SECOND INTERMEDIATE PROJECT REPORT

Deliverable D9.3

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6GSNS

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SECOND INTERMEDIATE PROJECT REPORT

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SHORT ABSTRACT	This second intermediate project report provides an overview of the results and achievements accomplished during the second year of the TARGET-X project.
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Executive Summary

This second intermediate project report contains an overview of the results achieved in the TARGET-X project by the end of the second project year. It highlights the main achievements and provides references to the relevant documents and deliverables.

The achievements span over the four application domains (verticals) Energy, Manufacturing, Automotive and Construction as well as the technology domain. Of relevance are applications / use cases of the 5G and beyond technology for the verticals and end users. Therefore, in all TARGET-X testbeds, the use cases have been described and investigated for the potential benefits. The benefits are investigated in the methodological assessment framework using key performance indicators (KPIs) and key value indicators (KVIs) from the verticals' users. This work is also discussed in a work item in the 5G-ACIA that is dedicated to the development of a calculation method of the business value of industrial 5G use cases.

The TARGET-X testbeds are heavily collaborating with the technology partners to integrate the beyond 5G technology into their testbeds and execute the large-scale pilots and use case implementations. Several use cases implementations and technology developments are ongoing.

TARGET-X provides Financial Support for Third Parties (FSTP) with a budget of 6.000.000€. The budget is distributed over two open calls, each offering a set of different topics that describe challenges to be solved by the third parties. The topics for the 1st and the 2nd open call were defined in collaborative efforts by the TARGET-X consortium partners. The 1st open call was completed and received 132 proposals for 48 topics. From this, 26 projects were executed in 2024. The second open call received 159 applications, and 40 projects started the support programme that will run until June 2025.

Finally, the project has participated in various events, and uses a website, LinkedIn channel, and the TARGET-X community for dissemination. The project has actively contributed to conferences, e.g. EUCNC, and industry fairs ensuring communication dissemination to technical as well as non-technical audiences across different verticals. A highlight was the TARGET-X Open Day, showing demonstrations and presentations both from the project consortium as well as prepared by the FSTP projects. Further, the project has published scientific papers and is building a community of supportive partners.

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List of Acronyms and Abbreviations

AAS	Asset Administration Shell
BLE	Bluetooth Low Energy
C-ITS	Cooperative Intelligent Transport System
CAM	Cooperative Awareness Message
CPM	Collective Perception Message
CV	Connected Vehicle
DENM	Decentralized Environmental Notification Message
eMBB	Enhanced mobile broadband
F2F	Face-to-face
FR2	Frequency Range 2
FRER	Frame Replication and Elimination for Reliability
FSTP	Financial Support for Third Parties
IFC	Industry Foundation Classes
IT	Information Technology
JCAS	Joint Communication And Sensing
KPI	Key Performance Indicator
KVI	Key Value Indicator
MAF	Methodological Assessment Framework
mMTC	massive Machine Type Communications
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer

OT	Operational Technology
PLL	Phase Locked Loop
PMU	Phasor Measurement Unit
PCB	Printed Circuit Board
QoS	Quality of Service
RAN	Radio Access Network
RDF	Resource Description Framework
RedCap	Reduced Capability
ROS 2	The Robot Operating System 2
SDR	Software-Defined Radio
SLAM	Simultaneous Localization and Mapping
SNS JU	Smart Networks and Services Joint Undertaking
TDD	Time Division Duplexing
TSN	Time-Sensitive Networking
URLLC	Ultra-reliable low-latency communication
WP	Work Package

1 Introduction

The TARGET-X project is one of the Smart Networks and Services Joint Undertaking (SNS JU) Phase 1 projects. There, it is allocated in Stream D "Large-Scale SNS Trials and Pilots". TARGET-X runs for 30 months and has started in January 2023. The project costs are more than 14 M€ of which 6 M€ are reserved for Financial Support for Third Parties (FSTP).

TARGET-X aims at accelerating the digital transformation in four verticals: Energy, Manufacturing / Robotics, Construction and Automotive. These key verticals jointly integrate beyond 5G technology in large-scale testbeds and evaluate the technology methodologically with Key Performance Indicators (KPIs) and Key Value Indicators (KVIs). The FSTP projects act as further innovation drivers.

This is reflected in the project's structure which is shown in Figure 1-1:

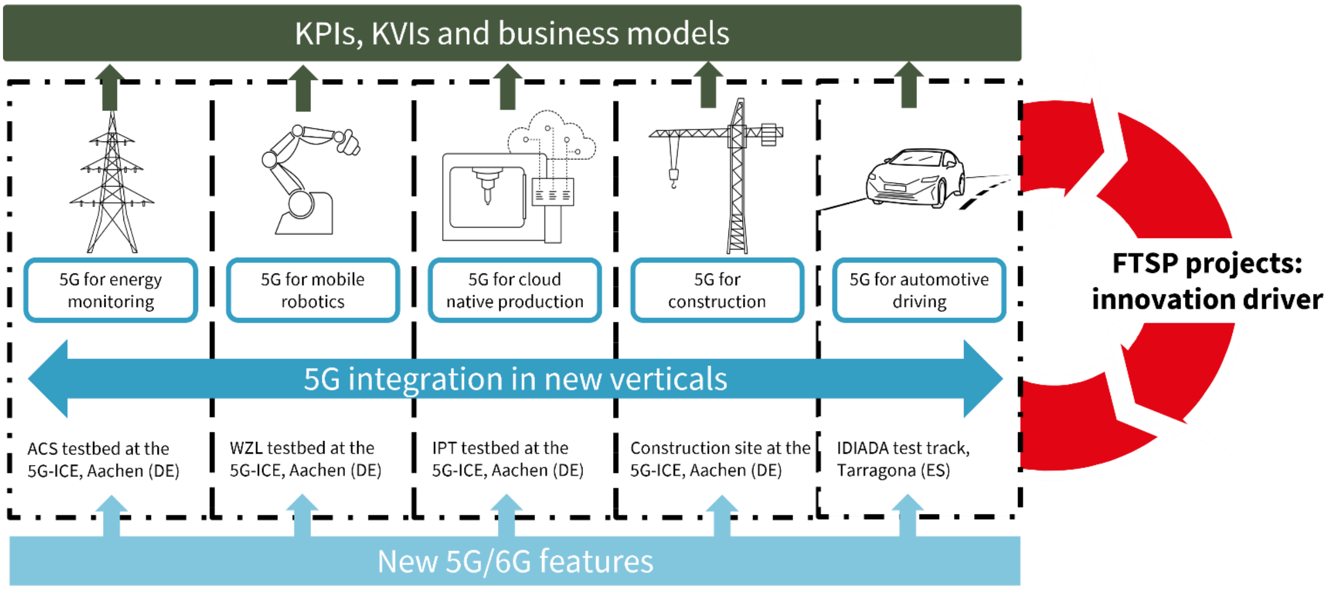

Figure 1-1: TARGET-X Structure

The TARGET-X Work Packages (WPs) can be mapped to the key elements of the TARGET-X structure: WP1 "Methodological Assessment Framework" focuses on use cases, business models and the methodological KPI /KVI assessment. The work packages 2-5 aim at the different verticals: Manufacturing (WP2), Energy (WP3), Automotive (WP4) and Construction (WP5). The WP6 Technology Evolution Beyond 5G prepares and integrates new 5G/6G features into the testbeds. WP7 facilitates the FSTP projects while WP8 takes care of communication and dissemination. The project management is located in WP9.

Figure 1-1 gives an overview of the testbeds in TARGET-X. They aim at evaluating and validating the 5G and beyond technology. The Energy testbed "5G for energy monitoring" is located at the 5G-Industry Campus Europe in Aachen, Germany, and uses the RWTH-ACS main building EON Energy Research Center as a testbed for energy monitoring. The Robotics testbed "5G for mobile robotics" uses the RWTH-WZL state-of-the-art mobile assembly laboratory that is also part of the 5G-Industry Campus Europe in Aachen, Germany. The Cloud Native Production testbed "5G for cloud native production" is located at the machine hall of the Fraunhofer Institute for Production Technology IPT, the central coordinator of the 5G-Industry Campus Europe. Both, the robotics as well as the cloud native production testbed aim at the Manufacturing vertical. The Construction testbed "5G for construction" implements a living lab on a reference construction site, that is also part of the 5G-Industry Campus Europe. The Automotive testbed "5G for automotive driving" is located at the Applus IDIADA test track in Tarragona, Spain, that covers 370 hectares and a mobile communication infrastructure.

This document is the second intermediate project report of TARGET-X and gives an overview of the project's achievements during its second year. It describes the relevant results and provides references to all deliverables, papers, and further output of the project. Some of these outputs can also be found on the TARGET-X website https://target-x.eu/ and in the project's community on Zenodo https://zenodo.org/communities/targetx/ . Additionally, it provides insights into the results of both open calls for FSTP and highlights some results from the projects executed during the first support programme.

1.1 Objective of the document

The objective of this second intermediate project report is to summarize the achievements of the TARGET-X progress across the various work packages and verticals during the second year of the project. This includes the achieved results and references to the relevant deliverables. For ongoing activities, the next steps and plans are described.

The objectives of the document align with the objectives of the TARGET-X project:

1. To demonstrate and validate industrial 5G/6G technologies and architectures in large-scale pilots in four different verticals.
2. Investigating 5G/6G and peripherical technologies across the whole value chain (devices, connectivity, service delivery) to identify, assess and propose new 5G/6G features targeting connected industries.
3. Enabling future use cases by self-adapting communication networks
4. Dynamic allocation of communication and computation resources across IT&OT
5. KPI and Key (Societal) Value Indicator (KVI) generation from real business cases validated on large scale trial sites
6. Enhance the 5G/6G ecosystem in the manufacturing & robotics, automotive, energy, and construction verticals
7. To disseminate and communicate the outcome of the TARGET-X project and contribute to standards, the scientific and industrial domains, and the subsequent SNS phases.

1.2 Structure of the document

The structure of this document orients at the overall structure of TARGET-X. This first chapter introduced the overall concept of TARGET-X. The following chapter 2 relates to WP1 "Methodological Assessment Framework" that targets use case descriptions and methodological assessment with KPIs and KVIs. In the next chapter, the TARGET-X testbeds that represent the WP2-5, describe their progress and work during the second year of the project, highlights results from the FSTP projects and describes the envisioned next steps. The following chapter 4 "Technology evolution beyond 5G" focuses on the technological developments and achievements during the second year. Then, the insights related to the FSTP is described. This is followed by a description of the communication and dissemination efforts. Chapter 7 concludes the document with a summary and gives an outlook for the rest of the project.

1.3 Relation to other activities

This deliverable is the first intermediate project report of the TARGET-X project. It is related to all the activities carried out in the project. In particular, it shows all the achievements of the work packages 1-8 during the second project year and points out the next steps. This way, it provides an overview of the current status of the project. A list of all related deliverables can be found in the References.

2 Use cases and methodological KPI/KVI assessment framework

2.1 Achievements during the second year

In the second project year of TARGET-X, work in WP1 has focused on the refinement of the Methodological Assessment Framework (MAF) and the KPI as well as the KVI. After the initial KPI and KVI set had been drafted and described in Deliverable 1.1 [TAR23-D11], the activities in WP1 focused on the adaption and further development of the KPI and KVI to capture the value proposition of each use case. One central remark in the first project review was to increase the involvement of potential end users from the different verticals. To address this remark, a change in perspective for the assessment of the use cases was introduced: To evaluate the value proposition of the use case, the perspective of a potential end user of the use case should always be taken. For the manufacturing vertical, for example, this is a production manager who is considering integrating a 5G-based use case into their production line. This production manager usually has no in-depth knowledge of communication networks and is therefore not overly interested in the technical characteristics of a 5G network, such as latency or data transfer rates. Instead, the production manager is interested in specific key figures that describe the performance of their production system and the impact of the introduction of the 5G-based use case on this production system, for example whether the throughput of their production system will change positively because of execution of the use case. In principle, this described evaluation perspective was already present in the design of the MAF and the associated KPI/KVI, but this aspect was again given greater focus in the further design process of the MAF as well as the KPI and KVI. Therefore, the guiding principle for the evaluation of each TARGET-X use case was derived in the following way: "*Take the perspective of the end user of the use case and describe what advantages the implementation and execution of the use case with 5G promises compared to the current state of the art*".

The basic concept of the MAF is described in Deliverable 1.1 of TARGET-X and pictured in Figure 2-1. It illustrated the principle of how both, the technical and economic goals are captured with the KPI, and the societal goals are captured with the KVI. This enables a homogenized and uniform assessment of the value proposition of each individual TARGET-X use case.

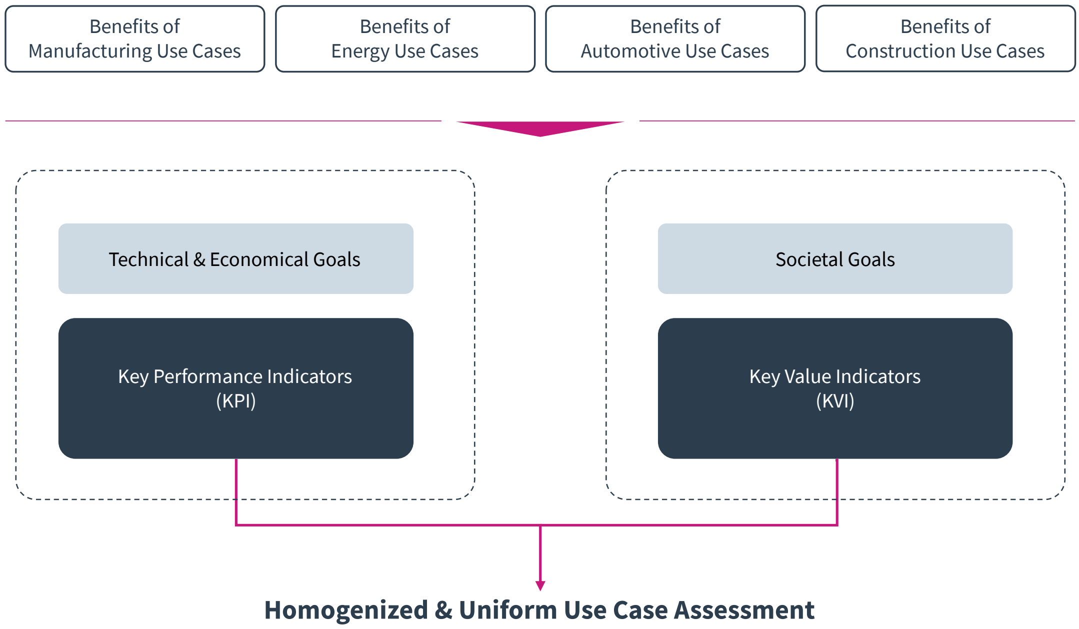

Figure 2-1 - Basic Principle of the TARGET-X MAF

In the second project year the basic principle was continuously refined based on the insights gathered in exchange with the verticals working on the individual use cases. The refined version of the MAF is pictured in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

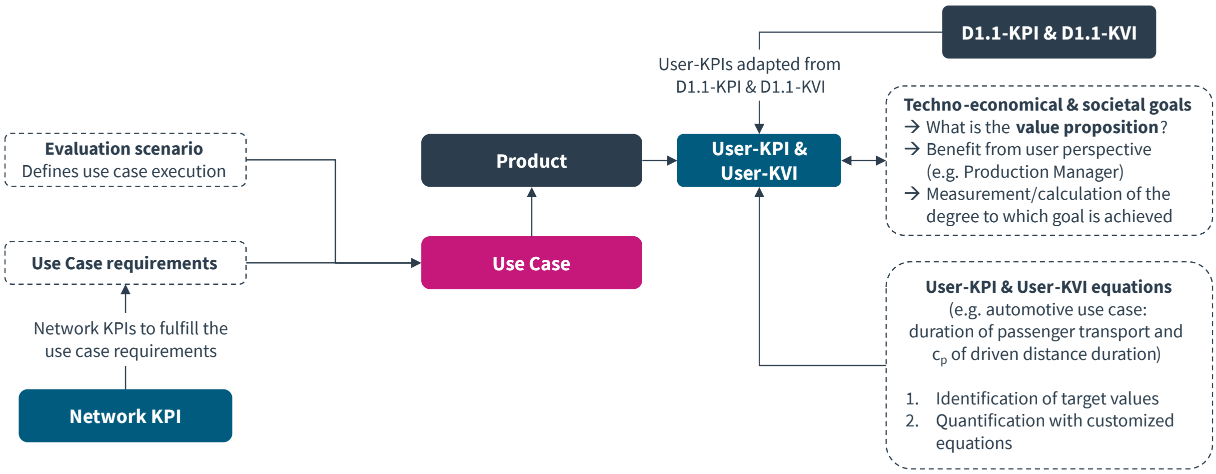

Figure 2-2 - Refined Version of the TARGET-X MAF

The following section contains a brief description of the core ideas of the MAF. A more elaborate description can be found in Deliverable 1.2 of TARGET-X [TAR24-D12].

