6G BRAINS Deliverable D2.4

Description and Analysis Results of the 6G BRAINS Secondary Use Cases

Editor:	Uwe Wostradowski (BOSCH)
Deliverable nature:	Report (R)
Dissemination level: (Confidentiality)	Public (PU)
Contractual delivery date:	31.01.2023
Actual delivery date:	31.03.2023
Suggested readers:	6G system architects, user requirements engineers.
Version:	1.0
Total number of pages:	62
Keywords:	Use cases, user stories, requirements, latency, localization accuracy, data rate, secondary use cases, integrated sensing, vital sign detection

Abstract

The attention to wireless connectivity as an important enabler for many modern applications in various segments continues to grow [29]. A transition from “fixed” to “mobile” in many segments including industrial manufacturing is a hot topic in many consortia. However, further improvements of wireless communication technologies are required to motivate their usage in new domains. For this, 6G BRAINS project offers a broad range of new techniques including terahertz (THz), light communication, massive AI, etc.

In our first Deliverable 2.1 [1], we did the first step towards identifying the most obvious applications that can benefit from 6G BRAINS technologies. While carefully reviewing the segments like production manufacturing, automotive industry, smart agriculture, etc., a list of relevant use cases has been created. The most challenging use cases built the basis for our requirements analysis summarized in clause 5 of this deliverable in form of technical use case descriptions, derived user requirements, KPI specifications, as well as user concerns. D2.1 [1] focused rather on the primary aspects of the upcoming releases of mobile communication 5G and B5G. In this deliverable, however, we address such new features like integrated sensing and identification, precise localization and tracking, physical layer security, vital sign detection, etc., that do not represent the primary aspect of data transmission and belong rather to a group of so-called secondary features. These secondary features, in fact, have a good potential to become a unique selling point of the next generations of mobile communication. We show how secondary features contribute to such use cases like self-aware automated guided vehicles, excitement level detection for amusement parks, cabin control in cruise ships, vulnerable road user awareness, and access control for home security.

[End of abstract]

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The research leading to these results has received funding from the European Union Horizon 2020 Programme under grant agreement number 101017226 – 6G BRAINS – H2020-ICT-2020-2.

Impressum

Full project title	Bring Reinforcement-learning Into Radio Light Network for Massive Connections
Short project title	6G BRAINS
Number and title of work-package	WP2: User/learning Requirements and System Architecture
Number and title of task	T2.1 Definition and Analysis of Primary and Secondary 6G BRAINS Use Cases
Document title	D2.4 Description and Analysis Results of the 6G BRAINS Secondary Use Cases
Editor	Uwe Wostradowski and Alexander Artemenko, Robert Bosch GmbH
Work-package leader	John Cosmas
Estimation of PM spent on the Deliverable	8 PM

Executive Summary

Current generations of mobile communication systems incl. 5G have recently received a lot of attention in such segments like industrial manufacturing, automotive, agriculture, etc. A comprehensive amount of time has been devoted to the analysis of these communication technologies with respect to their utilization as an enabling solution in various industrial domains. It has been detected that for a significant number of future applications even the latest releases of 5G provide neither sufficient Quality of Service nor the required feature set (e.g., precise localization and environmental perception) to enforce a quick deployment of 5G networks for private usage in such domains like industrial manufacturing and automotive sector. The propagation of 5G campus networks into these new domains is still quite slow.

At the same time, the weaknesses of 5G, that have been identified in many proof-of-concept activities, offer a solid basis for the discussions about the next generation of mobile communication systems, incl. B5G and 6G. In parallel, new techniques, which have been in discussion for some time and did not make it into 5G, show now high potential to enable new features in mobile communication systems. Such techniques might integrate sub-terahertz (sub-THz), light communication, massive AI, and other techniques developed in the project 6G BRAINS. With these techniques new features become possible or well-known features may improve significantly. Such features like precise localization and tracking, integrated sensing and identification, physical layer security, vital sign detection, etc. do not represent the primary aspect of data transmission and belong rather to a group of so-called secondary features. These secondary features, however, have a good potential to become a unique selling point of the next generations of mobile communication.

After our first analysis of possible new use cases in D2.1 [1], that focused rather on the primary aspects of the upcoming releases of mobile communication 5G and B5G, we address secondary features in this deliverable and show how they contribute to such use cases like self-aware automated guided vehicles, excitement level detection for amusement parks, cabin control in cruise ships, vulnerable road user awareness, and access control for home security.

Being under development in 6G BRAINS, different innovation aspects have been analysed and served as input to this document. Such aspects are (i) a novel combination of spectra like sub-THz and optical wireless communication (OWC) to enhance the performance with regard to capacity, reliability and latency, as well as to enable sensing capability, (ii) high resolution 3D Simultaneous Localization And Mapping (SLAM) of up to 1 mm accuracy (iii) a novel comprehensive cross-layer deep reinforcement learning (DRL) driven resource allocation solution to support the massive connections over device-to-device (D2D) assisted highly dynamic cell-free network enabled by Sub-6 GHz/mmWave/THz/OWC and (iv) AI-driven multi-agent DRL to perform advanced resource allocation. Furthermore, we build our document by carefully reviewing numerous results from such consortia and working groups like 3GPP, ETSI, 5GPPP, 5GAA, 5G-ACIA, ITU, IEEE, One6G, Hexa-X, etc.

Our analysis showed a very high potential of new secondary features in such domains like industrial manufacturing, amusement parks, cruise and automotive industries as well as smart home. Such important use case requirements like ranging precision, material identification,

vital parameters estimation accuracy and localization precision required in future application scenarios have been identified and roughly specified in this deliverable. Here, sensing and localization are essential enablers offering a lot of new possibilities and can become a unique selling point of the upcoming mobile communication technologies.

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Abbreviations

3GPP	3rd Generation Partnership Project
5G	Fifth Generation (mobile/cellular networks)
5GAA	5G Automotive Association
5G-ACIA	5G Alliance for Connected Industries and Automation
5G PPP	5G Infrastructure Public Private Partnership
6G BRAINS	Internet of Radio Light (project)
ACC	Adaptive Cruise Control
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
C2CCC	Car2Car Communication Consortium
CAPEX	Capital Expenditure
C-ITS	Cooperative Intelligent Transport Systems
CPM	Collective Perception Message
C-V2X	Cooperative Vehicle to X communication
D2D	Device to Device
DDLS	Digital Door Lock Systems
DRL	Deep reinforcement learning
DSRC	Dedicated Short-Range Communications
DTS	Driverless Transport Systems
E2E	End to End
ETSI	European Telecommunications Standards Institute
GNSS	Global Navigation Satellite System
Hexa-X	EU 6G Flagship Project, publicly funded

I 4.0	Industry 4.0
IAB	Integrated Access and Backhaul
ICAS	Integrated Communication and Sensing aka Integrated Sensing and Communication (ISAC) aka Joint Sensing and Communication (JSAC)
IMT	Internet Mobile Technology
IoT	Internet of Things
IP	Internet Protocol
ISAC	Integrated Sensing And Communication
ITS	Intelligent Transportation System
ITS-S	ITS Station
ITU	International Telecommunication Union
ITU-T	International Telecommunications Union - Transmission
IMU	Inertial Measurement Unit
JRC	Joint Radio Communications
KPI	Key Performance Indicator
LIDAR	Laser based Detection and Ranging
LOS	Line of Sight in a radio link
M2M	Machine to Machine
MANO	Management and Orchestration
MCU	Motion Control Unit
MIMO	Multiple Input Multiple Output
ML	Machine Learning
mMTC	Massive Machine Type Communications
Mosaic5G	Non-profit initiative fostering a community of industrial as well as academic contributors for open-source software development to realize an agile data-driven 5G service delivery platform

mUE	Mobile user equipment
NLP	Neuro-linguistic programming
NLOS	Non-Line of Sight in a radio link
One6G	Open technical organization to formulate 6G vision
OPEX	Operational Expenditure
PCB	Printed circuit board
PLC	Programmable logic controller
QoE	Quality of Experience
QoS	Quality of Service
RADAR	Radio based Detection and Ranging
R&D	Research and Development
RAN	Radio Access Network
SDG	Sustainable Development Goals
SDN	Software Defined Networks
SLA	Service Level Agreement
SWOT	Strengths, Weaknesses, Opportunities, and Threats
SLAM	Simultaneous Localization and Mapping
UE	User equipment
UN	United Nations
VAM	Vulnerable Road User Awareness Messages
VRU	Vulnerable Road Users

Definitions

User story: A user story is an informal and abstract description of problems and proposed solutions [1]. It focuses on who are the users, that have a problem and will use the proposed solution, and on the results and benefits and how they can be quantified, in such a way that it can also be understood by people without deep technical background.

Use case: A use case description has a finer granularity than a user story (such that from a user story several use cases could be derived). It is also more technical and describing in detail how the users of 6G BRAINS network solutions will accomplish a specific goal, including also technical requirements.

Primary features of mobile communication (also **primary application** or **usage** of mobile communication technology): Such features are related to handle, organize, manage, and control data transmission among users of the mobile communication network.

Secondary features of mobile communication (also **secondary application** or **usage** of mobile communication technology): Features like integrated sensing and identification, precise localization and tracking, physical layer security, vital sign detection, etc. do not represent the primary aspect of data transmission and belong to a group of so-called secondary features.

Secondary use cases: Secondary use cases rely on or use secondary features as core capabilities.

Cooperative Awareness (CA): Create and maintain awareness of ITS Services and to support cooperative performance of vehicles using the road network.

Decentralized Environmental Notification (DEN): Alerting road users of a detected event using ITS communication technologies.

Cooperative Perception (CP): A service complementing the CA service to specify how an ITS Service can inform other ITS Services about the position, dynamics and attributes of detected neighbouring road users and other objects.

Multimedia Content Dissemination (MCD): Control the dissemination of information using ITS communication technologies.

Positioning and Time management (PoTi): Providing time and position information to ITS applications and services.

1 Introduction

The attention to wireless connectivity as an important enabler for many modern applications in various segments continues to grow. A transition from "fixed" to "mobile" in many segments including industrial manufacturing is a hot topic in many consortia. However, further improvements of wireless communication technologies are required to motivate their usage in new domains. For this, 6G BRAINS project offers a broad range of new techniques including sub-terahertz (THz), light communication, massive AI, etc. New techniques can trigger a development of new features that are not part of previous generations of mobile communications.

Such new features like integrated sensing and identification, precise localization and tracking, physical layer security, vital sign detection, etc. do not represent the primary aspect of data transmission and belong rather to a group of so-called secondary features. These secondary features, in fact, have a good potential to become a unique selling point of the next generations of mobile communication. In this document, we show how secondary features contribute to several novel use cases in such domains like industrial manufacturing, amusement parks, cruise and automotive industries as well as smart home. We build our document by carefully reviewing numerous results from such consortia and working groups like 3GPP, ETSI, 5GPPP, ITU, IEEE, One6G, 5GAA, 5G-ACIA, Hexa-X, etc. An overview of use cases we analysed is in Annex A.

