D7.2

FIRST INTERMEDIATE PROJECT REPORT

The 5G-SMART project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 857008.

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Grant agreement number: Project title: Project acronym: Project website: Programme:	857008 5G Smart Manufacturing 5G-SMART www.5gsmart.eu H2020-ICT-2018-3
Deliverable type: Deliverable reference number: Contributing workpackages: Dissemination level: Due date: Actual submission date:	R: Document, report D26 All Public 2020-05-31 2020-05-28
Responsible organization: Editor(s): Version number: Status:	ERI-SE Leefke Grosjean V1.0 Final
Short abstract:	This deliverable provides a summary of the major results and achievements of the project during the first year of the project.
Keywords:	5G-SMART, 5G trial sites, 5G optimization, 5G use cases, 5G deployment

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This deliverable has been submitted to the EU commission, but it has not been reviewed and it has not been accepted by the EU commission yet.

Executive summary

This first intermediate project report contains an overview of the results attained in 5G-SMART up until the writing of this report. Main achievements are highlighted, and references are provided to the relevant deliverables and documents.

The results described in this deliverable address a wide range of challenges within the smart manufacturing sector. In the first year of the project, 5G-SMART has succeeded in making a broad analysis of smart manufacturing use cases, investigating the definition and characteristics of the use cases to be trialed at the three different trial sites of the project, but as well taking a look at more future-looking use cases. The related work on business models and network deployment options has made progress, but output and results on this will be provided at a later point in the project.

The work on the design and preparations for realizing the use cases at the trial sites have reached a milestone, after the design of the 5G communication network deployment has been finalized for all trial sites. Both at the Kista and the Aachen trial sites, the network deployment is furthermore already installed on site. The use cases to be trialed are under intense development, with the goal of having all use cases up and running early in 2021. A first demo was developed for one of the use cases at the Aachen trial site. At the Reutlingen trial site, the channel measurements and Electromagnetic Compatibility (EMC) tests are ready to be undertaken as soon as the restrictions due to the Corona pandemic allow this.

In terms of 5G optimization, the project has made a thorough gap analysis between the state of the art and the smart manufacturing use cases, focusing on 5G features, such as integration of 5G with Time-Sensitive Networking (TSN), 5G end-to-end time synchronization and 5G positioning.

Finally, the project has shown to have a successful dissemination and communication strategy, creating impact with publications, keynotes, standard contributions and demos. The dissemination indicators are above expectations, highlighting the relevance of the project in international fora. Undoubtedly, the impact of the corona pandemic on the dissemination poses a significant risk to the project in terms of communication, but measures have already been taken to redirect face-to-face dissemination to online actions.

Contents

1 Introduction

5G-SMART is a European Union funded project, that started 1st of June 2019 and is running for 30 months. The total project budget is a bit more than 10 M€ and there are around 27 full time person equivalents working during the project duration.

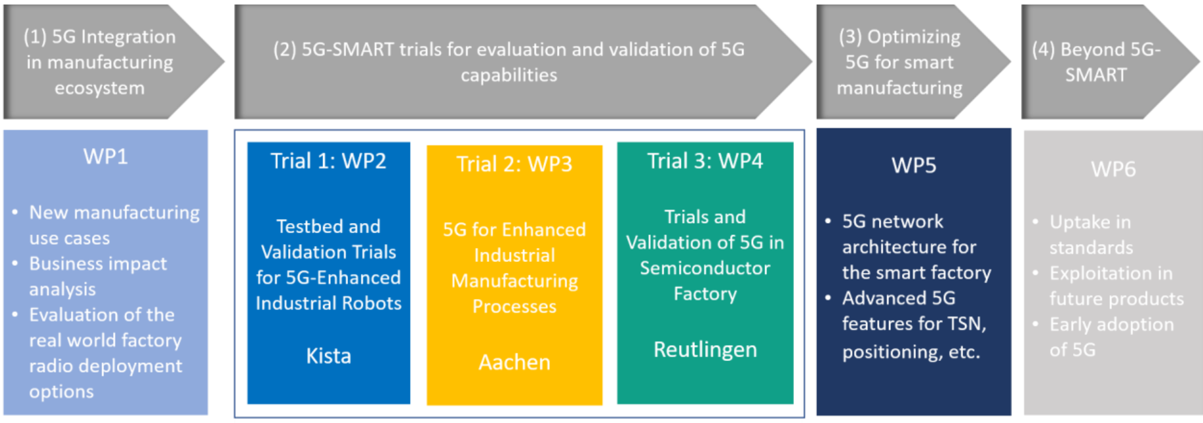

Figure 1 shows the structure of the project with its four focus areas, and the work packages (WPs) addressing these. The focus areas are:

(1) 5G integration in the manufacturing ecosystem.
(2) Trials for evaluation and validation of 5G capabilities.
(3) Optimizing 5G for smart manufacturing.
(4) Beyond 5G-SMART.

For the evaluation and validation of 5G capabilities three trial sites are built up by the project. These are at an Ericsson factory in Kista (Sweden), at the machine hall of the Fraunhofer Institute of Production Technology (IPT) in Aachen (Germany), and at a Bosch semiconductor factory in Reutlingen (Germany).

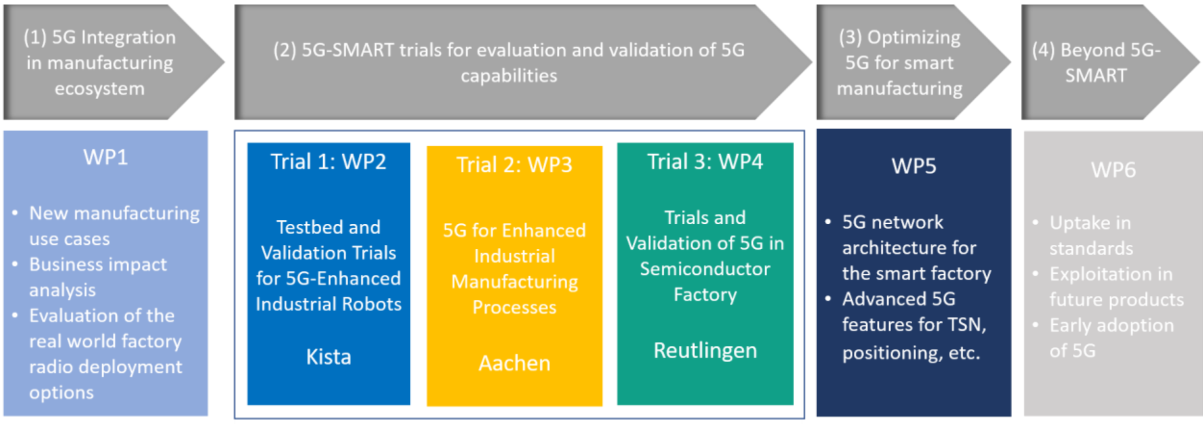

Figure 1: Project structure of 5G-SMART

This document is the first 5G-SMART intermediate project report, which gives an overview of the 5G-SMART achievements during its first year. In particular, this report highlights the main projects results and provides references to the deliverables, papers and other output, for interested readers who wish to learn more. All this information can as well be found on the project website, https://5gsmart.eu.