The outcome of the execution of each use case is defined as a *product*, which - together with the use case itself - is located at the center of the MAF. The product does not necessarily have to be a physical object, it can for instance also be the successful transport of a passenger with an autonomously controlled vehicle. Placing the product at the center of the MAF follows the principle of prioritizing end user's needs and wants, as they mostly care about the product generating a value proposition for them as the result of a successfully executed use case. This approach also aligns with one of the core objectives of TARGET-X, to accelerate the adoption of 5G (and 6G) in different industries as the concrete and tangible description of a use cases' value proposition is a crucial prerequisite for this objective. For each use case, a dedicated *use case owner* as a project member from the respective vertical has been defined in order to have one central person that is responsible for the collaboration with WP1.

Evaluation scenarios have been defined as another important component of the MAF. As a use case can be executed in a variety of different ways, the evaluation scenarios describe test cases for the exemplary and sequential execution of the use cases which will then be subject to the evaluation. The evaluation scenarios have been described in tabular form and are listed in Deliverable 1.2 [TAR24-D12]. Together with the *use case requirements*, the evaluation scenarios set the stage for the execution and evaluation of each use case. The use case requirements establish the link between the technical properties of the network and the actual product of the use case. For the successful execution of the use case, the use case requirements must be fulfilled by the network. This can, for example, be certain requirements regarding latency, throughput, or localization accuracy. In this way, another link is established between KPI (and KVI) evaluating the product of a use case and network KPI. Over the course of the second project year, a different understanding of the term KPI was frequently noticed within the project consortium. While network experts tend to interpret KPI as a description of network characteristics, domain experts (e.g. experts from the manufacturing domain) tend to interpret KPI as a way to describe the performance of production or construction system. Therefore, the KPI and KVI used for the evaluation of use cases were renamed to *User-KPI* and *User-KVI.* The illustration of both Network-KPI and User-KPI/-KVI in the MAF addresses the issue of different understandings among experts from different domains. User-KPI and User-KVI are both utilized to quantify the degree to which a techno-economical or a societal goal is achieved. For each use case, an adaption of the generic KPI and KVI from Deliverable 1.1 has been conducted to tailor the evaluation to each use case specifically. For this purpose, equations have been defined for the estimation-based calculation of each User-KPI and User-KVI. The goals are also formulated from an end user's perspective. For instance, a production manager might want to increase the capability of a particular process in the production environment through the implementation of a 5G-based use case. The techno-economical goals as well as the societal goals have been defined in Deliverable 1.1 [TAR23-D11] and have not been adapted in the second project year.

In parallel to the activities carried out in TARGET-X, WP1 members were also active in 5G-ACIA as rapporteurs responsible for a Work Item in Working Group 5 of 5G-ACIA [5GAC]. Working Group 5 of 5G-ACIA focusses on "Industrial 5G in Practice" and therefore acts as an exchange platform for a variety of different industry players in the realm of industrial 5G. The activities in 5G-ACIA by WP1 of TARGET-X were started in 2023 and continued in 2024. First, an internal report describing a simplified version of the evaluation methodology was created. The simplifications were implemented to enable easier transfer and applicability to different application scenarios. After the internal report was finalized, the creation of a whitepaper describing the methodology was started which will be finalized in the beginning of 2025. For the creation of the whitepaper, the scope was extended to companies outside of 5G-ACIA so that an Asian automotive Original Equipment Manufacturer (OEM) that already employs a 5G-based use case in production could be included in the evaluation. As of the writing of the report, the investigation of the automotive's OEM is still ongoing and the results of the evaluation will be published in the mentioned Whitepaper in 2025. The activity of WP1 follows the objective to include more end users in the development process of the MAF, as the technical discussion with companies outside of the TARGET-X project consortium provides valuable insights as well as validation from an expanded user circle.

2.2 Next steps

The described MAF forms the basis for evaluating the value proposition of each individual use case. The evaluation activities will be carried out and finalized in the third project year and disseminated to illustrate the potential 5G has to offer when applied in the different TARGET-X verticals. The consideration of use case requirements will additionally provide valuable insights for the technological evolution beyond 5G, as the currently existing (technical) limits for the full execution of the use cases can be tested. Over the course of the use case evaluations, the necessity to implement changes to the individual User-KPI or User-KVI might become apparent. These changes will then be implemented so that the final MAF with the final User-KPI and User-KVI will be available and disseminated after the TARGET-X project has concluded. Furthermore, the applicability of the MAF to FSTP projects will be checked to expand the use base of the MAF.

3 TARGET-X Testbeds

3.1 Energy testbed

The energy test bed within the TARGET-X project aims to further integrate 5G technology into the energy domain. This can either be for grid monitoring or increased energy awareness. These two use cases have different requirements. The grid monitoring use case depends on high sampling rates and high time tagging accuracy, whereas the energy awareness case requires a high energy metering accuracy. The test beds for both types of use cases are located at the 5G-Industry Campus Europe at RWTH Campus Melaten in Aachen. Both use cases focus on a 5G-enabled synchronized measurement devices that can be used for local grid monitoring as well as for the other verticals to measure the consumption of, for example, machines at a construction site.

Grid Monitoring

The grid monitoring case is carried out at the RWTH-ACS institute building and will focus on the voltage behaviour of the local low-voltage grid. In that building, different laboratories and workshops will be monitored for voltage and current of the local power grid. Further energy monitoring will be carried out at the construction test bed. The measurement data from both test beds will be sent to an edge cloud-like infrastructure that can visualize the data and handle short- and long-term storage. A more detailed description of the energy test bed is given in deliverables D3.1 [TAR23-D31] and D3.4 [TAR24-D34].

Energy Awareness

The energy awareness use case is utilizing the construction and robotics test bed. In the test beds different processes at the sites will be evaluated from an energy perspective. To achieve that, energy as well as current and voltage measurements are needed. This is accomplished by utilizing the edgePMU and extending it with a weatherproof box for inline measurements, which is called Meter-X. Further information about the construction site can be found in Section 3.5.

Achievements during the second year

During the second reporting period, deliverable D3.4 [TAR24-D34] was submitted. This deliverable shows the developments of the software and hardware stack during this period. Some key achievements are the development and testing of a custom 5G carrier board, a second revision of a PLL synchronization circuit, special test and evaluation hardware, as well as the extension of the software stack with new Ansible roles. The developments resulted in the building and deployment of a Meter-X device for the construction and robotics use case, as well as the building of an upgraded edgePMU device. Furthermore, stationary Meter-X boxes were deployed at the nergy trial site. The different deployments are shown in Figure 3-1.

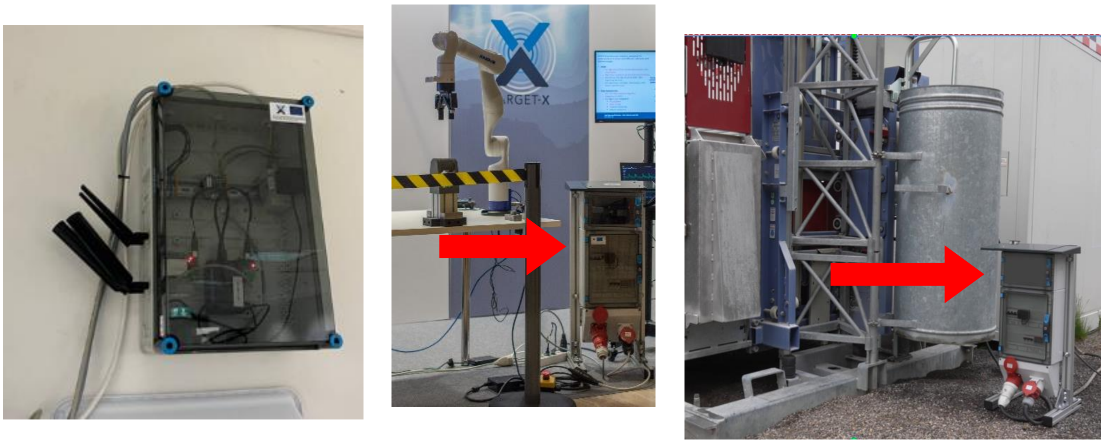

Figure 3-1: Stationary Meter-X at energy test bed (left), Meter-X at EUCNC with Robot (middle), Meter-X at construction test bed (right)

The Meter-X device was used for a demonstration at EUCNC 2024 as well as for preliminary measurements at the construction site. In addition, it was featured in a paper presented at the OSMSES 2024 [AUT24]. A second paper was presented at the PEDG 2024 [ALO24] about a highly specialized piece of test equipment for phase estimation.

5G carrier board

The 5G carrier board is specifically developed for the phasor measurements device. It contains the hardware to extract the PPS signal from a 5G modem. This feature is partially documented by some 5G modem module vendors, but it is hard to get a compatible firmware. Nevertheless, the carrier board is a very important piece of hardware since it provides a USB-C-based small form factor interface for the commercially available 5G modems. Within the project, different modem modules have been evaluated and tested with a locally available 5G SA and 5G NSA network. In both cases, a connection was established, and the configurations needed are now being incorporated with the automated deployment system. The developed board is shown in Figure 3-2. More details can be found in deliverable D3.4 [TAR24-D34].

Figure 3-2: 5G carrier board

PLL synchronization

The PLL synchronization presented in the last report was based on a bachelor's thesis and an off-the-shelf evaluation board. This is not a viable solution for the deployment of the edgePMU since the evaluation board is expensive and has a large form factor. Therefore, a custom USB-C-based board was developed and tested. The hardware is shown in Figure 3-3. More details are given in deliverable D3.4 [TAR24-D34].

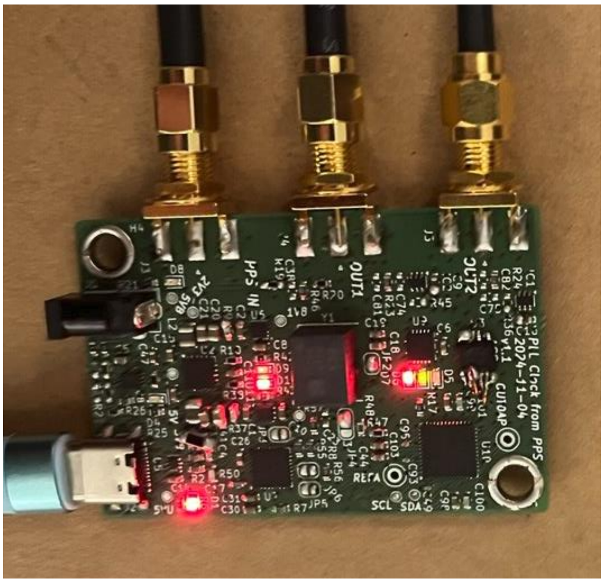

Figure 3-3: PLL Circuit with SMA for pulse per second input and clock outputs.

Evaluation hardware

For phasor measurements, a precisely generated signal with a known phase is key to evaluating the developed hardware and software stack. To achieve this, two customized hardware components were developed.

The device for reference phase measurement allows for a highly precise measurement of a given phase and can be used to evaluate the performance of the edgePMU. This device, in combination with off-the-shelf bench multimeters is used during the evaluation. The test setup and device are depicted in Figure 3-4 (right top and bottom). A more detailed explanation of the device is given in D3.4 and the corresponding paper [ALO24].

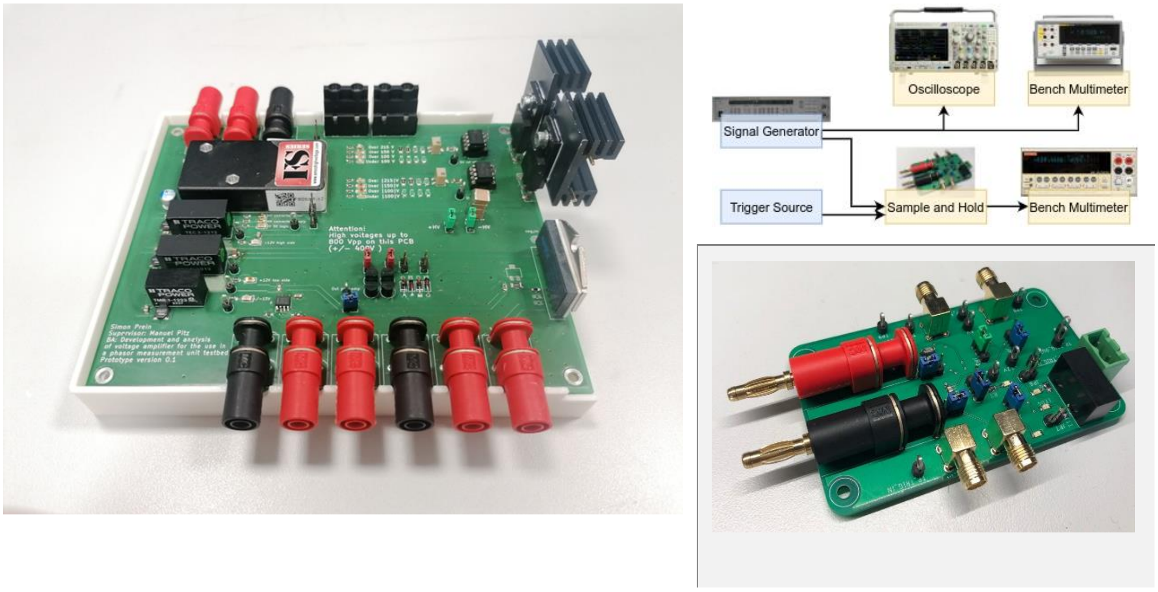

Figure 3-4: PMU signal amplifier (left), Sample and Hold circuit (right bottom), Phase estimation test setup (right top)

The second development is an amplifier that allows for a linear amplification from ±10 V up to ±250 V. This device is used to evaluate the PMU including the input stage. The developed hardware is depicted in Figure 3-4 (left) and further described in D3.4 [TAR24-D34].

Software stack

The software stack was extended with additional roles for the Ansible. Some of them are the 5G modem configuration, RS485 communication, Grafana and Docker deployment. Furthermore, the automated generation and customization of Raspberry Pi images was extended and updated. The results concerning the image generation and customization were presented at OSMSES 2024 [AUT24]. Additional information can be found in D3.4 [TAR24-D34].

Meter-X

In the last period, the Meter-X device was presented as a mock-up. Within this period, two of these devices were built. One was deployed at the construction test bed, and one was used for showcasing energy awareness topics for the robotics vertical. The hardware is shown in Figure 3-5 and more details are given in D3.4 [TAR24-D34].