1.1 Objectives of this Document

The main objectives of this document are to define and describe possible secondary usage of the techniques being developed in 6G BRAINS project. Furthermore, we identify secondary use cases, which rely on secondary features, and derive the most important user requirements from each one of them.

The "user story", which describes what exactly the user wants the system to do, provides the high-level overview of the relationships between the actors of different use cases, and the Wireless Communication system and is the basis of the work done in this document.

The secondary use cases are analysed from the end user perspective by describing how the user interacts with the system and by deriving end-to-end usage scenarios. Following this analysis, 5G/6G secondary features, that are required to provide such services, are identified and the appropriate set of Key Performance Indicators (KPIs) are derived and justified.

Following the use case's identification, analysis and KPIs derivation, the next objective of this document is also to consolidate the results in a table, that summarizes the use cases main requirements from the user point of view. This result can be useful as a guideline for future communication system developments.

1.2 Project Approach

The project 6G BRAINS intends to address a broad spectrum of novel technological aspects, which are going to have an impact on the next generation of the mobile communication. The motivation for these aspects comes from the analysis of user needs in different vertical sectors. We reviewed the results of market prediction and selected application sectors that are expected to have a significant market share in mobile communication technologies in the next decade. These sectors include representatives from the vertical industries like future industrial manufacturing, attraction parks, cruise industry, intelligent transportation systems (ITS) and smart home. For each of the selected sector, we collected appealing user stories that directly benefit from the mobile communication in general and secondary features in particular. After a careful review of the publicly available results out of the most recent EU and German national projects as well as current standardisation developments in the area of secondary usage of mobile communications, we selected a list of use cases that show significant challenge to the current 5G technology and require further improvements going beyond the possibilities of 5G. The analysis of these use cases, the derivation of their requirements and impact on future wireless networks focuses on secondary features and represents the core of this document.

1.3 Structure of this Document

The remainder of the document is organized as follows. **Chapter 2** gives an overview of the most promising secondary features that have been identified out of the 6G BRAINS project. In **Chapter 3**, we introduce application areas with high potential to accommodate novel secondary use cases. These application areas include Factory of the Future / Industry 4.0, amusement parks, cruise industry, intelligent transportation systems and smart home. Furthermore, in **Chapter 4** presents a detailed description of the selected use cases enabled by secondary features, starting with self-aware automated guided vehicles (AGVs), excitement level detection during a ride in an amusement park, room control through gesture detection in cruise ships, vulnerable road user awareness and access control systems for home security. **Chapter 5** consolidates all requirements from Chapter 4 including an overview of KPIs. The document ends with a summary of the findings and future recommendations in **Chapter 6**.

2 Secondary Features of B5G/6G Technology and 6G BRAINS Project

Such new features like integrated sensing and identification, precise localization and tracking, physical layer security, vital sign detection, etc. do not represent the primary aspect of data transmission and belong rather to a group of so-called **secondary features** of mobile communication. This secondary usage of a communication system has a goal to unleash new potentials of the mobile communication technology in different environments and can significantly contribute to the success of the technology in the market. This chapter introduces some of the secondary features we identified in the 6G BRAINS project. As a valuable input to this results, we used an overview of the Innovation Aspects of 6G BRAINS project from all project partners (see Deliverables 2.1 [1], 2.2 [2], 3.1 [3], 6.1 [4] for more details).

2.1 Secondary Features

There is no exact definition of secondary features that we could find in the literature. For our own definition, we assume secondary features to include capabilities of mobile communication technologies beyond data transmission. After reviewing such consortia and working groups like 3GPP, ETSI, 5GPPP, ITU, IEEE, One6G, 5GAA, 5G-ACIA, Hexa-X, etc. we conclude about the following list with no claim to completeness:

- Highly accurate relative/local positioning below 1 cm precision
- Global 3D localization
- Accurate ranging
- Integrated sensing incl. sensing-as-a-service, smart perception, gesture detection, vital signs detection
- Integrated imaging
- Material quality detection
- Internet of tags
- Integrated semantics
- Smart and self-learning networks incl. AI-as-a-service
- Security, trust and traceability
- Compute-as-a-service
- Security-as-a-service
- Etc.

In this deliverable, we will, however, focus on such secondary features like high-accuracy positioning, sensing and imaging, vital signs detection, and gesture detection only.

2.2 High-Accuracy Positioning

In ITU, radiolocation and radio direction finding services are well known terms that are used to address localization or positioning functions. In 6G BRAINS project, we use terms like positioning and localization for this purpose as seen in Table 1.

Table 1: Alignment with ITU Radio Regulations [5]

ITU	6G BRAINS	ITU definition
Radiodetermination	Positioning, localization	determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters
Radionavigation	SLAM	Radiodetermination used for the purposes of navigation, including obstruction warning
Radiolocation	Positioning, ranging	Radiodetermination used for purposes other than those of radionavigation.
Radio direction-finding	Direction determination	Radiodetermination using the reception of radio waves for the purpose of determining the direction of a station or object

In service requirements for the 5G system Stage 1 (Release 19) [6],Positioning and Ranging based services represent basic capabilities.

High-accuracy positioning service performance requirements are defined in [6] at 95 % confidence level for an absolute (A) or relative (R) positioning by 7 different positioning service levels starting from level 1 with 10 m up to level 7 with 0.2 m horizontal and vertical accuracy.

Ranging based services performance requirements are defined in [6] for different ranging , coverage and LOS / NLOS scenarios. KPIs are distance and direction accuracy at 95 % confidence level, relative velocity, largest ranging distance and interval between ranging operations as well as availability of the service. Scenarios like Long Distance Search have the lowest location (20 m) and direction accuracy (10°) requirements while scenarios like smart TV remoter need 10 cm location and +/- 2° direction accuracy.

6G BRAINS defined an architecture and a workflow for high-accuracy 3D positioning in [4] including functions like location databased virtual network function for e.g. cell-free mobile UEs and Simultaneous Localization and Mapping (SLAM). One goal is to improve location accuracy in 3D down to 1 mm.

2.3 Sensing/Imaging

In 6G-related workshops, e.g., Workshop on 6G organized by Hexa-X and ICT-52, sensing is discussed from several aspects. These are the following: (i) transportation of sensory data over a radio communication network, (ii) radio network as a sensor, e.g., radio network-based landscape detection, and (iii) UE having sensing capability like radio detection and ranging sensors (RADAR) by processing its own channel impulse responses and multiple antenna channels.

Imaging is being also discussed with several aspects like (i) sensing by using extreme high data rate sensors for real-time image calculation from sensory data like LIDARS, but also (ii) RADAR-like sensors with a very high number of antenna channels using advanced algorithms for imaging, e.g., Synthetic Aperture RADAR, based on accurate position data and physical channel impulse responses in millimetre wave bands below 100 GHz and above up to Terahertz (THz) bands of the UE.

Sensing and imaging might play a role in fixed equipment, where radio links can be used for integrated communication and sensing (ICAS) to determine positions and trajectories of road users without UE or without using high-accuracy position (as in clause 2.2) of the present document.

There was an analysis of the gaps between 6G and legacy RADAR in [7]. According to the results, such aspects like range resolution, angular resolution and location accuracy are expected to be significantly improved in 6G compared to the legacy RADAR systems. However, the latency for the sensing result is expected to be five times higher in 6G then in RADAR. More details will be available in upcoming HEXA-X deliverable.

2.4 Vital Signs Detection

The six classic vital signs are known. They include blood pressure, pulse/heartbeat aka heart rate, body temperature, respiration aka breath rate, height, and weight. These signs provide almost a complete picture of individuals' body vital functions and help to assess their general physical health [8]. Integration of mechanisms to detect vital signs into mobile communication systems can enable a large range of new applications and increase attractiveness of the technology for new domains (e.g., safety applications in industrial manufacturing).

There exist several works that apply mobile communication technology for respiratory and heartbeat detection. E.g., the authors of [9] proposed to use frequency-modulated continuous wave radar to measure the vital signs signals of multiple targets. They apply three-dimensional fast Fourier transform method to separate multiple targets and get their distance and azimuth information. Then, the linear constrained minimum variance-based adaptive beamforming technique is proposed to form a spatially distributed beams on directions of the targets of interest. Lastly, a compressive sensing based on orthogonal matching pursuit method and rigrsure adaptive soft threshold noise reduction based on discrete wavelet transform (RA-DWT) method are performed to extract the respiratory and heartbeat signals. According to [9], the results show that the degrees of agreement for respiratory and heartbeat are 89% and 87%, respectively, for two human targets.

Further feasibility studies are required to analyse different methods of vital signs detection as part of new generations of mobile communication systems and their applicability in different application domains.

2.5 Gesture Detection

Gesture detection is a well-known approach of interpreting human gestures used in different domains for control purposes. Game industry applies different methods out of computer vision discipline to detects gestures of players. Camera-based gesture recognition techniques are most popular here [10] .

Integration of mechanisms to recognise human gestures into mobile communication systems can enable a large range of new applications and increase attractiveness of the technology for new domains (e.g., control of robots in industrial manufacturing and smart homes).

Some works in this direction have been performed recently. E.g., a real-time radar-based gesture recognition system has been built and evaluated in [11]. According to the authors, the proposed multi-feature encoder could effectively encode the gesture profile, i.e., range, Doppler, azimuth, elevation, temporal information as a feature cube. A convolutional neural network is used then for gesture classification. To reduce the latency caused by the fixed number of required measurement-cycles in their system, authors proposed the use of short-term average/long-term average-based gesture detector, which detects the tail of a gesture. In the off-line case, the proposed gesture recognition approach achieves 98.47% and 93.11% accuracy using gestures from taught and untaught subjects, respectively.

Further feasibility studies are required to analyse different methods of gesture recognition as part of new generations of mobile communication systems and their applicability in different application domains.

Next, we present the application areas that have been selected for this work and show how the secondary features, which have been introduced in this section, can contribute to these areas.

3 Introduction of Selected Application Areas

This chapter gives an overview over selected application areas. Similar as in our first deliverable [1], we focus on high potential application areas that can accommodate novel secondary use cases. These application areas include factory of the future / Industry 4.0, amusement parks, cruise industry, intelligent transportation systems and smart home. Each of these areas will be introduced next. For every area, we show possible user stories and corresponding secondary use cases. Due to time limitations, we will provide a more detailed description of only one secondary use case per application area in the next section.

3.1 Factory of the Future / Industry 4.0

Industry 4.0 (I4.0) represents the next step in the development of the industrial manufacturing sector. Although the fourth industrial revolution is known for some time already, the process is still ongoing and there are many improvements expected soon.

