SECUR

Safety Enhancement through Connected Users on the Road

Deliverable 2.1

Technical document: 5G (Uu interface)

Project Name	SECUR	
Dissemination level	Public	
Work package	WP2: Suitability of the different technologies for the selected use cases	
Deliverable	V2X technologies description & performance	
Written by	Jean-Marie BONNIN	IMT Atlantique
Issue date	30/05/2022	
Reviewers	Yoan AUDEGOND	UTAC
	Léo CORNEC	UTAC
	Johannes HARTOG	VOLKSWAGEN
	Leo MENIS	AUTOTALKS
	Mahdi MOUSAVI	ZF
	Mikael NILSSON	VOLVO CARS
	Bettina ERDEM	CONTINENTAL
	Frédéric JOLY	RENAULT
	Didier LEDAIN	YOGOKO
	Andreas SCHALLER	BOSCH
	WP2 V2X Experts	
Keywords	5G, V2X, Cellular, performance, characteristics, technology, standard	
Version	Version 1.2	

IMT Atlantique

EXECUTIVE SUMMARY

This document is the technical document of 5G technology. It gathers general information, performances KPI (data rate, range & reliability, latency, congestion, mobility and positioning) and technology's characteristics.

The conclusion of academic studies shows that ITS communications using 5G operator networks could provide a variety of ITS services including safety related services with connectivity with a good level of quality of service.

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

TABLE OF CONTENTS

1. General information

1.1 Technology's name

5G

1.2 Operating frequency band

700 MHz, 1.9 GHz, 2.1 GHz, 3.5 GHz, 26 GHz

1.3 Standard (access layer)

1.3.1 Standardization organization

3rd Generation Partnership Project (3GPP)

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

The current version has been released in 2020. But the current deployment could be of previous releases. Anyway, it does not change for the basic Internet service.

1.3.3 Is the organization active?

The body is very active, and this specification is completed and the effort is more on the release 17.

1.4 Communication profile

To be defined.

1.5 All supported communication types (broadcast…)

The communication over Uu interface provides an Internet access to the device. All IP-based communication could be used.

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

Table 1 - Technology capability by V2X communication types

V2X Type	Supported or not?	Mandatory infrastructure(s)/hardware for the technology operability
V2V	Not Supported	Indirect communication could be done with V2N2V.
V2I	Not Supported	Indirect communication could be done with V2N2I.
V2N	Supported	OBU + gNB (new generation base station)
V2VRU	Not Supported	Indirect communication could be done with V2N2VRU.

1.7 TECHNOLOGY'S DEPLOYMENT MATURITY

Difficult to follow all the deployments across Europe and it will depend on the country. Moreover each operator made its own choices (bands, architecture, ...) and it has a strong impact on the performances. Difficult to forecast what will be the performances of these 5G networks in 2 years.

1.8 WHERE IS THE TECHNOLOGY USED? (ONLY WITH THE SAME COMMUNICATION PROFILE)

5G network are deploying fast in Europe but the coverage is still limited to urbanised area.

2. Performances

2.1 DATA RATE

2.1.1 BANDWIDTH

On preliminary deployments the bandwidth is highly variable and depend on the availability of the infrastructure. It is usually between tens and hundreds of Mbits/s.

2.1.2 PERFORMANCES

The performance of 5G networks and more specially the service adapted for mission-critical machine type communication (URLLC) will be well adapted for various ITS services with a very short latency, the support of high speed, high devices density, and an improved reliability (Figure 1). The mobile broadband service could be enough for most of the ITS services in area with a good coverage.

