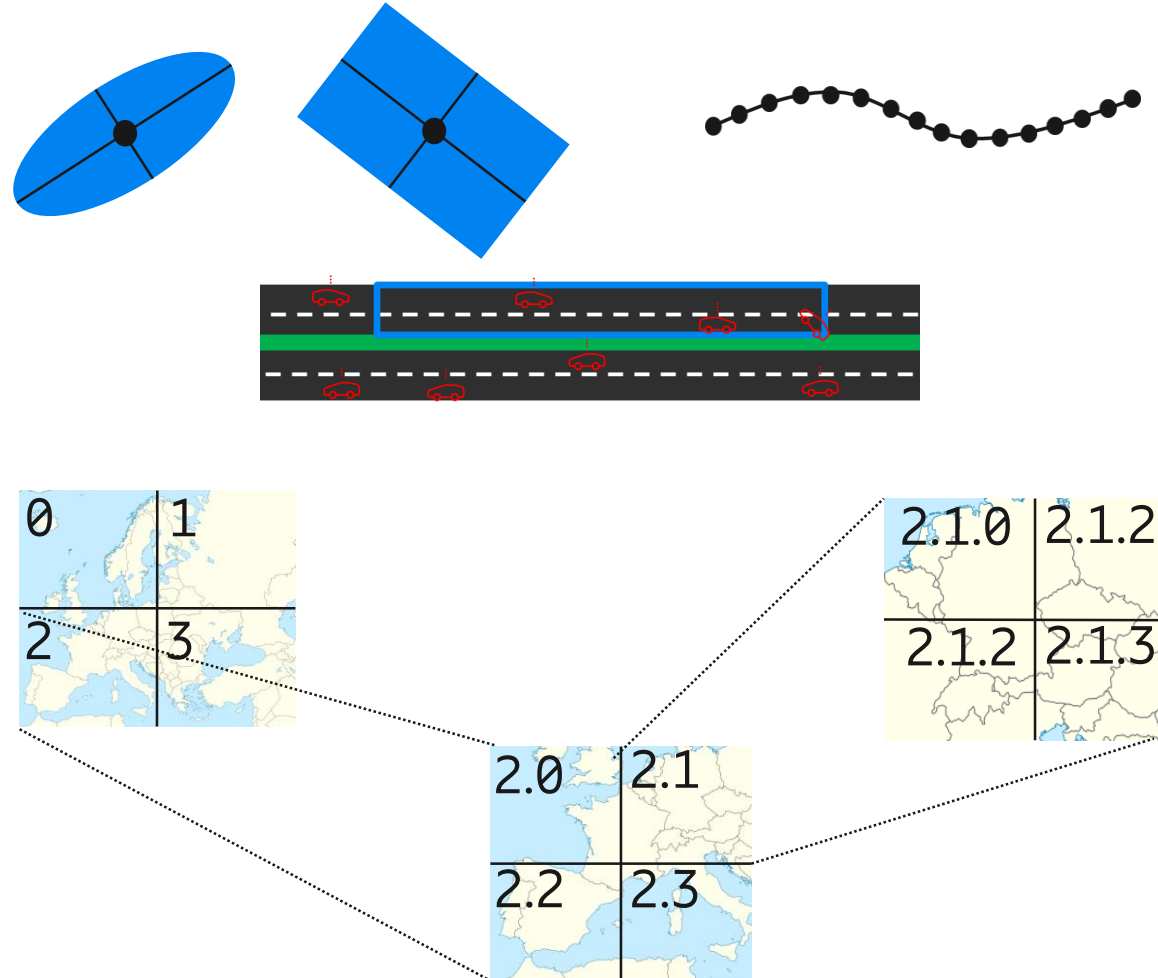
2) DENM: Decentralised Environmental Notification Message