In our first deliverable [1], we have already reported about different transition phases from a fixed to highly adaptable, flexible and fully connected manufacturing. These transitions include among many well-known I4.0 concepts the introduction of cyber-physical systems, digital twins, artificial intelligence, and massive connectivity incl. mobile technologies to the shop floor (see Figure 1). These techniques enable a higher level of variability and flexibility of the production.

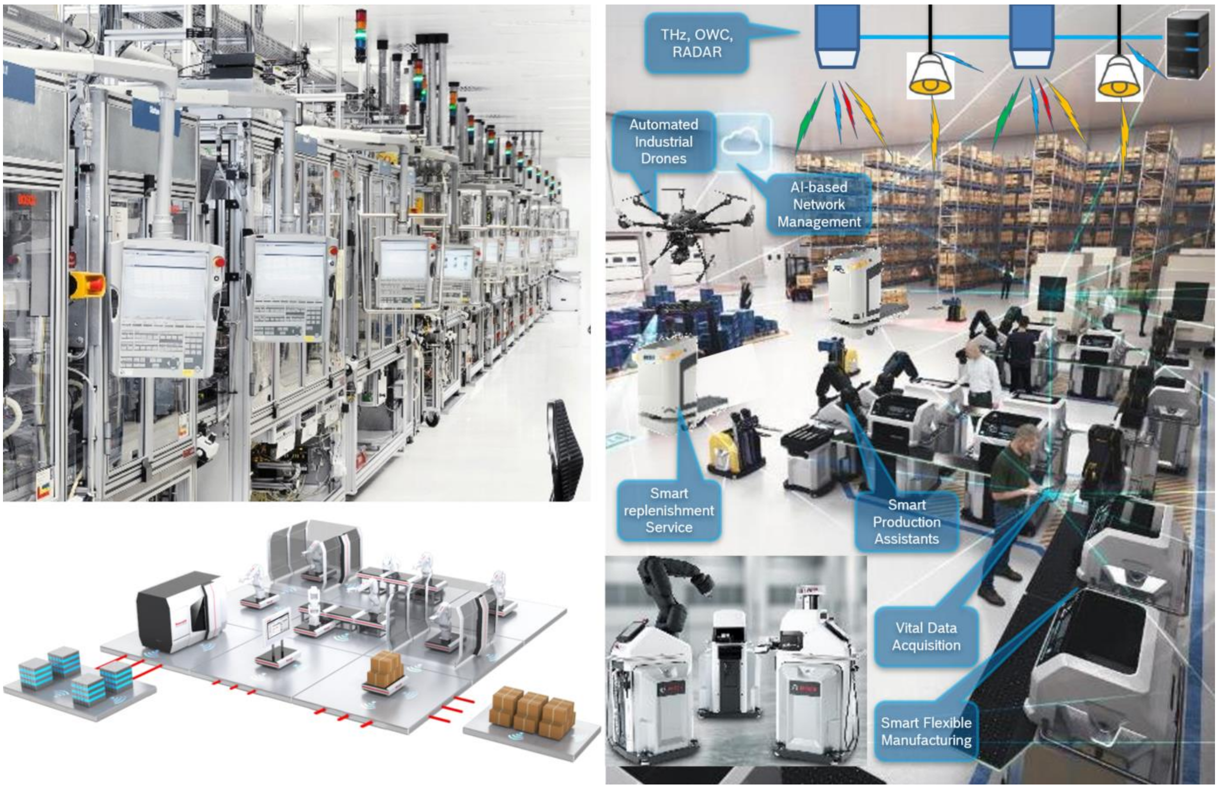

Figure 1: Factory of the future vision of the company Robert Bosch GmbH [Pictures: Bosch]

Secondary features can further contribute to the transformation of industrial manufacturing. There are many new applications that can be enabled by secondary functions. Some of these applications are shown in Table 2. As shown in the table, we detected multiple user stories, in which secondary features can be beneficial. For some user stories, several secondary use cases have been specified. In the last column, very general specifications of requirements with focus on secondary features are given.

Table 2: Possible applications in Industry 4.0 that can benefit from secondary features

User story	Use-Case	Key requirements
6G based awareness for cobots	Making the manufacturing process more efficient by using localization, ranging and sensing	Location accuracy, ranging, detection & identification of workers and other cobots
6G based awareness for AGVs/drones	Making the AGVs' operations more efficient and safer by using localization, ranging and sensing	Location accuracy, ranging, detection & identification of workers, obstacles, other AGVs
Localization of mobile control panels	Association and de-association	Ranging, detection & identification
Proximity services for workers and transport systems	Detect and identify workers, detect vital signs of workers for safety reasons	Location accuracy, ranging, detection & identification of workers and other cobots, vital signs detection accuracy, gesture detection accuracy
	Automated check-in of transport systems	
	Gesture-controlled robots and cobots	
Product quality assurance	Detect surface problems/ cracks / scratches	Imaging & crack detection
	Detect product/product parts in packages	

As mentioned above, we provide a more detailed description of only one secondary use case for every application area. In the group of Industry 4.0 use cases, we focus on self-aware AGVs in Section 4.1.

3.2 Attraction Parks

Attraction or amusement parks densely consolidate many attractions in a single area close to each other. There are usually many attractions for every age. The newest developments from different domains are always appreciated and serve the purpose of attracting more people.

Secondary features as described in the previous section can positively contribute to increase the attractiveness of new or old attractions. There are many new applications that can be enabled by secondary functions. Some of these applications are shown in Table 3. As in the previous application area, we detected multiple user stories, in which secondary features can be beneficial. For some user stories, several secondary use cases have been specified. In this document, we will describe the use case with focus on the excitement level detection using vital signs detection feature of the mobile communication.

Table 3: Possible applications in attraction parks that can benefit from secondary features

User story	Use-Case	Key requirements
Detect users in front of an attraction	After detecting the user in front of an attraction, the user is provided all required information about the attraction, can check-in automatically, can check-in into a virtual queue, etc.	Range up to 20 m Accuracy 1 m Detection & identification
Detection of user hand/arm/body gestures	Give the user possibility to control the attraction by detecting his/her body movements	High image quality Distance 0.5 m till 5 m Frequency 10 Hz
Vital parameters detection of visitors being inside of an attraction	Detect an excitement level of visitors (e.g., heartbeat) and integrate it into picture sold after attraction has been visited (motivation to buy a picture increases significantly)	Update rate of vital detection: >= 1 Hz Distance 0.5 m till 5 m
	Control the speed and acceleration of individual carriages of an attraction by monitoring the vital parameters of visitors inside the attraction. This increases the adoption of new “crazy” attractions.	

3.3 Cruise Industry

Cruise industry represents one of the main segments of the leisure travel and tourism sector, operating in various regions across the globe [12]. The revenue for 2022 was over 18 bn USD with a growth over 300% in 2021 compared to the previous year. Recent years were quite challenging for cruise industry because of the corona virus pandemic, but now there are very good expectations for the coming years [12].

Also, for this application area, secondary features can be beneficially used for existing applications on board or even new applications become possible. Some of such applications are shown in Table 4. As in the previous application areas, we detected multiple user stories and corresponding use cases, which can benefit from secondary features. In this document, we will describe the use case of a novel room control experience by using vital signs detection and gesture recognition features of the mobile communication.

Table 4: Possible applications for cruise ships that can benefit from secondary features

User story	**Use-Case**	**Key requirements**
Detect users in front of a vending machine	After detecting the user in front of a vending machine, the user is provided all required information about the content inside, can select & order/pay objects, etc.	Range up to 20 m Accuracy 1 m Detection & identification
Localization and navigation on a ship	Cruise ships are very large and orientation inside is difficult. Visitors can use localization through 6G to detect their current position and enable navigation on board.	Localization accuracy 2 m
Detection of user hand/arm/body gestures	Function control in the cab and health surveillance by classifying the user's body movements: light, TV, curtains, vital parameters for human presence and health monitor, etc.	Update rate of vital detection: >= 1 Hz Distance 0.5 m till 5 m Gesture detection
Safety: vital parameters detection and continuous monitoring	The average age of people on board is high. Monitor the vital parameters and detect anomalies to alarm first responder.	Update rate of vital detection: >= 0.1 Hz Distance 0.5 m till 5 m

3.4 Intelligent Transportation System

Intelligent Transportation Systems (ITS) offer services related to different modes of transport and traffic management to inform all kind of road users including vulnerable road users to increase efficiency and safety. Cooperative-ITS (C-ITS) defines secure and trustful data exchange, data formats and dictionaries by ad-hoc communication protocols for direct communication among road participants and between road participants and infrastructure. Sensing based on automotive radars for Automatic Cruise Control (ACC) and Anti-collision are also part of ITS. Dedicated Short-Range Communications (DSRC) provides communications between the vehicle and the roadside equipment like toll system.

According to ETSI committee ITS [13], C-ITS facility services represent the following:

- Cooperative Awareness,
- Decentralized Environmental Notification,
- Cooperative Perception,
- Multimedia Content Dissemination,
- VRU awareness
- Interference Management Zone
- Diagnosis, Logging and Status
- Positioning and Time management

Car 2 Car Communication Consortium (C2CCC) [14] and 5G Automotive Association (5GAA) [15], [16] and [17] provided a good overview of different ITS use cases. E.g., Figure 2 shows the 5GAA roadmap of ITS. In this document, we will describe only a single use case focusing on an improvement of VRU awareness using secondary features of mobile communication networks.

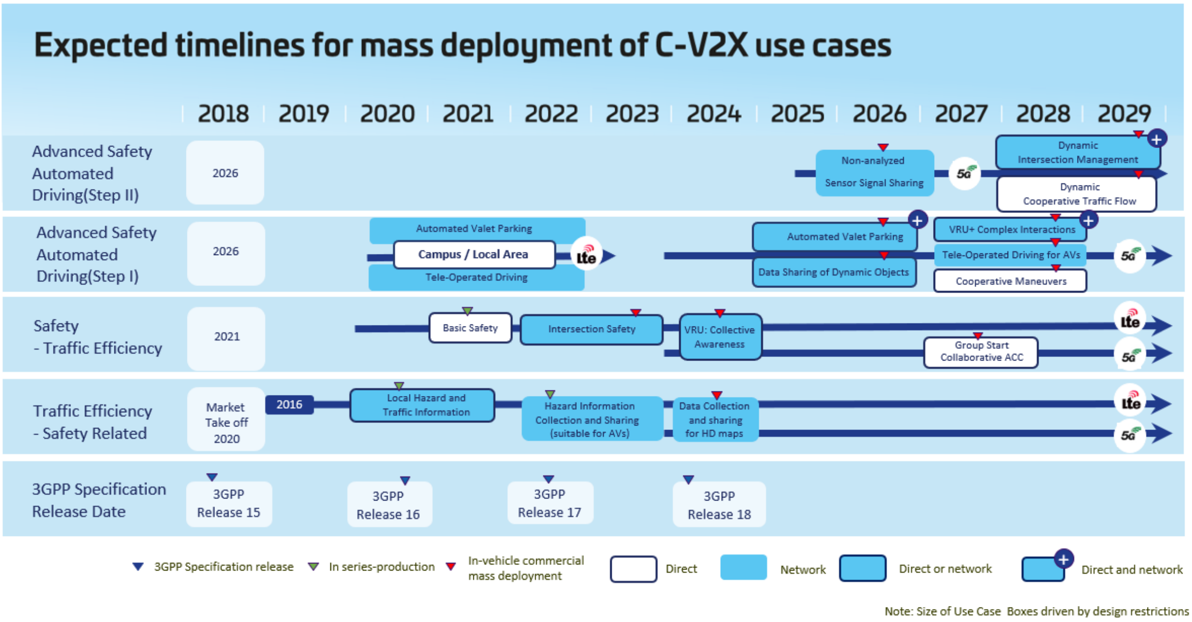

Figure 2: 5GAA roadmap, (Picture:5GAA [17])

3.5 Smart Home

Smart Home is a rapidly developing field of application with a household penetration rate doubling every 5 years from 8.13% in 2017 to 13.87% in 2022 and a revenue doubling every 3 years from 38 billion USD in 2017 to 79 billion USD in 2020 [18]. In this application field, an increasing number of solutions is being offered, e.g., for heating comfort and sustainable heat, living comfort and live consciously by connected sensing and actuation services, etc. IoT sensory data like room temperature, sound recognition for surveillance and speech-based control, video surveillance, door speech, access control systems as well as actuators like radiator thermostats represent use cases, which actively conquer the modern market.