1.1 Objective of the document

This document summarizes the progress made in 5G-SMART during the first year of the project. For all the ongoing activities, a brief outlook is given over next steps and future plans. Moreover, this deliverable collects references to all other documents already produced within 5G-SMART. With this document being an intermediate project report, its objective is very much aligned with the objectives of 5G-SMART. These objectives are:

(1) To demonstrate and evaluate 5G technologies and architecture capabilities for smart manufacturing use cases by validating related 5G KPIs defined in ITU/3GPP and 5G PPP as well as 5G support of concurrent usages of network resources by different vertical domains.
(2) To identify, assess and propose innovative advanced "industrial" 5G KPIs with more focus on industrial characteristics.
(3) To identify, assess and propose new 5G features targeting connected industries.
(4) To identify viable business models for 5G manufacturing use cases.
(5) To identify regulatory aspects with direct impact on the realization of 5G for smart manufacturing.
(6) To disseminate and exploit 5G-SMART outcomes and contribute to standards development organizations (3GPP/ITU-T/IETF/ETSI), regulatory forums, scientific and industrial domains.
(7) To contribute to the 5G Action plan for Europe, validating 5G capabilities ("phase 1" features) in real factory environments.

1.2 Structure of the document

This document is structured as follows: Section 1 gives an introduction to the deliverable. Section 2 provides insights into the achievements of 5G-SMART made in the areas of use cases, business models and network design (WP1). Section 3 focuses on the three different trial sites of 5G-SMART (WP2, WP3 and WP4). For each of the trial sites the efforts and progress made during the first year of the project are described. Section 4 treats the achievements towards 5G optimization made by 5G-SMART (WP5). An overview of the dissemination and communication efforts of 5G-SMART (WP6) is provided in Section 5. For each section the next steps to be taken from the project are briefly described. Section 6 concludes the document and gives an outlook about what to expect in the second year of the project.

2 Use cases, business models and network design

Factories of the future will be characterized by flexible, modular production systems, requiring flexible and versatile communications and computations. In typical application areas 5G technologies are expected to support their requirements. These application areas are, for instance, factory automation, process automation, Human-Machine-Interfaces (HMIs) and production IT, logistics and warehousing, process monitoring, advanced measurement systems for production quality control, maintenance. Each of these application areas contains a plethora of use cases with different requirements on the communication and computation infrastructure, which need to be mapped to the underlying 5G infrastructure.

2.1.1 Achievements during the first year

5G-SMART has made a careful choice in the use cases to be validated at the three different trial sites within 5G-SMART, assuring that they represent and combine elements of corner use cases of all the application areas. The trialed use cases are:

(1) 5G-connected robots and remotely supported collaboration of connected robots (Kista).
(2) Machine vision assisted real-time human-robot interaction over 5G (Kista).
(3) 5G-aided visualization of the factory floor (Kista).
(4) 5G for wireless sensor-based workpiece monitoring (Aachen).
(5) 5G versatile multi-sensor platform for digital twin (Aachen).
(6) Cloud-based mobile robotics (Reutlingen).
(7) TSN/Industrial LAN over 5G (Reutlingen).

For the trialed use cases, 5G-SMART has identified and analyzed their requirements and KPIs, not only in terms of performance and functional requirements, but also taking into account the “industrial” angle by investigating, for instance, operational requirements, thus going beyond the requirements established in 3GPP. Furthermore, 5G-SMART has identified forward-looking smart factory use cases together with their requirements. The forward-looking use cases are:

(1) 5G-enabled remote expert.
(2) 5G-empowered cross-domain and inter-company collaboration (e.g. lineside delivery).
(3) Autonomous Guided Vehicle (AGV) and Unguided Autonomous Vehicle (UAV) real-time trajectory refinement with Artificial Intelligence (AI) for smart factories.
(4) 5G-enabled metrology and process control across machine and factory boundaries.
(5) 5G-enabled seamless device plug and play.
(6) AI-assisted production quality management.

All findings related to the use cases are summarized in Deliverable D1.1 (5GS20-D110).

In terms of business models, 5G-SMART aims at analyzing the business value created due to the implementation of a 5G network. An assessment framework and methodology are in the process of being developed in order to evaluate the business value creation for the industrial actors. This activity has the ambition to go beyond conventional comparison of costs (e.g., for hardware, running costs, etc.) and the generated revenues, by also taking into account the value creation by 5G due to the introduction of new products and services, which could further enhance the daily business. The findings of this activity will be summarized in a later deliverable. This deliverable will as well include the findings on Mobile Network Operator (MNO) business models made by 5G-SMART. Various MNO engagement options are analyzed in terms of value creation and business aspects. The deliverable presenting the results of these activities is planned for May 2021.

In alignment with the business model activity, 5G-SMART works on identifying different network deployment options for smart factories. The work so far has been on surveying different Radio Access Network (RAN) deployment options and narrowing down the deployment scenarios to be further investigated to the most relevant ones. In particular, the co-existence scenario of a macro 5G network with a factory network has shown to be of interest. A paper on this topic is in preparation by the 5G-SMART consortium. In addition to that, a first paper on performance evaluation of 5G radio configurations for industry 4.0 was submitted early in the project (MMS+19). The deliverable D1.4 summarizing all findings in this activity is planned for November 2020.

Overall, the work by 5G-SMART on use cases, business models and network design has so far had a strong focus on performing a gap analysis between the existing state-of-the-art, the existing general target KPIs and the actual needs more specific to the smart factory. This is a necessary step to take the work for the smart manufacturing sector to the next level and serves as an input for the technical work in the project.

Having Information Technology (IT) and Operational Technology (OT) partners on board, 5G-SMART has early in the project identified the need for defining a common language and common understanding of important terms in order to facilitate the discussions. This work is seen not to be valuable just for 5G-SMART but for the manufacturing sector in general and will be made available at the project website.

2.1.2 Next steps

The next steps in the work on use cases, business models and network design involve the finalization of the activity on analysis and evaluation of the network deployment options for smart factories, with the related deliverable being due in November 2020. Furthermore, strong focus will be given to the work on business models, with next steps including the application of the assessment framework and methodology developed within 5G-SMART to relevant use cases. The work on finding a common language and understanding of important terms will continue throughout the entire project time.

3 5G trials across Europe

3.1 Kista trial site

At the Kista trial site, 5G-SMART will validate 5G-enabled industrial robotics. The setup consists of two stationary robots and a mobile robot that will collaboratively solve a task, with major parts of their control functionality being moved into the edge cloud. In another use case, video analysis will be added to the robot control. Here, the purpose is to explore possibilities of enhancing real-time human-robot interactions. Finally, a use case of providing visualization of production-related information to the personnel on the factory floor is developed. The feasibility of these different approaches will be validated via the 5G NR network. A use case setup is illustrated in Figure 2.

