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Acronyms

Acronym	Explanation
IoT	Internet of Things
EU	European Union
EC	European Commission
WP	Work package
KPI	Key Performance Indicator
AB	Advisory Board
ICB	Impact Creation Board
TMC	Technical Management Committee
PC	Project Coordinator
EPC	Ethics Privacy Committee
GA	General Assembly
BDM	Business Development Manager
ICT	Information and Communication Technology
R&D	Research & Development
IEA	Innovative Exploitable Assets
KB	Knowledge Briefs
CERT	Computer Emergency Response Team
ECSO	European Cyber Security Organization
NIS	Network and Information Security
CSIRT	Computer Security Incident Response Team
ENISA	European Network and Information Security Agency
FP7	Seventh Framework Programme for Research and Innovation of the EU
CIP	Competitiveness and Innovation Framework Programme
CAGR	Compound Annual Growth Rate
SDN	Software Defined Network
AR	Augmented Reality
VR	Virtual Reality
APAC	Asia-Pacific

MEC	Multi-Access Edge Computing
vMEC	Virtualized Multi-access Edge Computing
FPGA	Field Programmable Gate Array
SoC	System on a Chip
FLF	Federated Learning Framework
FLF-DMLC	FLF Distributed Machine Learning Component
FLAI	Federated Learning Accelerating Infrastructure
FLF-DMOS	FLF Distributed Model Optimisation and Synchronisation
FLF-DMP	FLF Distributed Model Personalization
BNN	Binary Neural Network
UI	User Interface
UX	User Experience
AI	Artificial Intelligence
SV-IoT-NF	Secure Vertical Internet of Things Network Framework
NG IoT	Next Generation Internet of Things
PHY-L	Physical Layer
MID-L	Middleware Layer
INT-L	Intelligence Layer
PLA-L	Platform Layer
APP-L	Applications Layer
SPV-L	Security & Privacy Vertical Layer
MQTT	Message Queue Telemetry Transport
CoAP	Constrained Application Protocol
HTTP	Hypertext Transfer Protocol
ML	Machine Learning
LCP	Lightweight Crypto Primitives
CFA-IoT-N	Control Flow Attestation for IoT Nodes
AR-VR-CF	Augmented Reality Virtual Reality Contextual Framework
IoT-DTE	Internet of Things Digital Twin Environment
KPIM	Key Performance Indicator Manager

RaV	Reports and Visualisation
ECM	Energy Consumption Manager
EPES	
IoTaIS	Internet of Things and Intelligence System
GIoTS	Global IoT Summit
GLOBECOM	IEEE Global Communications Conference
GCIoT	IEEE Global Conference on Internet of Things

Executive Summary

This deliverable outlines the technical, scientific innovation management plan of the TERMINET project with respect to the H2020 program and call requirements to safeguard innovation and excellency in the project. The technical and innovation objectives are presented following by an overview of the management strategies followed for these objectives. In the context of the report the need for an innovation solution like the one proposed by TERMINET project is backed with a brief market analysis on the main subcomponents of the project alongside the key innovation points of the project in regard to the WP they belong. At the end the report presents a quantification of innovation and a methodology for the continuous assessment of innovation throughout the whole project's duration.

1 Introduction

1.1 Purpose of the Deliverable

The purpose of this Deliverable is to outline the technical and scientific innovation management plan of the TERMINET project to ensure innovation and excellency.

1.2 Relation with other Deliverables and Tasks

This deliverable relates with all of the Tasks of the TERMINET project, as it directs its entire technical plan.

1.3 Structure of the Deliverable

The report is organized in the following sections:

- Section 2 presents the objectives of technical and innovation management following a description of methodologies that can be applied in the context of innovation management in the project. Also mentions EU initiatives regarding IoT cybersecurity and innovation.
- Section 3 presents a brief market analysis for each key area in TERMINET project as well as the key innovation points.
- Section 4 outlines and maps innovation points to specific WPs of the TERMINET project.
- Section 5 presents goals, KPIs and method to safeguard proper and timely technical development, to maintain a certain high level of innovation and dissemination of the project.
- Finally, section 6 presents the conclusions of this report.

2 Technical and innovation management

2.1 Technical and innovation management objectives

Innovation management is widely applied in the European Union and projects that pose technological advancements. Though each project and case define it differently leading to a variety of definitions about innovation management [1]. In its simplest form, innovation can be seen as anything that is different and has an impact. To define innovation management though we can use the definition provided by the European Commission as "the overall management of all activities related to understanding needs, with the objective of successfully identifying new ideas and managing them, in order to develop new products and services which satisfy these needs". Horizon 2020 is the largest publicly funded research and innovation program in the EU and is a program designed to develop cutting edge technology that can be commercialized and exploited.

A number of entities are collaborating in the context of innovation management in order to safeguard that a certain high level of innovation is maintained throughout the TERMINET project. These entities are the Advisory Board (AB), the Impact Creation Board (ICB), the Technical Management Committee (TMC) and the Project Coordinator (PC).

Advisory Board is responsible to ensure that the results and strategies followed satisfy the requirements of the stakeholders. AB will act independently from the project but in collaboration with a number of entities such as the Ethics and Privacy Committee (EPC), the Technical Management Committee (TMC), the Security Advisory Board (SAB) and the ICB.

Projects business and technical strategy falls in the responsibilities of ICB. The purpose of the board is to provide guidance, direction and governance at a higher level to General Assembly (GA) ensuring successful delivery of innovation from the project to the market. The ICB includes the Business Development Manager (BDM) as its chairman and all the WP leaders.

The Technical Management Committee consists of all the WP leaders as well as the rest of the technical staff of the project. Main purpose of the committee is to gather existing knowledge and experience regarding innovation management and effectively promote TERMINET's results.