Figure 3-5: Two Meter-X devices

edgePMU

As the Meter-X is developed specifically for energy awareness and use in a mobile application, the edgePMU, which is a subset of the Meter-X, is also further developed for stationary use in grid monitoring applications. The major difference is that the Meter-X device additionally contains a dedicated metering device for long-term monitoring applications and energy measurements, whereas the edgePMU is specifically developed for voltage and current monitoring with high phasor reporting rates. The latest version of the edgePMU is shown in Figure 3-6 and more details are given in D3.4 [TAR24-D34]

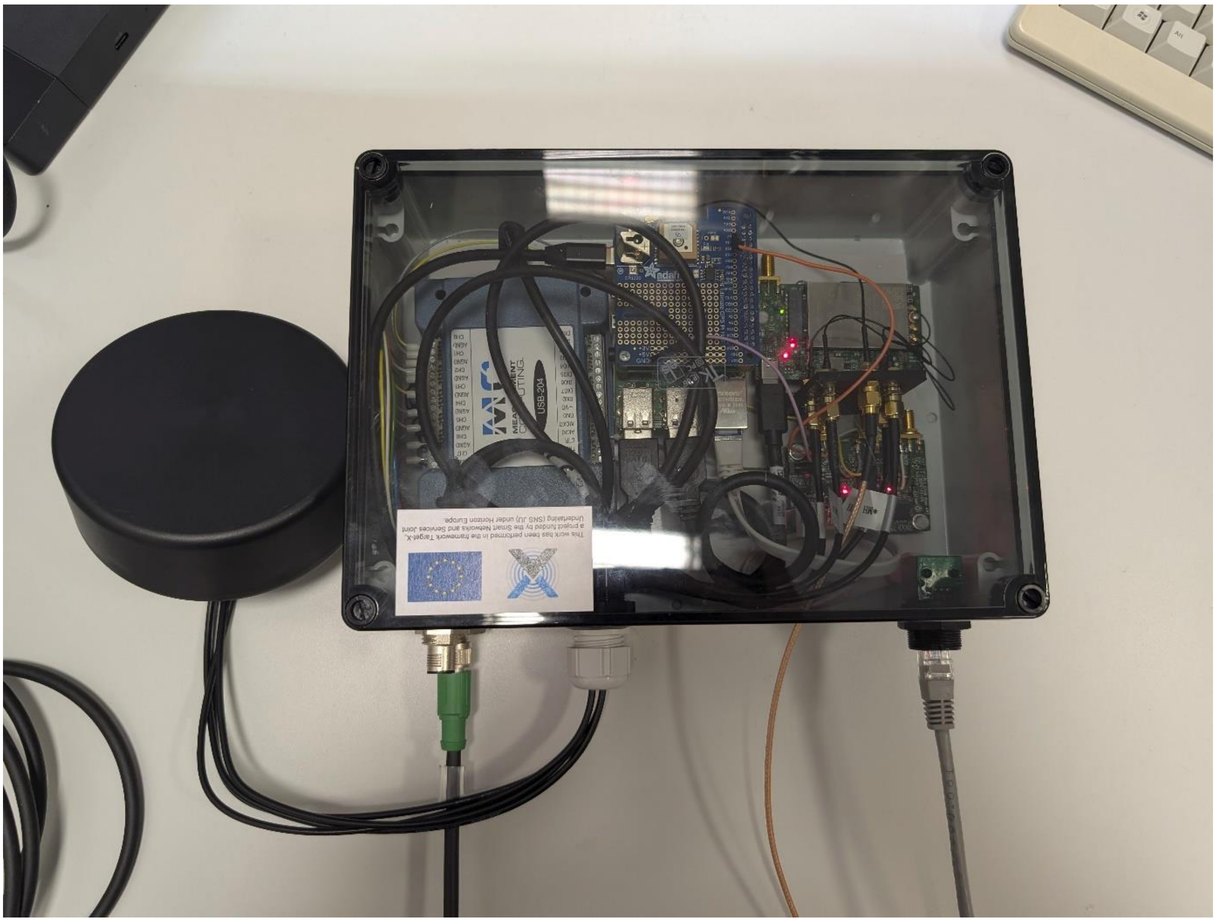

Figure 3-6: edgePMU hardware

Highlights from FSTP projects

The first round of FSTP projects successfully finished within this evaluation period. During that period the following projects have been mentored:

- 5GEdge_ForecastOptimiser,
- DAEMON-LEC-5G,
- EHBear,
- FAST-SEM,
- LENSE,
- Linc, and
- Open Energy Box.

The major findings, challenges and learnings were:

- Even though 5G is already deployed rather widely all over Europe, the low-power variant of 5G (5G NB-IoT) lacks public deployment. This variant offers higher bandwidth and lower latency compared to the current revision of NB-IoT. The FSTP project investigating this topic had to evaluate the technology with a software-defined radio (SDR), instead of the original plan to evaluate the technology in the public network. The results are promising and can be used in different low-power applications.

- An energy harvesting use case was evaluated. The approach is using a custom-designed generator that can be mounted to a bearing. The goal is to build self-sufficient bearing monitoring systems. This idea is intriguing, but it was not possible to fully supply the monitoring and 5G hardware via this approach. The use of 5G-NB IoT could be an interesting solution for this.
- All projects showed novel approaches to utilizing 5G technology for energy monitoring, harvesting and forecasting including potential business cases.

Next steps

The next steps for the energy vertical are acquiring and evaluating the measurements of the deployed field devices at the construction trial site, robotics trial site, and the energy trial site. This includes the evaluation of the electrical measurements as well as the learnings concerning 5G communication, deployment procedures and developed hardware. Further refinements of the platform and hardware will also be part of the work in the next period. Finally, the mentoring of the second round of FSTP projects will be ongoing.

3.2 Cloud native production testbed

The Cloud-native testbed for the TARGET-X WP2 for manufacturing specific use cases. It involves the integration of wireless IoT sensors into manufacturing machines, tools, and workpieces to realize use-cases, namely real-time environmental condition monitoring, tracking, and tracing, and inline quality assurance. The environmental condition monitoring for the machine involves integrating a sensor platform to monitor conditions such as power consumption, air flow rate, coolant feed rate, vibration, etc., and send to the edge cloud for processing and analysing the condition. The track and tracing use case involves tracking the workpiece and localizing it on various processes while monitoring the condition of the workpiece, such as vibration, temperature, etc. Both the use cases focus on the features beyond 5G, such as Asset Administration Shell-based data management and low power data transmission using RedCap devices. The third use case, inline quality assurance, explores the time-sensitive networking feature in the 5G network that can be exploited for real-time quality assurance and control. The first two use cases use the factory edge cloud system, where the data is received, analysed, and visualized.

Achievements during the second year

As part of the WP2, several implementations and developments have been made to satisfy the use cases and realize beyond 5G features. The overall architecture required for environmental condition monitoring, tracking, and tracing use cases has been conceptualized and represented as shown in the picture.

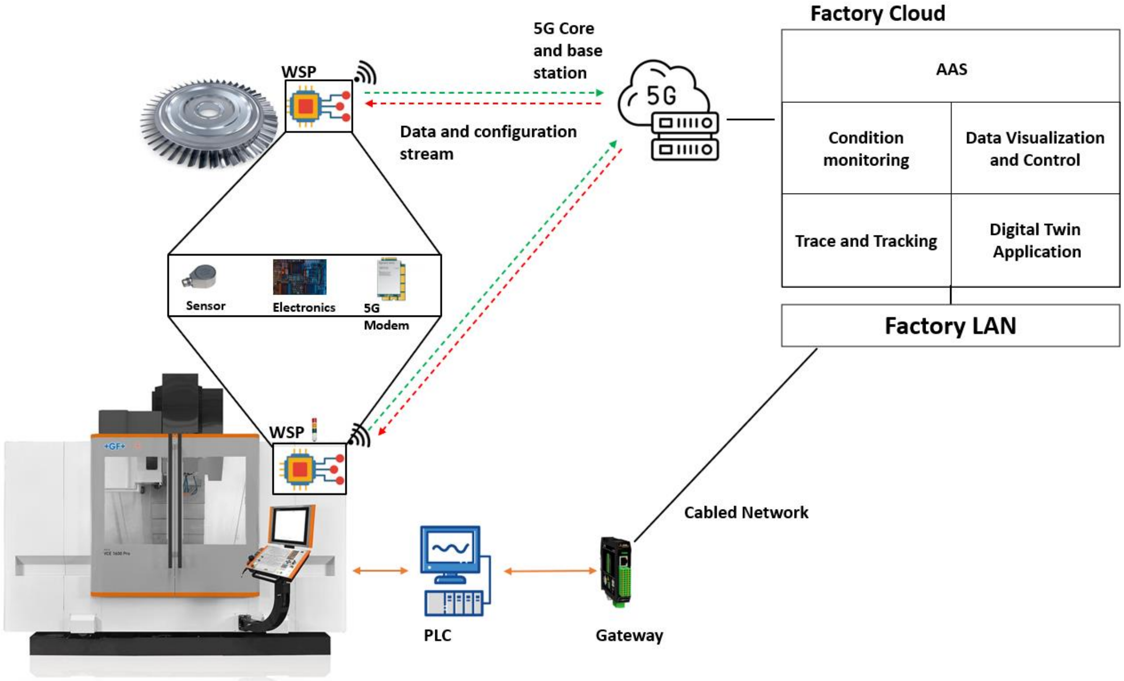

Figure 3-7 : Solution architecture for the 5G use cases "Environmental Condition Monitoring" and "Track & Tracing"

To support the architecture, the wireless sensor platform hardware that meets the requirements of the usecases, are designed and developed by Marposs. The hardware architecture and the developed version of the hardware are shown in Figure 3-8 and Figure 3-9 below.

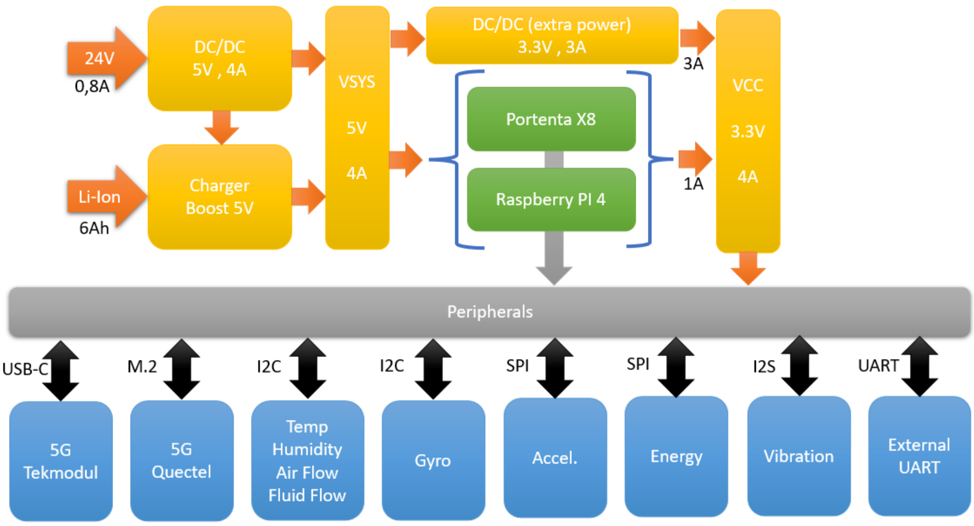

Figure 3-8 : Hardware specification of the wireless sensor platform developed by Marposs

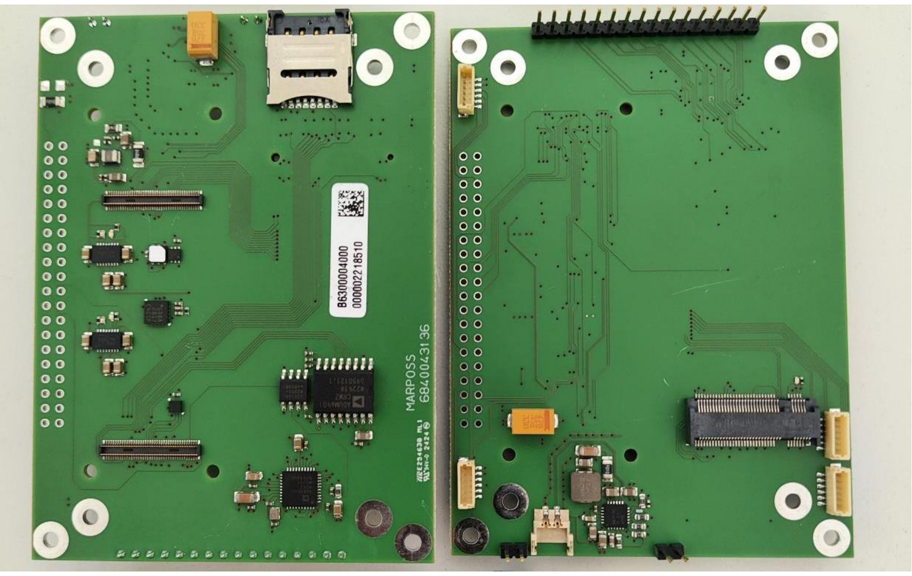

Figure 3-9 : Hardware for wireless sensor platform

The hardware versions have already been tested, and the prototype software for the hardware based on Raspberry PI has been developed and shown on TARGET-X open day. The software is currently being optimized to meet the use case requirements. In addition, Marposs developed an energy monitoring box, see Figure 3-10, based on the above hardware that can be installed in the milling machine and sends the data to the cloud over the 5G module developed by Fivecomm.

Figure 3-10 : TARGET-X Energy monitoring box.

The benefits and requirement of the AAS for wireless sensor platform hardware have been discussed to support the hardware and contribute to the beyond 5G features. This model of sensor hardware can be used to enhance the performance of the hardware and end application, as well as supporting features such as dynamic reconfiguration, sensor data interpretation, device management, etc.

RedCap features have been introduced to the IPT indoor network for the low-power transmission required for the wireless sensor platform. The first RedCap modules have already been tested, and further tests are currently being carried out in the IPT indoor network.

Several measurements, such as Frame Replication and Elimination for Reliability (FRER), have been carried out on the 5G URLLC test bed with TSN and the standard 5G network for the use case of inline quality assurance. The results are compiled and are being submitted as a journal paper. For more information regarding the use cases and the developments, deliverable 2.4 has been submitted.

Highlights from FSTP projects

The FSTP project 5GProMain and Bilen-5G successfully finished phase 2, and their implementation was done and tested in Fraunhofer IPT. Their work has been presented as part of the TARGET-X Open Day. Bilen-5G and 5GProMain focus on the Asset administration shell for asset management and IoT devices, enabling seamless integration and interoperability while providing abstraction from the core of the AAS. The project Astreo-Energy-5G has applied for an extension and has already finished the hardware for the energy meters and will soon be tested in the Fraunhofer IPT 5G network.

Next steps

The following steps involve developing the cloud infrastructure represented in the solution architecture. The initial discussions are done, and the developmental efforts have started. There was some potential for optimization for the sensor hardware, and Marposs is already developing the second version. The software for the sensor hardware is in development and developed according to the data model developed in parallel with Marposs and Fraunhofer IPT.

The localization feature needed for the track and tracing use-case is initially planned over Bluetooth Low Energy (BLE). The necessary architectures and algorithms are researched, and the necessary modules are integrated into the hardware. The evaluation of the algorithms is in development and is expected to be finished by the first quarter of 2025.

3.3 Robotics testbed

Building on the achievements of the first year, the Robotics testbed in WP2 advanced the edge-controlled automation use case with mobile manipulation. The primary objective for the second year of the robotics stream in WP2 was to implement the wireless edge-controlled robotics use case utilizing 5G NSA networks, as documented in D2.3 [TAR24-D23]. Key efforts centred on developing a Robot Operating System 2 (ROS 2)-based software stack to support tasks such as mapping, localization, motion & path planning, perception, and dynamic task execution. To address the robot's limited onboard processing capacity, edge computing was leveraged to offload computationally intensive processes like Simultaneous Localization and Mapping (SLAM), motion and path planning, simulation and object detection to a high-performance edge server. Refinements to 5G communication addressed network limitations, including packet loss and bandwidth constraints, aiming to improve real-time data exchange between the robot and edge server. These enhancements were intended to support the reliable execution of pick-and-place operations for battery packs within the WZL testbed's NSA network, as showed in the Figure below.