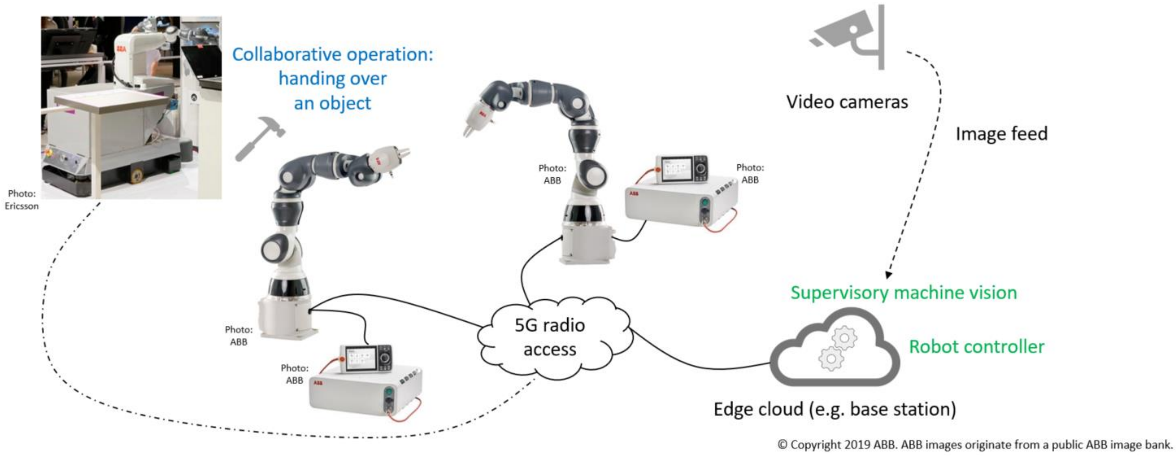

Figure 2: A use case setup at the Kista trial site

3.1.1 Achievements during the first year

The main focus of 5G-SMART in the first year of the project has been on understanding and defining the different use cases to be trialed and on designing the 5G trials testbed. KPIs and requirements for each of the use cases have been investigated and the results are summarized in deliverable D1.1 (5GS20-D110). A deeper insight into the design of the 5G-based testbed for industrial robotics can be found in deliverable D2.1 (5GS20-D210). Here, the architecture components are identified from the application-level perspective and their key functional roles are described. Communication interaction among the components is specified, also highlighting 5G support for it. Inter-connectivity configurations are defined that allow for a systematical evaluation of, e.g. a trade-off between the quality of sensor data needed for robotics-related functions, output rate demands of that data on network resources, and the overall processing latency for possible data compression. This is considered to be very valuable for the validation phase. Furthermore, D2.1 provides an analysis of the hardware equipment and software for implementing the 5G testbed, along with the specification of their main features and capabilities. This concerns both the industrial robotics equipment as well as the underlying 5G infrastructure. The work on designing the prototype software applications and modules for the implementation of the 5G testbed has started.

In the first year of the project, significant progress has been made on the network design for the testbed and a final solution of the 5G infrastructure deployment has been agreed upon. In the Kista trial site a 5G non-standalone (NSA) high band solution is pre-tested and has shown good performance results towards the demanding requirements of the industrial robotics use cases. The 5G deployment will make use of a 5G millimeter wave (mmWave) radio in combination with the Ericsson Radio Dot System. In terms of spectrum, the system will utilize mmWave within the range of 27.5 GHz – 27.9405 GHz (time-division duplex, TDD) and an LTE anchor in the mid-band ranges (1780.1 - 1785.0 MHz for uplink and 1875.1 - 1880.0 MHz for downlink). The spectrum has been secured and the 5G equipment has been installed on site. The details on the 5G deployment can be found in deliverable D2.1 (5GS20-D210). Figure 3 illustrates a schematic overview of the 5G deployment.

Overall, the progress of the work within 5G-SMART at the Kista trial site is according to plan.

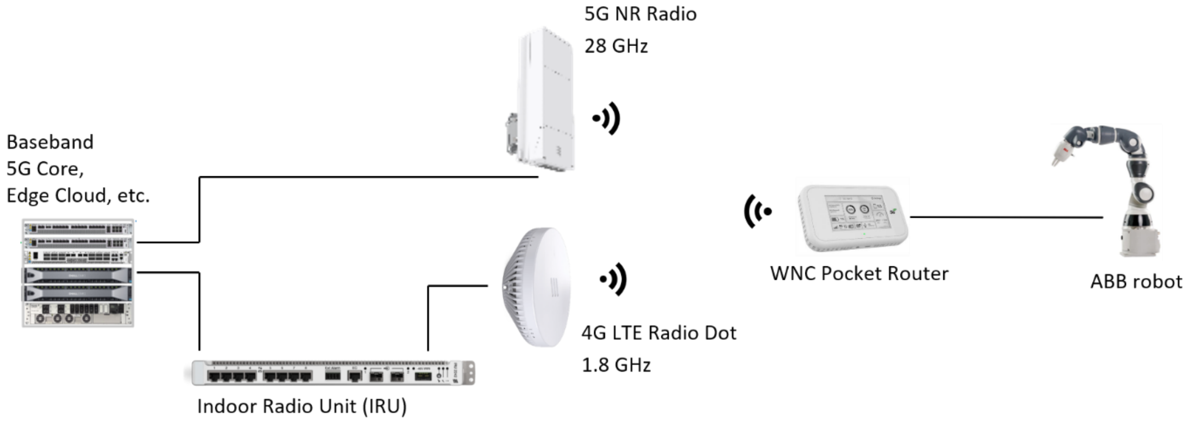

Figure 3: 5G deployment at the Kista trial site

3.1.2 Next steps

The next steps for the Kista trial site will focus on the implementation of the robotics-related prototype software, including the Augmented Reality (AR)-based application for robot status visualization. The implementation efforts comprise a detailed planning for stepwise delivery of the results across all three use cases, which would also allow to produce several demos and, thus, support the project's dissemination activities. Furthermore, a first setup of the lab infrastructure at ABB premises in Västerås is planned and built to develop and functionally test the use cases before actually moving them for evaluation to the Kista trial site.

3.2 Aachen trial site

At the Aachen trial site, on the shop floor of the IPT, 5G-SMART works on realizing two important use cases: 5G-based wireless acoustic emission (AE) measurements and a multi-sensor platform (MSP) for monitoring of workpieces and machines. Both use cases are described in detail in deliverable D1.1 (5GS20-D110).

Combining flexibility and versatility with the requirements of production industries is a major challenge, that needs to be addressed as a large variety of possible sensors and applications on the shop floor is required to be covered. The MSP developed within 5G-SMART has the ambition to allow an easy connection of different subsystems, sensors or other data infrastructure, while at the same time being a highly ruggedized and compact device. Figure 4 illustrates the use case setup. The MSP will be integrated into multiple machines and attached to multiple work pieces. Furthermore, a cloud-to-machine communication pipeline will be integrated.