In terms of innovation management, Project Coordinator is responsible to report to the ICB any emerged issues or matters relevant to its procedures.

The major goals of innovation management in TERMINET regard the ability of the project to align with novel technologies, maintain commercial interest and properly disseminate and promote the results of the project. To satisfy these goals three objectives are prioritized for the technical and innovation management. First and most important is to adequately promote the exploitation of R&D results of the project making an impact to the European ICT market and improve its innovation capacity. This can be associated with the second objective which is to incorporate novel technologies relevant to the latest market trends. Thus leading to the third objective that is to ensure that research activities and technological development keep up with the rapid technological evolution.

In Figure 1 the steps of the innovation management methodology that could be implemented in the TERMINET project are presented. The first steps regard the realisation of the project needs and the identification of opportunities in the relevant market taking into consideration existing solutions. Following steps cover the generation of the strategy and development of the plan that will be followed. Then the standar procedure of design, implementation and test will occur before final launch of the solution to the market.

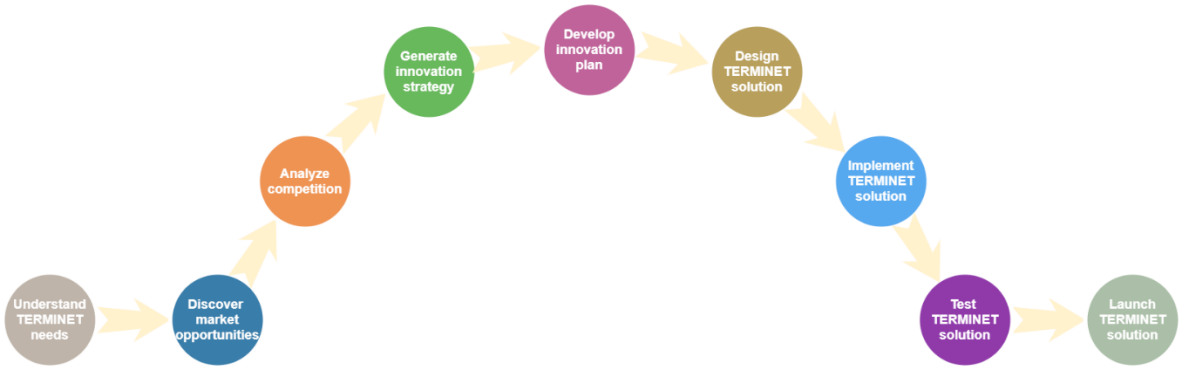

Figure 1 Innovation management methodology

The above strategy will be implemented by performing a set of actions. These are the following:

- Collaborate with similar research projects and share skills and knowledge
- Keep track of technological innovation and evolution of the technology
- Introduce novel activities in the context of innovation management
- Participate in relevant events and conferences to collaborate with possible stakeholders
- Include end-users to project's meetings to exchange knowledge and get feedback regarding the project status and outcome.

2.2 Innovation management strategy of TERMINET overview

As mentioned above one of the major objectives of TERMINET project is to adequately promote the exploitation of the results from the research and development conducted during the projects lifetime. This does not include only dissemination of novel techniques developed in the project but also the impact that TERMINET poses for innovation in the relevant market. In other words, the purpose is not only the steer dissemination of the results but also the exploitation of them.

To increase the possibility that the project will become an innovative and commercial success story certain preparation is required by the involved organizations. The members of the project need to be prepared to address issues related with the activities needed for the exploitation of the solution in the market.

As mentioned in the previous chapter, technical and innovation management strategy involves collaboration with similar research projects, some of which are SerIoT, SPEAR, SDN-microSENSE.

Collaboration between projects enhances knowledge and skill sharing and various technologies or components developed in other projects could be used in the context of TERMINET. An example of such technologies and knowledge is IoT security solutions developed in SerIoT or insights about the SDN developed in SDN-micorSENSE. In order to improve the credibility of the developed solution the project will need to participate in academic conferences and the largest European trade fairs and workshops. This approach will help to reach and appeal to potential stakeholders and end users while also provide an entry point of the developed solutions to the ICT market. Lastly continuous alignment with the latest trends and technological evolution will result in an improved outcome and an innovative product with higher commercial interest.

Figure 2 Technical and Innovation Management Strategy actions

In addition to the above actions two additional methodologies will be used to ensure innovation throughout the project. The first method will be to identify IEA in the projects components. IEA stands for Innovative Exploitable Assets and they are isolated subcomponents of the project that can contribute to increased generated value. Three types of IEA have been identified methodologies, technological bricks and standards. Outcome of this method will be a map to Value Creation for the TERMINET project regardless of the complexity of each sub component.

The second method will be applied on top of the identified IEA and aims to transfer information between stakeholders of the IEA. The method derives from Lean Engineering and is one of its core approaches [2]. A3 Knowledge Briefs will capture IEAs critical information as well as information about the added value and the business scenario that benefits from it. IEA creators will be responsible to share the IEA with contributors and business partners involved. Aim of these reports are to promote discussion and converge Partners interests.

2.3 EU initiatives for IoT & cybersecurity

Cybersecurity is one of the key focus points in the European Union. A plethora of policy documents, legislation and strategies have been devised and developed to address related issues. Many actions, projects and organizations alongside the relevant legislation have been realized by the EU to improve and protection against such issues.

2.3.1 Organizations

ENISA which stands for "European Network and Information Security Agency" is the European Union's agency dedicated to Cybersecurity. Some of its core responsibilities are to support and collaborate with the Member States Computer Emergency Response Teams (CERTs), organize and perform cybersecurity related exercise throughout the whole union, collect and evaluate data regarding cyber threats or breaches in Europe, raise awareness and collaborate with stakeholders in the cybersecurity field. Moreover aims to promote risk assessment and management methodologies in the context of information security aiming to improve the ability of minimizing, detecting and mitigating potential risks.

