CREATE-IoT

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CROSS FERTILISATION THROUGH ALIGNMENT, SYNCHRONISATION AND EXCHANGES FOR IoT

H2020 – CREATE-IoT Project

Deliverable 04.03

EU research and innovation activities overall plan

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Summary					
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Document history

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1.00	30-09-2017	SINTEF	Final version submitted.

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1. EXECUTIVE SUMMARY

1.1 Publishable summary

This document is the "EU research and innovation activities overall plan" and describes the planned activities that will contribute to the integration and coordination of IoT activities with European research and innovation activities, as part of WP4 of the CREATE-IoT project. This framework plan will be the guidance for coordination between the different initiatives related to IoT. Specific goals have been formulated and targets defined.

1.2 Non-publishable information

This document is public.

2. INTRODUCTION

2.1 Purpose and target group

2.1.1 Purpose

The purpose of this EU research and innovation activities overall plan is to outline and plan an investigation into the various research and innovation activities in the area of IoT.

The scope includes all European entities (such as cPPPs, JTIs and industry associations) that are more or less related to research and innovation in the area of IoT.

2.1.2 Target group

The target group for this inventory study consists of different subgroups:

- Public Authorities and European Innovation policy makers
- The related entities that will be able to benefit from the presented results.

The groups can be regarded as the stakeholders of this study and will be denoted as such.

2.1.3 Objectives

The goal of this document is to provide an overview of strategic research agendas documents of different European initiatives and depict the technological and applications related to IoT in order to identify the areas of interest fro these initiatives. In this context, “overlap” is not an element be avoided, but in fact it can be seen as a sign of wide interest. However, in case of overlap, we should at least aim for *consistent terminology* and a *unified direction* to ensure IoT is well-addressed. Moreover, the different Strategic Research and Inovation Agenda (SRIA) documents of the IoT related entities in general (and AIOTI in particular) should be well aligned with many other SRIA documents that include IoT.

In line with the goal described above, the work of task T4.2 focuses to provide the desired *coordination* and *alignment* between different IoT-related initiatives in Europe, represented by the different entities, each with their own community. Furthermore, the aim is also to ensure adequate inclusion of IoT in the various SRIA documents with consistent terminology.

2.1.4 Strategy

The strategy proposed in this plan is a multi-step approach, where five phases are defined:

1. Inventory phase: short IoT-focused summaries will be provided of each of the 20 SRIA documents of the different entities identified.
2. Interview phase: interviews will be conducted with key representatives of the different entities; summary reports of the interviews will be included.
3. Consolidation phase: clustering of the various findings per entity, from both the document study and the interview conducted, combined with general impressions. The clustering rules will be determined based on similarity patterns in the resulting findings. Hence, the clustering could be by technology, by use cases, by vertical segment or any other similarity found.
4. Feedback and Alignment phase: feedback is provided as consultancy to the stakeholders in the form a written report of the combined findings, including recommendations how to better align to the European IoT landscape and how to use more consistent terminology
5. Reporting phase: The overall conclusions of this study are reported (including observations and recommendations) in de final deliverable D04.05.

The results of the EU research and innovation activities will be described in D04.05 "*EU research and innovation activities overall plan-evaluation*", also part of WP4 of the CREATE-IoT project.

2.2 Contributions of partners

The following partners are contributing to this task 04.02: PHILIPS, SINTEF, ATOS, GRAD, ISMB.