Figure 5 illustrates the second use case under development at the Aachen trial site. Here, a 5G-connected AE sensor is integrated into a milling machine and used to monitor the milling process of a jet engine component. The system will be validated by the latency between a tool break and its detection.

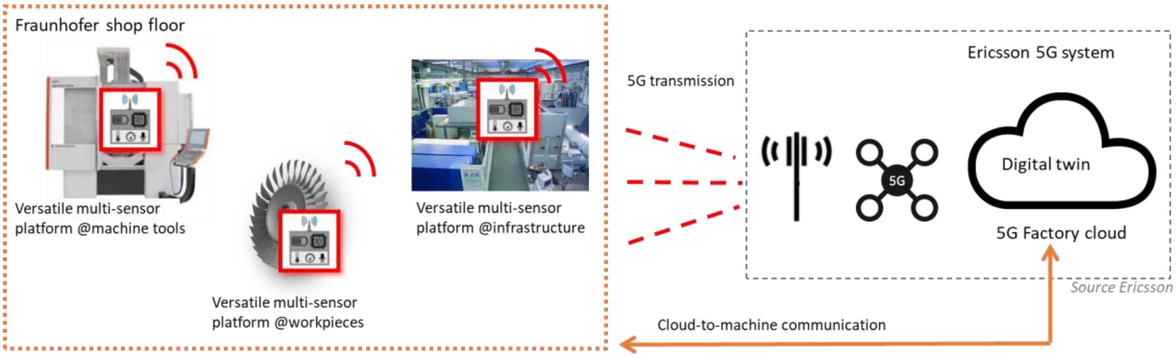

Figure 4: The MSP use case at the Aachen trial site

3.2.1 Achievements during the first year

For the MSP use case, the project has agreed on a hardware concept as high-level architecture, while a first prototype is in preparation. Regarding the connectivity, all requirements have been specified. A detailed description of the sensor systems as well as the edge cloud infrastructure is provided in deliverable D3.2 (5GS20-D32). This deliverable includes the description of the measurement parameters as well, and the requirements analysis and possible solutions to enable the tradeoff required to ensure flexibility and good performance of the prototype.

The work on the AE measurement system has reached a number of milestones during the first year of the project. A first demonstrator of the AE sensor system when used in a drilling process was built (5GS-YOU). The sensor, which is directly placed on the work piece itself, allows a previously unknown process proximity and transmits the data via 5G. An idea of the setup is given in Figure 5. It is demonstrated that this use case targets time-critical process optimization inside a factory. Using a system of smart sensors, a flexible cloud environment and a 5G communication infrastructure, real-time monitoring and control of highly complex processes are now possible. Both wear or breakage of the tool and process errors can be detected at an early stage of production and intercepted by immediate process control. This ensures the high quality of the product and enormous cost savings due to reduced rejects or necessary post-processing of workpieces. The AE sensor was supposed to be shown at MWC 2020 and EuCNC 2020, but the demo possibility at both events has been cancelled due to the Corona pandemic. Figure 6 gives an idea of the demonstrator setup, the related YouTube video explains the details (5GS19-AED). The AE sensor demo is planned to be showcased at future events.

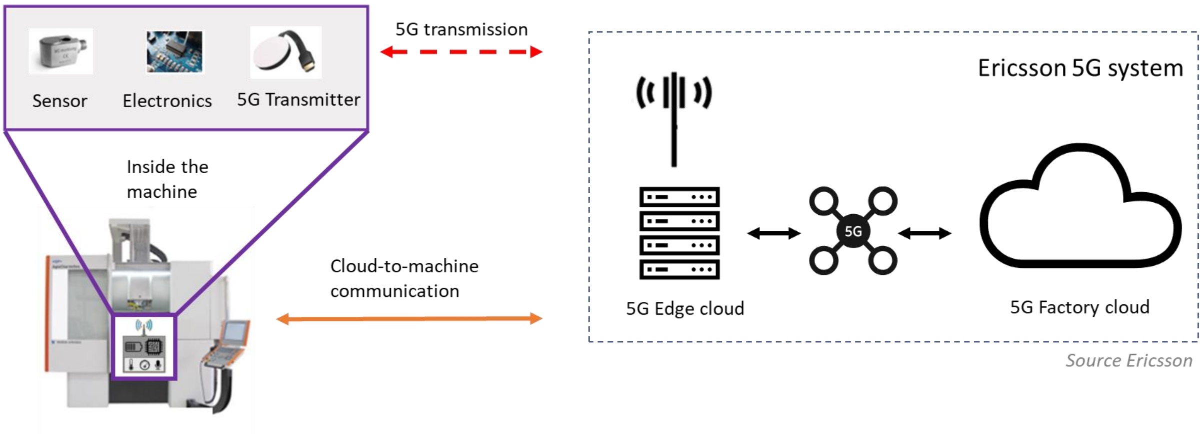

Figure 5: AE sensor use case at the Aachen trial site

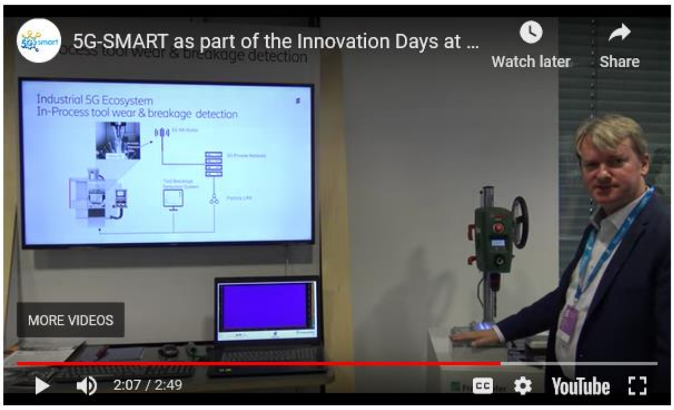

Figure 6: YouTube video of the AE demonstration

As another important step at the Aachen trial site, the 5G network deployment design has been finalized that will address the requirements of the use cases on the factory floor. The 5G deployment will go hand in hand with the wider 5G Industry Campus Europe (5G-ICE) installation, that covers the Melaten Campus of RWTH Aachen University including the IPT shop floor. The network chosen to be deployed at the Fraunhofer IPT trial site is a dedicated on-premise 5G NSA network operated as a non-public network (NPN). In practice, this means that all the network functions, including the evolved packet core (EPC) or 5G core, will be deployed on the shop floor. For the 5G NR system, the deployment is on frequency band n78 (3.7-3.8 GHz). For the 4G LTE part, the frequency band B40 (2.3-2.32 GHz) is utilized (both bands TDD). Licenses for both bands have already been granted by the national regulator. During the project lifetime the network will be upgraded to 5G stand-alone (SA). A description of the Aachen trial site together with the 5G system, all infrastructure elements and an overview of the validation tests to be performed, can be found in deliverable D3.1 (5GS19-D310). A schematic overview of the initial NSA 5G deployment is given in Figure 7. Recently, a major milestone has been achieved when installing the 5G equipment on the trial site. The IPT trial site is now operational.

Overall, the progress of the work within 5G-SMART at the Aachen trial site is according to plan.

