SECUR

Safety Enhancement through Connected Users on the Road

Deliverable 2.1

Technical document: 4G (Uu interface)

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EXECUTIVE SUMMARY

This document is the technical document of 4G technology. It gathers general information, performances KPI (data rate, range & reliability, latency, congestion, mobility and positioning) and technology's characteristics.

ITS communication using 4G operator networks could provide connectivity for some of the ITS services including safety related services when the network coverage is very good. Anyway, usually the latency is too variable and depend too much on the load of the network to be trusted for safety related services.

ABBREVIATIONS

3GPP	3rd Generation Partnership Project
4G	4G is the fourth generation of broadband cellular network technology, succeeding 3G and preceding 5G
5G	In telecommunications, 5G is the fifth-generation technology standard for broadband cellular networks
5GAA	5G Automotive Association
ASIL	Automotive Safety Integrity Level
BC	Bicyclist
BLE	Bluetooth Low Energy
C2C-CC	Car 2 Car Communication Consortium
CAM	Cooperative Awareness Message
CBR	Channel Busy Ratio
C-ITS	Cooperative Intelligent Transport Systems
CPM	Cooperative Perception Message These messages broadcast information on detected object to its surrounding.
D2VO	Datex-II Vehicle Obstruction
D2WRRC	Datex-II Weather Related Road Conditions
DENM	Decentralized Environmental Notification Message
ECTL	European Certificate Trust List
ETSI	European Telecommunications Standards Institute
EU	European Union
GDPR	General Data Protection Regulation
IP	Internet Protocol
ITS-G5	Direct communication technology based on Wi-Fi. European name for WAVE or DSRC.
IVS	In-Vehicle Signage
KPH	Kilometers per hour
KPI	Key Performance Indicator
LOS	Line-of-sight
LTE	Long Term Evolution
MAPEM	MAP Extended Message
NLOS	Non-line-of-sight
OBU	On-Board Unit
PC	Passenger Car
PC5	Direct communication technology based on mobile network (3GPP). PC5 is one part of C-V2X/LTE-V2X that enable direct communication between objects.
PD	Pedestrian
PDR	Packet Delivery Ratio
PER	Packet Error Rate
PKI	Public Key Infrastructure
PTW	Powered Two-wheeler
REL	Release
RSU	Road Side Unit
RTK	Reel Time Kinematic
SB	Steering Board
SPATEM	Signal Phase And Timing Extended Message

TTC	Time To Collision
UC	Use case
UK	United Kingdom
Uu	Radio interface in cellular communication between a user equipment (UE) and the cellular network base station.
V2I	Vehicle-To-Infrastructure
V2N	Vehicle-To-Network (Uu communication)
V2P	Vehicle-To-Pedestrian
V2V	Vehicle-To-Vehicle
V2VRU	Vehicle-To-Vulnerable Road User
V2X	Vehicle-To-Everything (i.e. vehicle to any type of other station)
VAM	VRU Awareness Message
VRU	Vulnerable Road User (motorcyclist, bicyclist and pedestrian)
WG	Working Group
WP	Work Package
WP1	SECUR Work Package n°1: Accidentology study
WP2	SECUR Work Package n°2: V2X technologies study
WP3	SECUR Work Package n°3: Potential of V2X to improve ADAS performances and final use cases selection
WP4	SECUR Work Package n°4: Development of testing connected targets
WP5	SECUR Work Package n°5: Test and assessment procedures

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1. General information

1.1 Technology's name

4G | LTE

1.2 Operating frequency band

800 MHz, 900 MHz, 1.4 GHz, 1.8 GHz, 2.1 GHz, 2.3 GHz, 2.6 GHz

1.3 Standard

1.3.1 Standardization organization

3rd Generation Partnership Project (3GPP)