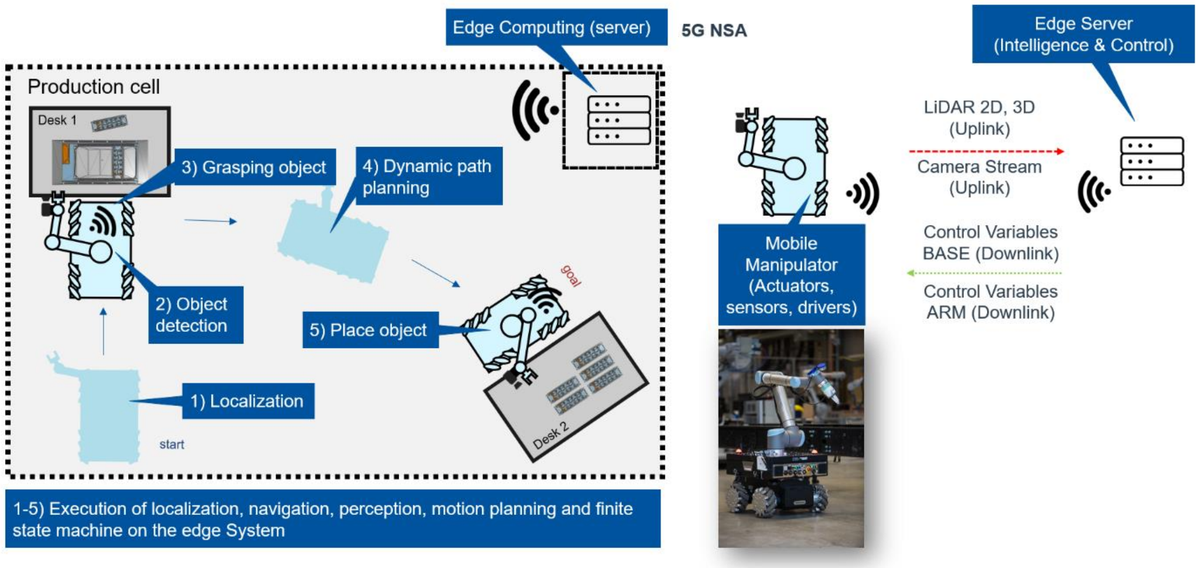

Figure 3-11: Figure 3.11: Execution of localization, navigation, perception, and motion planning with edge computing on the local server. Source: [TAR23-D23, TAR24-D2.3].

Achievements during the second year

During the second year of the TARGET-X project, substantial progress was made in implementing the edge-controlled automation use case with mobile manipulation. These efforts aimed to address the challenges of dynamic industrial environments while leveraging 5G connectivity and edge computing to support high-performance robotic applications, as presented in detail in D2.3 [TAR24-D2.3]. The achievements during this period are categorized as follows:

Technical Advancements

The development of a comprehensive ROS2-based software stack formed the foundation for the system's functionality. This stack enabled essential tasks such as mapping, localization, motion and path planning, perception, and dynamic task execution, as shown on the left-hand side of Figure 3-12. Key highlights include:

- **Edge Computing for Task Offloading**: Due to the robot's limited onboard processing capacity, computationally intensive tasks such as Simultaneous Localization and Mapping (SLAM), navigation (path planning), motion planning of the arm, perception, and simulation were offloaded to a high-performance edge server. The edge server managed the intelligence and processing of sensor data, including high-bandwidth inputs from (2D & 3D) LiDARs and cameras sent via the uplink.
- **Real-Time Operation**: The edge server's powerful architecture ensured low-latency, reliable processing, enabling the edge controlled of the mobile manipulators robot to safely detect objects, plan paths, and avoid collisions with humans or static and dynamic obstacles.
- **Simulation and Validation**: NVIDIA Isaac-Sim was utilized to simulate the entire system and validate the software stack under controlled conditions. This reduced deployment risks by ensuring robustness in the testbed environment.

Integration of 5G NSA networks: Addressing the limitations of traditional wireless technologies, the system integrated 5G NSA networks to ensure reliable real-time communication, as shown on the left-hand side of Figure 3-12. Key improvements included:

- Refined uplink (sensor data transmission from the robot to the edge server) and downlink (control commands sent back to the robot) pipelines minimized packet loss and ensured data reliability and low latency, critical for safe and effective operation.
- The utilization of 5G NR positioning enhances the global localization capabilities, reducing dependence on LiDAR for large-scale positioning tasks. This approach maintained precision while lowering hardware costs and improving operational efficiency.

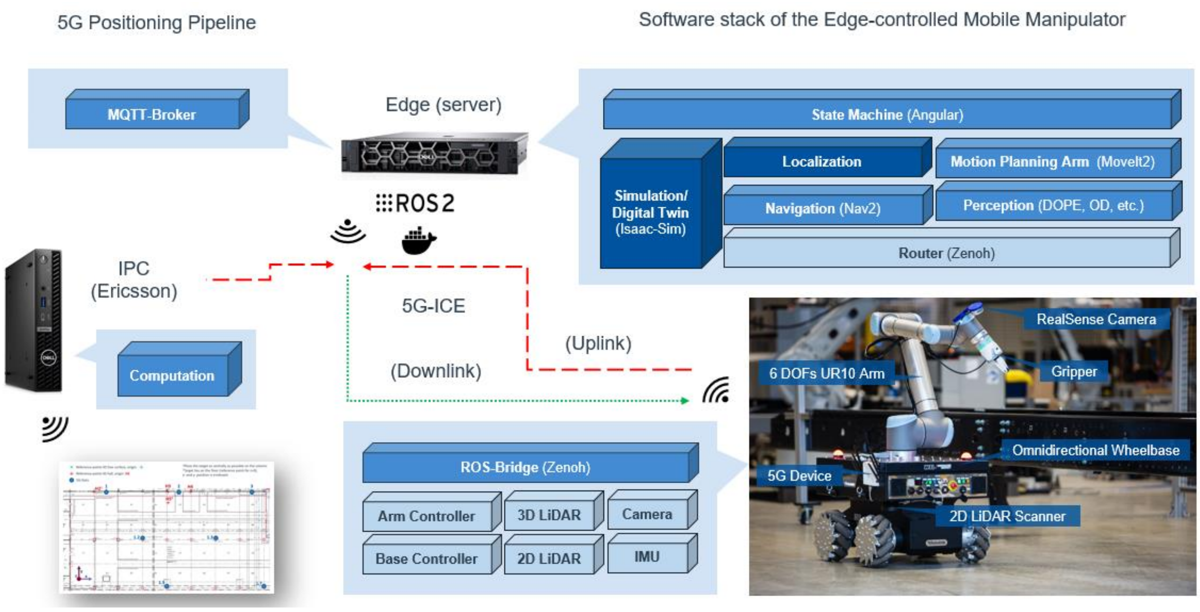

Figure 3-12: Architecture of the edge-controlled automation with mobile manipulation. On the left is the 5G Positioning Pipeline. On the right is the software stack for edge-controlled mobile manipulation [TAR24-D2.3].

Use Case Implementation

The primary use case focused on automating the pick-and-place operation of battery packs, a common task in industrial settings. The workflow involved:

- Localization and navigation: Using 5G NR positioning for global localization and LiDAR for finer localization, the robot accurately identified its position and planned efficient paths to its target, utilizing Nav2.
- Perception and motion planning: The perception system, powered by FoundationPose, detected battery packs and estimated their poses, while the MoveIt2 framework planned collision-free trajectories for the robotic arm.
- Task execution: All tasks, from grasping the battery packs to transporting and placing them at designated locations, were controlled through edge-based computation. The low-latency communication enabled safe and reliable task execution in real-time, that is, within a time frame that meets operational demands without noticeable delays, ensuring smooth operation and safety in dynamic environments.

These advancements demonstrated the feasibility of edge-controlled robotics in a manufacturing environment, showcasing adaptability to dynamic conditions while prioritizing safety and efficiency.

Collaboration

Collaboration with WP6 and Ericsson will facilitate benchmarking of 5G NR positioning against traditional LiDAR-based localization, validating its suitability for hybrid systems, which will be presented in the validation phase (D2.5). Three FSTP-funded projects were mentored, contributing new insights into the integration of 5G technologies in robotics.

Performance Evaluation

Latency and reliability: The 5G network demonstrated significant reductions in latency and improved packet delivery rates, essential for real-time edge-controlled operations.

Safety-critical operations: Reliable data transmission and low latency were especially critical for tasks such as object detection and collision avoidance, ensuring safe interaction with humans and dynamic objects.

Localization accuracy: The 5G NR positioning system currently achieves an accuracy of approximately 1 meter, which, while less precise than LiDAR systems (1–3 cm), presents significant potential in extended manufacturing shop floors. LiDAR systems, with practical ranges of 100–250 meters, can face limitations in larger environments. In such scenarios, 5G positioning demonstrates promise as a scalable solution, particularly when combined with hybrid sensor fusion strategies. By integrating 5G NR for global localization and LiDAR for fine-grained positioning, the system supports precise navigation and task execution across diverse manufacturing settings.

Highlights from FSTP projects

The first open call focused on testing 5G technologies in edge robotics applications. All three projects successfully completed their third milestone and concluded their mentoring phase. Below are the key highlights:

- SBPath-5G. Objective: Testing 5G with a public provider. Challenges: Raised discussions on assessment with the WP1 framework, which were eventually discarded.
- Li-Disarm:AI. Objective: Testing 5G in collaboration with another research partner.
- CoRoCa. Objective: Scheduled 5G connection tests at RWTH-WZL during CW31 2024. Similar to SBPath-5G, assessment discussions using WP1 framework were raised and later discarded.

The second open call includes six projects, all of which have successfully completed their first milestone (Initial Milestone Plan - IMP) and are currently progressing through the second stage. The mentoring phase remains ongoing, and the projects address the expected topics with improved alignment, particularly in robotics integration (ROS) and communication technologies.

- MARS-Mobile Autonomous Robotic. Topic: Large-scale Objects 3D Scan with Mobile Manipulators. 5G connection tests will be conducted at RWTH-WZL.
- ROS2-BANDIT. Topic: ROS2 Topic Sniffer for Bandwidth Management in Wireless 5G/6G Networks. Tests of their solution will be conducted with their own 5G system.
- MM-IA. Topic: Assembly of Flexible Components with Mobile Manipulators.
- Ros6GBUSBridge. Topic: Integration of Ethernet Bus Protocols (ProfiNet, EtherCAT, CC-Link) with ROS2 on Embedded Systems. 5G connection tests will be conducted at RWTH-WZL.
- GRiSP.io ROS2 Topic Sniffer. Topic: ROS2 Topic Sniffer for Bandwidth Management in Wireless 5G/6G Networks.
- ROS2 on 5G Embedded Systems. Topic: Integration of Ethernet Bus Protocols (ProfiNet, EtherCAT, CC-Link) with ROS2 on Embedded Systems.

The second open call projects show significant improvement in addressing the expected topics compared to the first. They demonstrate stronger alignment with robotics (ROS) integration and communication technologies. Additionally, several FSTP projects facilitated bidirectional knowledge exchange, providing valuable insights for both mentors and beneficiaries.

Next steps

Looking ahead, the robotics testbed will prioritize the following:

1. Further optimization of the 5G NR positioning pipeline to achieve greater accuracy and reliability, particularly in reducing reliance on LiDAR for global localization tasks.
2. Enhancing the ROS2-based software stack with advanced algorithms for perception and motion planning, including adaptive capabilities for dynamic environments.
3. Conducting extensive performance evaluations under varying industrial conditions to validate system robustness and scalability.
4. Supporting and integrating outcomes from the mentored FSTP projects to further enhance the testbed's capabilities.

3.4 Automotive testbed

In the automotive testbed, the focus is on deploying tools and mechanisms that facilitate cooperative perception, enable the creation of automotive digital twins, and increase safety in tele-operated driving by integrating Quality of Service (QoS) prediction. The main objective is to evaluate the performance of these automotive use cases using 5G networks in IDIADA Connected Vehicle Hub (CVH) or IDIADA testbed (Figure 3-13). The testbed includes a 5G NSA network (it also includes 2G/3G/4G networks), an edge computing facility, a hyperscaler public cloud, and connected vehicles.

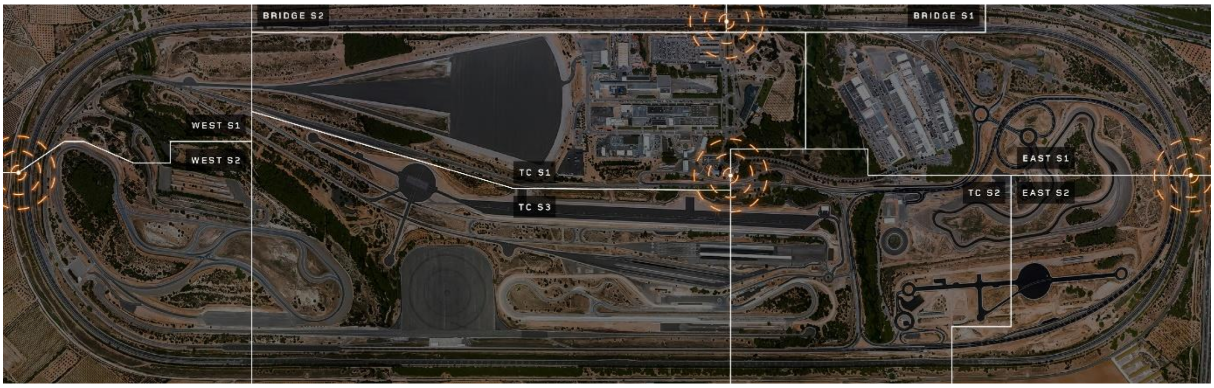

Figure 3-13 IDIADA Connected Vehicle Hub - Technologies.

Achievements during the second year

In the second year of the project, the objective was to develop prototypes for the three use cases and the related automotive toolsets. In addition, off the shelves and TARGET-X customized measurement tools were used to collect real life service and network KPIs in IDIADA CVH. Finally, the possibility of extending the compute continuum was investigated and use cases where it can be beneficial were identified. To do so, weekly and bi-weekly meetings, in addition to a workshop in Barcelona were held. The description of the toolsets and the preliminary results of network and service Key Performance Indicators (KPIs) have been documented in Deliverable D4.2 [TAR24-D4.2]. The customized measurement tools and the extended compute continuum will be described in the deliverable D4.3 next year [TAR25-D43]. Finally, the work on the definition of the testcases for the final demonstration started and different testcases were identified. In particular, the testcases of predictive QoS for Tele-operated Driving (ToD) were selected.

In the cooperative perception use case, vehicles' perception of the environment will be enabled through the exchange of sensor information between vehicles and infrastructure, and among vehicles. Two scenarios have defined for this use case: zero visibility intersection (Figure 3-14 a) and road damaged vehicle (Figure 3-14 b) as described in Deliverable D4.1 [TAR23-D41].

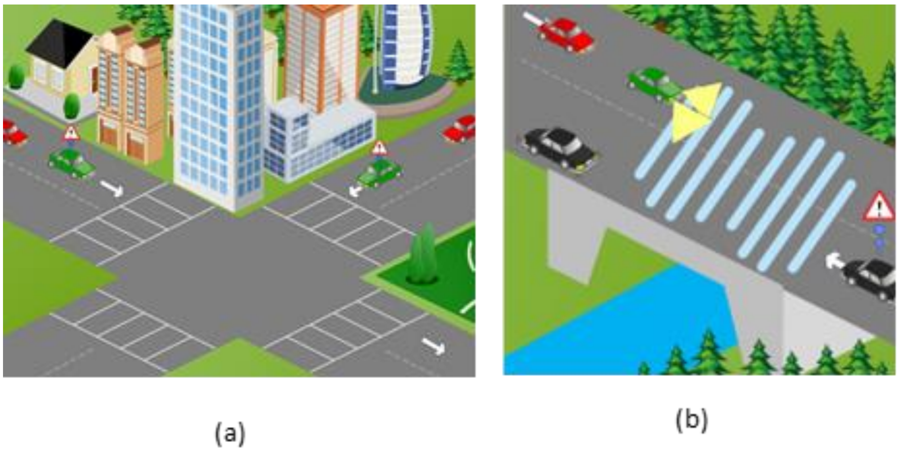

Figure 3-14 Cooperative perception scenarios (a) zero visibility intersection and (b) road damaged vehicle [TAR23-D41].