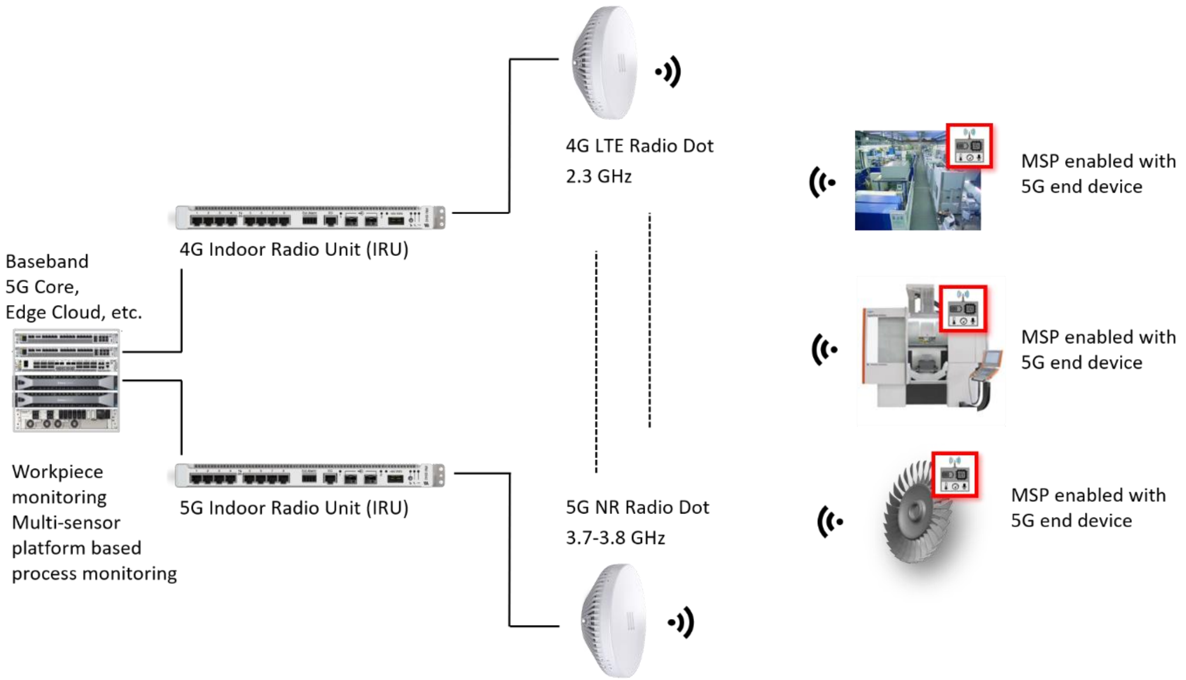

Figure 7: 5G deployment at Aachen trial site

3.2.2 Next steps

In the coming months, the first prototype for the MSP will be realized and tested. The AE sensor will be further improved. Both sensors will benefit from developments on the 5G device side. Furthermore, the factory cloud system will be deployed at the Aachen trial site. First virtual machines will be set up for data and signal processing and data bases for digital twin approaches. The 5G infrastructure will be migrated to SA.

3.3 Reutlingen trial site

At the Reutlingen trial site, 5G will be validated in a Bosch semiconductor factory environment from two different perspectives. First, the work focuses on 5G radio propagation in the production environment to ensure that 5G can provide the required stable connectivity and coverage throughout the factory floor, and that it provides the electromagnetic compatibility (EMC) levels as required in the semiconductor factory. Second, 5G will be validated on the application-level, by efficiently realizing two use cases on the factory shop floor: a cloud-based mobile robotics use case and an industrial LAN/TSN-over-5G use case. Figure 8 and Figure 9 illustrate the use cases, respectively. Both use cases are described in more detail in deliverable D1.1 (5GS20-D110).

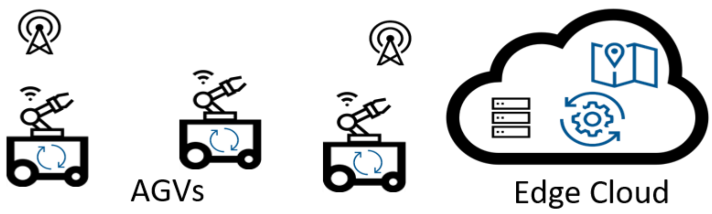

Figure 8: The mobile cloud robotics use case at the Reutlingen trial site

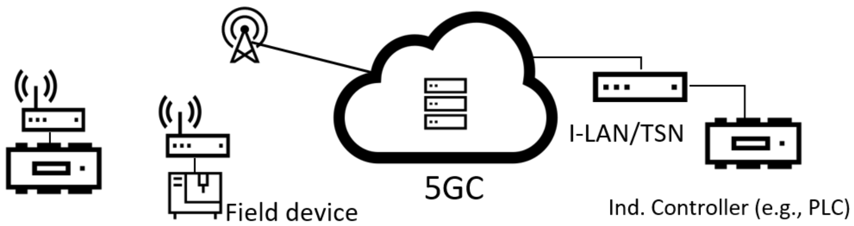

Figure 9: The TSN use case at the Reutlingen trial site

3.3.1 Achievements during the first year

Providing coverage throughout the factory floor is one of the first requirements towards a 5G deployment. With factories being typically covered with various tools and machines, this is not a straightforward task. Understanding the 5G channel characteristics in a local in-factory network is therefore a crucial step. The environment in the Bosch semiconductor factory is particularly challenging as it involves narrow corridors, high walls, and a large amount of reflective material/equipment. 5G-SMART has prepared a test setup for measuring the 5G radio signal properties, such as signal strength, impulse response, delay and angular spread, on site at the semiconductor factory in Reutlingen. Figure 10 Figure 10: Front view of the 3.7 GHz LuMaMi system (left) and mmWave propagation sounder (right).shows the measurement system developed by Lund University. Several possible measurement locations have been identified across the production floor, taking into account moving and stationary objects, as these have a potential to increase or decrease the number of available multipath and line-of-sight components. Ray-tracing simulations have been designed to predict the received power, profiles of shadow fading, as well as small-scale delay and angular parameters. These simulations will serve as a benchmark for comparing the measurement results against. The application for the frequency licenses has been completed. The measurement campaign will involve measurements in the 3.7-3.8 GHz band as well as in mmWave (26 GHz frequency band). Originally, the measurement campaign was planned to take place in April 2020, but it had to be shifted due to the Corona pandemic restrictions. As soon as the situation allows, the measurement campaign will be started. The results of the campaign will be documented in the upcoming deliverable D4.2 and potentially serve as valuable input for the installation of the 5G equipment.