An exemplary and non-exhaustive list of smart home products is presented below and shown exemplary in [18]:

- 360° Indoor Camera
- Outdoor Siren
- Motion Detector
- Outdoor Camera
- Radiator Thermostat
- Light control
- Smoke Alarm
- Room thermostat
- Shutter control
- Smart Home Controller
- Door/window contact
- Water Alarm and Water Alarm safety kit
- Smart Plug, etc.

The above products as well as many other products and services can benefit from secondary features of mobile communication technologies. Some examples are given in Table 5. Out of the use cases presented in the table, we focus on access control systems in this document, because digital door lock system market revenue is estimated near to 15 bn USD in 2026 in [18] and use cases with similar requirements are present in other sectors like industry 4.0, automotive, etc.

Table 5: Possible applications in smart homes that can benefit from secondary features

User story	Use-Case	Key requirements
Home security	Easy, touchless grant and control access	Presence detection over small distance, secure authentication (prohibit man-in-the-middle attacks)
	Intruder detection	Detection range up to 30 m Doppler-based sensing
Access control	Trustworthy Digital Door Lock System (DDLS) by accurate localization and gesture recognition to unlock door	Ranging up to 3 m, positioning in cm accuracy and Doppler-based sensing
SLAM for robots	6G provides localization service for robot navigation	Detection range up to 30 m, position accuracy 5 mm

4 Secondary Use Cases / Technical Description

This chapter describes the use cases, which have been selected for a detailed analysis. There is one use case for each application area described in Chapter 3.

At this point, we want to highlight that 6G BRAINS is not aiming to prepare a full-blown demonstration of any of the use cases listed below. However, many of the technological innovations from 6G BRAINS will be demonstrated without an integration in all-in-one demonstrator. Here, every work package (WPs 3, 4, 5, and 6) creates its own local demonstration focusing on the aspects being under investigation in the corresponding package.

4.1 Industry 4.0: Self-Aware AGVs

A so called "factory of the future" represents one the most challenging application domain for future mobile communication systems incl. B5G and 6G. Many specific use cases representing this scenario have been described in different bodies including 3GPP and 5G-ACIA. From the vast list of specific "factory of the future" use cases, 6G BRAINS identified several, which require further improvement of the current 5G technology. These use cases have been presented in Deliverable 2.1 [1]. In the present deliverable, we focus on use cases that benefit from secondary features of the mobile communication. Some of such use cases have been introduced in Table 2. This section provides significant details on one selected use case: self-aware Automated Guided Vehicles (AGVs).

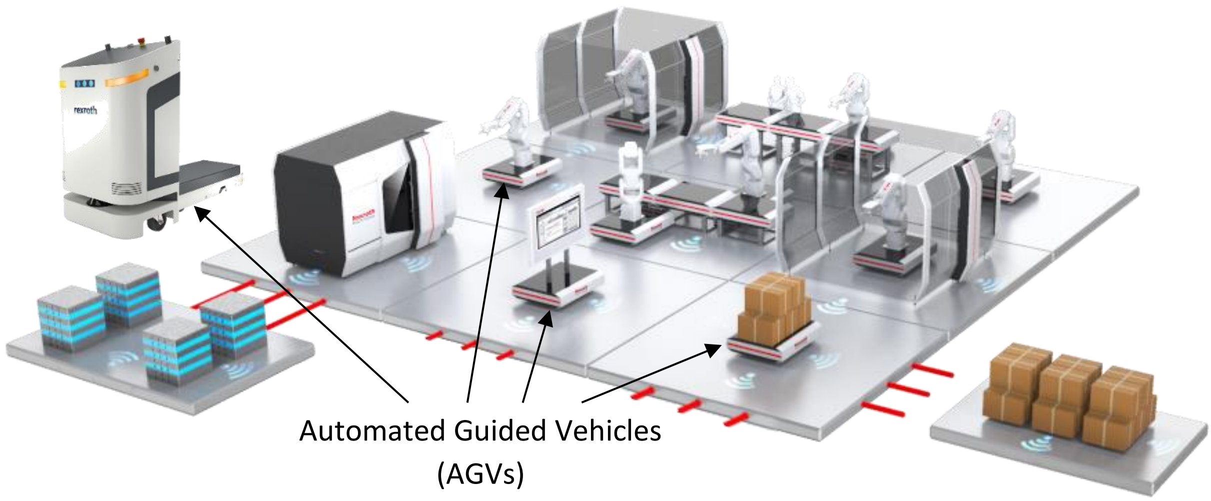

Figure 3: Automated Guided Vehicles in the Bosch vision of the future manufacturing [Pictures: Bosch]

As depicted in Figure 3, this use case describes a typical driverless transport system (DTS) scenario in production environments. In this document, we focus only on those functions of DTS (often referred to as AGV) that apply secondary features of the mobile communication:

- 2D localization within factory campus for navigation
- Ranging and sensing of obstacles in the environment

- Human presence detection
- Floor surface problems detection

4.1.1 Description

Overview	
User story	In Factory of the Future, AGVs play an important role and take care of such tasks like driverless and autonomous transport of material and goods from and to production lines. They also can carry robot equipment (e.g., a robot or gripper arm) to flexibly support the assembly process.
Use case	In this use case, we focus on the following functions of AGVs: • 2D localization within factory campus for navigation • Ranging and sensing of obstacles in the environment • Human presence detection • Floor surface problems detection These functions require a wireless communication network that offers the following features: • High-accuracy positioning • Sensing and imaging • Vital signs detection
Storyline	An AGV fleet provides intra-logistic transportation and traversing in the factory. An AGV can also be part of an assembly process by picking and placing parts using a gripper arm with sensors mounted on the AGV. For a safe and efficient navigation on the shop floor, precise positioning service is required. Furthermore, AGVs, being mobile, can serve the purpose of regular monitoring of the production facility. Integrated 6G sensing feature can enable accurate object detection and tracking around AGVs, anomaly detection of surface irregularities on the shop floor, and improves safety, process tracking and logging, etc. Using the vital signs detection, AGVs can better distinguish between living and non-living objects and act accordingly in case of critical proximity. Also, critical state of workers around an AGV can be detected, so that such cases like injuries, heart attacks, unconsciousness can be quicker detected so that corresponding measures can be taken faster.

Goal/Aim	With low initial and recurring effort, utilization of AGVs in combination with a B5G/6G communication system should significantly improve factory efficiency, safety, required job time and associated costs.
Main challenges	• Simultaneous communication and sensing, imaging, ranging, localization, perception with one communication system only; in worst case utilization of a small fraction of the bandwidth for secondary features • Coordination between primary and secondary usage • Ultra-high precision (1 cm and 1 degree) positioning for AGVs • 2D localization, i.e., position estimation of AGV, in radio multi-path shop floor environments • Position estimation with limited number of reference points • Human presence / vital parameters detection • Simplified till zero-touch deployment/integration of new AGVs • Reduced maintenance costs at acceptable invest

4.1.2 Actors, Tools and Services

Actors, Tools & Services	
Actors and Stakeholders	• Factory AGV Fleet manager • Network provider and operator • Factory owner • Production process manager • Associated Worker, law giver, working councils, insurance companies
Databases	• Database for storing AGV fleet positions and job scheduling and logging • Database for storing results of the object detection and tracking mapped to the shop floor coordinate system • Logging of the alarming events related detection to living objects based on vital signs detection
Sensors	• Mobile communication transceiver device as a sensor
AI/ML and other control loop algorithms	• AI/ML-improved object detection and tracking • Teach-in of docking and path navigation • Scheduling of AGV fleet • Redirection of AGVs in case of path blocking • AI/ML-based network scheduling for QoS provisioning • Alarming of living objects

Actuators	• AGV motion control system and Motion Control Unit (MCU) • Production process orchestration agent • Factory AGV fleet job planning agent • Network optimization and QoS provisioning (based on network slicing) agent
Communication platform	Primary function: • Communication platform shall support ultra-low latency and jitter for data transmission and can include such technologies like sub-THz, mmWave, sub-6 GHz, OWC, cell-free, IAB, localization, etc. • The support of edge computing services like offloading of video processing shall be part of the communication platform. • QoS shall be provisioned by means of network slicing. Secondary function. Communication system shall provide the following: • Simultaneous communication and sensing with one system only • Precise 2D localization, SLAM, ranging for improved fleet management and planning • 3D perception of the environment • Integrated imaging/sensing • Human presence / vital parameters detection • Simplified till zero-touch deployment/integration of new AGVs

4.1.3 Execution

Execution	
Preconditions (inputs)	• AGVs have enough power to operate • Communication, compute and localization platform is available and stable
Trigger	AGV fleet job planning agent triggers / schedules AGV to run a job.
Service flow	After receiving a request for a transport job, a fleet planning agent assigns a new job to an available AGV and informs the communication and compute system about new participant along with requirements for communication, localization, sensing and perception functions. The network optimization and QoS provisioning agent assigns/modifies a corresponding network slice to provide the required QoS for the time of the operation.
Post conditions (outcomes)	• AGV docks in home base. • Network optimization and QoS provisioning agent is informed about stop of operation.

	• The network and compute resources shall be relieved and reallocated to a different service in a short period of time.