- PHILIPS: Task leader. Coordinates the activates and contributes to alignment with the European initiatives and leverage the existing network in ECSEL, Penta, ITEA, PPP's as 5G/Photonics etc. to align on the next steps on IoT in Europe between those organisations. An overall plan will be generated in order to set specific goals for different organisations and this will be done through further alignment of the Strategic Research & Innovation Agendas (the SRIAs) that defines research priorities for these domains and the alignment and coordination of regional, national and European research, innovation and deployment.
- SINTEF contributes to the implementation of a coordination body that will ensure an efficient interplay of the various elements of the IoT-FA and liaise with relevant initiatives at EU, Member States and international levels. In Nordic Region, will liaise with public research/innovation agencies in order to better streamline funds for supporting IoT road mapping activities. Contributes to collaboration, coordination, cooperation and strengthen the existing links with following initiatives 5G, FoF, Robotics, ECSEL, Partnership on Smart Cities and Communities, EIP on Active & Healthy Ageing and the FA on Automated Road Transport. These will be done through, further alignment of the SRIA that defines research priorities for these domains and the alignment and coordination of regional, national and European research, innovation and deployment.
- ATOS will lead the interlinking with this cybersecurity PPP. Further, ATOS contributes to establish strong links with existing European initiatives in which ATOS is already present. ATOS will be responsible of establishing and sustaining the link with the forthcoming Cybersecurity PPP (announced for June-July 2016).
- GRAD will provide links with the 5G ETP (Networld 2020) and the European Innovation Partnership on Agricultural Productivity and Sustainability (EIP-AGRI).
- ISMB will contribute to strengthen links with existing European initiatives where ISMB is involved in. will liaise with the Italian IoT ecosystem and relevant initiatives at national level, promoting the link to AIOTI and sharing the results of the large-scale pilot projects. ISMB will also contribute to the analysis of the IoT role in the context of the Circular Economy. They will also support the integration and coordination with Factories of the Future PPP through the participation in EFFRA, the official representative of the private side in the PPP. ISMB also support the link with 5G ETP (Networld 2020).

2.3 Relations to other activities in the project

There are some relations to other activities in the project:

- At the input side, standardised and preferred terminology to be used from WP2, task 2.1
- At the output side, the results of this study will be described in D04.05 "EU research and innovation activities overall plan-evaluation", which will go from here to the different entities identified who can use it to align the different SRIA documents related to IoT and who can use these results to have better synergies among different initiatives and collaborations.

3. EU RESEARCH AND INNOVATION

3.1 Relevant entities / stakeholders for IoT

There are many "entities" active in Europe that represent the interest of some group of stakeholders. Such entities can be an industry association, a contractual PPP (Public-Private Partnership) or other body representing the interest of players in the R&D on IoT in Europe. As much as twenty relevant entities have been identified that are subject to this study.

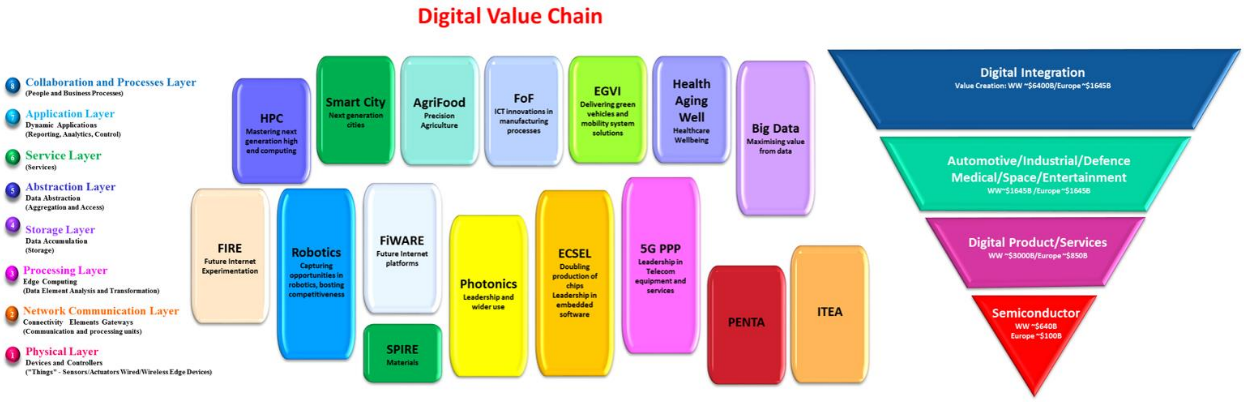

Figure 1: EU research and innovation over the IoT layered architecture

Table 1: List of relevant entities

#	Entity name	Type	Entity Description	Objective
1	ECSEL	JTI	JTI on Electronics Components and Systems	Contribute to the development of a strong and globally competitive electronics components and systems industry in Europe. The key role of the ECSEL JU is to keep Europe at the forefront of technology development in the area of Electronic components and systems. These are a pervasive Key Enabling Technology (KET), impacting all industrial branches and many aspects of modern life. The concept of "smart" is based on integrating semiconductor chips running embedded software to provide functionality and features that are useful to society. ECSEL JU combines ENIAC (AENEAS), ARTE-MIS and EPoSS bringing together the Electronic Components and Systems research sectors. It is managed by a number of boards representing key stakeholders.
2	Artemis-IA	IA	IA on CyberPhysical Systems	The association for actors in Embedded Intelligent Systems within Europe that represents its members in ECSEL Joint Undertaking and promotes the R&I interests to the European Commission and the Public Authorities.
3	AENEAS	IA	AENEAS	An association providing networking