ECSO which stands for "European Cyber Security Organization" is a self-funded non-profit organization. The goals of the organization are to improve the European digital autonomy, develop a competitive European cybersecurity ecosystem and enhance protection of the European Digital Single Market via trusted solutions.

2.3.2 Legislation

European Commission adopted, in 2013, the Directive (2013/40/EU) requesting EU members to update their national laws adopting tougher criminal penalties in an attempt to prevent large-scale cyber-attacks on information systems.

EU Network and Information Security (NIS) Directive (EU2016/1148) was proposed by the commission in 2016 including three parts. The first part was regarding the supervision of critical infrastructure by each EU member, the second part was forcing each EU member to establish authorities responsible for cybersecurity incidents the "Computer Security Incident Response Team" CSIRT and the last part aimed to ensure collaboration about cybersecurity between the countries of the EU.

EU Cybersecurity Act is introduced by the commission in 2017. The act concerns the expansion of ENISA and its capabilities creating an EU-wide certification framework.

2.3.3 Projects

SerIoT (Secure and Safe Internet of Things) began on the 1st of January of 2018. The project's has a lifetime of 36 months. It is funded by the Horizon 2020 framework program and consists one of the EU H2020 Research and Innovation Action projects in the EU. The project focuses to the optimization of security in IoT platforms and networks. It offers a secure SerIoT platform that can be applied to provide security in any IoT platform or network.

NGIoT (Next Generation Internet of Things) is an initiative and growing community of projects that aim to raise the Europe's position in the IoT world. It is a network of ongoing projects related to IoT-empowered solutions and business models. Projects under the umbrella of NGIoT work to achieve the goals of H2020 and collaborate with technology networks that include areas such as cloud, computing on the Edge, Artificial Intelligence, 5G, cybersecurity and blockchain. Projects in the community of NGIoT are IoT-NGIN, ASSIST-IoT, INGENIOUS, IntellIoT, VEDLIoT as well as TERMINET.

IoT-NGIN (Next Generation Internet of Things as part of Next Generation INternet) presents an innovative and modern research, with the role of "Next Generation IoT Engine" in order to reinforce the Next Generation of IoT, as an essential component of the Europe's Next Generation Internet. Due to IoT-NGIN a patterns based meta-architecture that includes growing, legacy, and upcoming IoT architectures is disclosed. Furthermore IoT/M2M and 5G/MCM communications, which include secure-by-design micro-services to distend the edge cloud paradigm, are optimized within the project. In addition, IoT-NGIN empowers autonomous IoT systems through privacy-preserving federated ML and ambient intelligence, with Augment Reality support and user and self-aware. Among the main concerns of IoT-NGIN are also Distributed IoT cybersecurity and privacy, using for instance SSIs and interconnected DLTs for Meta-Level Digital Twins implementation.

ASSIST-IoT (Architecture for Scalable, Self-, human-centric, Intelligent, Secure and Tactile next generation Internet of Things) is a research project sponsored by EU H2020 ICT-56-2020 which intends to implement and validate, a decentralized, open reference architecture, related enablers, tools and services, to empower in many aspects human-centric applications. Due to ASSIST-IoT project, a merged novel multi-level semi-autonomous decentralized edge-cloud architecture, complemented by cross-cutting electronic enablers will be designed, implemented and validated in a practical and quantifiable way. This architecture will support successive integration and lifelong viability of domain-agnostic, interactive, smart, decentralized, self-sufficient, expansible, tight and reliable IoT ecosystems.**iNGENIOUS' (Next GENeration Internet of Things sOlutions for the Universal Supply chain)** intention is to provide a Next-Generation IoT (NG-IoT) solution, emphasizing on 5G and the deployment of Edge and Cloud computing IoT extensions. Providing solutions for smart networking and data management with Artificial Intelligence and Machine Learning technologies, is also a main intention of INGENIOUS Project. INGENIOUS utilizes the 5G Infrastructure Association and Alliance for Internet of Things Innovation as well, in order to enhance fields such as smart manufacturing and smart mobility.

IntellIoT (Intelligent, distributed, human-centered and trustworthy Internet of Things environments) is supported by the EU with funds of nearly 8 million euro. It constitutes a Pan-European Research and Innovation project. IntellIoT stimulates the development of sophisticated IoT and Artificial Intelligence devices and systems. It consists of a consortium of 13 partners from 9 different countries. Objectives of the project are to enable a competitive ecosystem and to facilitate and enrich the process of finding solutions applicable in the fields of agriculture, healthcare and manufacturing in Europe. In order to achieve end-user trust, sufficient security and privacy by design, IntellIoT enables technologies such as 5G, Augmented Reality, cybersecurity, distributed technology and tactile internet. Within the next 3 years, small and medium-sized enterprises and startups in Europe will be supported by IntellIot with funds and access to technologies via projects implemented cooperatively with consortium partners. The

unprecedented rising performance of computer systems and IoT systems specifically, leads to the improvement of the quality of our life as we are able to solve and automate a constantly increasing number of challenging problems. For this reason, a novel next-generation IoT architecture, applicable to key sectors such as transportation, manufacture and household is more necessary than ever. Applications such as those mentioned above, require too complex systems and for this reason, most of the traditional approaches start to fall through. The very high computational power required, the quantity of data accumulated and the enormous complexity of algorithms used, are some of the main characteristics of these systems. Moreover, vital challenges for such systems are the security issues, privacy, and strength and how will be handled.