4.1.4 Requirements

Requirements	

User requirements	• Simultaneous communication and sensing with one system only
	• Precise 2D localization, SLAM, ranging for improved fleet management and planning
	• 3D perception of the environment to improve
	  ○ Docking and pick-up
	  ○ Transport
	  ○ Anticollision
	  ○ Assembly using gripper arm
	  ○ General increase of AGVs self-awareness for autonomy
	• Integrated imaging/sensing for
	  ○ Exact gripper location
	  ○ Quality assurance
	  ○ Obstacle tracking
	• Human presence / vital parameters detection
	• Simplified till zero-touch deployment/integration of new AGVs
	• Reach system cost target
	• AGVs shall run safely and correspond to functional safety requirements from IEC 61508, ISO/IEC 17025 and ISO/IEC 17020
	• The whole system operates in “zero-touch” mode after teach-in: AGV switched on and is triggered to “go” by fleet management agent based on Enterprise Resource Planning System

Functional architectural requirements	• All operational technology components belong to a safety and security critical zone of the production and have no direct connection to the outside world incl. Internet. • To enable high flexibility of the production process, functions that require Internet must run on secure IT components behind a firewall. • There is no connection to a data base of workers that can enable deduction of workers identities after sensing or imaging. Privacy requirements shall be met.
Technical KPIs	• Coverage of indoor environments within the factory facility • Support for medium speed mobility up to 10 m/s • High service availability of 99.999 % • Slice configuration/reconfiguration within 1 s

	• Localization accuracy during navigation/traversing: 2 cm • Localization accuracy during docking in supply area for on- or offload: 1 cm • Localization accuracy during AGV operation as part of assembly process: 5 mm • Ranging accuracy towards obstacles: 5 mm • Human presence detection with reliability of 99 % • Vital parameters detection accuracy 90 %
Relevant standards	• Communication networks: 3GPP 22.804 [19], 3GPP 22.855 [20] • Functional safety: IEC 61508 [21], ISO/IEC 17025 and ISO/IEC 17020 • EU machinery directive 2006/42/EC [22]

4.2 Amusement Parks: Excitement Level Detection During a Ride in an Amusement Park

This use case represents an extension of a well-known service of selling visitor pictures, which is offered in large attractions in amusement parks. Here, we suggest to detect excitement level of visitors during their ride, e.g., on a roller coaster (see Figure 4) in order to increase the motivation to buy pictures by integrating the detection result as well as to revisit an attraction after some time. A more detailed description is given in the following subsections.

Figure 4: Roller coaster as a typical attraction in amusement parks [Picture: Bosch]

4.2.1 Description

Overview	
User story	Amusement parks attract visitors by providing new experience in different attractions. To help visitor to memorize it, attractions offer pictures to be sold after a visitor finishes a ride, e.g., on a roller coaster. Integrating an excitement level detection into an attraction and printing the result on a visitor's picture positively impacts image selling and motivates visitors to use the attraction again sooner.
Use case	In this use case, we focus on an excitement level detection function that estimates the excitement level of visitor using vital parameters recognition feature of the mobile communication system installed in the attraction.
Storyline	We assume that the next generation of the mobile communication systems will be installed in many amusement parks and provide different ICAS features including vital parameters recognition. Along with the usage of this feature to increase safety in amusement parks, it can be used to detect excitement levels of visitors by monitoring their heartbeat rate during a ride. It is assumed that the system can detect heartbeat rate of individuals several times during their ride. The recorded values can be then printed as an overlay on the picture of the same person and motivate him or her to buy the picture. Also, visitors might consider revisiting the same attraction in a shorter time to compare if their excitement changed relative to the previous ride.
Goal/Aim	This use case shall contribute to revenue increase using communication systems in amusement parks industry by offering a new service to visitors. The communication system shall still provide data communication services along with the new secondary features.
Main challenges	• Simultaneous communication and sensing, imaging, ranging, localization, perception with one communication system only and in worst case by utilization of only a small fraction of the bandwidth for secondary features • Coordination between primary and secondary usage • Passive human presence / vital parameters recognition in short period of time (no visitor EU required) • Privacy agreement for personal data estimation and storage (incl. heartbeat rate) • Simplified till zero-touch deployment/integration • Reduced maintenance costs at acceptable invest

4.2.2 Actors, Tools and Services

Actors, Tools & Services	
Actors and Stakeholders	• End user, visitor • Attraction operator • Network provider and operator • Amusement park owner • Picture service provider • Law giver, work councils, insurance companies
Databases	• Database for storing personal information of visitors incl. heartbeat rate and pictures/photographs
Sensors	• Mobile communication transceiver devices as sensors
AI/ML and other control loop algorithms	• AI/ML-improved vital parameters detection
Actuators	• Augmentation of sensor data on the respective image of the visitor
Communication platform	Primary function: • Communication platform is used to communicate sensor data to the image augmentation and printing service device. Secondary function. Communication system shall provide the following: • Simultaneous communication and sensing with one system only • Human presence and vital parameters detection incl. heartbeat rate detection of individuals in a short period of time • Simplified till zero-touch deployment/integration of new sensors

4.2.3 Execution

Execution	
Preconditions (inputs)	• Visitors join on a ride • Attraction ride begins • Communication and sensing platform is available and stable. The network and compute resources are allocated correspondingly.

Trigger	The sensing system estimates vital parameters of visitors on pre-specified positions of the ride as soon as the corresponding position is reached.
Service flow	After the ride begins, sensing system performs several heartbeat rate estimations for each individual in specified locations on the ride. After the ride is over, all sensor data are transmitted to the edge device for storing and further processing. A ML approach can be used to create an approximation for the sparse sensor data to create a heartbeat diagram. The result is augmented on the picture/photograph created for every individual on the ride. At the exit of the attraction, each visitor is offered to purchase the resulted picture.
Post conditions (outcomes)	• The individual data are removed in all sensors and edge devices after individual pictures are created. • The network and compute resources shall be relieved.

4.2.4 Requirements

Requirements	

User requirements	• Simultaneous communication and sensing with one system only
	• Integrated imaging/sensing for
	    ○ Human presence / vital parameters detection
	    ○ Reliable visitor detection
	    ○ Adequate vital parameters detection accuracy that enables an excitement classification
	• Reasonable system cost target
	• Sensing and communication system shall have no negative impact on the safety of the attraction (functional safety requirements from IEC 61508, ISO/IEC 17025 and ISO/IEC 17020)
	• The whole system operates in “zero-touch” mode after installation and calibration
	• Simplified till zero-touch deployment/integration of new sensors

Functional architectural requirements	• All operational technology components of the attraction belong to a safety and security critical zone of the amusement park, and therefore have no direct connection to the outside world incl. Internet and cannot be manipulated using mobile communication system. • Functions that require Internet must run on secure IT components behind a firewall to enable high flexibility of the excitement level detection and augmentation.

	• There is no connection to a data base of individuals that can enable deduction of visitors' identities at any time. Privacy requirements shall be met.
Technical KPIs	• Guaranteed coverage of areas, in which measurements are taken • Support for very high-speed mobility up to 60 m/s • High service availability of 99.9 % • Human presence detection with reliability of 99 % • Vital parameters detection accuracy 80 %
Relevant standards	• Communication networks: 3GPP 22.804 [19], 3GPP 22.855 [20] • Functional safety: IEC 61508 [21], ISO/IEC 17025 and ISO/IEC 17020 • EU machinery directive 2006/42/EC [22]

4.3 Cruise Industry: Room Control through Gesture Recognition

Cruise industry offers an application area very rich on possible utilization of secondary features as presented in Section 3.3. In this document, we will present details on the use cases related to a room control using gesture recognition feature of the next generations of mobile communication systems.

4.3.1 Description

Overview	
User story	Cruise industry represents the part of the recreation sector offering a unique constellation of new experiences, transportation and entertainment for customers. To attract customers, cruise ships provide state-of-the-art and beyond state-of-the-art technical solutions of different kinds to their customers. While on board, customers are using their cabins as their private areas. By providing an amusement way of cabin control functions, visitors of cruise ships can get a unique experience in entertainment.
Use case	In this use case, we propose to use secondary features of mobile communication systems like gesture recognition, human presence detection, localization and tracking, etc. for cabin control.
Storyline	We assume that the next generation of the mobile communication systems will be installed in cruise ships incl. cabins of passengers. We also assume that the communication systems will offer ICAS features including vital parameters detection, gesture recognition high-accuracy positioning and tracking, etc. Along with the usage of these features for safety on-board by detecting vital parameters of passengers (incl. seasickness), a new way of cabin control can be

	enabled. Customers can control lights, TV, curtains, doors, heating and cooling systems, can order food or beverages to the cabin, etc. by using a gesture recognition feature of the communication system built into their cabin.
Goal/Aim	This use case shall contribute to the revenue increase from using communication systems in cruise industry by offering new services to passengers. The communication system shall still provide data communication services along with the new secondary features.
Main challenges	• Simultaneous communication and sensing, imaging, ranging, localization, perception with one communication system only; in worst case utilization of a small fraction of the bandwidth for secondary features • Coordination between primary and secondary usage • Passive human presence / vital parameters recognition in short period of time (no UE hardware required) • Privacy agreement for personal data estimation and storage (incl. passengers' identification, vital parameters estimation, etc.) • Simplified till zero-touch deployment/integration • Reduce maintenance costs at acceptable invest

4.3.2 Actors, Tools and Services

Actors, Tools & Services	
Actors and Stakeholders	• Passengers • Attraction operator • Network provider and operator • Cruise ship owner • Law giver, work councils, insurance companies
Databases	• Database for storing personal information of passengers incl. passengers' identities, vital parameters like heartbeat rate, etc.
Sensors	• Mobile communication transceiver devices as sensors (it can include both fixed infrastructure devices like base stations, antenna heads or relays and UE devices)
AI/ML and other control loop algorithms	• AI/ML-based improvement for sensing/classification capabilities
Actuators	• Control devices of passengers' cabins/rooms

Communication platform	Primary function: • Communication platform is used for data exchange among passengers' devices and cabin infrastructure. Secondary function. Communication system shall provide the following: • Simultaneous communication and sensing with one system only. • Human presence and vital parameters detection incl. heartbeat rate detection of passengers in a short period of time and detection of seasickness. • Simplified till zero-touch integration/on-boarding of new passengers' devices with visual and haptic feedback mechanisms.

4.3.3 Execution

Execution	
Preconditions (inputs)	• Passengers go on a cruise and visit their cabin. • Cruise has begun. • Communication and sensing platform in cabin is available and stable. The network and compute resources are allocated correspondingly.
Trigger	The sensing system periodically detects vital parameters of passenger/passengers in a cabin.
Service flow	After a passenger/passengers enter the cabin, the cabin control system detects their presence using ICAS. By using pre-specified gestures, passengers can control lights, TV, curtains, doors, heating and cooling systems, can order food or beverages to the cabin, etc. Furthermore, the system can detect vital parameters of passengers improving safety on-board. A ML approach can be used to let the passengers teach the system to recognize individual commands. System can do a classification of passengers (e.g., child/adult) to un-block a corresponding set of functions (e.g., ordering alcoholic drinks).
Post conditions (outcomes)	• In case no passengers are in the cabin, cabin control system returns to periodic detection of human presence. • The network and compute resources shall be relieved. • After the cruise, the passengers' data are removed from the system.