			Association on micro and nanoelectronics enabled systems and applications	opportunities, policy influence & supported access to funding to all types RD&I participants in the field of micro and nanoelectronics enabled components and systems.
4	EPoSS	IA	Industry Association on Smart Systems	An industry-driven policy initiative, defining R&D and innovation needs as well as policy requirements related to Smart Systems Integration and integrated Micro- and Nanosystems.
5	ITEA	EUREKA Cluster	EUREKA cluster on Software Intensive systems	The EUREKA Cluster programme supporting innovative, industry-driven, pre-competitive R&D projects in the area of Software-intensive Systems & Services (SiSS).
6	PENTA	EUREKA Cluster	EUREKA cluster on Micro and nanoelectronics enabled systems and applications	A EUREKA Cluster in micro- and nano-electronics that supports the vision, strategy and planned implementation contained in the European Industrial Strategic Roadmap for Micro- and Nano-Electronic Components and Systems as prepared by the Electronic Leaders Group.
7	BDV/BDVA	cPPP/IA	Big Data Value cPPP and Big Data Value Association	Private association founded to boost research, development and innovation related to Big Data, as well as promoting its uptake across professional and private users. BDVA represents the private (industry-led) side of the EU BDV PPP.
8	CyberSecurity /ECSO	cPPP/IA	European Cyber Security Organisation (ECSO), the association behind cPPP	ECSO is the industry-led contractual counterpart to the European Commission for the implementation of the Cyber Security Contractual Public-Private Partnership). The main objective of ECSO is to support all types of initiatives or projects that aim to develop, promote, encourage European cybersecurity. Further, ESCO is instrumental in providing support to the EC for a new certification scheme. ECSO members include large companies, SMEs and Start-ups, research centres, universities, clusters and association, users and operators, as well as European Member State's local, regional and national administrations, countries part of the European Economic Area (EEA) and the European Free Trade Association (EFTA) and H2020 associated countries. Identified as having particular interest for interactions are: • In WG1 (standardization, certification, labelling and trusted supply chain) is focusing on the proposal of a new certification framework for the European Union. • In WG3 (Vertical market applications /Sectoral demand), sub-group on Smart Cities, Smart Buildings (convergence of digital services for Citizens), and other Utilities which covers IoT domain.

				• In WG6 (Strategic Research and Innovation Agenda) IoT has been identified as one of the pillars of Secure ICT Infrastructures.
9	RRI-SSH	CSA	Responsible Research and Innovation (RRI) and Social Sciences and Humanities (SSH)	Two intertwined cross-cutting issues of broad relevance in H2020 for pro-active uptake of societal (RRI-SSH) issues. The CSA (Coordination and Support Action) project U4IoT will support the LSPs (Large Scale pilots) of the IoT-1 call in order to actively engage end-users in the LSP design, deployment and assessment. Pilots shall be citizen-driven, involving existing and local communities at an early stage and addressing a combination of sustainability areas. The corresponding activities should accompany the pilots, analyse societal, ethical and ecological issues related to the pilots, and develop recommendations for tackling IoT adoption barriers including educational needs and skill-building. Responsible research and innovation (RRI) is an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation. Social Sciences and Humanities (SSH) research is fully integrated into each of the general objectives of H2020. Embedding SSH research across H2020 is essential to maximize the returns to society from investment in science and technology.
10	FoF/EFFRA	cPPP/ IA	Factories of the Future cPPP/Industry driven association	"Factories of the Future" Public-Private Partnership (PPP) is focused on advanced manufacturing Research and Innovation, with the purpose of increasing EU industry competitiveness and sustainability in the framework of the next industrial revolution, namely Factories 4.0. European Factories of the Future Research Association (EFFRA) is the official representative of the private side in the "Factories of the Future" PPP. EFFRA promotes pre-competitive research on production technologies within the European Research Area, also organizing consultations activities with experts to collect contributions to define EU funded call topics.
11	5G-PPP	cPPP	cPPP on 5G networking	The 5G infrastructure public private partnership (5G-PPP) has been initiated by the EU Commission and the European ICT industry (industry manufacturers, telecommunications operators, service providers, SMEs, and researches). Within the 5G-PPP, the 5G Infrastructure Association (5G-IA) represents the private side and the EU