In both scenarios when a Connected Vehicle (CV) enters a new area, it will communicate with the Cooperative Intelligent Transport System (C-ITS) and exchange information about the road layout, other static details, and other connected vehicles to build a detailed understanding of its environment. The exchange of information is performed using Cooperative Awareness Message (CAM), Decentralized Environmental Notification Message (DENM), and Collective Perception Message (CPM) as shown in Figure 3-15. During the second year, the C-ITS was developed and integrated in the Edge system of IDIADA CVH. In addition, two vehicles (instrumented vehicle, and autonomous vehicle – CAVride) were equipped with 5G modems, GPS, and the Vehicle-to-everything (V2X) protocol stack. First functional evaluation was performed, and all messages were exchanged successfully.

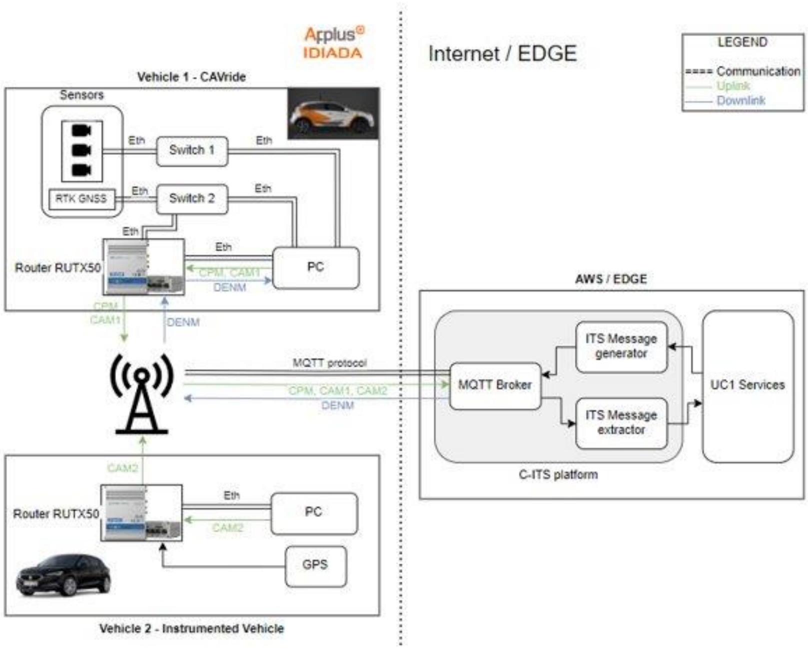

Figure 3-15 Developed C-ITS for the cooperative perception use case.

The objective of the automotive digital twin use case is to create a digital twin to be used in the evaluation of the performance of cooperative perception techniques using simulation before performing real life tests. In the automotive digital twin use case, a virtual replica of the vehicles, road environment, and messages exchanged between the CVs and the C-ITS were created using data collected from scenario 2 of the cooperative perception use case Figure 3-16. In addition, the developed digital twin supports the addition of virtual vehicles to simulate stopped vehicles on the highway. This will be used to simulate cooperative perception solutions in a simulator before performing costly and time-consuming real-life evaluation.

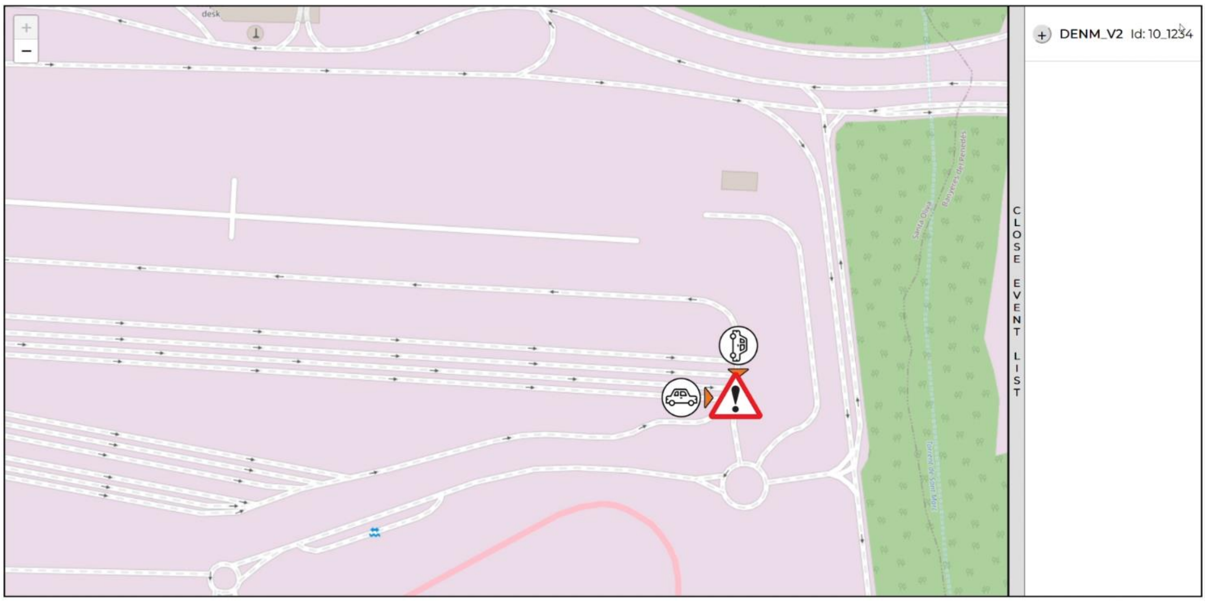

Figure 3-16 A snapshot of the automotive digital twin showing a DENM message.

The objective of the predictive QoS for ToD use case is to demonstrate the importance of accessing network performance information through 5G features to avoid sudden breaking in the case of tele-operated driving. To do so, the team of WP4 developed a tele-operated driving system and toolsets allowing such exchange of information between network and tele-operated driving application Figure 3-17.

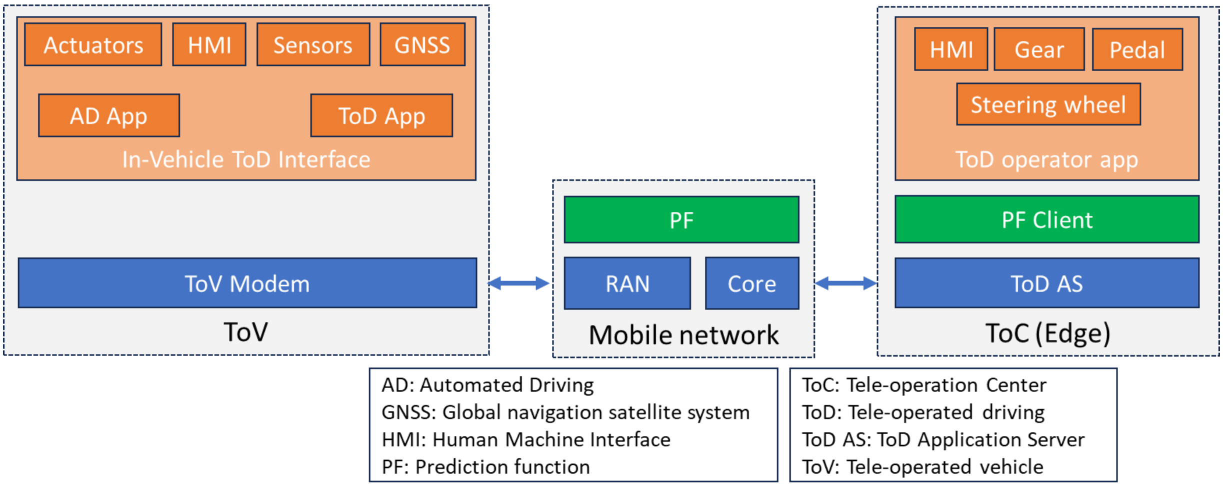

Figure 3-17 Functional architecture of the predictive QoS for ToD use case [TAR24-D4.2].

The developed toolset extract network performance and status data from the network (cell status) and from other connected vehicles (latency, throughput, jitter, signal level, etc.). The collected data is then used by the toolset to assess if the current cell or surrounding cells has a performance problem (not enough throughput or long latency) and notify the Tele-operation Center (ToC) about this issue so that the remote driver can take the decision of breaking or rerouting with enough time ahead of the problem. In real life this will allow the remote driver to avoid areas with bad coverage, which can lead to having the Tele-operated vehicle (ToV) stuck in the middle of a road.

Furthermore, the team of WP4 developed a measurement tool to evaluate network performance through KPIs such as latency, throughput, and signal level. In addition, a service performance KPI tool was developed to measure service KPIs such as one way latency in uplink and downlink, data rate, throughput, jitter, etc.

Finally, several use cases were discussed to study the feasibility of extended cloud continuum. These use cases include cooperative perception, dynamic measurement tools, and voice recognition. In addition, we are having discussions with one of the FSTP projects (Impact-XG) to assess the possibility of integrating such a concept in their project. The idea here is to integrate a simple orchestrator that can switch the deployment of an application between the CV system or the edge system considering the goodness of the network connectivity and keeping in mind the energy consumption in the vehicle.

Highlights from FSTP projects

Seven FSTP projects were finalized in the second year of TARGET-X. These projects are Demeter, RTR, SPARTA, V-STREAM, HybridCAVs, CO-PARKNET, and Dyno Safe. The topics covered included Digital twins' generation methodology for road safety, API deployment to abstract connectivity and data collection process for automotive applications, Remote supervision for Autonomous Driving, Vehicle platooning, connected ambulance, Cooperative perception for connected and automated vehicles, and Dynamic Operational Design Domain (Dynamic ODD) according to network conditions.

In summary, all projects achieved their declared objectives and their demos were successful. Some of the interesting conclusions and challenges faced by these projects are summarized below:

- Early 5G devices, including the Xiaomi 13 DS 5G and iPhone 14 Pro 5G, may still face challenges with battery life and heat management when connected to 5G networks.
- In one of the projects that was demonstrated in public roads, one challenge was the bad coverage inside tunnels, which will be a serious challenge in deploying 5G networks and beyond and guarantee service continuity all over the roads.
- Not all 5G user equipment support the testing band N77 although their datasheet claims it.
- Conducting throughput tests on public networks can be very expensive. Signal strength measurements allow a first and good estimate on network performance regarding potential throughput. For 5G NSA, the measured 4G anchor band typically provides insights about 5G performance, as cells are typically collocated.
- One of the participants in the open call selected a technology whose classification as "true 5G" was uncertain at the time of the project. The technology in question, 5G NB-IoT, sparked debate due to its characteristics: while it is compatible with 5G, many argue it is closer to 4G/LTE than to 5G. As a result, it was decided to explore alternative approaches.

Next steps

The ongoing work in the second year was focused on the design and deployment of the three use cases and the development of the measurement tools. In the next year, four main activities will be the focus of the WP4 team:

- Finalizing the test cases for the three use cases and evaluate the latter through the identified KPIs
- Investigate more on the possibility of cloud computing extension to end users
- Monitor the six FSTP projects of the second open call
- Identify potential requirements/recommendations for the design of future mobile networks to enable efficient deployment of connected vehicles and related applications.

3.5 Construction testbed

The main goal of WP5 is the real-time aggregation of on-site information by exploiting the capabilities of 5G/6G technologies to enable the reclaiming of building materials and building elements in controlled deconstruction processes. Under this scope the following objectives are being pursued:

1. Real-Time process monitoring e.g., 3D-visual feedback and energy usage.
2. Development of an adaptive deconstruction process using robots and real-time on-site information to deconstruct the experimental setup in a controlled way.
3. Deployment of an experimental setup for the developed deconstruction process.

Figure 3-18 Bird view of the construction testbed.

Achievements during the second year

During the second year of the project, the activities in WP5 focused on the further development and prototypical implementation of the use cases on the construction test bed. To progress further towards full 5G integration in the use cases, the team addressed network limitations, including packet loss and bandwidth constraints, with the aim of improving real-time data exchange between robot and edge server, robot and operator, and robot to robot.

To set a realistic basis and starting situation for the deployment of the 5G enabled deconstruction process, a demonstrator structure was designed and planned together with some of the beneficiaries of the first open call. The design and planning of the multi-material demonstrator structure are based on cradle-to-cradle principles. This design decision implies that all connections between individual elements or structural groups are detachable so that the elements can be dismantled non-destructively. Hence, from a design point of view, the prerequisites are in place for the reclaiming of building materials and building elements through deconstruction.

To ensure interoperability of the digital model of the demonstrator structure among the different stakeholders, the beneficiaries of the first open call and their mentors agreed on using the IFC format as exchange format for all digital building models. For further use in the WP5 use cases, the individual IFC models of the beneficiaries were converted to linked building data. However, inconsistencies in the property naming during export from design software hindered the data model interoperability. To address this shortcoming, the WP5 team proposed a method to unify properties when converting IFC-formatted building models into semantic web formats and to facilitate sharing user-defined and software-specific property mappings. The findings were presented at the LDAC2024 [ORA24]. With the proposed method, inconsistencies in the data due to model export from different software vendors were administered and controlled. To facilitate future collaborations, it was recommended that the BuildingSMART data dictionary definitions for RDF property mapping be used.

About the construction machines that are to be used in the automated deconstruction process, however, there are limitations in terms of movement precision, size and weight of individual components that can be handled by the machines. Another limitation concerns the location of the elements within the demonstrator to be reached safely by the machine. In addition, there are structural dependencies between individual building elements and modules, so that not every building element that fits to the capabilities of the deconstruction machine can be dismantled without first removing other parts of the demonstrator. For the available machines' capabilities, the WP5 team decided to study the deconstruction of a steel beam from the demonstrator structure that was built by the FSTP partners as an exemplary case. It is an HEB120 beam that weighs approximately 50kg. To safely handle the steel beam during the deconstruction process, a magnetic end effector, as shown in Figure 3-19, is designed specifically to grip an H-shaped steel beam. It features four magnetic grippers, all controlled via MQTT. The end effector's shape and angles are tailored to securely hold the steel beam's profile. The upper grippers make contact with the beam's outer sides, while the lower grippers grip the inner sides, ensuring a firm and reliable hold.

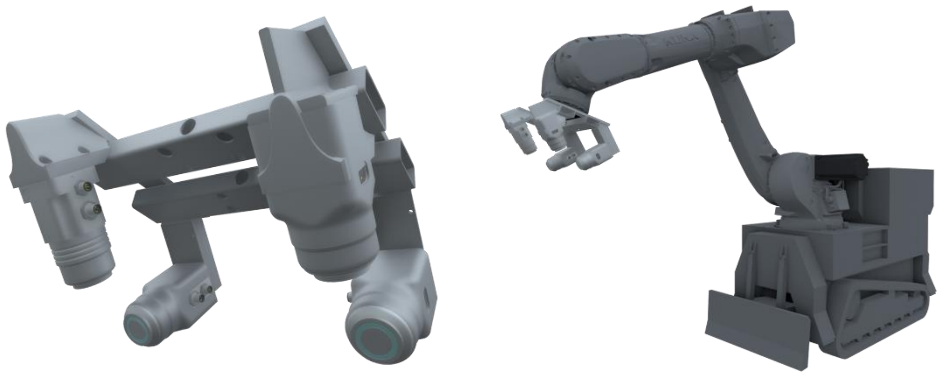

Figure 3-19 Left: A close-up rendering of the magnetic end effector. Right: The end effector mounted onto the deconstruction robot.