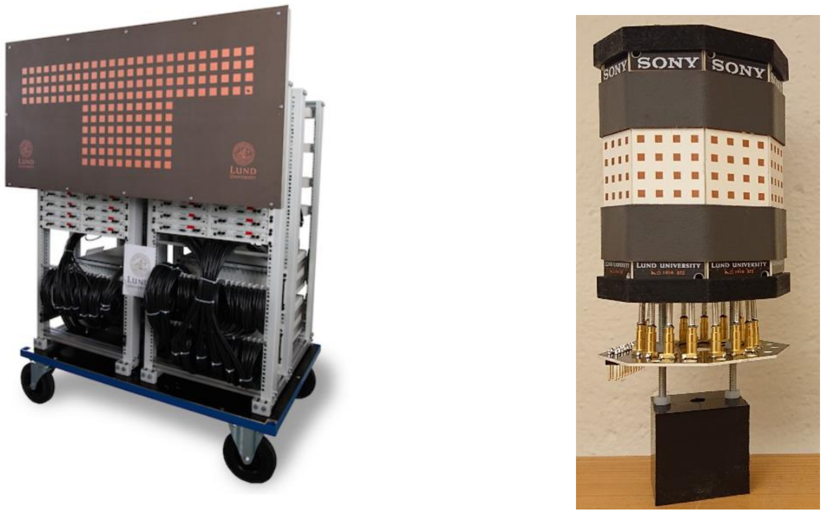

Figure 10: Front view of the 3.7 GHz LuMaMi system (left) and mmWave propagation sounder (right).

In order to install 5G in industrial environments, a major requirement is that 5G is electromagnetically compliant with the industrial equipment on site. One area with very strong requirements on the compatibility is the testing area of wafers in semiconductor manufacturing. 5G-SMART has prepared a test setup for electromagnetic compatibility of 5G within the semiconductor manufacturing plant of Bosch. With the help of a vector signal generator, uplink or downlink 5G NR signals are generated at 3.7 GHz, amplified and transmitted via a Horn antenna. In the wafer test area of the plant, devices-under-test will be extensively tested with this setup, to see possible impacts of 5G communication on the production of semiconductors in the factory. The results will be made available in the upcoming deliverable D4.2.

For the cloud-based mobile robotics use case, significant effort has been put into the development of the use case during the first year of the project. Here, the decision has been taken to realize a collaborative Autonomous Guided Vehicle (AGV) use case, using both a research and a commercial AGV platform. With the research platform the project will show how 5G and cloud technologies can be leveraged to enable novel collaborative control solutions based on the cloud-native realization of the AGV control. The intelligence of the research AGV is removed from the platform itself, reimplemented and extended in a cloud native manner in the edge cloud. The certified commercial AGV platform is planned to be connected over 5G and used to show the benefit of collaborative knowledge collected in the factory cloud (e.g., using the common map of the research and commercial AGVs for trajectory planning). Since commercial platforms are typically closed, changing the connection technology to 5G, as well as, applying custom high-level control instead of their legacy (closed) software packages is expected to be a challenge. On the other hand, these platforms are well suited for demonstration and testing in real factory environment. In order for the research AGV to guarantee a correct and safe operation on the factory floor, a number of different sensors will be installed on the platform. These include, for instance, safety laser scanners, LiDAR, depth cameras and ultrasonic sensors. Figure 11 shows a CAD drawing of the research AGV, illustrating a snapshot of the ongoing design process.

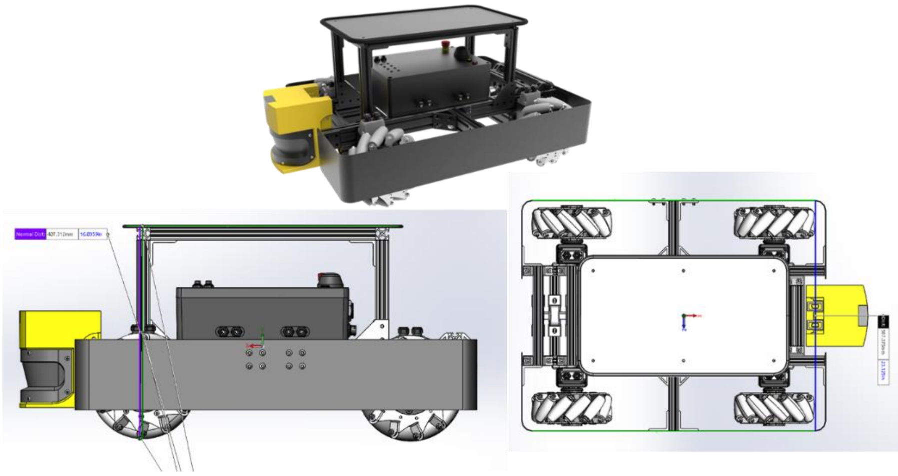

Figure 11: CAD drawings of the research mobile AGV platform

Specifying functional and system design as well as finding suitable equipment has shown to be very challenging due to the very demanding requirements and constraints of the real-life factory floor. A major milestone has been achieved when deciding for a suitable AGV platform and setup that supports the before mentioned functionalities while at the same time taking into account all constraints. In the upcoming months, the work can now focus on the implementation of the use cases. The results will be summarized in deliverable D4.3 towards the end of the project.

For the TSN-over-5G use case, the focus during the first year of the project has been on designing a real-life scenario, which can be implemented and tested on the factory floor. So far, the detailing and specification of various steps of the use case implementation have been completed, including the end-to-end system architecture. Furthermore, the choices with regard to the required hardware components that will be utilized for this purpose have been finalized. In the upcoming month the work will focus on the implementation and integration of the use case. The details of the use case validation together with results of conducted measurements will be documented in the deliverable D4.3, which is due at the end of the second project year.

The design of the 5G deployment has been finalized in the first year of the project. The 5G system is a 5G standalone (SA) system at 3.7 GHz, using Ericsson's Radio Dot System to cover two cells. A schematic view is given in Figure 12. The final design and installation of the 5G trial system in the semiconductor factory is planned to occur in the coming months and will be documented in the upcoming deliverable D4.1. This deliverable will include all considered requirements and constraints as well as the deployment model.

The progress of the work within 5G-SMART at the Reutlingen trial site is for some activities delayed by 3-4 months due to the effects of the Corona crisis.