4.3.4 Requirements

Requirements	

User requirements	• Simultaneous communication and sensing with one system only
	• Integrated imaging/sensing for
	    o Human presence / vital parameters detection
	    o Reliable passenger detection
	    o Adequate gesture recognition to detect multiple gestures of passengers. False detection shall be minimized till 0.1 %.
	    o Adequate vital parameters detection accuracy that enables amusement functions and supports safety improvement on-board (incl. seasickness detection).
	• Reasonable system cost target.
	• Sensing and communication system shall have no negative impact on the safety of the cabin control functions (functional safety requirements from IEC 61508, ISO/IEC 17025 and ISO/IEC 17020)
	• The whole system operates in close to “zero-touch” mode after installation and calibration.
	• Simplified till zero-touch deployment/integration of new passengers’ equipment.

Functional architectural requirements	• All operational technology components of the cabin belong to a safety and security critical zone of the cruise ship, and therefore have no direct connection to the outside world incl. Internet and cannot be manipulated using mobile communication system. • Functions that require Internet must run on secure IT components behind a firewall to enable high flexibility of the cabin control system. • There is a connection to a data base of passengers that can enable deduction of passengers’ identities. Privacy requirements shall be met.
Technical KPIs	• Guaranteed coverage of cabin area for reliable gesture recognition and vital parameters detection. • Positioning accuracy of passengers within the cabin < 10 cm. • False detection rate at 0.1 %. • Reliability for gesture recognition and vital parameters detection 99 %. • Support for low-speed mobility up to 2 m/s • High service availability of 99.9 % • Human presence detection with reliability of 99 % • Vital parameters detection accuracy 80 %

Relevant standards	• Communication networks: 3GPP (e.g., 3GPP 22.804 [19], 3GPP 22.855 [20]) • Functional safety: IEC 61508 [21], ISO/IEC 17025 and ISO/IEC 17020 • EU machinery directive 2006/42/EC [22]

4.4 ITS: Vulnerable Road User Awareness

The United Nations (UN) organized a High-Level Meeting on Global Road Safety in 2022, where VRUs were a key topic towards UN Sustainable Development Goals (SDG) 11 and 13 [23]. More details can be found in [24].

Increasing safety for Vulnerable Road Users (VRU) by warning functions in VRU UEs and non-VRU equipment like cars and roadside equipment is the motivation for development and deployment of secondary features.

VRU awareness use case definition assumes interoperation between vehicle-based and portable safety devices are available in [25] and require new secondary features like sensing as well as improved accuracy and availability of existing secondary features like positioning of UEs to enable acceptable true positive and true negative warning error rates. Vulnerable Road Users (VRU) awareness functional architecture and requirements are defined in [26].

The following use case description and requirements analysis set the focus on VRU warning function as a service by the 6G network. Secondary features are the basis. Focus is set on warning between VRUs to avoid or mitigate accidents between, e.g., pedestrians and bicyclists. This will help to shift individual traffic from today's high number of cars to an increasing number of bicyclists and pedestrians. In Figure 5, a typical VRU awareness scene is presented.

Figure 5: Vulnerable Road User awareness scene (Source: Bosch)

4.4.1 Description

Overview	
User story	Despite the SDGs, traffic density and diversity of traffic modes are increasing on roads and sidewalks by trucks, cars, vans, motorcycles, e-bikes, bicycles, scooters, e-scooters, in-line skaters, pedestrians and many more. VRUs require more road traffic safety measures to lower both number and severeness of accidents.
Use case	VRU are walking, bicycling or using other means of personal transportation in parallel to or crossing of a driving lane of cars and other faster road user than themselves. The VRUs are not aware of a traffic situation around and conflicts, e.g., between pedestrians and a bicyclists can easily happen at any time. So, a suitable VRU awareness function is required to notify VRUs in danger.
Storyline	High-accurate positioning via a Global Navigation Satellite System (GNSS) is not possible, because of failing position fix due to GNSS

	blocking by buildings and missing correction data link to VRU UE or the VRU does not carry a UE. Dependable high-accurate positioning of the VRU and VRU's trajectory is done by radio-based positioning of the VRU's UE, fixed roadside ICAS-capable equipment and enable a prediction of a collision and a setting of a warning trigger.
Goal/Aim	Avoid or mitigate collisions between VRUs by triggering a warning of the VRU to enhance VRU's understanding of traffic situation.
Main challenges	• Dependable high-accurate positioning data of VRUs • Determination and sharing of ICAS-based position estimation • Security & privacy • Acceptable latency • Acceptable accuracy estimation of VRU direction • Warning trigger with acceptable error rate to VRU UE • Warning trigger with acceptable error rate to VRUs without UE

4.4.2 Actors, Tools and Services

Actors, Tools & Services	
Actors and Stakeholders	Every VRU including road-side fixed infrastructure, legislation, law enforcement (police), OEMs wearables, IMT industry.
Databases	For location and tracking of VRU, e.g., by Distributed Ledger [4].
Sensors	All kind of sensors in smart phones incl. network-as-a-sensor and ICAS in road-side equipment to estimate the trajectory of all VRUs.
AI/ML and other control loop algorithms	Sensor data fusion-based estimation of UE position and direction [4]. including confidence interval of the estimation. Algos for every VRU to estimate the collision probability and trigger a warning if the probability is reaching a threshold.
Actuators	Sound, lights, vibration, and speech convey the warning information to the endangered VRU.
Communication platform	IMT including D2D cell-free ad hoc networks and ICAS in fixed road-side equipment [4].

4.4.3 Execution

Execution	
Preconditions (inputs)	UE of VRU offers warning of critical situations and can be used for high-accurate positioning by the network using muti-band links like in [4]. Road-side equipment is capable of warning VRUs and can sense or image traffic situation to estimate VRU locations. All locations and directions are in a database and accessible for the collision probability estimating and warning service deployed in edge computing for low latency. The warning service is always available and allocates resources dynamically.
Trigger	The service is triggered periodically depending on the speed and distances among road users.
Service flow	Extracted from [26] 1. VRU self-positioning. The VRU has sensors and potentially other sources allowing it to determine its own properties, including its location and velocity. 2. Evaluation whether the VRU is at potential risk from other road users based on road layout and dynamic state of both VRUs. 3. Evaluation of safety message by all parties involved. 4. VRU at-risk sends ego-status information. 5. Periodic risk assessment by a service deciding on criticality of VRU's directions and velocity vectors by predicting trajectories and possible conflicts of road users with a confidence level of critical state. 6. Warning or action to protect the VRU.
Post conditions (outcomes)	Warning service is set back to detect presence of VRUs.

4.4.4 Requirements

Requirements	
User requirements	Vulnerable road users (VRUs) want to be aware of critical situations and must be notified by VRU warning function even if VRU is not carrying any kind of UE at all to be as safe as in a car.
Functional architectural requirements	• Functions that trigger VRU warning should be deployed as close as possible to the current VRU location to guarantee the minimal latency. • VRU localization quality meets acceptable level w.r.t. accuracy, low latency and high availability.
Technical KPIs	• Warning update rate like sampling rate in [26]: e.g. 10 Hz. • Min. speed: 1 km/h (pedestrian) to max. speed 60 km/h (bicycle). • Position accuracy 0.2 m (3σ). • Direction accuracy 10°. • Minimal Time to Collision: 3 s. • UE density: 0.1 VRUs / m^2. • Service availability of 99.9 %.
Relevant standards	ETSI TS 103 300-2 V2.2.1 (2021-04) [26]. ETSI TS 103 300-3 V2.1.2 (2021-04) [27].

4.5 Smart Home: Digital Door Lock System (DDLS)

In Industry 4.0, both end user and access system owner want easy, secure, reliable, touchless grant and control access to a certain space, e.g., a car or a warehouse, but also execution control of functions, e.g., identify and grant access to an AGV in a factory warehouse. Figure 6 gives an overview of multiple industrial use cases including the *use case of mutual device identification and authentication* presented in upcoming 6G BRAINS deliverable 6.2.

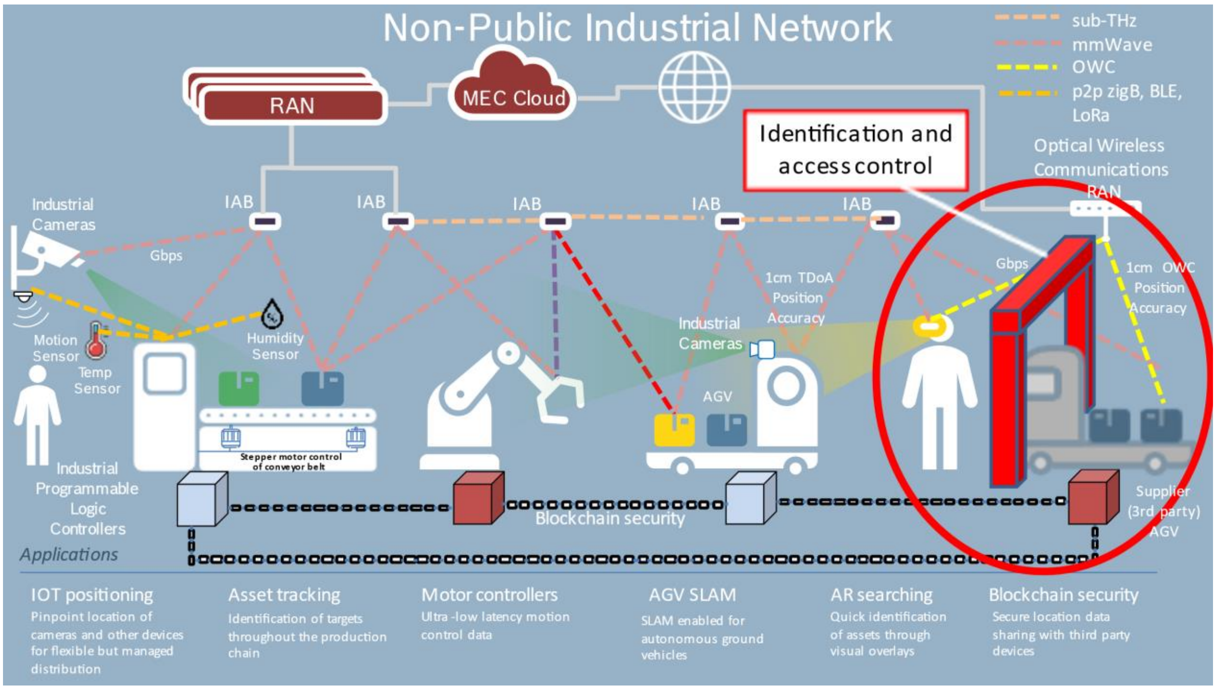

Figure 6: Identification and access control in an industrial application area [picture: 6G BRAINS]

As described in Section 3.5 of the present document, a promising market segment of smart home application area are digital door lock systems (DDLS).