				Commission the public side. The 5G-IA is committed to the advancement of 5G in Europe and to build global consensus on 5G. The 5G-PPP's objectives are to deliver solutions, architectures, technologies and standards for the next generation mobile networks and communication infrastructures.
12	SPIRE/A.SPIRE	cPPP/IA	cPPP related to Sustainable Process Industry/linked Association	The Sustainable Process Industry through Resource and energy Efficiency (SPIRE) is a contractual Public-Private Partnership dedicated to innovation in resource and energy efficiency enabled by the process industries. SPIRE is driven by the European Process Industry and fully aligned with the strategic goals defined by the European Commission in the Europe 2020 strategy and across its various flagship initiatives such as the "Innovation Union", an "Industrial Policy for the Globalisation Era", “Resource efficient Europe” and an “Agenda for new skills and jobs”. A.SPIRE is the European Association which is committed to manage and implement the SPIRE Public-Private Partnership
13	EIP AHA	EIP	EIP Active Healthy Ageing	The European Innovation Partnership in Active and Healthy Ageing (EIP on AHA) is a pilot initiative launched by the European Commission to foster innovation in the field of active and healthy ageing. The concept of European Innovation Partnerships (EIPs) is a new approach to EU research and innovation. It brings together all relevant actors at EU, national and regional levels across different policy areas to handle with specific societal challenges and involves all the innovation chain levels.
14	EIP SmartCities	EIP	EIP Smart Cities	The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) brings together cities, industry and citizens to improve urban life through more sustainable integrated solutions. This includes applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, intelligent use of Information and Communication Technologies (ICT), etc. It combines Information and Communication Technologies (ICT), energy management and transport management to come up with innovative solutions to the major environmental, societal and health challenges facing European cities today.
15	EIP AGRI	EIP	European Innovation Partnership for Agricultural productivity and	EIP Agri aims to foster a competitive and sustainable agriculture and forestry sector that "achieves more from less". It contributes to ensuring a steady supply of food, feed and biomaterials, and to the sustainable

			Sustainability	management of the essential natural resources on which farming and forestry depend. EIP-AGRI is not a PPP, but a hub that brings together innovation actors (farmers, advisors, researchers, businesses, NGOs, etc) and helps to build bridges between research and practice.
16	Robotics	cPPP	cPPP on Robotics	The public private partnership in robotics (Robotics PPP) consist of the robotics industry, research, academia and the EU Commission to launch a joint research, development and innovation programme in order to strengthen the competitive position of European robotics. Developing the next generation of intelligent robots to keep European manufacturing competitive. Entering new markets in agriculture, healthcare, transport, security and utilities. The public side is represented by the EU Commission (The Directorate-General for Communications Networks, Content and Technology), while the private part is represented by the non-profit association euRobotics AISBL (Association Internationale Sans But Lucratif).
17	IoT-EPI	EU Funded Initiative	European initiative led by projects funded under the call ICT-30-2015.	IoT-European Platforms Initiative (IoT-EPI) is a European Initiative addressing the new EU-funded H2020 programs about IoT platforms development and interoperability. IoT-EPI is coordinated by two consortia i.e., Unify-IoT and Be-IoT and involves seven research and innovation projects funded under the call ICT-30-2015 - Internet of Things and Platforms for Connected Smart Objects.
18	Autonomous Transport FA	EU Focus Area (FA)	Autonomous Transport Focus Area	Cross-cutting activities (Focus Areas) H2020 connected to ERTRAC
19	FIRE	Open research environment	Future Internet Research and Experimentation	Future Internet Research and Experimentation (FIRE) is an initiative launched and financed by the EU Commission, with the ambition of being Europe's' Open Lab for Future Internet research, development and innovation. FIRE offers cutting edge test facilities to experiments with networks, infrastructures and tools in a multidisciplinary test environment. The aim is to make large-scale experimental research at a lower cost in a more rapid way. The AmpliFIRE support action project provides a forum for industry, researchers and social stakeholders to drive FIRE towards the best facilities and model for their needs.
20	AIOTI	IA	Independent Industrial IoT Association	The Alliance for Internet of Things Innovation was initiated as a result of the European and global IoT technology and market developments. AIOTI aims to create and master sustainable innovative European IoT ecosystems in the global context to address the challenges of IoT technology and applications deployment including standardisation,

				interoperability and policy issues, in order to accelerate sustainable economic development and growth in the new emerging European and global digital markets

Each of the various entities will be addressed by one of the partners of T04.02 as for each of the entities listed, an allocation has been made over the participating partners in this task.