In relation to the objective of the development of an adaptive deconstruction process using robots and real-time on-site information, the paper "Development of an adaptive deconstruction process using robots and real-time on-site information" [WU24] was presented at this year's ISARC conference in May. In the following, the described framework was extended by a connection to a blazegraph[1] triple store. The triple store contains the linked building data model of the demonstrator. Querying SPARQL results from Unity to pull data from the triple store was successful. Moreover, the sequential construction of the demonstrator was included in the linked data model. Thus, objects can be visualized in XR according to construction sequence given by the manufacturer. was presented at this year's ISARC conference in May. In the following, the described framework was extended by a connection to a blazegraph . The triple store contains the linked building data model of the demonstrator. Querying SPARQL results from Unity to pull data from the triple store was successful. Moreover, the sequential construction of the demonstrator was included in the linked data model. Thus, objects can be visualized in extended reality (XR) according to construction sequence given by the manufacturer.

Besides that, a communication infrastructure between ROS1 and ROS2 via ROS1_bridge was created to be able to connect the adaptive path planning framework for ROS2 also to ROS1 based machines. Likewise, applications can cope with the generation change of the robot operating system ROS and integrate automated machinery from previous projects into the unified framework. The generation change in the robot operating system from the first to the second generation also causes the need for a dockerization of the setup since ROS1 requires the operation system Ubuntu 18.04 whereas ROS2 requires Ubuntu 22.04. The framework is then extended to support MQTT protocol using the MQTT2ROS package.

With regards to the XR assistant for deconstruction planning, it was integrated into the deconstruction process as preliminary step that takes place before the automated process starts. The operator or any worker can visualize the geometries and building element information using the XR application via 5G connection to the 5G edge server. The app works such that the data is pulled from the triple store and it is relayed to the operator for deconstruction. Through the apps' interface the operator can request additional information about the building elements such as internal geometries of wiring or connectors and integrate this knowledge into the robotic path planning for the deconstruction process.

For the automated deconstruction process, the machine/robot with markers for deconstruction is deployed, the markers are used to localize the coordinates of the machine and the building elements. Using the XR application, the operator can then choose the building elements that are to be deconstructed and simulate the motion of the articulated arms to the desired position. Once the simulation is done, the operator can confirm the path taken in the simulation and move the actual machine to the desired position for gripping.

Lastly, the basic ideas for a safety assistance concept for automated construction machinery were presented at the RobArch 2024 conference [KIR24] and afterwards adapted for the deconstruction process. The following developments will address enhancing the modelling of dynamic machine workspaces and machine-to-machine communication.

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https://blazegraph.com/

A detailed technical description of the prototypical use case deployment is contained in deliverable D5.2 [TAR24-D5.2].

Highlights from FSTP projects

As part of the first open call, the ReStage multi-material demonstrator was set up on the construction testbed during July and August 2024. To build the structure, some of the beneficiaries had teamed up to demonstrate their individual 5G-related use cases on a joint structure. These were the projects Demon, LesMiro and Data_Exchange. In addition, a sustainable solar power supply was provided by the Remocontrol project during the construction works by which construction machines and tools could be powered. The TokenMe 5G project was able to show how their solution can contribute to more safety and predictability on construction sites. All beneficiaries also took part in the RWTH Open Campus Event and the TARGET-X Open Day which took place co-locatedly in Aachen on September 17, 2024.

Figure 3-20 Construction works on the construction testbed during the setup of the ReStage demonstrator.

Next steps

Ongoing work in the second year will focus on summarising the prototypical developments and deployments of the use cases in deliverable D5.2. Next year the main activities of the WP5 team will be to:

- Finalise, evaluate and refine the use case setups and deployments

- evaluate the use cases against the identified KPIs/KVIs.
- Mentor the twelve FSTP projects related to the design topics of the second open call.
- Identify potential requirements/recommendations for the design of future mobile networks to enable efficient deployment of (automated) setup and deconstruction and related applications.

4 Technology evolution beyond 5G

4.1 Achievements during the second year

Introduction

In the first year, special attention was given to the introduction of the set of technology bricks that we agreed as consortium to be and remain relevant in the evolution of 5G technology towards 6G. In the second year of execution, we have been evaluating the introduced bricks by performing dedicated testing of introduced functionality towards technology KPIs, such as latency, throughput, and coverage.

Realtime ecosystem

5G communication shows packet delay variations, which are undesired for some of the applications. The packet delay variations come from several factors including the wireless channel disturbances causing unsuccessful decoding of the packets at the receiver, which need to be retransmitted by the cellular communication protocol stack, processing delays at the terminal device as well as at the network side, protocol signalling overhead, alignment delays of a packet with the transmit opportunity, etc. [ANS22]

We have investigated the use of IEEE 802.1 CB scheme to enhance resilience of 5G communication and reduce packet delay variations. IEEE 802.1 CB scheme is also known as Frame Replication and Elimination for Reliability (FRER) [IEEE17-802-1cb]]. As shown in the figure below, FRER sends frames after replication at the ingress point on several disjoint paths. The elimination function at the egress endpoint combines the replica copies of a frame and deletes any extra (redundant) frames. So, FRER is a "per-frame" 1+n redundancy function. There is no need for failure detection or switchover mechanisms like in other redundancy schemes. Although, the goal for FRER is to achieve zero loss, when used in mobile networks, this function also has a side effect on latency reduction until multiple paths are active. While FRER picks up the fastest replicated copy of the packet, the overall side effect of using redundant paths is effective reduction of the overall latency. This is illustrated in the figure below on the right, where the compound latency distribution indicates lower latency and smaller jitters compared to any individual single path.

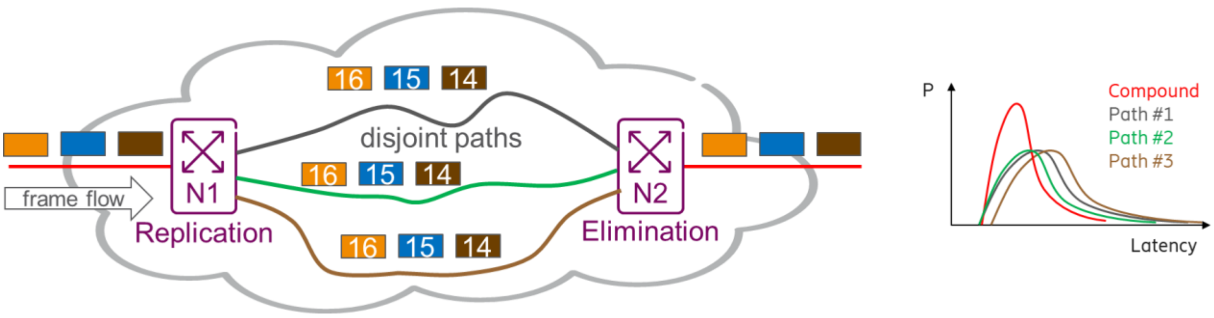

Figure 4-1: Illustration of the FRER scheme with replication and elimination operations carried out at the ingress and egress points, respectively. The side effect of FRER on latency reduction is illustrated on the right

In our 5G integration tests with FRER, we have used commercially available TSN switches as well as the 5G non-public networks and 5G UEs. We have used both replicated paths on the same 5G system using multiple 5G UEs as well as multiple 5G systems. The tests have been conducted in a real production environment at the Fraunhofer IPT shopfloor with Ericsson deployed 5G systems in the 3.7-3.8 GHz local industry spectrum as well as the 26 GHz spectrum. Our tests confirm the benefits of using FRER for enhancing reliability of 5G communication. For instance, the use of two UEs in the same 5G system operating in the 3.7-3.8 GHz spectrum band has shown up to 20% latency reduction for the 99.99th percentile of latency distribution compared to that of the single path. Similarly, the use of two redundant paths with redundant 5G systems operating in the 3.7-3.8 GHz frequency range and 26 GHz range have shown up to 24% of latency reduction for the 99.99th percentile value compared to a single path. The use of FRER with redundant paths has shown a clear advantage when the mmWave transmissions are (heavily) blocked in an industrial deployment scenario due to a moving machine part or a mobile device (e.g., Autonomous Mobile Robot going behind a metal chamber or cabinet).

mmWave spectrum

Millimeter wave (mmWave) deployments, in the 5G frequency range 2 (FR2), offer several features and benefits in industrial environments. For instance, 5G FR2 deployments feature high capacity and data rates, capable to serve industrial use cases at scale with extremely high throughput both in uplink and downlink. In this regard, we have evaluated the throughput performance of the 5G NSA mmWave system at Fraunhofer IPT under different channel conditions and time division duplexing (TDD) frame structures. Initial performance evaluations have shown that a stable throughput of 3,6 Gbps in downlink (8x100 MHz, TDD pattern 2 with special slot 2) and 1,6 Gbps in uplink (4x100 MHz, TDD pattern 6 with special slot 6) can be achieved.

Another key feature for 5G FR2 systems is the low latency, which can be enhanced thanks to its support to higher subcarrier spacing (SCS) frequencies supported in TDD deployments. In this context, our preliminary results indicate that the latency bound at high percentiles is considerably improved under line-of-sight (LoS) conditions. The measured RTT latency (L3 ping, 16 ms interval, 64 bytes) is 2,8 ms. Nevertheless, it is yet unclear what would be the expected performance of a 5G mmWave system in realistic industrial environments. Metals and machinery can cause significant reflection, scattering, and absorption of mmWave signals. Therefore, we started assessing the throughput and latency performance of the 5G mmWave system under challenging channel conditions by placing devices far away and in non-line-of-sight (NLoS) locations. For this purpose, we acquired the necessary hardware to be able to measure the high throughput and low latency at any location on the shopfloor. In the coming months, we plan to continue systematically evaluating the 5G mmWave system performance and include the key results in the upcoming WP6 deliverable, D6.5.

Beyond the characterization of the 5G mmWave system at Fraunhofer IPT, we continued enhancing the deployment on the shopfloor by installing and deploying a second mmWave cell on the opposite side and aisle of the shopfloor as it can be observed in Figure 4-2.

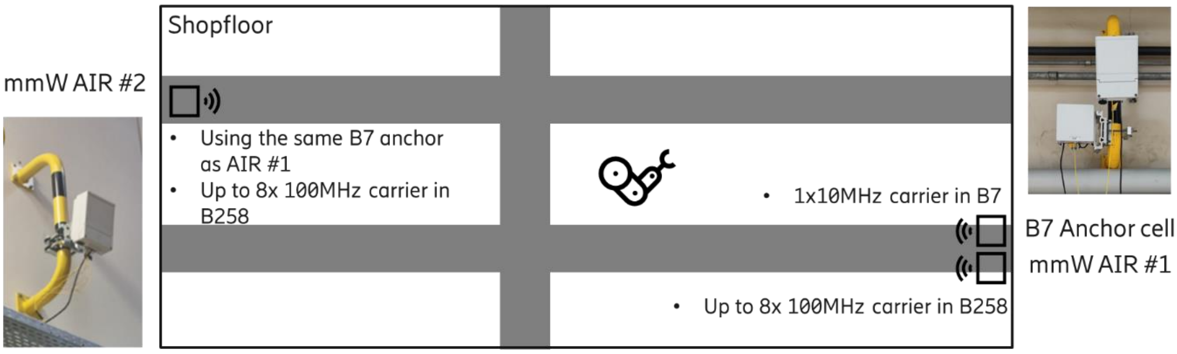

Figure 4-2. Location of the 5G mmWave system at Fraunhofer IPT.

The location of the new mmWave radio (AIR #2) was strategically installed on the opposite corner of the shopfloor where the previous mmWave radio was (AIR #1), thus providing line-of-sight at almost any location on the shopfloor. Even though the two sites are facing against each other, there is no direct line of sight between the two sites. This is due to the tall machinery, shopfloor cranes and building pillars on the shopfloor. From an operational point of view, this means that transmission errors due to interference issues are not likely to cause a relevant performance degradation, even if both sites are operated on the same 800 MHz spectrum. Alternatively, the sites can also be operated on nonoverlapping spectrum with a total of 400 MHz per site. Walktests have shown that a seamless handover between the two sites is working fine when moving the UE from one site coverage area to the other. A reattach or reconfiguration is not required.

The new 5G mmWave deployment is based on an NSA system, with a shared LTE anchor radio and two different NR cells. It allows to further investigate the realistic deployment of 5G mmWave systems in industrial environments, as well as detailed testing when it comes to mobility and handover scenarios between the two sites. In the upcoming months we will investigate the performance of the 5G system when both mmWave cells are active.

Positioning with 5G

The indoor positioning system, deployed at the robotics testbed, was out of operation for part of the year and needed to get some licenses renewed. This process took longer as planned due to unforeseen administrative challenges. Finally, in September, all administrative challenges were resolved, and licenses could successfully be renewed. The positioning system is now being re-calibrated and shall soon be fully available.

In parallel to resolving license issue for the indoor system, we also evaluated solutions to secure more accurate positioning for outdoor use. For outdoor services GNSS with RTK correction is proposed as preferred solution. RTK information can be provided through any Internet connection, which resulted in many different protocols being used. They can be seen as proprietary and/or only supported by a small subset of the ecosystem. We therefore demonstrate in the project the 3GPP standardized solution “LTE Position Protocol (LPP)”. The name is misleading, as it is also standardized and used with 5G and new features are being added in still ongoing standardisation. The end-to-end system was set up initially with PC and then evolved to run on an Cradlepoint/Ericsson 5G Router. Initial measurements conducted in IDIADA and the 5G Campus Europe indicate decimetre-accurate positioning.

Asset administration shell (AAS)

5G NW AAS and 5G UE AAS design are finalized. 5G NW AAS contains network identifier, network performance, device connectivity, positioning, dispersion analytics and device session management submodels with selected submodel elements as data to be managed by the AAS. On the other hand, 5G UE AAS contains equipment, SIM, QoS, positioning, radio and capabilities submodels. These submodels are carefully decided to be included in the AAS design to meet TARGET-X requirements. The implementation of 5G NW AAS is realized using Eclipse BaSyx SDK. Supportive services that consume EP5G and 3GPP APIs are also developed to update submodel element values in 5G NW AAS. For ease of development, mock services for the required EP5G and 3GPP APIs are also developed. This removes testbed dependencies during implementation phase. On the other hand, 5G UE AAS is implemented using AAS Package Explorer as AASX file format, uploaded to the BaSyx Environment and the 5G UE AAS submodel elements are dynamically updated with values from the Fivecomm UE. IPT 5G NW testbed integration of 5G NW AAS and 5G UE AAS is finalized. Further details can be found in Deliverable D6.4 [TAR24-D64].

Reduced capability in 5G – RedCap

The feature is designed to provide a balanced approach between the high-performance capabilities of 5G and the needs of devices that don't require full 5G performance. Generally speaking, RedCap is positioned to address use cases that are today not best served using enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC) or massive machine type communication (mMTC) solutions.

RedCap is helping expand the NR device ecosystem, enabling the growth of even more 5G use cases, and targets specific devices that require moderate data rates, reduced complexity, and lower power consumption compared to full-scale 5G devices. These devices might include wearables, industrial sensors, or smart meters, which don't need the high throughput or ultra-low latency of full 5G capabilities.

By offering a "reduced capability" option, RedCap enables:

- Cost Efficiency: Devices can be less expensive to manufacture because they don't require all the components necessary for full 5G functionality.
- Extended Battery Life: By optimizing the power consumption, devices can operate longer on battery power, which is crucial for IoT applications.
- Simplified Design: Devices are less complex, which can reduce the time to market and improve reliability.