1.3.2 Standard Level of maturity [draft/in work/released/rework]

Release in 2017

1.3.3 Is the organization active?

Yes

1.4 Communication profile

3GPP Release 14

1.5 All supported communication types (broadcast…)

V2N

1.6 V2X systems capability (V2V, V2I, V2N, V2VRU)

Table 1 - Types of Communication supported

V2X Type	Supported or not?	Mandatory infrastructure(s)/hardware for the technology operability
V2V	Not Supported	Possible with an indirect communication with V2N2V
V2I	Not Supported	Possible with an indirect communication with V2N2I Hybrid communication from National back end to RSU
V2N	Supported	Telecom Operator Infrastructure + OBU (with SIM card)
V2VRU	Not Supported	Not possible with a direct communication but possible with V2N2VRU for warning information and no time critical event like TCU does today.

1.7 TECHNOLOGY'S DEPLOYMENT MATURITY

4G cellular networks are largely deployed across Europe. All countries have several 4G infrastructure operated by different mobile phone operators. Nevertheless, the coverage is not perfect, and it remains some white area even if the coverage of several operators are combined.

2. Performances

2.1 DATA RATE

2.1.1 BANDWIDTH

We usually observe a minimum bandwidth of few Mbits/s and a maximum of tens Mbits/s. The bandwidth is highly variable and depend on the distance with the base station, the frequency band in use and the load (number of user).

2.1.2 PERFORMANCES

Table 2 - Data rate performances

Type	Value
Outdoor tests [Mbit/s] - Nominal	Download: 45 | Upload: 10 [1]

In figure 1 the design goals of the 4G technology are represented in a spider chart. The actual performances of the current network could be ahead of the target in some area but depending on the coverage and the network condition (load, speed, obstacle) performances could sometimes fell short of the expectations.

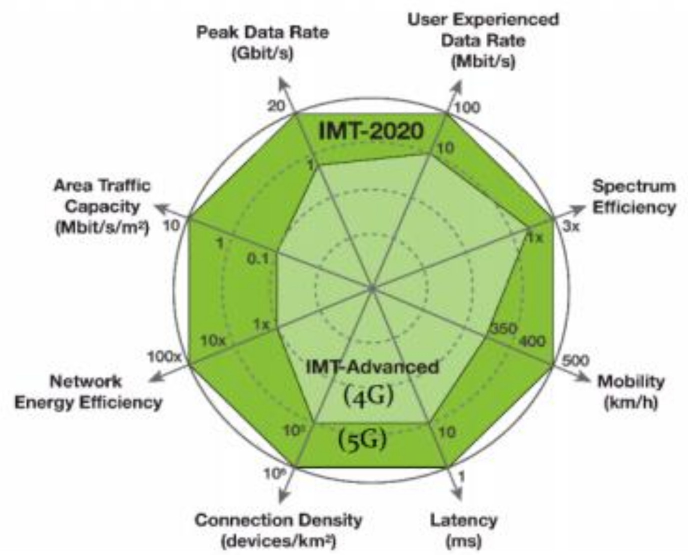

Figure 1: Benefits of 5G compared to 4G [2]

2.2 Range and reliability

4G infrastructure are largely deployed across Europe, usually with several operators in each country. In area where 4G is not available, 3G is used automatically by terminals with a strong impact on performances. All services using 4G communication have to deal with lack of connectivity in some areas.

2.2.1 Consequences

When using a long-range network such as 4G or 5G networks all messages travel from vehicles toward a server who is in charge to forward to vehicles messages that are relevant for them. The server has to "know" where vehicles are (in which area) to be able to choose the right message. Another way to implement this is to let vehicles subscribe to an "area" using a Publish/Subscribe approach.

2.3 Latency

The latency is also highly variable and depend on the radio access network (load, frequency bands, distance with the base-station) but also on the core network of the telecommunication operator. The observed latency is usually between 30ms to 60ms and can be around 100ms in bad network conditions. Moreover, most of the study in the literature has been made with the first version of LTE, today LTE-A is deployed almost everywhere in Europe. It shows better performances. It is difficult to find representative studies since current networks are far better than the first 4G deployments and experiment using experimental infrastructure are often too specific (low load, dedicated core networks, ...) to give realistic results.