NAT: Network Address Translation

Challenges & solutions – georeferencing

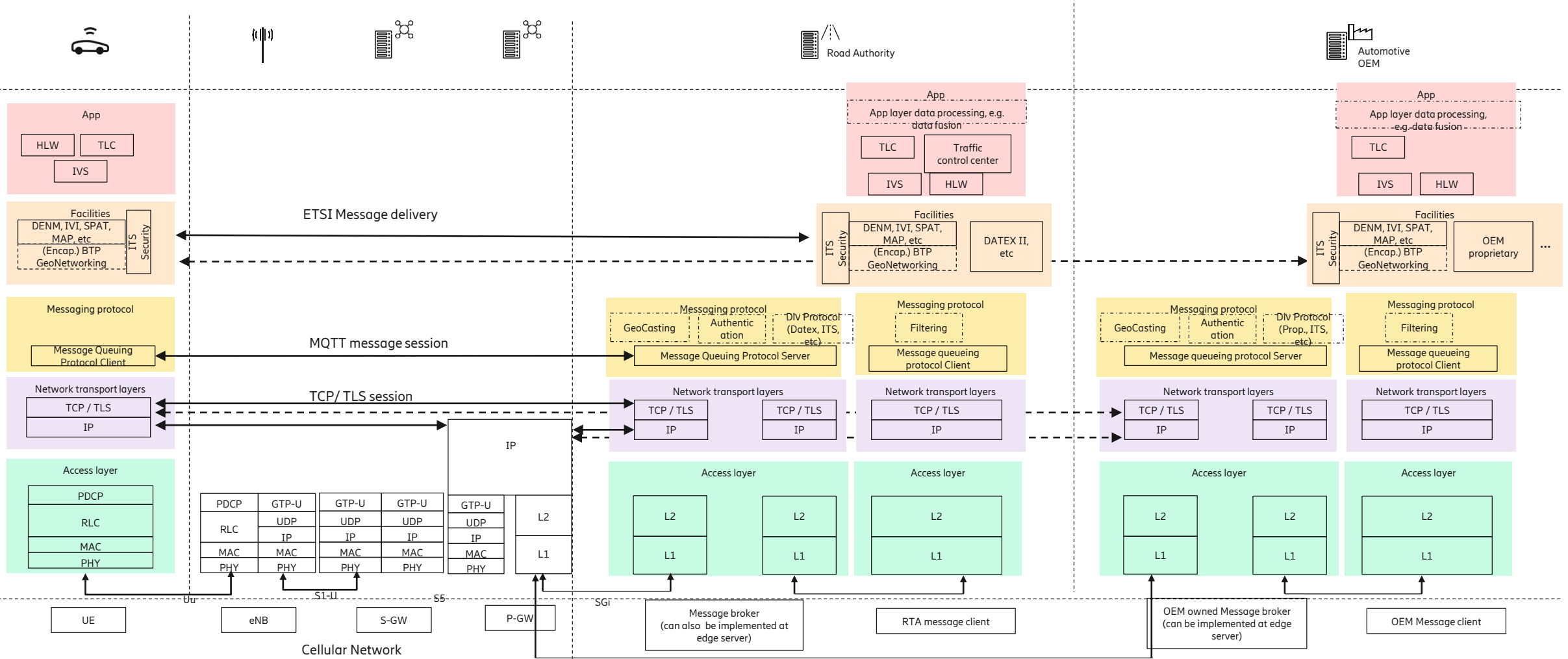


- GeoNetworking protocol allows (rotated) ellipse or rectangle
- Different services/messages have different ways for georeferencing, e.g.:
 - Single positions
 - List of positions
 - Position at road and distance from there (one or both directions)
- Geo information systems (GIS) / navigation systems
 - Quadtree
 - Open Location Referencing (OpenLR)
 - Navigation Data Standard (NDS)



1)

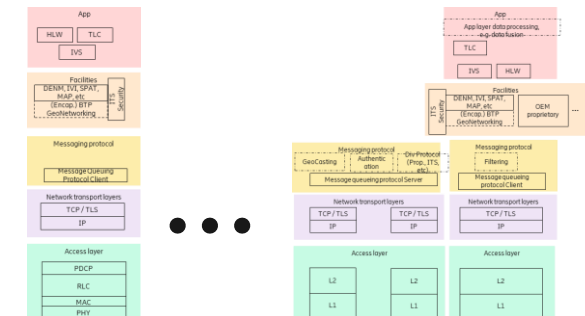
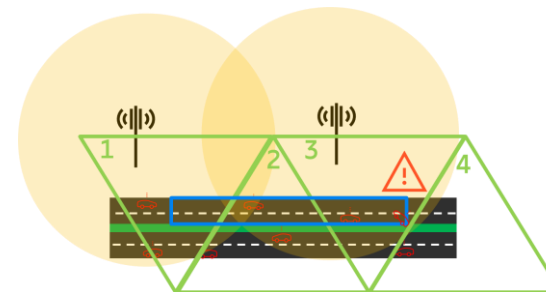
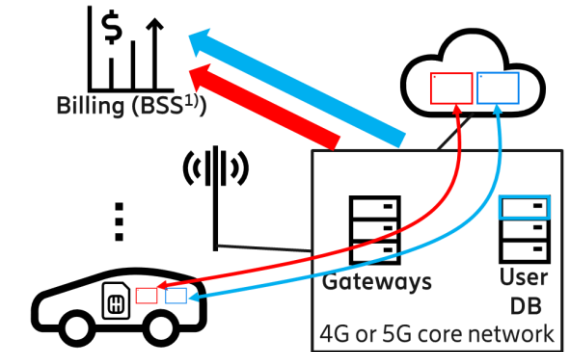
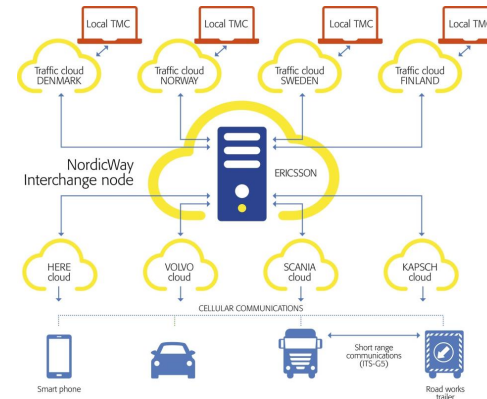
Summary