VEDLIoT (a Very Efficient Deep Learning Internet of Things platform) enables artificial intelligence and deep learning technologies to manage the huge complexity. This project utilizes the distributed approach in order to divide the application into minor and more efficient pieces and work cooperatively in large systems in the IoT, utilizing Artificial Intelligence-based algorithms that are allocated over IoT devices from edge to cloud. Concerning the hardware, VEDLIoT render the Cognitive IoT platform, exploiting European technology, which can be placed at any level of the continuous computation, starting from the sensor nodes and then edge to cloud after configuration. Based on use cases in the crucial sectors of automotive, manufacturing and smart homes, Cognitive IoT platform is backed by satisfactory security and robustness. To sum up, VEDLIoT Project provides a framework for the NG Internet driven by IoT devices which have a vital role for cooperatively solving complex DL applications across a distributed system.

2.4 EU Initiatives on innovation

In addition to the initiatives mentioned above, European Commission has taken steps to improve innovation. A tool has been introduced by the name of Innovation Radar [3] and offers a set of actions that helps projects reach market and commercialize their solutions. Focuses in the detection of innovation in FP7, CIP and Horizon 2020 projects. Innovation Radar aims to:

- Detect innovators and innovations with high potential through assessment of innovations developed
- Guides project members about the suitable steps they need to follow to increase possibility to reach the market
- Provides support for various on matters such as networking, access to finance, Intellectual Property and others that could help reach commercialization.

3 Overview of Next Generation Internet of Things Market

3.1 TERMINET Business Soundness

Market size of IoT technologies is expected to greatly increase in the coming years, this is evident due to market analysis conducted in the specific areas one of which is presented in Figure 3 which depicts the forecast of total installed IoT devices by 2027 [4]. Size and growth rate of the technologies included in the TERMINET project clearly show that there is plenty of room for novel ideas and solutions. More specifically Software Defined Networking market is expected to grow to $28.9 billion by 2023, an increase around 328% compared to the size of the market at 2018 ($8.8 billion) where the Compound Annual Growth Rate (CAGR) is calculated at 26.8%. The continuously increasing need to deploy more and more mobile devices to corporate networks is the main reason behind the substantial growth witnessed in the specific area. Another reason that contributes to that growth is the digital transformation in enterprise which result in the adoption of technologies such as SDN. Similar growth is reported for the global edge computing market, the blockhain IoT market, the artificial intelligence market, the AR/VR display market as well and the predictive analytics market.

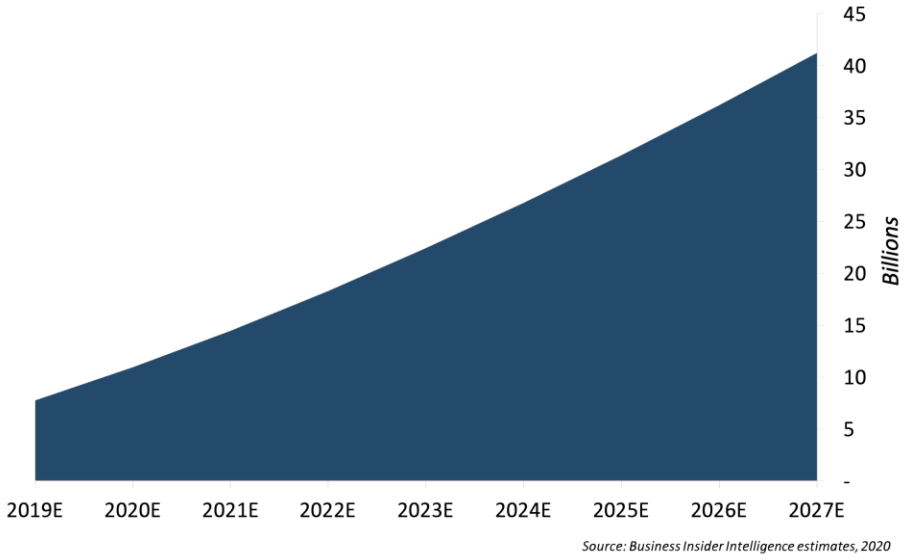

Figure 3 Forecast: Total IoT Device Installation Base

Specifically Global edge computing is expected to grow to $9.0 billion by 2024, an increase around 321% compared to 2019 ($2.8 billion) at a CAGR of 26.5%. At the same time blockchain IoT market is expected to grow to $3,021 million by 2024, more than 3000% compared to $113.1 million in 2019, at a CAGR of 92.92%.

In the case of artificial intelligence the market size is expected to grow to more than $190 billion, more than a 1000% increase compared to 2017 with a CAGR of 36.62%. Cloud based applications, big data and an increased interest and demand for intelligent virtual agents are the main reasons behind the growth

of AI market. Another reason contributing to this growth is the adoption of deep learning and NLP technologies in various sectors of the society. More and more applications incorporate AI for use in finance, agriculture, marketing and law.

AR and VR display market growth follows the same pattern expecting it to grow to $4.4 billion by 2024 at a CAGR of 21.8%, an increase around 275% compared to $1.6 billion in 2019. The main reasons behind AR/VR market size growth are the increased adoption of such devices in a variety of applications, the increased demand for OLED micro-displays in AR/VR devices and the technological advancement which expands the use of micro-displays in AR/VR. Geographical segmentation of this market defines two key areas North America and APAC. North America being a technologically advanced region and already having many global players that feature AR solutions is expected to contribute greatly to the growth of the market. Though APAC is expected to have the leading role for the expanding of this market's size.

Lastly the predictive analytics market is also expected to grow. More specifically it will grow more than 269% from $4.6 billion in 2017 reaching to $12.4 billion in 2022 at a CAGR of 22.17%. The reason behind this increase is the huge volume of individual and organizational data that are now available and used by businesses and their analysts to form predictions.

Taking into consideration the figures and the general picture that the market analysis of the key components in TERMINET, shows that there are a lot of commercialization opportunities for the solutions developed in the projects context. Market potential will be better identified in the context of WP10. Viability, sustainability and scalability of vast and various exploitation schemes will be evaluated and form the final business plan of the project aiming to offer the ability to the consortium to form a new entity to exploit the TERMINET platform.