In state-of-the-art door systems, several sensors and HMIs like number pads, RFID cards or dedicated biometric sensors are needed for a secure access control. The user needs to perform quiet some actions to get an access. The access rights owner needs to care for setup of the DDLS and shall maintain the access rights.

Before access is granted to a person, an identification, authentication and a proof of access rights needs to be done. To further increase security, the person, or the group of persons, who want to get access, need to be localized, classified and logged as persons. Biometric-based authentication is already in use to unlock UEs and can be used for authentication at the door, but for security reasons only in combination with UE localization to avoid man-in-the-middle attacks as well as to control the number and identity of the accessing persons.

If the door is unlocked, it is maybe interesting to count the number of accessing persons and to perceive when all persons are in a safe distance to the door to automatically close and lock the door.

A 6G-enabled DDLS is described in the following.

4.5.1 Description

Overview	
User story	End user wants to have effortless access to a house. House owners or facility managers want to minimize effort for access rights management and to maximize security against misuse and unauthorised access. An access protocol is wanted and shall fulfil data protection directives. DDLS OEMs are looking for future proof solutions with high reuse of already existing solutions, e.g., authentication based on sensors inside UEs.
Use case	End user wants to get access.
Storyline	House owner grants access rights and sets conditions for a user that shall get access to the house. A UE is set up with the necessary information distributed by 6G from the DDLS. To increase security of authentication and limit the chances to man-in-the-middle attacks, both, UE and DDLS have 6G ICAS approach to check access conditions, e.g., by special gesture. End user approaches to the door, DDLS manages access for the end user.
Goal/Aim	A secure, easy-to-deploy and easy-to-maintain access system from all stakeholder perspectives.
Main challenges	• Standards for interoperability and security for all technical stakeholders. • UE and DDLS security. • Sensing by 6G modules in the door or at the door.

4.5.2 Actors, Tools and Services

Actors, Tools & Services	
Actors and Stakeholders	House owner, Digital door lock system OEM, end user, insurance companies, IMT industry.
Databases	Store access rights list.
Sensors	• ICAS for people approaching, classification and counter at entry by • UE integrated sensors for biometry like face and fingerprint recognition for authentication.
AI/ML and other	• People classification by Doppler signature of movement.

control loop algorithms	• Identification of approaching UE. • Tracking of UEs and persons to open or close door safely.
Actuators	Door lock and unlock components as well as door opening and closing systems.
Communication platform	ICAS-enabled 6G platform for location in cm range accuracy and communication.

4.5.3 Execution

Execution	
Preconditions (inputs)	• Location and sensing services are available at the DDLS. • End user and UE access rights list in database (e.g., distributed ledger). • DDLS is in sensing state to detect approaching persons and UEs.
Trigger	UE is approaching a DDLS.
Service flow	DDLS detects approaching UE and classifies them as users based on location and sensing service. DDLS identifies UE and checks in database if UE is a whitelisted device and sends a request for identification to the approaching user's UE. The users authenticate themselves based on the UE's biometric sensors. If users are successfully authenticated, and number of users match to the number of persons classified as such in front of the door, access is granted by DDLS and DDLS checks if the safety distance for door opening is given, and the door gets opened. The access event is logged by DDLS, and the passing persons are tracked until all persons have passed the door and are in safe distance to close the door.
Post conditions (outcomes)	DDLS gets into sensing state to detect approaching persons and UEs.

4.5.4 Requirements

Requirements	
User requirements	• Automatic identification of UE. • User gets authentication request sent by DDLS. • Safe passing through the door without contact to open or close the door
Functional architectural requirements	• UE access rights shall be included in a database. • DDLS shall have access to location and ICAS service to trigger an authorisation request. • Such functions like classification, number counting, localisation and tracking of persons are present in the solution.
Technical KPIs	• Localisation accuracy 10 cm. • Direction accuracy below 10°. • Update rate 10 Hz. • Classification of movements up to 30 km/h. • Reliable user classification as walking person (by ICAS service). • Service availability of 99.99%. • Secure communication by network control.
Relevant standards	

5 Consolidated Requirements

This chapter consolidates all requirements and provides an overview of KPIs and general user concerns. First, we list an overview of the key requirements in Table 6 as a result of the use case analysis in the previous chapter.

After our first analysis of possible new use cases in D2.1 [1], that focuses rather on the primary aspects of the upcoming releases of mobile communication 5G and B5G, we address secondary features in this deliverable and show how they contribute to such use cases like self-aware automated guided vehicles, excitement level detection for amusement parks, cabin control in cruise ships, vulnerable road user awareness, and digital door lock systems for home security. In difference to other work related to secondary usage of mobile communication (e.g., [28]), this work has a broader range of secondary features addressed in the mentioned use cases. So, additionally to such conventional features like ranging and localization, we present several new feature groups incl. vital parameters sensing and gesture recognition. Table 6 shows the results for the analysis of the key requirements for all features across all five use cases.

This deliverable represents one of the first results for the analysis of possible secondary features in the coming generations of mobile communication. The latter include 5G-Advanced (e.g., Rel-18), WiFi7 and 6G.

At the time when this deliverable is written, integrated communication and sensing as a new feature is still at its very early stage. Many aspects still need to be discussed and specified. Some of them are:

- Level of integration for simultaneous communication and sensing,
- Layer, in which functions and subfunctions of ICAS need to be implemented,
- Optimized placement/deployment of ICAS functions/subfunctions, etc.

[Disclaimer] At this point, we want to highlight that the presented values show the result of our use case analysis. These values indicate the user expectations and do not represent a commitment for the outcomes of the 6G BRAINS project.

Table 6: Overview of the key requirements for the secondary features

	Self-aware AGVs	Excitement level detection	Cabin/room control	Vulnerable road user	Digital door lock system
Type of communication and sensing	ICAS	ICAS	ICAS	ICAS	ICAS
Accuracy of positioning	< 2 cm (navigation) < 1 cm (docking) < 5 mm (assembly)	n/a	< 10 cm	< 15 cm Direction < 10°	< 10 cm Direction < 10°
Accuracy of ranging	< 5 mm	n/a	< 10 cm	< 15 cm	< 10 cm
Coverage area	99.9 %	99 %	99 %	99.9 %	99.9 %
Covered distance (from an access point)	within the facility	within the facility	within the facility	< 200 m	within the facility
Service availability	99.999 %	99.9 %	99.9 %	99.9 %	99.99 %

Table 6 continues on next page

	Self-aware AGVs	**Excitement level detection**	**Cabin/room control**	**Vulnerable road user**	**Digital door lock system**
Vital parameters sensing: - **Human presence detection** - **Latency** - **Update rate** - **Accuracy** - **False alarms**	 99 % 1 s 1 Hz 90 % < 0.01 %	 99 % 1 s 1 Hz 80 % < 1 %	 99 % 1 s 1 Hz 80 % < 0.1 %	 99 % 1 s 10 Hz 90 % < 0.01 %	 99 % 1 s 1 Hz 90 % < 0.01 %
Gesture recognition: - **Latency** - **Update rate** - **Accuracy** - **False detection**	 1 s 1 Hz 90 % 0.01 %	 n/a n/a n/a n/a	 1 s 1 Hz 99 % 0.1 %	 n/a n/a n/a n/a	 n/a n/a n/a n/a
Movement speed of UE	< 10 m/s	n/a	n/a	1 – 60 km/h	< 30 km/h
Movement speed of users without UE	< 5 m/s	< 60 m/s	< 2 m/s	1 – 17 m/s	< 30 km/h
Time critical handover support	Yes	No	No	Yes	No
User equipment density per m²	0.33-3	0.1	0.01	Vehicles: 0.003 VRUs: 0.01	0.01
Slice configuration / reconfiguration time for secondary features	1 s	1 s	1 s	1 s	1 s

6 Summary of the Findings

This deliverable focuses on secondary usage of mobile communication and shows a very high potential of new features in such domains like industrial manufacturing, amusement parks, cruise and automotive industries as well as smart home. Being under development in 6G BRAINS, different innovation aspects have been analysed and served as input to this document. Such aspects are (i) a novel combination of spectra like Sub-6 GHz, sub-THz and optical wireless communication (OWC) to enhance the performance with regard to capacity, reliability and latency, as well as to enable sensing capability, (ii) high resolution 3D Simultaneous Localization And Mapping (SLAM) of up to 1 mm accuracy (iii) a novel comprehensive cross-layer deep reinforcement learning (DRL) driven resource allocation solution to support the massive connections over device-to-device (D2D) assisted highly dynamic cell-free network enabled by Sub-6 GHz/mmWave/THz/OWC and (iv) AI-driven multi-agent DRL to perform advanced resource allocation. Furthermore, we reviewed numerous results from consortia and working groups like 3GPP, ETSI, 5GPPP, 5GAA, 5G-ACIA, ITU, IEEE, One6G, Hexa-X, etc.

The new techniques listed above show high potential to enable new features in mobile communication systems or to significantly improve already well-known features. Such features like precise localization and tracking, integrated sensing and identification, physical layer security, etc. do not represent the primary aspect of data transmission and have been named secondary features in this report. In comparison to the work of others, this work has a broader range of secondary features addressed in the presented use cases. So, additionally to such conventional features like ranging and localization, we present several new feature groups incl. vital parameters sensing and gesture recognition.

In this work, we describe the following use cases: self-aware automated guided vehicles, excitement level detection for amusement parks, cabin control in cruise ships, vulnerable road user awareness, and digital door lock systems for home security. Such important use case requirements like ranging and localization precision, user identification, vital parameters estimation and gesture recognition accuracy, false alarm and false detection rates have been identified for different future application scenarios and roughly specified in this deliverable. Here, sensing and localization are essential enablers, offer a lot of new possibilities and can become a unique selling point of the upcoming mobile communication technologies.

At the time when this deliverable is written, integrated communication and sensing, as a broad term for many new features, is still at its very early stage. Many aspects still need to be discussed and specified.

Next, we want to highlight that 6G BRAINS is not aiming to prepare a full-blown demonstration of any of the use cases listed in this document. However, many of the technological innovations from 6G BRAINS will be demonstrated without an integration in an all-in-one demonstrator. Here, every work package (WP 3, 4, 5, and 6) creates its own local demonstration focusing on the aspects being under investigation in the corresponding package.

Moreover, the outcomes mentioned in this deliverable will be propagated into the relevant consortia like 5GAA and 5G-ACIA as well as standardization bodies like 3GPP as part of 6G BRAINS dissemination activities.

7 References

[1] A. Artemenko *et al.*, '6G BRAINS D2.1 Definition and Description of the 6G BRAINS Primary Use Cases and Derivation of User Requirements', Jun. 2021, doi: 10.5281/zenodo.5185388.