	Data Rate	Latency	Availability/ Reliability	Battery Lifetime	Device Size
Wearables	Reference data rate: DL: 5-50 Mbps UL: 2-5 Mbps	Relaxed	N/A	Up to 1-2 weeks	Compact form factor
Industrial Wireless Sensors	<2Mbps	<100ms	99.99%	At least a few years	N/A
Video Survellance	2-4 Mbps for economic video; 7.5-25 Mbps for high-end video	<500ms	99%-99.9%	N/A	N/A

Table 1: Requirements on RedCap enabled device

The capabilities of a Release 17 RedCap device compared to those of Release 15 NR devices include:

- Bandwidth reduction
- Reducing the maximum number of MIMO layers
- Relaxation of the maximum downlink modulation order

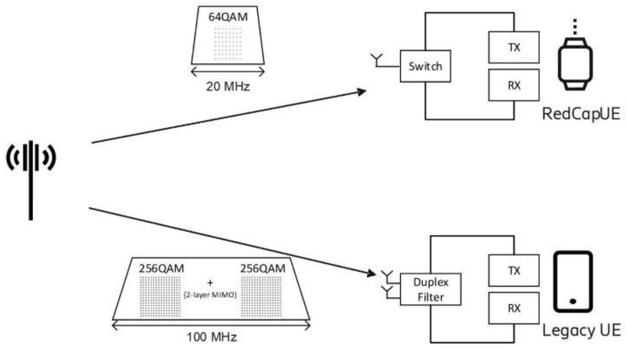

Figure 4-3: Simplified representation of differences between legacy and RedCap UEs

Overall, RedCap is part of the broader strategy to make 5G more versatile and accessible for a wide range of applications, ensuring that it can support not only high-performance devices but also those with more modest requirements.

Given these characteristics, a decision was taken in the WP6 group to introduce RedCap into the testbed at Fraunhofer to allow for exploration with the sensor platform use case. After acquiring the prototype baseband software, we created and loaded the needed configuration files to update the regular midband cell to accept RedCap devices, next to regular devices. First engineering samples of RedCap modules were sourced and tested with the RedCap SA network. Initial testing showed incompatibilities between network and device implementation that were further troubleshooted and are still being worked on by the module provider.

Mapping of technologies and use cases

As we are moving into the final stages of our project, we have revisited our matrix from D6.1 [TAR23-D61] in the face-to-face project meeting at our partner Marposs. A mapping exercise was performed to reconfirm that all technology bricks, as described in D6.2. [TAR23-D62] are incorporated into, at least, 1 vertical to allow for a proper assessment in the final deliverable for work package 6.

The figure below illustrates the outcome of the clustering work we performed with the whole consortium, determining in which of the verticals use case(s) we will validate the technology bricks.

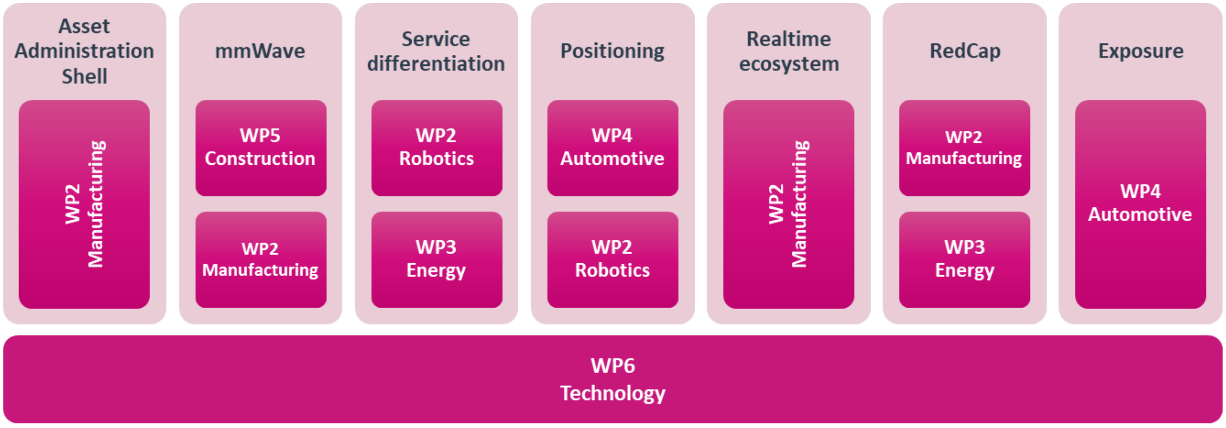

Figure 4-4 Matrix of technology evaluation in verticals

Cyber Security Aspects

When developing innovative solutions for wireless industrial communication, the consideration of cyber security aspects plays an important role, especially regarding the transfer of the developed solutions into industrial practice. For this reason, the aspect of cyber security is also considered within the scope of TARGETX in Task 1.5 focusing on a concept for cyber security. The cyber security task is an overarching task that will be intensified in the final six months of the project, as the increasing technical maturity of the use cases in this project phase enables cyber security aspects to be considered in more detail. So far, discussions regarding the scope and the objectives in the area of cyber security have taken place. As a results, it was decided among the project consortium that the focus will exclusively be on the aspects of wireless data exchange and processes on the edge, in the ROS, etc. will not be considered. The scope of the cyber security aspect is therefore limited exclusively to wireless communication. Furthermore, four guiding questions, that will be answered for each use case have been defined to evaluate how cyber security-related aspects can impact a specific use case:

1) What are the effects if external control is taken over the use case?
2) What are the effects if the privacy of the communication for a use case is invaded?
3) What are the effects if data which is exchanged during use case execution is poisoned?
4) What are the effects if the wireless communication is forced to break down through external attacks?

The answers for these guiding questions will enable a risk assessment of cyber security-related threads for each individual use case. Based on the risk assessment, proactive measures will be derived which are divided into the three categories of prevention, detection, and response. This way, a holistic cybersecurity concept will be developed. This will address an important obstacle which is concerns regarding the secure operation of 5G based use cases for industrial users.

4.2 Highlights from FSTP projects

In WP6, one project was mentored during Open Call round 1. The BenchMotiv project responded to our Golden Unit challenge, a challenge to design a HW platform on which a set of standardized tests can be executed. The goal of the Golden Unit is to have a reference device that can be used to validate other devices in the network under test.

After successful development, the solution was tested in a TARGET-X testbed. A LinkedIn post was released to report on the visit. The results of the project were presented during the TARGET-X Open Day.

During 2024, the selection process for Open Call round 2 was concluded, and 4 project proposals successfully passed all the selection process steps. The 4 projects have responded to 2 challenges, so we have 2 projects working on a same challenge. The mentoring plans have been created by the project teams, supported by mentors for WP6. The projects have now started to work on the development tasks.

Additionally, two FSTP projects accompany the cyber security-related activities and are mentored by WP1. In 5G-SAIIoT, an authentication mechanism for end devices is developed using a 3-layer approach to ensure authentication of end devices on three layers (device layer, network layer, and cloud layer. In SCAX, a solution is developed to detect vulnerabilities using open-source tools on the physical layer. The two projects thus contribute to activities in the prevention category (5G-SAIIoT) and activities in the detection category (SCAX) and thereby accompany the cyber security related tasks of WP1.

4.3 Next steps

In the last phase of the project, increased focus is placed on finalizing the integration of the technology bricks of WP6 with the use cases from WP2 to WP5, to assure that coverage of each of the bricks is given. With the use coverage in place, the applicability evaluation of those bricks in the evolution towards 6G will be measured, disseminated and documented in the final deliverables.

Dissemination is given extra attention in this phase of the project, and WP6 will contribute to white papers and other dissemination activities. The learning we have collected and are still being collected, will be reported to representatives of standardization organizations.

The evaluation of coverage and propagation characteristics of mmWave in indoor industrial environments showed better than expected results, triggering the ambition to also perform mmWave evaluation in the construction testbed. The goal of this activity is to assess how this spectrum can mitigate some of the uplink challenges in the construction use case.

5 Financial support for third parties in TARGET-X

5.1 Achievements during the second year

The objectives in WP7 are to launch and manage two Open Calls along the project to select up to 100 third-parties to feed the verticals use cases of WP 2,3,4,5.

From the 1st of February 2024 the 1st Support Programme was conducted. The Support Programme lasted 7 months and for most of the beneficiaries ended on the 13th of September 2024. 6 projects signed amendments to the SubGrant Agreement and have individual end date for the Support Programme.

In accordance with EC standards and the procedures established in the Grant Agreement, the Selection Committee has validated all documents and meeting minutes for the completed stages of the Support Programme. The payments were processed.

After the 1st Support Programme, all beneficiaries were asked to fill out two surveys:

- The survey to evaluate the technical progress and mentoring services of the FSTP process
- The survey to evaluate the administrative and financial services of the FSTP process

The partial results of survey number 1 are the following:

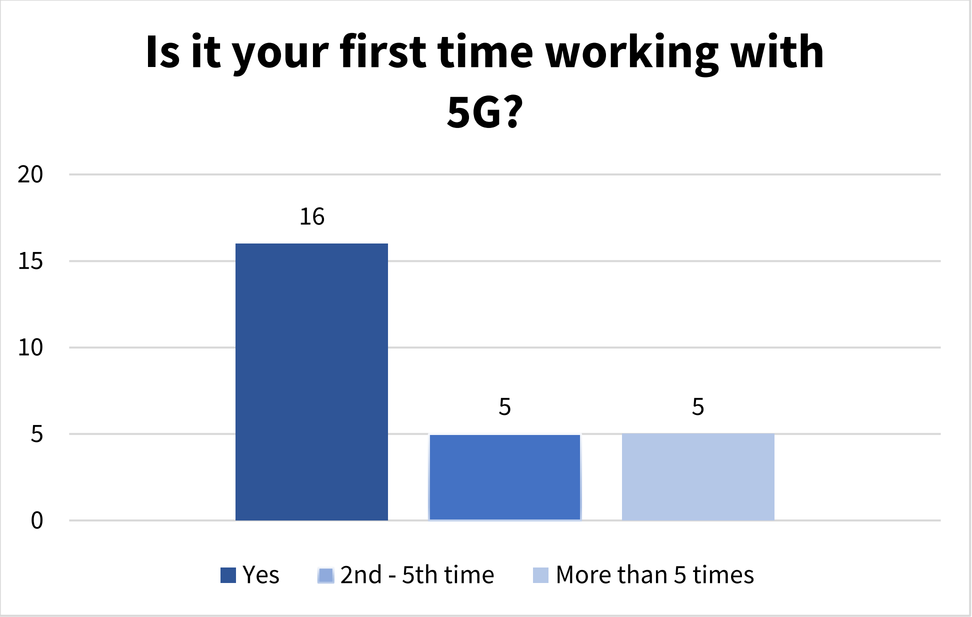

Figure 5-1 – Answers to "Is it your first time working with 5G?"

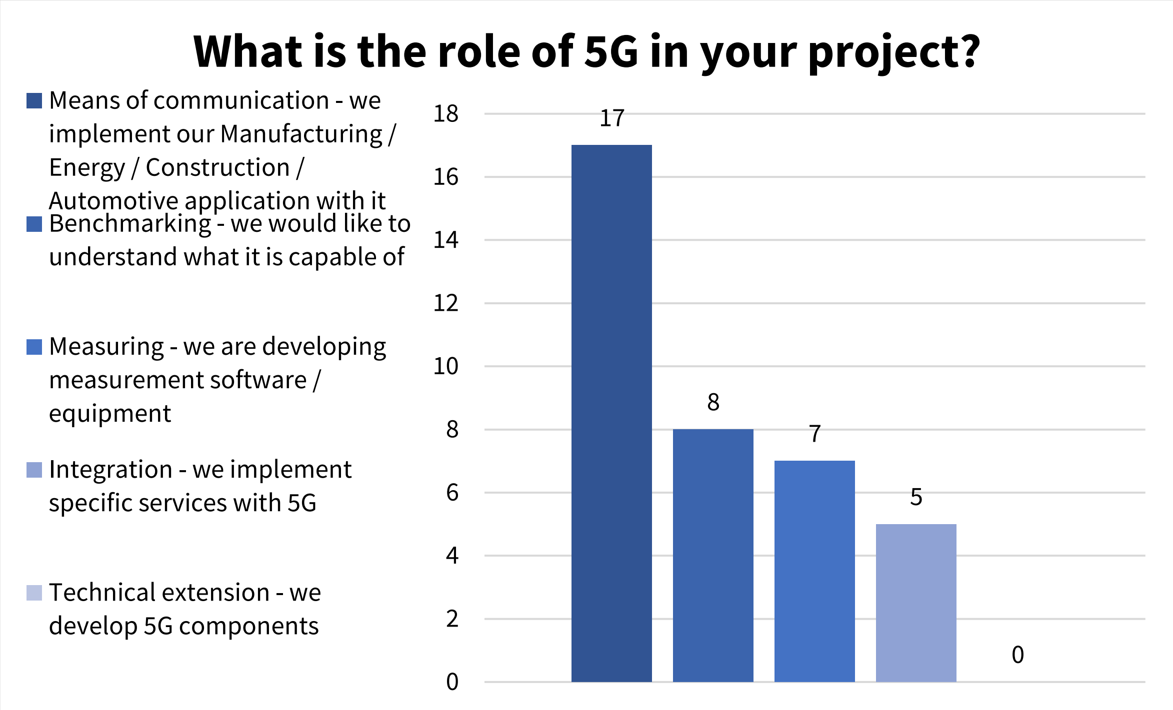

Figure 5-2 - Answers to "What is the role of 5G in your project?"

For most projects, the role of 5G was a means of communication. Also, benchmarking the technology is a relevant part of the projects, as for many of the projects it is the first time working with 5G.

With the support of WP7 Partners, FundingBox prepared the TARGET-X 2nd Open Call:

- Package of Open Call documents:
    a. Guide for Applicants
        i. Annex 1 Topics Description[2]
        ii. Annex 2 Information Clause
    b. Frequently Asked Questions
    c. Open Call Announcement
    d. Application Form
    e. and Guide for Evaluators
- Microsite (https://target-x-2oc.fundingbox.com)
- Helpdesk (https://spaces.fundingbox.com/spaces/iot-community-target-x-helpdesk)

The second Open Call was launched on 6th of December 2023, with the initial deadline on 28th of February 2024. Due to the low number of applications, the TARGET-X Consortium Partner decided to extend the deadline for one week – to the 6th of March 2024. The extension had no impact to the project activities and the timeline.

During the TARGET-X 2nd Open Call the WP7 partners engaged a significant number of applicants through a variety of means, including social media (LinkedIn) posts, newsletters, online and on-site

[2] The topics for the TARGET-X 2nd Open Call were established by the TARGET-X Consortium Partners through collaborative efforts before launch of the Open Call (the 6th of December 2023)

events. Two online events Info Day (14th of December 2023, 12 PM) and 'How to apply?' (18th January, 2024 at 2 PM) webinar was organized via the ZOOM Platform.

159 proposals were submitted in the 2nd Open Call.
The first phase of evaluation process was the Admissibility and Eligibility Check. At this stage, the eligibility criteria were checked against a declaration of honour or self-declarations included in the application form. All submitted proposals passed the phase.

Second phase of the evaluation process was In/Out Scope Screening carried out by the Selection Committee. The Selection Committee reviewed proposals in terms of the general objectives of all proposals assessing the following aspects:

- Scope. The objectives of the proposal must fit within the scope of the TARGET- X project as described in the Guide for Applicants (GfA). In particular, the proposal should directly address one of the topics proposed by the TARGET-X 2nd Open Call.
- European Dimension. The project should have a european dimension.

118 proposals passed this phase.

Next, the proposals were evaluated by external evaluators regarding excellence, impact and implementation. Each proposal was evaluated by the two independent expert. No conflict of interest was indicated at this stage. Each evaluator produced an 'Individual Evaluation Report', the evaluators scored each criterion on a scale from 0 to 5. At the end of this phase the Evalution Consensus Group took place, during all external evaluators agreed on a common position. 70 proposals reach the threshold, which were 3 for individual criteria, and the overall threshold (sum of the three criteria) was 10.