3.2 Key Innovation Points

The Table 1 presents a comparison of the TERMINET against relevant EU funded projects in 6 different scientific areas. It is evident that TERMINET solution includes all the necessary technologies to provide a complete and modern solution suitable for the next generation of IoT.

Table 1 Comparison of TERMINET with relevant EU research projects

	Distributed AI	Tactile IoT	MEC	Predictive Analytics	IoT Platform as a Service	Intelligent IoT Devices
NGIoT	✓	✓		✓	✓	
Fed4IoT	✓				✓	
BRAIN-IoT	✓			✓	✓	✓
FeatureCloud	✓			✓		
SEMIoTICS			✓	✓	✓	✓

INTER-IoT					✓	✓
PrEstoCloud	✓		✓	✓		
DECENTER	✓		✓		✓	✓
ObjectBox IoT-1			✓		✓	
symbIoTe					✓	✓
SerIoT	✓		✓	✓		
SecureIoT	✓			✓	✓	✓
FINoT	✓				✓	✓
CO-ADAPT				✓	✓	✓
SDN-microSENSE			✓	✓		
FORESIGHT	✓					
ENACT				✓	✓	✓
SCOTT					✓	✓
COMPOSE					✓	✓
MONICA					✓	✓
TERMINET	✓	✓	✓	✓	✓	✓

TERMINET will enable the on-demand deployment and scaling of MEC servers. The SDN concept will provide the means for resource allocation and offloading decisions [5]. Integration of SDN concept in MEC will offer programmability capabilities and will add an efficient service management the ability to perform service trials. SDN will provide dynamic service provisioning in order to satisfy performance requirements. Also a global view of the edge nodes will be accessible to the MEC servers due to SDN. Moreover network slicing concept [6] can be implemented with the use of SDN and virtualization technologies. Network slicing will ensure resource sharing among services and quality data by creating separate network slices for use with raw IoT data and conventional user data. TERMINET provide accelerated computing in the edge even for resource-intensive tasks via the FPGA SoC approach. TERMINET will also reduce overhead associated with the development and deployment of compute tasks to the edge devices. Additionally, new business opportunities will be introduced to mobile operators through monetization of vMEC resources.

TERMINET's SDN enabled middleware layer will connect massive heterogeneous IoT devices in a single platform. In addition, IoT devices and their capabilities will be explored to measure heterogeneity. Low latency communications will be achieved through compression [7] and compressive sensing techniques [8]. In the context of TERMINET Tactile IoT scenarios based on Recursive InterNetwork Architecture (RINA)

will be analyzed in order to implement optimized protocols that further reduce latency, communication overhead while at the same time increase reliability.

TERMINET will offer solution to issues associated with AI training on the edge through FLF-DMLC and FLF-DMOS components. Deep neural networks compression and optimization will be achieved with the use of binary values (BNNs) reducing not only the size of the models but also the computations required. At the same time various techniques will be applied to improve convergence. This will allow to greatly reduce prediction times, computation cost and time making the models suitable for edge devices and real-time applications. Moreover, through TERMINET-FLF averaging approaches and federated learning algorithms will further improve performance of established deep neural network architectures.

TERMINET will offer the ability to its users to perform practical tasks having a number of valuable information at their disposal in their field of view through an AR UI. For this purpose, TERMINET will extent and combine gesture/activity and context recognition technologies for AR/VR with UX methodologies and interfaces to achieve having contextual information displayed to the user and enable him to interact or provide feedback.

TERMINET will integrate Immersive Analytics and Collaborative Immersive Analytics to provide a pleasant and captivating VR experience. Latency issues will be addressed employing 5G technologies and hand gesture recognition will be provided with the use of machine learning technologies. TERMINET AR/VR will fully immerse its users engaging all of their senses thus creating new interaction paradigms.

TERMINET will provide novel attestation mechanisms to ensure that only authenticated and trustworthy edge devices participate. TERMINET will provide novel techniques emphasizing to scalability and to support for heterogeneous devices based on Control-Flow Attestation [9] and Direct Anonymous Attestation Schemes [10]. In addition, novel identity management tools and procedures will be developed based on blockchain technologies.

TERMINET will take advantage of blockchain technology. Blokchain technology will be responsible to for the validation of the data exchanged and the transparency of the AI-enabled services. Also through blockhain system Intellectual property will be protected and monetized while it will also automate the actions required to change static agreements

TERMINET will utilize a blockchain based system to support the validity of data received from the different layers of the system including IoT measurements, the transparency of the AI-enabled services and the creation of a framework to protect and monetize Intellectual Property Rights.

4 TERMINET Technical Innovation Overview per WP

Four technical work packages (WP) have been defined for the needs of TERMINET project. Those are the WP3 (SDN-enabled vMEC-S), WP4 (Federated Learning Framework), WP5 (Secure Vertical IoT Network Framework SV-IoT-NF) and WP6 (Real-time NG-IoT Applications & Services). The chapter presents those key areas that offer novelty and innovation to the solution developed in the TERMINET project.

The following table (Table 2 List of TERMINET deliverables with high innovation potential) presents a list of TERMINET deliverables that will be closely monitored since they are considered highly innovative.

The deliverables characterized with increased potential for innovation have been identified and presented in the following table (Table 2) in order to help monitoring them. Focus will be given in these deliverables aiming to assure high innovation level during the whole development of the TERMINET solution. Various project activities such as meetings as well as extrovert activities like open events and workshops will offer the ability to additionally monitor and assure that innovation remains at high levels.