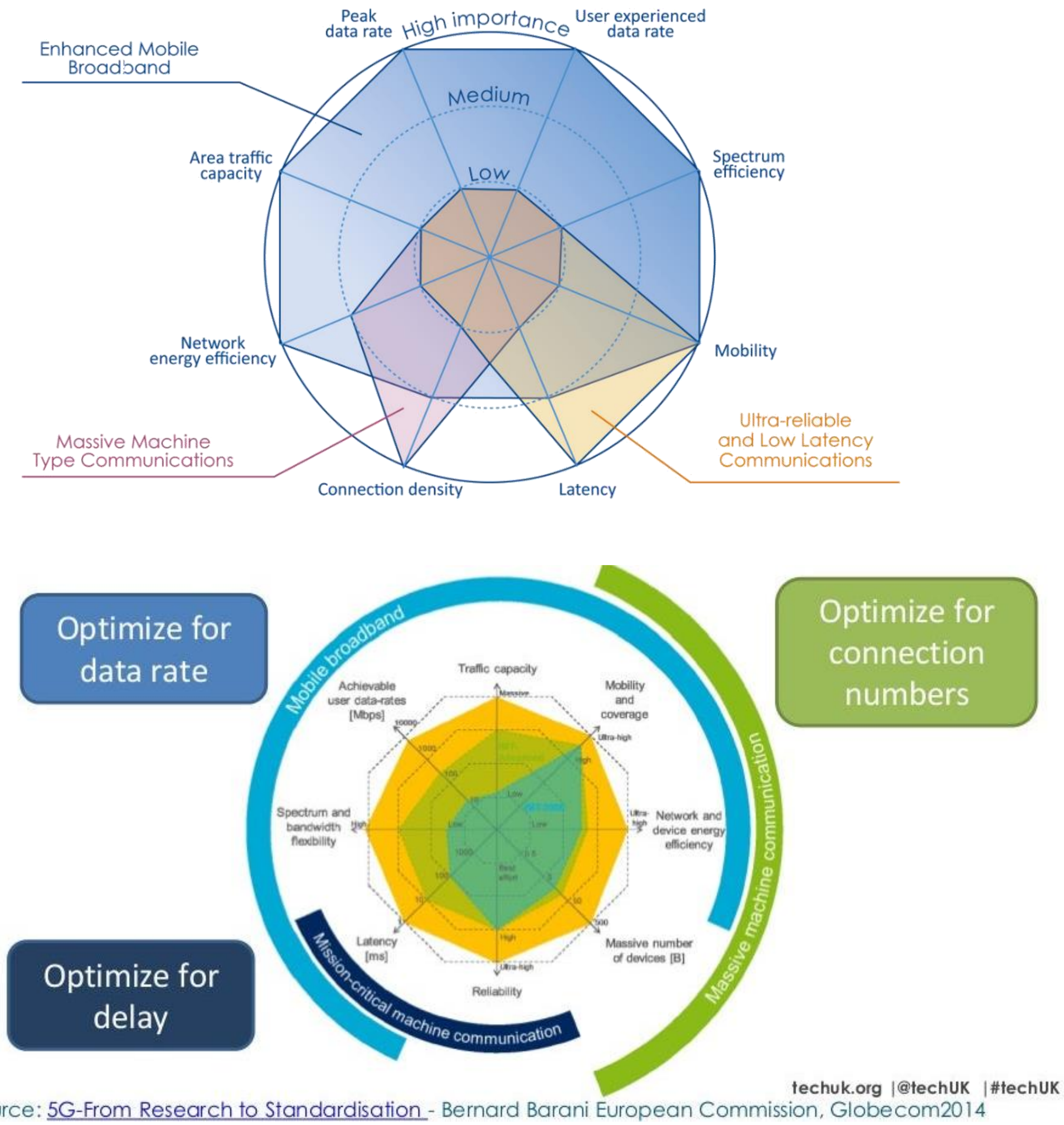

Figure 1: 5G Performances adapted to various services[1]

[1] https://www.etsi.org/images/articles/Spider-chart.png

2.2 Range and reliability

The performance of a 5G network depend on the deployment and the way the operator configures its services on it, especially in terms of QoS and resource reservation. Moreover, it will be possible to combine the services of several operators obtain and better service.

The range will also depend on what we consider, it could be relative to the coverage of a given network operator (usually a country) or the range of a base station which depends on the frequency bands (from tens of kilometres to hundreds of meters in urban area).

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 offered by 5G networks are very good. For broadband services it is usually comparable to what we have over domestic optical fiber access (<10ms) for the access network contribution.

When the ITS Application Server will be located in the premises of the network operator and near the field (Mobile Edge Computing), the delay will be in the order of few ms [1].

As for all infrastructure-based communication, the performance strongly depends on the quality of the coverage. In the experimentation done in [2] they observed a RTT of 50-60ms between the car and the Mobile Edge computing facilities, but this latency could reach 500 ms when the coverage is poor which is too much for most of the safety-related services [3].

2.3.1 Testing context

In the context of Uu communication the relevant latency includes the travel time in the core network or at least in the edge access when mobile edge computing facilities are used. Some of the study [2] include the treatment delay in order to show the overall reaction time of the service. This makes the comparison difficult since in include algorithmic performances of the service in the picture. Anyway, it gives a good idea of what is achievable. Sometimes RTT (Round Trip Time) is used which should include only both the time between the source and the destination and the return [3] [4] [5].

On actual 5G test infrastructure [4] obtained a latency of about 10 ms and a higher throughput than with the other technologies (ITS-G5 and LTE).

Some interesting studies show the performances of 5G Uu technology to support advanced ITS services such as platooning or cooperative perception relying on a V2X server.

2.3.2 Consequences

The technology is relevant for safety services thanks to its short latency, but its availability depends on the coverage. Moreover MEC (Mobile Edge Computing) could further reduce the latency observed by the services since to most important component of the delay comes from the RTT between the local infrastructure and the core network. In [3], they show a delay of about 12ms when 5G core is used and around 6ms using edge computing facilities. It is worth to note that this performance could be achieved using the URLLC slide, the delay would have been longer with the general public mobile broadband slice, i.e., a normal subscription.