Based on the 'Ranking List' produced by the external evaluators, the Selection Committee with the support of two external experts and the external ethics expert (with voice but without vote) decided, by Consensus, the 'Provisional List of FSTP recipients' and a 'Reserve List'. 40 proposals were pre-selected to take part in the TARGET-X Support Programme.

The last part of the evaluation process was Formal and Ethics Check. One project resigned and the next from the 'Reserved List was taken. One micro-consortium partner was found in financial difficulties and was not eligible, the new entity was proposed by the applicant (micro-consortium leader) and approved by the Selection Committee.

The final number of beneficiaries of the second Open Call is 40 projects (65 entities).

PHASE	TIME	RESPONSIBLE	NUMBER OF PROPOSALS
THE ADMISSIBILITY AND ELIGIBILITY CHECK	6/03/2024	FUNDINGBOX	159 proposals
IN/OUT SCOPE SCREENING	11/03/2024 – 20/03/2024	THE SELECTION COMMITTEE	118 proposals
INDEPENDENT INDIVIDUAL EVALUATION	25/03/2024 – 09/04/2024	THE EXTERNAL EVALUATORS	-

EVALUATION CONSENSUS GROUP	11/04/2024	THE EXTERNAL EVALUATORS	70 proposals
CONSENSUS MEETING	23/04/2024	THE SELECTION COMMITTEE, TWO EXTERNAL EVALUATORS AND ETHICS EXPERTS	40 proposals
ETHICS REVIEW	-	FOUR EXTERNAL ETHICS EXPERTS	-
FORMAL CHECK	24/04/2024–01/06/2024.	FUNDINGBOX	40 proposals

TITLE	TOPICS IN 1st OPEN CALL	PROJECTS SELECTED IN THE 1st OPEN CALL	TOPICS IN 2nd OPEN CALL	PROJECTS SELECTED IN THE 2nd OPEN CALL
METHODOLOGICAL ASSESSMENT FRAMEWORK	2	0	2	-
MANUFACTURING	10	8	12	12
ENERGY	6	6	7	6
AUTOMOTIVE	14	7	3	6
CONSTRUCTION	7	5	13	12
TECHNOLOGY EVOLUTION BEYOND 5G	9	1	7	4
	48	27	44	40

The 2nd Support Programme started on the 1st of October 2024. Each FSTP project has an assigned mentor. The mentor serves as the daily contact for the beneficiary to support them in carrying out the project, particularly with technical issues.

FBA remains available to beneficiaries to address any administrative and financial issues.

The Stage 1 was successfully completed by all the beneficiaries – Individual Mentoring Plans and Mentors Assessments were submitted. The validation process proceeded smoothly, with the Selection Committee validating all documents and meeting minutes. Payments have been processed.

5.2 Next steps

The 2nd Support Programme is ongoing. According to the timeline, after each milestone the validation of the payments will be carried out by the Selection Committee and payments will be made. In total in both Open Calls there are 98 entities. Due to leftovers in FSTP budget, there will be the amendment prepared for assigning € 120 000 for FSTP awards.

6 Dissemination and impact

TARGET-X employs a dedicated work package for communication and dissemination to coordinate the contribution of all project partners working on relating activities and to enable a joint strategy for communication and dissemination to reach a maximum impact of the activities. The objectives of work package 8 are:

1. to maximize the external impact of the project by means of a multi-fold dissemination strategy to provide relevant information to all stakeholders and facilitate market adoption of the project's results.
2. to coordinate the industry-related, strategic dissemination activities of the project towards regulation, standardization, and other forums.

6.1 Achievements during the second year

Figure 6-1: sTARTUp Day Estonia

In the second year of the project, we were successful in pursuing our dissemination goals. The first quarter of the year was marked by the second open call, which was open to interested parties from 6 December 2023 to 6 March 2024. The offer was disseminated through various channels: newsletter, website, social media. To a reach an even bigger audience, partners of the consortium had a booth at a specialized fair for start-ups, sTARTUp Day (25 January 2024, Riga, Estonia), and held a seminar on the offers and requirements of the second open call. Two additional webinars (Q&A sessions) were conducted to facilitate the application process. The second open call was successfully finished with a number of 159 proposals first accepted. To provide relevant information to all stakeholders and facilitate market adoption of the project's results, the consortium partners joined several specialized fairs, conferences and congresses and panels to address audiences in the target industries. To name a few: TSN/A Conference 2024 (1-2 October, Stuttgart, Germany) was joined with the aim to present 5G-FRER test results for an industrial use-case. The study was conducted in the Target-X WP 6 scope. The 20th International Conference on Network and Service Management" (28 - 31 October 2024 in Prague, Czech Republic), was joined to present "Enhanced Positioning Services with Predictions for Smart Factories". For the construction sector, partners joined the "2024 European Conference on Computing in Construction" and presented their findings on "An ontology to enable signal strength estimation for nomadic networks on construction sites". For the automotive vertical, partners contributed to the 6G-IA 5G for CAM Working Group telco and SNS ICE GUIDE webinar, where they presented the work done in TARGET-X to enable automotive applications through 5G. For the Methodological Framework, the project joined a Workshop on KVI /KPI in May 2024 in collaboration with other Stream-D projects.

6.2 EUCNC & 6G Summit

The project has placed a particular focus on participation in the "2024 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)" in Antwerp, Belgium, from 3rd to 6th March 2024. In addition to a booth with a demonstrator on energy sensoring, the project partner i2Cat joined the session: "From 5G to 6G Support for CAM (5G6GCAM)", with focus on "Accelerating the Uptake of 5G for Automotive". We also chaired the special session: "Large Scale Trials and Pilots: Challenges and Opportunities", with focus on the main challenges as well as visions and approaches to sustainability in the large-scale trials.
Partner Neutroon had the opportunity to present the TARGET-X paper "On the TSN and 5G network integration approaches, 5G features proof, advantages and challenges".

Figure 6-2: Panel at EUCNC & 6G Summit

Figure 6-3: Booth at EUCNC & 6G Summit

TARGET-X Open Day

On September 17th 2024 the consortium invited a broad audience to a first public Open Day in Aachen, Germany, to the 5G-Industry Campus Europe, as one of the testbeds. The full-day event gave space to the FSTP-projects to present their research achievements in the project as well as insights to the demos from Robotics, Manufacturing, Construction, Energy and remotely Automotive. We welcomed roughly 80 European visitors from research and industry.

Figure 6-5: TARGET-X Open Day Robotics

Figure 6-4 TARGET-X Open Day Automotive

Figure 6-7: TARGET-X Open Day Manufacturing

Figure 6-6: TARGET-X Open Day Construction

In October 2024, the project manager joined the 5G Techritory event in Riga, Latvia, and participated in the co-creation event: "From 5G to 6G: Leveraging Key Trends and 5G Evolution to Shape 6G for Vertical Sectors." Besides, the project manager participated in a podcast recording focused on Stream D projects, with insights into "Lessons Learned from Conducting Vertical Experiments in 5G/6G Testbeds. Link to the podcast: https://rss.com/podcasts/snsice/1782028/.

Figure 6-8 Janina Gauß at 5G Techritory Panel

6.3 Statistics

The website continues to be used for communication about the project and is very frequently visited. The latest publications, videos and deliverables are uploaded and linked on the project website: PUBLICATIONS - TARGET-X. The website received an average of 5.000 visits a month, which contributes significantly to the dissemination of the project.

WEBSITE (01.01.2024 – 24.11.2024)	
VIEWS	55.990
VISITORS	6.738

LinkedIn

With around 600 followers, the page is relatively successful in direct comparison to similar project pages and reached almost 39.000 impressions in 2024 with its content.

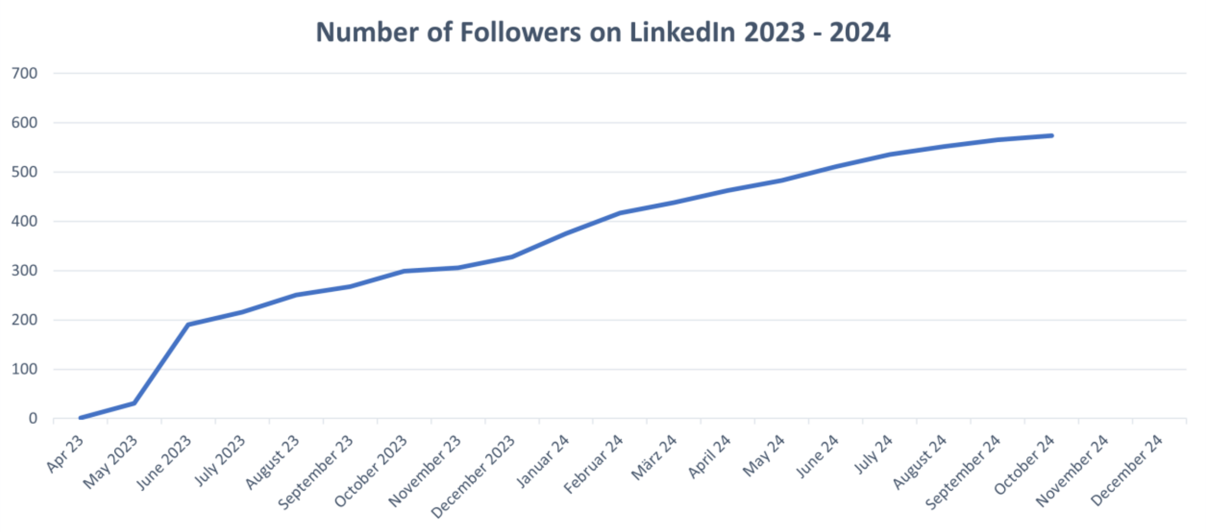

Figure 6-9 Development of followers

6.4 Publications

Authors	Title	Conference /Journal	DOI/Link
P. A. Ganeshamurthy; S. K. Gurumurthy; F. Ponci; A. Monti	A New Formulation of Dynamic-Phasor-Based State Estimation With Inclusion of an Equality Constraint	EEE Transactions on Instrumentation and Measurement (Volume: 73)	10.1109/TIM.2024.3398107 https://ieeexplore.ieee.org/document/10522749.
H. Wu; M. Zöcklein, S. Brell-Cokcan	Unified framework for mixed-reality assisted situational adaptive robotic path planning enabled by 5G networks for deconstruction tasks	2024 Proceedings of the 41st ISARC	10.22260/ISARC2024/0022 https://www.iaarc.org/publications/2024_proceedings_of_the_41st_isarc_lille_france/unified_framework_for_mixed-reality_assisted_situational_adaptive_robotic_path_planning_enabled_by_5g_networks_for_deconstruction_tasks.html
L. Kirner; M. Zöcklein; J. Oraskari; S. Brell-Cokcan	Loosely coupled observation processing and data exchange system for complex teams of on-site construction robots	Conference: Robotic Fabrication in Architecture, Art and Design 2024	https://www.researchgate.net/publication/384892681_Loosely_coupled_observation_processing_and_data_exchange_system_for_complex_teams_of_on-site_construction_robots
L. Kirner; J. Oraskari; M. Zöcklein; A.	An ontology to enable signal strength estimation for nomadic	2024 European Conference on Computing in Construction (2024 EC³), Crete, Greece	10.35490/EC3.2024.202 https://www.researchgate.net/publication/382294038_An_ontology_for_sign

Möller; S. Brell-Cokcan	networks on construction sites		al_strength_estimation_of_nomadic_5G_networks_on_construction_sites
S. M. Darroudi; N. Domènech; M. Grandy; R. Guerra-Gomez	On the TSN and 5G network integration approaches, 5G features proof, advantages and challenges	2024 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit), Antwerp, Belgium	0.1109/EuCNC/6GSummit60053.2024.10597062 https://ieeexplore.ieee.org/document/10597062
M. Pitz; F. Wege; N. Eiling; S. Vogel; Vincent Bareiß; A. Monti	Automated Deployment of Single-Board Computer Based Grid Measurement and Co-Simulation Equipment	Open-Source Modelling and Simulation of Energy Systems (OSMSES) 2024	https://ieeexplore.ieee.org/document/10668996
M. Pitz; S. K. Gurumurthy; M. M. Nowak; S. Lankes; F. Ponci; A. Monti	A Low Cost Phase Estimation Device for PMU Phase Validation	IEEE 15th International Symposium on Power Electronics for Distributed Generation Systems (PEDG 2024)	10.1109/PEDG61800.2024.10667414 https://ieeexplore.ieee.org/document/10667414
V. Jung	Enabling Circular Construction: Evaluating ICDD for Effective Deconstruction Processes	35. Forum Bauinformatik, fbi 2024	10.15480/882.13525 https://tore.tuhh.de/entities/publication/c09019d1-a52d-4c02-9bbe-9c87df6a8de5

6.5 The Supportive Partners Program

In the second year of the TARGET-X project, the Supportive Partner Program was launched. Supportive partners are organizations in the 5G/6G area interested in cooperating with the TARGET-X project in a 'win-win cooperation mode'.
The work performed at the beginning of this task started by preparing the online form to be filled out by the potential Supportive Partners. The online form is available under this link.

The value propositions for the Supportive Partners are:

- Boost Organization Visibility
  By sharing the new opportunity provided by TARGET-X project within their network, companies can boost their visibility.
- Grow the network
  Participation in TARGET-X project provides an opportunity to network with the new organizations.

- Enhance Reputation
  Supporting the TARGET-X project can have a positive impact a organization's reputation.
- Shape the Future
  Contributing to the TARGET-X Project and taking part in the development and testing of cutting-edge mobile communication solutions.

By the end of the 2024 in TAREGET-X project nine Supportive Partners are involved.

Growth Hacking Strategy

The FundingBox prepared a Growth Hacking Strategy for the TARGET-X Community, which platform is on Discord.

These strategic key actions for growth were identified:

- Paid Media Campaign
  - LinkedIn
  - Reddit
- Marketing Materials:
  - Infographics
  - Memes
- Influencer Partnerships:
  - Identify top influencers
  - Collaborate on content
  - Cross-Promotion

By integrating these strategic actions, the TARGET-X Community can successfully attract new members, establish a strong brand and become a go-to resources for 5G/6G experts, SMEs and Midcaps across Europe.

6.6 Next steps

In the upcoming months the consortium will provide evidence of their research results with relevant scientific publications. A joint white paper on lessons learned and requirements is also planned. A major final event, likewise the Open Day, and an event involving the FSTP projects are planned to disseminate the project. Technical webinars are to be offered to publicize the use cases of the project even more.

7 Conclusion and impact

In the second intermediate project report, the main accomplishments of the TARGET-X project during the second year are emphasized. The report includes references to the project deliverables and demonstrates significant progress made by TARGET-X in its second year of execution. The project report builds directly on the first intermediate project report [TAR23-D92].

Technology developments of hardware and software, and implementations and deployment of use cases has taken place across all testbeds and vertical's work packages. The implementations have been supported by the technology evolution work package, where the communication features have been identified. The features are integrated into the large-scale pilots in the five testbeds. The completion of the several milestones shows that the testbeds are already operational.

The methodological assessment framework has been defined and the KPI/KVI evaluation across the four verticals Energy, Manufacturing, Automotive and Construction has started to facilitate the joint evaluation of the beyond 5G features. In the evaluation the real benefits for the verticals are the main focus.

The first support programme for FSTP took place and led to the execution of 26 projects. From the second open call, from 159 proposals, 40 projects started the support programme. The entities of the 66 projects significantly account for the extension of the 5G ecosystem in the manufacturing & robotics, automotive, energy, and construction verticals. The entities involve directly in benchmarking and integration of 5G.

In conclusion, the second intermediate project report of TARGET-X demonstrates significant progress and achievements in various application domains, successful collaboration of end users and technology partners, and provides insights into the activities of financial support for third parties. The project's communication and dissemination efforts have also been effective in reaching a wide range of audiences.

In the upcoming year, the use case implementations and the application testing will continue, as well as the joint activities with the beneficiaries of the second open call. This will lead to a broad range of implementations, testing and demonstrations.

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