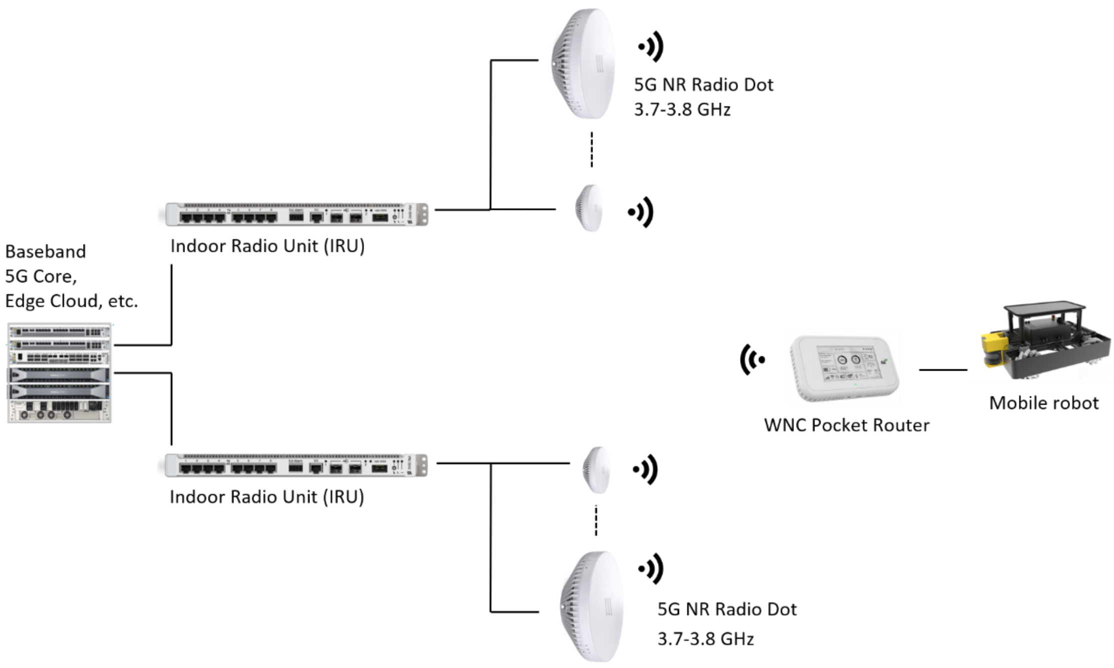

Figure 12: 5G deployment in the Bosch semiconductor factory

3.3.2 Next steps

For the 5G deployability evaluation in the semiconductor factory, i.e., channel measurements and EMC tests, the next step is to transport the developed equipment to Reutlingen, set up the test environment in the factory and conduct the field measurements according to the designed plans. For the 5G network installation, the next step will focus on completing the development of the experimental 5G network unit, transporting it to Reutlingen and setting it up in the designated area in the factory. In addition, when it comes to the realization of the use cases, the focus over the next couple of months will be put on the design and development of software components as well as test applications. This includes testing and integrating various software and hardware components of the system.

4 5G optimization and design for manufacturing

Today's manufacturing plants have a communication infrastructure, that is mainly based on wired industrial LAN, which largely relies on fieldbuses and Ethernet technologies. Factories of the future will however have an increasingly large part of the communication being wireless. To meet the stringent requirements on timely delivery and reliable transport, the latest specifications for 5G are targeting ultra-reliable and low-latency communication (URLLC). When introducing 5G into manufacturing plants, 5G-TSN-integration plays a major role. A key challenge is to ensure that 5G technologies are compatible and interwork with TSN or Industrial LAN. 5G-SMART focuses on developing and optimizing 5G technical features and solutions, that enable seamless integration of current as well as future manufacturing applications. This workstream includes work on new technological features that should potentially be supported by 5G standardization and their implementation impact. Furthermore, 5G network architectures are investigated and developed, taking into account the use case analysis made within the project. The development of an industrial-centric framework for network management and configuration is also part of this work stream. Apart from providing 5G-supported connectivity, technical features of time synchronization and positioning will be essential for manufacturing applications, particularly where robotics and AGVs are considered.

4.1.1 Achievements during the first year

In the first year of the project, a thorough state of the art analysis has been performed for several 5G features relevant for vertical industries. This analysis has been done based on a literature survey looking at e.g. 3GPP, IEEE and ITU, but as well taking the input from the work within 5G-SMART on use cases, requirements and network design into account. The following 5G features have been identified as particularly important for the manufacturing sector:

(1) 5G-TSN integration.
(2) End-to-end time synchronization.
(3) 5G-supported positioning in manufacturing plants.

For each of these features, a gap analysis has been performed between the state of the art and the requirements as seen from the use cases investigated in the project. Moreover, technical features have been evaluated, and, first recommendations are proposed to standardization organizations. Deliverable D5.1 (5GS20-D510) summarizes the outcome so far and provides an intermediate report on new technological features to be supported by 5G standardization and their implementation impact.

The significant progress in the areas of time synchronization and network architectures is visible in the contributions and impact created towards the research community and standard organizations. Apart from conference paper submissions, the project prepared a magazine article on 5G-supported time synchronization for smart manufacturing, which is currently under review. Four contributions on integration of 5G with time-sensitive networking (TSN) for industrial automation were made to the 5G-TSN work item of 5G-ACIA. Regarding the work on network architectures, partners of 5G-SMART have contributed to the investigations of the deployment architectures in the NGMN report on “5G E2E Technology to support verticals URLLC requirements” (NGMN19). Several contributions to standards have been made in the area as well (5GS-SCS).

A seamless integration of the manufacturing applications and the existing industrial communication systems with a wireless 5G system component requires an aligned configuration and network management of the entire communication system (including 5G and non-5G components). 5G-SMART therefore has the ambition to develop a framework of network management and configuration addressing some of the use cases investigated in the project. In a private 5G network, the management of the required reliability and specific network resources for the industrial applications will be made by the network slice manager (NSM). A prototype of the NSM has been designed and implemented in the first year of the project.

4.1.2 Next steps

The next steps in the work stream on 5G optimization and design for manufacturing involve the evaluation of the developed new 5G features, e.g. of time synchronization. Regarding the network architecture options, the project will in the following year focus on NPN impact analysis as well as NPN analysis with respect to time synchronization. The work on network management and configuration continues with analyzing network management requirements and enhancing the NSM tool.

5 Dissemination and impact

5G-SMART implements a coordinated dissemination and communication plan that foresees presentation and publication of project results at scientific conferences, journals, workshops, consumer expos, industry groups and forums, magazines and cross-project consortia, etc. In the first year of the project, the focus has been on stimulating the international research community, increasing the visibility of the project, promoting the exchange of knowledge regarding the introduction of 5G in the manufacturing industry, and thus accelerating the expected impact. Deliverable D6.1 (5GS19-D610) summarizes the impact and dissemination plan of 5G-SMART. Deliverable D7.1 (5GS19-D710) describes the project's homepage (https://5gsmart.eu).

The communication activities aim at interacting with both technical and non-technical audiences with the overall aim of spreading awareness of 5G technology in Industry 4.0. Dissemination activities include showcasing the use of 5G for smart manufacturing in a number of demonstrations and validation events, as well as contributions to international conferences, workshops, training and teaching activities. The dissemination and impact plan of 5G-SMART includes the following major activities:

(1) International conferences, workshops, journals, magazines and books.
(2) Workshop organizations.
(3) Participation in and contribution to European cluster and standardization meetings.
(4) Interaction with worldwide consortia, fora and institutes.
(5) Participation in public industry events and exhibitions.
(6) Academic dissemination.

5.1.1 Dissemination and public communication

Early on in the project, 5G-SMART has identified a number of major activities for disseminating and communicating news and results of 5G-SMART. Following this plan, 5G-SMART has already come a long way in the first year of the project, with a track record of several published articles in peer-reviewed conferences, several keynote speeches, the organization of a workshop, another special session and the presence at trade fairs, just to mention some of them. However, it has to be noted that several of the planned activities have been cancelled or postponed due to the Corona pandemic. Concrete measures taken by the project as a reaction to this, are a stronger focus on online events, and more efforts made into producing videos or other visualization material. Furthermore, online dissemination alternatives are investigated and addressed.