2.4 Congestion

The resistance to congestion is difficult to assess with current deployment. Moreover, the service offered by cellular operator will evolve and one can provide service differentiation that can protect safety related message from the congestion. 5G network has been designed to support multiple services with various constraints on the same infrastructure. However, there is no measurement already done in the literature.

2.5 Mobility

5G has been designed to support high mobility with a reliable connectivity.

2.6 Positioning

2.6.1 Can the technology provide a localization? What precision?

5G sub-6GHz can also be used to achieve coarse location (20m). 5G mmWave promises sub-meter location accuracy eventually, assuming sufficient infrastructure. Unfortunately, it will be available only in area covered in the mmWave bands.

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

5G 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

In the future, 5G network could provide a location service, probably with few meters of accuracy. It is too early to say what will be the actual performances.

3. Technology Characteristics

3.1 Supported messages

Table 2 - Supported V2X messages of 5G

Type	Rate	Theoretical size
IPv4/v6	100 Mbits/s - 1Gbits/s	No limits

5G Uu communication technology could be used to send any type of V2X messages, but a relay server is required to relay the messages toward an area or a specific destination vehicle. This V2X server could be located in the premises of the operator near the field (Mobile Edge Computing), in the core of the mobile network, or somewhere on the Internet. The location and the capacity of the V2X server will have a strong impact on the latency observed by services.

3.2 Cohabitation and interferences

Table 3 - Cohabitation and interference between 5G and 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
WiFi	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. Telecom operators must comply with the RGPD requirements and could only use privacy-sensitive data for what is necessary to operate their services.

A 5G 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?

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 5G 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 identifier used in the communication stack and observable should be modified simultaneously to avoid the linkage of two consecutive pseudonyms. When using 5G 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 5G mobile operator networks could provide a variety of ITS services including safety related services with connectivity with a good level of quality of service. Such demanding services can be offered only in area where the coverage is good enough. 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 (i.e. its IP address). The mobile network operator on its side has access to user identity and location as for any mobile phone. The capability of 5G network to meet the SECUR use-cases requirements strongly depend on the coverage. In general, the performances 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. Even if the network has been designed to be able to offer very low latency (~1ms), this could be done at the expense of a specific slice (set of resources) and it is almost impossible to guaranty the performance in terms of latency and throughput in a public network deployed for broadband services.

5G networks show good performances when the coverage is ok but could from time to time be unable to meet service requirements when the device is at the border or out of the coverage. In Europe, the coverage is still very limited outside urban area.

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 (i.e. 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.

However, it will require a subscription with a telecommunication operator and the availability of services using such connectivity strongly depend on the 5G coverage. The performance of such service will also depend on how ITS application server is included in the network operator infrastructure. In other words, it will depend on the efforts (reserved radio resources, dedicated slice, computing capabilities, ...) telecom operators are prepared to make specifically to support ITS services. It is still difficult to know who will pay for ITS services and then what could be the business models of the envisioned ITS services. The necessary investments will be made by telecommunication operators only if they will generate a good return.

It is worth noting that dedicated infrastructure could be deployed on the road infrastructure premises and could be well adapted to provide ITS high value services to the users of the road infrastructure. The same infrastructure could then serve multiple purposes including safety related ITS services with a high degree of dependability.

ACKNOWLEDGEMENTS

The SECUR Project consortium would like to acknowledge for their support and work all the Partners and Third Parties involved:

Partners

Contributors

REFERENCES

[1] R. Justus, P. Sossalla, S. Itting, F. Fitzek et M. Reisslein, *5G Campus Networks: A First Measurement Study.*

[2] A. Raouf, E. Davies, M. Broadbent et N. Race, *Evaluating the Real-World Performance of 5G Fixed Wireless Broadband in Rural Areas.*

[3] A. Azza, S. Hicks, M. A. Riegler et A. Elmokashfi, *Predicting High Delays in Mobile Broadband Networks.*

[4] M. N. Tahir et M. Katz, «Performance evaluation of IEEE 802.11p, LTE and 5G in connected vehicls for cooperative awareness,» Engineering Reports, 2021.

[5] O. Al-Saadeh, G. Wikstrom, J. Sachs, T. Ilaria et D. Lister, *End-to-End Latency and Reliability Performance of 5G in London.*

[6] M. Kutila, P. Pyykonen, Q. Huang, W. Deng, W. Lei et E. Pollakis, «C-V2X supported automated driving,» IEEE International Conference on Communications Workshops (ICC Workshops), 2019.

[7] A. Lekidis et F. Bouali, «C-V2X network slicing framework for 5G-enabled vehicle platooning applications,» IEEE 93rd Vehicular Technology Conference (VTC2021-Spring), 2021.

[8] M. N. Tahir, F. Sahar et B. Nouman, *Car-to-Car Communication Using ITS-G5 & 5G.*

TABLE OF ILLUSTRATIONS