Table 2 List of TERMINET deliverables with high innovation potential

Deliverable No.	Deliverable title	Deliverable date	Task No.
D3.1	Early Version of the TERMINET SDN-enabled vMEC Scheme	M15	T3.1
D3.2	Final Version of the TERMINET SDN-enabled vMEC Scheme	M26	T3.2
D3.3	Public Version of the TERMINET SDN-enabled vMEC Scheme	M26	T3.3
D4.1	Federated Learning Accelerating Infrastructure	M24	T4.1
D4.2	FLF-DMLC System Specifications	M26	T4.2
D4.3	FLF-DMOS System Specifications	M28	T4.3
D4.4	FLF-DMP System Specifications	M30	T4.4
D5.1	TERMINET Attestation Model and Specification	M26	T5.1
D5.2	TERMINET Collective Attestation Policy Enablers Design	M28	T5.2
D5.3	TERMINET Distributed and Decentralised Blockhain Framework	M28	T5.3
D5.4	TERMINET Secure Vertical IoT Network	M30	T5.4
D5.5	Public Version of the TERMINET Secure Vertical IoT Network	M30	T5.4
D6.1	5G Schemes for Supporting Tactile Internet Solutions	M30	T6.1
D6.2	VR System and Haptic Interface	M32	T6.2
D6.3	AR System and Haptic Interface	M32	T6.2
D6.4	IoT Digital Twin Environment and Prediction Models	M32	T6.3
D6.5	Inventory for Intelligent IoT Devices	M32	T6.4

D6.6	User Panel Components	M34	T6.5

4.1 Work Package 3 - SDN-enabled vMEC Approach

Currently existing cloud computing and IoT solutions are not suitable or able to support real-time applications. Due to their design heavy computation remains at the cloud increasing cost and posing privacy issues. Contrary new systems and solutions more and more require low latency and faster computations. In addition, the number of connected IoT devices greatly increased over the years and is expected to explode in the near future. Traditional ways of managing connected IoT devices are no longer viable. These reasons drive the need for a new approach that will reduce costs and latency, ensure data privacy and will be able to support the increased complexity that management of a huge number of connected devices has.

WP3 will leverage Software Defined Networking (SDN) and virtualization and will offer a novel SDN-enabled, virtualized Multi-access Edge Computing (vMEC) reference architecture to pose as reference framework for the NG IoT application.

The following objectives have been defined for the success of WP3:

- To design and implement an SDN-enabled communication protocol between the PHY-L and the MID-L layers by using an SDN-enabled GW in the PHY-L and an SDN controller in the MID-L
- To provide the S-APIs and the southbound interfaces to enable different IoT data protocols (i.e., Message Queue Telemetry Transport–MQTT, Constrained Application Protocol–CoAP and Hypertext Transfer Protocol–HTTP) to communicate with a set of heterogeneous IoT devices (between the PHY-L and the MID-L)
- To design and implement effective and efficient mechanisms for streaming analytics in order to transform the incoming unfiltered IoT data to IoT data streams in the MID-L
- To design and develop IoT hardware abstraction mechanisms using semantic technologies as a part of the MID-L
- To design and implement the orchestration mechanisms for efficient runtime resource management and edge service lifecycle management, taking into account the need for provisioning and managing resources and deployed services over cloud-platform, platform-platform, and platform-edge computing settings

4.2 Work Package 4 - Federated Learning Framework

As mentioned above another aspect for NG IoT applications is privacy which is compromised by traditional IoT systems. Previous implementations rely on central servers or the cloud for heavy computation and data analysis thus moving a large volume of sensitive information from the IoT devices to the cloud. The innovation of WP4 lies in moving to a decentralized approach for the NG IoT. WP4 will provide a set of innovative mechanisms and tools for moving AI to the edge by using cutting-edge ML technologies,

avoiding data collection and offering decentralized analytics, privacy by design and data protection. The key characteristic of the AI enabled edge devices will be the embedded ML solutions, while coping with performance, privacy and personalization.

The following objectives have been defined for the success of WP4:

- Development of the FLF Distributed Machine Learning Component (FLF-DMLC), the distributed system based on federated architecture
- Development of FLF Distributed Model Personalization (FLF-DMP) which includes the methods that adapt edge AI models in each device improving convergence and personalization.
- Development of the Distributed Model Optimization and Synchronization component (FLF-DMOS) which will implement of a set of intelligent algorithms for model optimization and compression, real-time synchronous and asynchronous communication with the edge devices. It will be built on top of popular and open source deep learning technologies and will correspond to the unique requirements of distributed, low power edge IoT devices.
- Development of the Federated Learning Accelerating Infrastructure (FLAI) that will support the federated learning functions, by enabling the autonomous provision, management, and optimization of a virtualized acceleration framework
- Design and implementation of distributed machine learning functionalities built on-top of the TERMINET-FLF, enhanced by the FLF-DMLC, delivered as an additional mechanism to improve the ML technologies at the edge devices.
- Development of the TERMINET Federated Learning Framework (TERMINET-FLF) platform to support and integrate all developed components and algorithms.

4.3 Work Package 5 - TERMINET Security, Privacy & Trust

This WP aims to deliver a novel framework that will be responsible to safeguard the integrity of resources in the system, supported devices and data exchanged. In this context an end-to-end IoT security will be provided based on leading technologies like attestation modelling and distributed/decentralised blockchain. For the needs of this work package novel attestation mechanisms for trust management and device authentication services will be realized in order to enhance security and privacy.

The following objectives have been defined for the success of WP5:

- Development of sophisticated Lightweight Crypto Primitives (LCP) and Control Flow Attestation for IoT Nodes (CFA-IoT-N) to address diverse vulnerabilities and treats of the edge, by determining appropriate attestation mechanisms that will be utilized by trust management and device authentication services
- Employment of the LCP and CFA-IoT-N mechanisms to enforce participation of trusted devices in combination with enterprise-level or privacy-preserving signature schemes
- Utilize distributed and decentralised blockchain for transactions in the IoT ecosystem thus ensuring a trustworthy environment for transactions and preserving enterprise-level privacy and security.