2.3.1 Testing context

Most of the study rely on simulation to evaluate the performance of 4G infrastructure for ITS services ([2] [3] [4]). System level simulation could give relevant results but performance in the real world would strongly depend on the configuration of the network.

Only end-to-end latency or application-level freshness (age of information) are relevant for C-ITS services. In [5] they measure the vehicle-to-vehicle delay when V2X messages are relayed by the core network or by mobile edge computing facilities. In [6] they use the probability to “see” neighbours as KPI.

2.3.2 Performances

Table 3 - Latency performances

Type	Value
Theoretical	10 ms
Outdoor tests - Nominal	50 ms - 100ms
Outdoor tests - Min	20 ms
Outdoor tests - Max	> 100 ms

Note that the lower latency (< 20ms) is obtained only in very good configuration (dedicated infrastructure) [7].
In [5] authors compare the performances of several Mobile Network Operators in Munich urban area and show that the RTT delay remains under 100 ms in 97% of the time. It is worth to note that these results are obtained in a very well covered urban area, they would have been different in the center of Brittany for instance. This is consistent with the speed test global index performance[1] which gives a one way mean latency under 40ms for deployed mobile networks.
In experimentation that IMT Atlantique did on available public network, latencies between 50 & 100 ms have been measured when everything is ok and much high latency (several hundred of ms) when the coverage is poor. This does not say what would be the performance if network operators provide specific QoS configuration for ITS services.

Mobile network operators have tools to differentiate services that could protect the V2X advantage V2X traffic in its competition with other traffic. They use these tools to offer a better quality of service to Voice over LTE traffic. Without such mechanisms, the performance of LTE networks would depend on the load (and the number of users) in the current cell.

[1] https://www.speedtest.net/global-index. Note that there is no differentiation between 4G and 5G networks in these results.

2.3.3 Consequences

As latency is highly variable, it is difficult for an ITS services to rely on such communications for safety related services if delay has to be under 1s for this service. In addition, the hole in the coverage will induce large delay and then packet errors.

2.4 Congestion

Latency is highly variable and depend on the load and the coverage. In some condition there is almost no bandwidth available which induces very high latency (up to few seconds). Congestion in 4G results in bigger latency, so not a separate topic in this technology.

Anyway, recent experiments on actual deployment in well covered area (e.g. [5]) show very good performance with low variation in latency. The concern come from the area where the coverage is poor or when the network is overloaded. Mobile network operators have the possibility to protect specific traffic as it is done for VoLTE (Voice over LTE) using service differentiation mechanisms.

2.5 Mobility

The 4G technology has been designed to support terminal mobility. Current deployed infrastructure support VoLTE (Voice over IP) service which have low latency requirements but can withstand packet losses. Any way each change of base station (handover) can induce a variation in the delay and losses. Of course, it strongly depends on the quality of the coverage.

Some limitations for communication at high speed are known (handover, loss of connection, reduction of bandwidth etc), but in most cases these do not prevent usage.

2.6 Positioning

2.6.1 Can the technology provide a localization? What precision?

Depending on the country 4G network could provide a location or not. In Europe the location is provided by the identifier of the cell and in some network by the relative position to several cells (triangulation). The location is then given with a low precision that depend on the size of the cells and on the deployment environment (> 50m).

2.6.2 How does the technology can improve the precision of the GPS positioning?

LTE can be used as a data transport for RTK data to improve location accuracy or to provide satellite information to assist GNSS receivers in acquiring a faster fix.

2.6.3 Consequences

LTE networks does not provide a good positioning by themselves, but they could participate in improving GPS positioning accuracy and reactivity.

3. Technology characteristics

3.1 Supported messages

Table 4 - Supported messages

Type	Rate	Theoretical size
IPv4/6	1 - 100 Mbits/s	No limits

4G networks provide an IP service (v4 and/or v6). All ITS message can be transported in such IP message.