[2] Q. Wang *et al.*, '6G BRAINS D2.2 Network Requirements, Key Function Blocks and System Architecture', Aug. 2021, doi: 10.5281/zenodo.5205535.

[3] D. Dupleich, N. Han, J. Cosmas, G. Eappen, and K. Ali, '6G BRAINS D3.1 3D Laser measurement of one factory at Bosch with 3D cloud scanner and 3D hand scanner', Sep. 2021, doi: 10.5281/zenodo.5786456.

[4] '6G BRAINS D6.1 Technical Specification of the 3D Location Architecture'. [Online]. Available: https://6g-brains.eu/deliverables/#.

[5] 'Radio Regulations Edition of 2020', *ITU*, 2020. https://www.itu.int:443/en/publications/ITU-R/Pages/publications.aspx?parent=R-REG-RR-2020&media=electronic (accessed Jan. 10, 2023).

[6] '3GPP TS 22.261 V19.1.0 (2022-12) Service requirements for the 5G system Stage 1 (Release 19)'. [Online]. Available: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3107.

[7] A. Behravan *et al.*, 'Positioning and Sensing in 6G: Gaps, Challenges, and Opportunities'. arXiv, Nov. 02, 2022. Accessed: Jan. 18, 2023. [Online]. Available: http://arxiv.org/abs/2211.01183.

[8] M. Kebe, R. Gadhafi, B. Mohammad, M. Sanduleanu, H. Saleh, and M. Al-Qutayri, 'Human Vital Signs Detection Methods and Potential Using Radars: A Review', *Sensors*, vol. 20, no. 5, Art. no. 5, Jan. 2020, doi: 10.3390/s20051454.

[9] Y. Wang, Y. Shui, X. Yang, Z. Li, and W. Wang, 'Multi-target vital signs detection using frequency-modulated continuous wave radar', *EURASIP Journal on Advances in Signal Processing*, vol. 2021, no. 1, p. 103, Oct. 2021, doi: 10.1186/s13634-021-00812-9.

[10] J. Kobylarz, J. J. Bird, D. R. Faria, E. P. Ribeiro, and A. Ekárt, 'Thumbs up, thumbs down: non-verbal human-robot interaction through real-time EMG classification via inductive and supervised transductive transfer learning', *J Ambient Intell Human Comput*, vol. 11, no. 12, pp. 6021–6031, Dec. 2020, doi: 10.1007/s12652-020-01852-z.

[11] Y. Sun, T. Fei, X. Li, A. Warnecke, E. Warsitz, and N. Pohl, 'Real-Time Radar-Based Gesture Detection and Recognition Built in an Edge-Computing Platform', *IEEE Sensors J.*, vol. 20, no. 18, pp. 10706–10716, Sep. 2020, doi: 10.1109/JSEN.2020.2994292.

[12] 'Statista, INDUSTRIES & MARKETS: Cruise industry worldwide, Dossier'. 2022. [Online]. Available: https://www.statista.com/study/11547/cruise-line-industry-statista-dossier/

[13] M. Arndt, 'automotive Intelligent Transport Systems (ITS)', *ETSI*. https://www.etsi.org/technologies/automotive-intelligent-transport (accessed Jan. 20, 2023).

[14] 'C2CCC Guidance for day 2 and beyond roadmap (07-2021)'. Jul. 09, 2021. [Online]. Available: https://www.car-2-

car.org/fileadmin/documents/General_Documents/C2CCC_WP_2072_RoadmapDay2AndBeyond_V1.2.pdf.

[15] '5GAA, "A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs", September 2020'. Jul. 21, 2020. [Online]. Available: https://5gaa.org/content/uploads/2020/09/A-Visionary-Roadmap-for-Advanced-Driving-Use-Cases-Connectivity-Technologies-and-Radio-Spectrum-Needs.pdf.

[16] '5GAA C-V2X Use Cases and Service Level Requirements Volume I – 5G Automotive Association', Dec. 02, 2020. http://5gaa.org/news/c-v2x-use-cases-and-service-level-requirements-volume-i/ (accessed Dec. 27, 2022).

[17] '5GAA C-V2X Use Cases Volume II: Examples and Service Level Requirements (10-2020)', Oct. 20, 2020. http://5gaa.org/news/c-v2x-use-cases-volume-ii-examples-and-service-level-requirements/ (accessed Dec. 27, 2022).

[18] 'Statista Dossier on smart home'. 2021. [Online]. Available: https://www.statista.com/study/27165/smart-homes-statista-dossier/.

[19] '3GPP TR 22.804 V16.3.0 (2020-07) Study on Communication for Automation in Vertical Domains (Release 16)'. [Online]. Available: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3187.

[20] '3GPP TR 22.855 V18.0.1 (2021-06) Study on Ranging-based Services (Release 18)'. [Online]. Available: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3771.

[21] 'IEC 61508 Edition 2.0 2010-04 COMMENTED VERSION Functional safety of electrical/electronic/programmable electronic safety-related systems'. [Online]. Available: https://webstore.iec.ch/preview/info_iec61508%7Bed2.0.CMV%7Den.pdf.

[22] *Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (Text with EEA relevance)*, vol. 157. 2006. Accessed: Jan. 25, 2023. [Online]. Available: http://data.europa.eu/eli/dir/2006/42/oj/eng.

[23] 'UN Resolution A/RES/70/1 Transforming our world: the 2030 Agenda for Sustainable Development'. Sep. 25, 2015. [Online]. Available: https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement.

[24] 'UN Resolution A/RES/74/299 Improving global road safety'. Aug. 31, 2020. [Online]. Available: https://www.un.org/pga/76/wp-content/uploads/sites/101/2021/11/A_RES_74_299_E.pdf.

[25] 'ETSI TR 103 300-1 V2.3.1 (2022-11)'. Accessed: Nov. 29, 2022. [Online]. Available: https://www.etsi.org/deliver/etsi_tr/103300_103399/10330001/02.03.01_60/tr_10330001v020301p.pdf.

[26] 'ETSI TS 103 300-2 V2.2.1 (2021-04)'. Accessed: Oct. 24, 2022. [Online]. Available: https://www.etsi.org/deliver/etsi_ts/103300_103399/10330002/02.02.01_60/ts_10330002v020201p.pdf.

[27] 'ETSI TS 103 300-3 V2.1.2 (2021-04) Intelligent Transport Systems (ITS); Vulnerable Road Users (VRU) awareness; Part 3: Specification of VRU awareness basic service; Release 2'. [Online]. Available: https://www.etsi.org/deliver/etsi_ts/103300_103399/10330003/02.01.02_60/ts_10330003v020102p.pdf.

[28] 'Hexa-X Deliverable D3.1 Localisation and sensing use cases and gap analysis'. [Online]. Available: https://hexa-x.eu/wp-content/uploads/2022/02/Hexa-X_D3.1_v1.4.pdf

[29] '3GPP TR 22.837 V0.3.0 (2022-11) Study on Integrated Sensing and Communication (Release 19)'.

[30] '3GPP TR 22.856 V0.3.0 (2022-11) Feasibility Study on Localized Mobile Metaverse Services (Release 19)'. [Online]. Available: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=4046.

Annex A Overview of the Relevant Secondary Use Cases

Below, a subset of the state-of-the-art use cases in relevant sectors is presented. This overview has been created to identify the most interesting use cases that motivate the work in 6G BRAINS project and provide valuable insights in the user needs. Many aspects presented below served as an input for requirements analysis in this project.

Document	Use cases
Use Cases in Draft 3GPP TR 22.837 Feasibility Study on Integrated Sensing and Communication [29]	Intruder detection in smart home
	Pedestrian/animal intrusion detection on a highway
	Rainfall monitoring
	Transparent Sensing Use Case
	Sensing for flooding in smart cities
	Intruder detection in surroundings of smart home
	Sensing for railway intrusion detection
	Sensing Assisted Automotive Manoeuvring and Navigation
	Unmanned aerial vehicle (UAV) flight trajectory tracing
	Sensing at crossroads with/without obstacle
	Network assisted sensing to avoid UAV collision
	Sensing for UAV intrusion detection
	Sensing for tourist spot traffic management
	Contactless sleep monitoring service
	Protection of Sensing Information
	Health monitoring at home

	Service continuity of unobtrusive health monitoring
	Sensor Groups
	Sensing for Parking Space Determination
	Seamless XR streaming
	UAVs/vehicles/pedestrians detection near Smart Grid equipment
	Autonomous mobile robots collision avoidance in smart factories
	Roaming for sensing service of sports monitoring
	Immersive experience based on sensing
	Accurate sensing for automotive manoeuvring and navigation service
TR 22.856 Feasibility Study on Localized Mobile Metaverse Services clause 5 [30]	5G-enabled Traffic Flow Simulation and Situational Awareness
	collaborative and concurrent engineering in product design
	Spatial Anchor Enabler
	Spatial Mapping and Localization Service Enabler
	Immersive Gaming and Live Shows
	AR Enabled Immersive Experience
	Supporting multi-service coordination in one metaverse
	Synchronized predictive avatars
	Internet Protocol (IP) Multimedia core network Subsystem (IMS)-based 3D Avatar Communication
	Virtual humans in metaverse

	Digital asset container information access and certification
	interconnection of mobile metaverses
	Access to avatars
	Virtual store in a metaverse marketplace
	Work delegation to autonomous virtual alter ego
	Privacy-Aware Dynamic Network Exposure in Immersive Interactive Experiences
TS 22.104 V18.3.0 (2021-12) Service requirements for cyber-physical control applications in vertical domains (Release 18)	Mobile control panels with safety functions (non-danger zones)
	Process automation – plant asset management
	Flexible, modular assembly area in smart factories (for tracking of tools at the work-place location)
	Augmented reality in smart factories
	Mobile control panels with safety functions in smart factories (within factory danger zones)
	Flexible, modular assembly area in smart factories (for autonomous vehicles, only for monitoring purposes)
	Inbound logistics for manufacturing (for driving trajectories (if supported by further sensors like camera, GNSS, IMU) of indoor autonomous driving systems))
	Inbound logistics for manufacturing (for storage of goods)
Use cases from Hexa-X Deliverable D3.1 [28]	E-Health for All
	Earth Monitor
	Institutional Coverage

	Autonomous supply chain
	Gesture Recognition for Human-machine Interface
	Augmented Reality user in a shopping mall
	Augmented reality for placing virtual objects in the real world
	Telesurgery, remote surgery
	Patient tracking and monitoring
	Localisation of milliscale robots
	Placement of medical equipment on the body
	Sensor Infrastructure Web
	Infrastructure-less Network Extensions and Embedded Networks
	Automatic Public Security
	Local Coverage for Temporary Usage
	Digital Twins for Manufacturing
	Immersive Smart City / Localisation of control utilities
	Traffic monitoring
	Landscape sensing
	Digital twins of smart buildings
	Digital Twins for Sustainable Food Production
	Collaborative robot localisation
	Environment mapping

	Object sensing
	Fine localisation of vehicles