- Development of the TERMINET Secure Vertical IoT Network Framework (SV-IoT-NF) which will be the main component that satisfies the needs mentioned above as well as providing data privacy and confidentiality based on anonymization techniques.

4.4 Work Package 6 - Real-time NG-IoT Applications & Services

Integration of AR/VR devices in IoT systems pose a number of challenges especially for cases where these devices require training. To address those challenges an NG IoT system should incorporate specific characteristics, besides developing a suitable framework for AR/VR devices, such characteristics are low latency, flexibility and AI support. The novelty of this WP is that provides a tactile IoT model as a collaborative paradigm that enables humans and machines to interact with their environment in real-time using haptic interaction and AR/VR capabilities. In addition it aims to provide the means for predictive maintenance and supply chain optimization utilizing digital twin's concept [11].

The following objectives have been defined for the success of WP6:

- Enable high capacity and low latency connections by leveraging 4G/5G technologies for delivering real-time and physical (haptic) experiences remotely
- Design and development of the AR-VR-CF, which includes the AR, VR systems that incorporate haptic interactions for the TERMINET components within the tactile contextual framework
- Development of the IoT Digital Twin Environment (IoT-DTE) and operation state prediction schemes for real-time monitoring and optimisation of critical IoT equipment behavior.
- Development of the I-IoT-DI, which encloses the supporting properties and interaction methods with different types of new intelligent IoT devices within TERMINET.
- Development of the panels and dashboards for interfacing with the TERMINET users, by including all necessary APIs to enable applications and services developed by any party to be interfaced with the TERMINET layers. Furthermore, the development of the three components, namely the KPI Manager (KPIM), the Reports and Visualisation (RaV) component, and the Energy Consumption Manager (ECM).

5 Technical Progress and Innovation KPIs

5.1 Technical Progress Continuous Assessment Framework

Each technical goal of TERMINET's project pairs with a determined objective index. Table 3 presents the way the progress of each goal will be calculated through the years by the consortium. In particular, throughout the project's lifetime, a group of nine technical objectives will be observed. Within these objectives the preparation of use cases, standardization and certification, the availability of structural components agreed by the consortium partners, the policy recommendation, the availability of the SDN-enabled MEC Scheme, the availability of Federated Learning and Secure Vertical IoT Network frameworks and the availability of the developed NG-IoT Applications and Services are included. The confirmation and initiation of new business models and the Contribution to on-going EPES activities and stakeholders are also included to these technical objectives.

Table 3 Measurable Indicators of TERMINATE Objectives

A/A	Objective	1st Year	2nd Year	3rd Year
1	Availability of architectural elements designed and agreed.	[100%] of specifications completed.	[70%] of specifications implemented.	Successful integration and validation of the TERMINET architecture.
2	Availability of the SDN-enabled MEC scheme	[100%] of specifications completed.		
		[30%] of specifications implemented.	[90%] of specifications implemented.	Specifications Implemented
		[5%] of interconnection specification with the Federated Learning Framework	[70%] of interconnection specification with the Federated Learning Framework	Interconnection with the Federated Learning Framework fulfilled
		[5%] of interconnection specifications with the Secure Vertical IoT Network Framework	[70%] of interconnection specifications with the Secure Vertical IoT Network Framework	Interconnection with the Secure Vertical IoT Network Framework fulfilled
		[5%] of interconnection specifications with the NG-IoT Applications and Services Hub	[70%] of interconnection specifications with the NG-IoT Applications and Services Hub	Interconnection specifications with the NG-IoT Applications and Services Hub fulfilled
3	Availability of the Federated	[100%] of specifications completed.		Integration completed

	Learning Framework	[10%] of specifications implemented.	[70%] of specifications implemented.	Deployment, validation and demonstration
4	Availability of the Secure Vertical IoT Network Framework	[100%] of specifications completed.		Integration completed
		[10%] of specifications implemented.	[70%] of specifications implemented.	Deployment, validation and demonstration
5	Availability of the NG-IoT Applications and Services Hub	[100%] of specifications completed.		Integration completed
		[5%] of specifications implemented.	[60%] of specifications implemented.	Deployment, validation and demonstration
6	Use Case preparation, validation and demonstration.	[0%] of methodology and Use Case guidelines taking into account technical WP output.	[20%] validated methodology	[100%] technical testing.
		[0%] preparation of TERMINET.	[20%] first assessment on Use Cases.	[100%] assessment and configuration optimisation.
7	Policy recommendation, certification and standardisation	[100%] of specifications completed.	[60%] of specifications implemented.	Integration completed
				Deployment, validation and demonstration
8	Validation and introduction of new business.	Regulation, barriers and recommendations available.		Analysis of cost-benefit and cost-effectiveness of the TERMINET project foreground completed.
		Availability of first version of the business models.	Full financial models included in the second iteration of business models.	Lessons learnt and completion of validations in the six Use Cases.
9	Contribution to on-going EPES activities and stakeholders.	First roadmap completed.	First round of implementation of TERMINET.	Roadmap and impact creation reports completed and ready for further exploitation.

5.2 Innovation Continuous Assessment Framework

The research carried out and the innovation within the TERMINET project may hold particular interest for NG IOT experts and any associate party with relevant technologies. For every distribution activity which is attended below, there is a relevant index. Concerning the definition of the KPIs, TERMINET's participants will examine and consider all crucial scopes.

An initial attempt has been already conducted to identify the appropriate KPIs as a mean to evaluate TERMINET's results and success.