3.2 Cohabitation and interferences

Table 5 - Cohabitation and interferences between 4G and the other V2X technologies

Technology's name	Co-channel coexistence [OK] / Interferences [NOK]	Interoperability [OK / NOK]
ITS-G5 based on IEEE 802.11p	NA	NA
PC5 based on 3GPP rel 14	NA	NA
PC5 based on 3GPP rel 16	NA	NA
4G	OK	OK
5G	OK	OK
BLE	OK	NOK
Wi-Fi	OK	NOK

3.3 Security

3.3.1 Consideration of GDPR

The technology meets the requirements of GDPR. By design, pseudonymization with sophisticated pseudonym and authorization ticket change strategy.

A 4G network operator knows where its active terminals are and then, we have the same concern than with mobile terminals but the use of such information by telecommunication operators is well regulated.

3.3.2 Does the technology meet the EU requirements in term of security?

This technology meets the requirements of EU in term of security. EU has published dedicated requirements as EU Certificate Policy and EU Security Policy. Moreover, PKI is used.
Telecommunication infrastructures are very important and telecom operators have to follow number of rules defined par security agency to guarantee the proper functioning of the network. This technology meets the requirements of EU in term of security, since there is no permanent identifier exchanged on the radio without protection. All the traffic between the vehicle and the ITS server should be encrypted, the operator does not have access to the content of C-ITS messages. In our understanding the ITS server does not have to know the identifier of the

subscriber. And there is no way for the ITS world to associate the identifier of the subscriber with a V2X message.

Any way we could have a concern in the way ITS services can be implemented using 4G and more generally Internet communications. The concern is related to the interaction between IP-based communication and pseudonym certificates used in ITS messages. Upon pseudonym change all observable identifiers used in the communication stack should be modified simultaneously to avoid the linkage of two consecutive pseudonyms. When using 4G IP services there is no easy way to ask for a change in the IP address. It is then easy for the ITS server to link consecutive pseudonyms. One way to solve this issue would be to establish a new session (if the network does not give the same address to a new session).

CONCLUSION

ITS communication using 4G operator networks could provide connectivity for some of the ITS services including safety related services when the network coverage is very good on the best effort, when issue of network coverage, servers' interoperability. Anyway, usually the latency is too variable and depend too much on the load of the network to be trusted for safety related services. Even in area where the network is not good enough for safety services requiring low latency, 4G-Uu based communication remain relevant for a variety of ITS services, especially in area where 5G infrastructure is not yet available. The capability of 4G network to meet the low latencies use-cases requirements strongly depend on the deployment and the configuration of the mobile telecom operator infrastructure and where (how far) are the server used to relay V2X messages. It is almost impossible to guaranty the performance in terms of latency and throughput in a public network deployed for broadband services. Moreover, the car will not be able to anticipate the variation of the delay that could impair safety time critical services. In most of the European city 4G networks are available but could from time to time be unable to meet service requirements (defined in SECUR D2.2). They are also not able to cope with safety service in countryside (outside of highways) where the coverage is poor.

Depending on the way ITS services are implemented, privacy issue could be raised in the central ITS server that could have access to a permanent identifier of the vehicle (ig. Its IP address) which is a violation of the specific EU policies. The mobile network operator on its side has access to user identity and location as for any mobile phone.

Moreover, today there is pilots to work on the interoperability of different OEM & National roads authority servers to communicate and support the features. However, there is no European regulation yet to upload data to exchange servers.

Using 4G Uu communication will require a subscription with a telecommunication operator and the availability of services using such connectivity strongly depend on the 4G coverage. Depending on the business model of the service, the subscription fees could be paid by the service provider or by the end user.

This type of communication could be anyway very useful to integrate in the ITS ecosystem vehicle or other users that do not have V2X capabilities. It is also interesting when low latency is not required, for example to give navigation information far ahead from an accident. It could also be useful to integrate non-V2X capable vehicles or users in the C-ITS eco-system.

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