The presence in social media is an important asset of 5G-SMART's communication strategy. The project's website (http://www.5gsmart.eu), the LinkedIn account (5GS-LIN), as well as Twitter (5GS-TWI) posts register a large number of visitors. These channels are used to publish the results produced by the project, the project's presence at various events, upcoming events, as well as other news about the project. The project's YouTube channel (5GS-YOU) is used to publish presentations that have been recorded.

Table 1 contains the dissemination and communication activities linked to the project during its first year, from June 2019 to May 2020.

Activity	Number of activities	Comment
Participation in a conference as invited speaker or presenter	3	
Participation in a workshop as invited speaker or presenter	0	
Conference paper published or accepted	3	
Submitted scientific papers	6	
Organization of workshops	1	1 has been cancelled due to COVID19
Organization of special sessions	0	1 has been cancelled due to COVID19
Organization of panels	1	
Participation to an event other than a conference or workshop	7	
Exhibition	1	1 has been cancelled due to COVID19
Flyer distribution	0	1 has been cancelled due to COVID19
Training	1	
Social media, number of posts LinkedIn, Twitter	30	
Website, number of actions	10	
Video/film	2	
Trade fair	0	2 have been cancelled due to COVID19
Participation in activities organized jointly with other H2020 project(s)	2	
Press release	1	
Non-scientific and non-peer reviewed publications	1	
Communication campaign	0	

Table 1: Number of 5G-SMART dissemination and communication activities during the first year

5.1.2 Standardization and regulation activities

The synergies with standardization and regulatory bodies have been identified as important for the project to accelerate its impact. The project partners of 5G-SMART continuously participate to standardization and regulatory bodies meetings such as 3GPP and ETSI, industry alliances such as 5G-ACIA, and European Union project partnerships such as 5G-PPP. Moreover, 5G-SMART has industry partners in the project consortium that are key drivers and active members of relevant standardization bodies, both in the communication network industry as well as the manufacturing industry. In the first year of the project, 5G-SMART has therefore succeeded in making strong efforts in standardization and regulatory activities. The latter examples include 4 contributions to the 5G-TSN integration work item of 5G-ACIA and a number of contributions made to ITU (5GS-SCS).

5.1.3 Next steps

In the following project year, the intention is to intensify the publication of academic articles, as well as to start holding open day events and showcase demos to disseminate the main findings of the project. The corona pandemic affects certain face-to-face dissemination actions. The mitigation efforts by the project as a reaction to this will be intensified, assuring that the project's communication activities continue successfully. Communication work on social networks will continue as before, as well as 5G-SMART’s participation in international events.

6 Conclusion and outlook

In this intermediate project report, the main achievements made by 5G-SMART during the first year of the project are highlighted. References to the deliverables of the project are provided. The intermediate project report shows that 5G-SMART has made significant progress during the first year of the project execution.

The thorough analysis of requirements and KPIs of the trialed use cases as well as future looking use cases, has laid an important foundation for the project. During this work, the need for a common terminology and understanding between ICT and OT organizations has been identified, which has been addressed by 5G-SMART, and will continue to be addressed during the lifetime of the project. Building on the analysis of the requirements and KPIs of the trialed use cases, the development of the use cases has already come a long way, with for instance, a first demonstrator being already produced for the Aachen trial site. The 5G deployment design has been finalized for all three trial sites, and both the Aachen and Kista trial sites are already operational. The Reutlingen trial site is expected to be operational in autumn 2020. In the second year of the project, the use case development for the trial sites is going to be in the focus, with the goal of having a setup ready for validation tests at all the sites.

With the channel measurement and EMC testing setup being ready to bring to the Reutlingen trial site, the project is prepared to conduct and evaluate the measurements, as soon as the restrictions due to the Corona pandemic allow this.

The work by 5G-SMART on the development of new 5G features has taken an important step with the analysis of the state of the art and subsequent gap analysis when comparing with the requirements of trialed and future-looking smart manufacturing use cases. In the following year, the project will focus on evaluating features which relate to the integration of 5G with TSN and Industrial LAN, 5G-supported positioning, and time synchronization. Furthermore, several 5G network architecture options will be assessed, while the work on developing an industrial-centric framework for network management and configuration will be intensified.

Having already surveyed different RAN deployment options for smart manufacturing use cases in the first year of the project, the project will in the following year move to the evaluation phase for these options. The work on analyzing the business value created by 5G has already kicked off with an assessment framework and methodology starting to take shape. This framework and methodology will be further refined in the upcoming months.

In terms of the project's communication and dissemination, unfortunately several planned activities had to be cancelled due to the Corona pandemic. Still, it is clear from the presence of 5G-SMART in conferences, panels, exhibitions, etc. as well as from its dissemination track record, that the project has already succeeded in stimulating the international research community, increasing its visibility, and promoting the exchange of knowledge regarding the introduction of 5G in the manufacturing industry.

In the upcoming months strong focus will be put on online activities to assure a continued success of the project, despite the limitations due to the Corona pandemic.

Appendix

List of abbreviations

AE	Acoustic Emission
AGV	Autonomous Guided Vehicle
AI	Artificial Intelligence
AR	Augmented Reality
EMC	Electromagnetic Compatibility
EPC	Evolved Packet Core
HMI	Human-Machine-Interface
ICE	Industry Campus Europe
LAN	Local Area Network
LTE	Long Term Evolution
mmWave	Millimeter Wave
MNO	Mobile Network Operator
MSP	Multi Sensor Platform
NPN	Non-Public Network
NR	New Radio
NSA	Non-standalone
NSM	Network Slicing Manager
RAN	Radio Access Network
SA	Standalone
TDD	Time-division Duplex
TSN	Time-sensitive Networking
URLLC	Ultra-reliable and Low-latency Communication
UAV	Unguided Autonomous Vehicle

Table 2: List of abbreviations

References

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5GS19-D610	5G-SMART, Deliverable 6.1, "Impact and dissemination plan for academic research, development of industry, standardisation and regulation synergies", August 2019
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5GS20-D210	5G-SMART, Deliverable 2.1, "Design of 5G-Based Testbed for Industrial Robotics", May 2020
5GS20-D320	5G-SMART, Deliverable 3.2, "Report on System Design Options for Monitoring of Workpieces and Machines", May 2020
5GS20-D510	5G-SMART, Deliverable 5.1, "Report on new technological features to be supported by 5G standardization and their implementation impact", May 2020
5GS-LIN	5G-SMART, LinkedIn page, https://www.linkedin.com/company/5gsmart/
5GS-SCS	https://5gsmart.eu/standard-contributions/
5GS-TWI	5G-SMART, Twitter account, https://twitter.com/5G_smart
5GS-YOU	5G-SMART, YouTube channel, https://www.youtube.com/channel/UCdhRYuUuSfT97tIivMGLRIg
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