1 Scientific quality of the project's research operations:
  1.a Number of publications made by the Consortium partners.
  1.b Number of attendances in exterior events and presentations given by Consortium partners.
2 Coordination between Consortium partners:
  2.a Number of collective published works.
  2.b Number of remote and in-office meetings involving different partners in order to execute joint work.
3 Project's exposure at the European and global level:
  3.a Monthly visits average of project's website.
  3.b Number of reports in radio/news/magazines/blogs.
4 Project exhibition for commercial issues:
  4.a Beneficial assessment of the NG IOT solution evolved throughout the use cases trial.
  4.b Number of promotion presentations given by consortium partners to different interest parties.

Table 4 Distribution activities indexes

Product	Target Audience	Indexes (target ranges are given where possible)
Workshops co-located with major conferences (e.g. IEEE International Conference on Internet of Things and Intelligence System (IoTaIS), Global IoT Summit (GIoTS), IEEE Global Communications Conference (GLOBECOM), IEEE Global Conference on Internet of Things (GCIoT), etc.)	Scientific communities of artificial intelligence, machine learning, edge computing, blockchain technologies, etc. Industry/end users	Number of workshops (1-2 per year) and Number of participants in each workshop (~50)
On-site demonstrations	Scientific communities of artificial intelligence, machine learning, edge computing, blockchain technologies, etc. Industry/End-users	≥ 2 demonstrations
Scientific papers, targeting workshops, conferences and journals, such as IEEE Internet of Things Journal, Internet of Things - Journal – Elsevier, IEEE – Wireless Communications, IEEE – Transactions on Wireless Communications, IGI Global –	Scientific communities of artificial intelligence, machine learning, edge computing, blockchain technologies, etc.	Number of workshop papers published (1- 3 per-year) Number of conference papers published (1-2 per-year) Number of journal papers published (1-2 per-year)

Protocols and Applications for the Industrial Internet of Things, etc.)		
Social networks posts, to take advantage of modern communication channels for wider dissemination	Scientific communities of artificial intelligence, machine learning, edge computing, blockchain technologies, etc. Industry/End-users	Number of TERMINET posts (≥10), Number of contacts (≥100), Number of likes (≥ 50 likes / share), Number of comments (≥2 com. / share)
Participation and/or Attendance to exhibitions	Industry/End-users	Number of project brochure copies delivered (≥20)
Project web site, providing scientific papers, **public project deliverables, and software tools**	Scientific communities of artificial intelligence, machine learning, edge computing, blockchain technologies, etc.	Top 5 Search Engine Page Ranking (SEPR)

TERMINET's primary intention is to provide a novel next generation reference architecture based on cutting-edge technologies in order to enhance the efficiency of existing IOT systems. The outcomes of TERMINET project will be accessible and obtainable for a variety of different audiences with diverge needs and objectives.

Result-based and interactive activities and local market targeting as well are mandatory in order to activate the interest. In addition, communication activities such as marketing operations supported by companies will give publicity to TERMINET's framework. In order to enhance public awareness and interest, some communication indexes have been identified by TERMINET project.

Table 5 Communication activities indexes

Product	Target Audience	Indexes (target ranges are given where possible)
Online publishing (online magazines, newspapers, blogs)	Non-specialized audience, general public, policy makers.	≥ 5 publications / year ≥ 500 views
Inclusion of light content for non-specialized audience in the project website, blog, social media, as well as publishing "lighter" versions of project newsletters, leaflets, flyers, etc.	Non-specialized audience, general public, policy makers.	# of non-specialized material ≥5
Participation in media (TV, newspapers, radio) events in order to communicate TERMINET results of the project and explain its benefits to EU citizens,	Non-specialized audience, general public, policy makers.	# of media appearances ≥5

industry, etc.		
TERMINET news will appear in blogs and websites targeting nonspecialized audience, especially the youngest one, focusing on technology news and trends.	Non-specialized audience, general public, policy makers.	# of reads ≥100

Results of TERMINET project will continue to be disseminated even after the end of the project. Specifically partners of the project will maintain its presence in the web and social media. In addition, open access research papers will be available through IEEE Xplore, ACM Digital Library, Springer and Elsevier to keep achievements of the TERMINET project accessible to the public. Table 6 presents the post-project dissemination activities.

Table 6 Sustainable post-project dissemination channels and their content

Dissemination Channel	Sustainable Dissemination Content
Open Access Publications	• Open access research papers will be available as through IEEE Xplore, ACM Digital Library, Springer, Elsevier, etc. • Together with the corresponding copyright notice, research papers and whitepapers will be made available on social media platforms and the project's web-site.
Website	• Information about the project's objectives, WP structure and consortium. • Links to TERMINET's social media channels such as Twitter, LinkedIn Group, Facebook Page, and YouTube channel. • Blog about TERMINET's IoT activities and IoT-related topics in general.
Social Media	• Facebook page will provide a historical news feed for TERMINET's public relations activities • LinkedIn Group will provide a look-up tool for conversations related to TERMINET's R&D work and IoT vision in general.

6 Conclusions

The purpose of this deliverable is to present the technical, scientific and innovation management strategy of TERMINET project. Taking into consideration the market analysis for each main sub component of the project it is evident that there is plenty of room and need for the innovative solution that TERMINET has to offer. In addition, a comparison with similar on-going or finished research projects in the EU is given alongside innovation points for each WP further backing the above assumption.

TERMINET will incorporate cutting-edge technologies related to Software–Defined Networking (SDN), multiple-access edge computing (MEC), Federated Learning (FL), Augmented and Virtual Reality (AR/VR), Blockchain and Predictive Analytics in order to provide a reference architecture for next generation IoT (NG IoT) platforms. In addition, it will introduce new intelligent IoT devices and market-oriented use cases.

To assure that the goals and objectives defined in the context of the TERMINET project are met, the technical, scientific and innovation plan should be implemented alongside the development of the project and until its termination. Proper implementation of the plan presented will ensure that the project follows the needs of the relevant market and that results maintain a high level of innovation and commercial significance.

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