Summary & conclusion



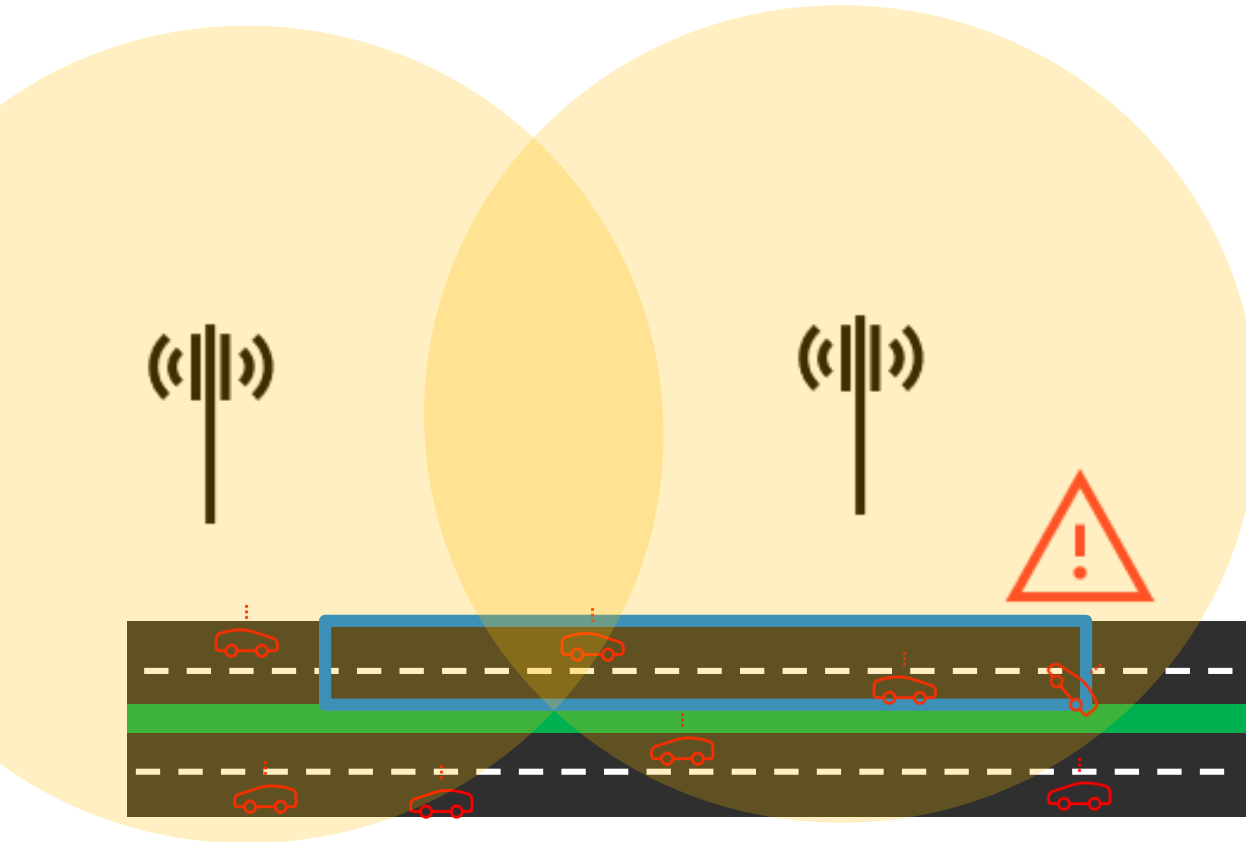
- Solutions are ready for identified challenges of C-V2X service provisioning with commercial 4G cellular networks
 - Interoperability → Backend interexchange
 - QoS & charging → Preconfigured dedicated bearers
 - Geocasting → IoT message queueing protocols
- **Already today (4G) long-range C-V2X can support C-ITS services**
- Long-range cellular modems are already widely deployed in vehicles
- Road / transport authorities do not need to deploy dedicated network hardware (Road Side Units) for C-ITS over long-range C-V2X
- Long-range C-V2X can complement short-range V2X and accelerate market penetration of C-ITS services



1)



Challenges & solutions – geocasting: MBMS



Long-range solutions:

- Multimedia Broadcast Multicast Service (MBMS)
 - Replicates broadcast behaviour of short-range communications but usually with much larger areas
 - Need precise mapping of geographic coordinates to cell coverage
 - MBMS not widely deployed

 Warning area specified in DENM²⁾ message

1) CAM: Cooperative Awareness Message

2) DENM: Decentralised Environmental Notification Message