3.2 The entity's SRIA document

For each of the stakeholders (as identified in section 3.1) an investigation will be done into their SRIA. Such document describes the scope of the Research and Innovation than an entity entails and includes strategic scope envisioned. In every SRIA we would expect the scope of the SRIA to be expressed by specific Research and Innovation challenges, both on IoT technology and on IoT applications (whenever applicable).

Although such documents have different names at the different organisation, they will be identified and an inventory will be provided of their content in relation to IoT.

3.3 Interview with key representative

Furthermore, the investigation also includes a personal interview with a key representative of the entity after some study of their SRIA document. During the interview, the initial findings will be shared and discussed with the representative to come to possible corrections and additional findings. An indicative set of questions has been defined for such interviews to ensure consistency that will allow aggregation of the results.

Moreover, we will connect with relevant Activity Groups (AGs) in the IoT European Large-Scale Pilots Programme.

4. European IoT research and innovation activities over the IoT architectural layers

4.1 Introduction

This chapter provides a preview of IoT elements and technologies in line with the IoT architecture layers in order to introduce the IoT topics addressed in the SRIA of different European initiatives to anticipating the future results that will become available in D4.4 on EU research and innovation activities overall plan-evaluation when the outcome of the interviews will be presented.

4.2 IoT layered architecture

The table below defines the important components in the various layers of the IoT architecture that supports the analysis of the features of different IoT platforms making the comparison of various solutions easier.

Table 2: Mapping the IoT Platforms components to eight layers IoT architecture

IoT Architectural Layer	Components	Definitions
Collaboration	Business system integration	Enables integration with existing enterprise and other external systems
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards
	Development environment	Provide integrated development environment to simplify developerment of apps
Service	Service orchestration	Supports mashup of different data streams, analytcs and service components
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed
Abstraction	Event and action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics
Storage	Storage/Database	Cloud based storage and database capabilities (not including on premise solutions)
Processing	Device management	Enables remote maintenance, interaction and management capabilities of devices at the edge
	Edge analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity
	Edge gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform
Physical Layer	Operating system	Offers low-level system SW managing HW, SW and runs applications
	Modules and drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level

Physical layer

The basis for all IoT technologies is the hardware, e.g. without the infrastructure (e.g. datacentres, servers, etc.) there is no cloud service. The physical layer is the first option to design IoT systems "from the ground", e.g. by integrating relevant functions already on chip level, thereby building entire systems (SOC = system on chip). Advantages of this approach are usually a high level of security and reliability. On the other hand, this approach offers only a limited amount of flexibility regarding the use cases.

Network communication layer

The role of communicating information in entirely new contexts: sensor technology enables actions in the world to give rise to data while network links allow to create and communicate. This includes transmissions between devices and the network, across networks, and between the network and low-level information processing occurring. Data communication networks have multiple functions, as described by ISO 7-layer reference model. The IoT systems contain many levels in addition to the communications network.

Processing layer

The layer addresses the edge computing, data element analysis and transformation, analytics, mining, machine learning, pervasive considering that autonomic services are provided through ubiquitous machines in both "autonomic" and "smart" way.

The processing layer convert network data flows into information that is suitable for storage and higher-level processing and provides the ability to process and act upon events created by the edge devices and store the data into a database in the storage layer.

The requirements for the processing layer are connected to the need for highly scalable, column-based data storage for storing events, map-reduce for long-running batch-oriented processing of data and complex event processing for fast in-memory processing and near real-time reaction and autonomic actions based on the data and activity of devices and the interconnected systems.

Edge computing requires processing at the gateway level and the enterprise applications leverage edge devices data in end-to-end value streams involving edge devices and people within digitized processes.

Storage layer

The IoT stakeholders addressing this layer consider the efficient storage and organization of data and the continuous update of data with new information, as it made available through the capturing and processing channels. Archiving the raw and processed data addresses the offline long-term storage of data that is not needed for the IoT system's real-time operations. Centralized storage considers the deployment of storage structures that adapt to the various data types and the frequency of data capture.

Relational database management systems can be used that involves the organization of data into a table schema with predefined interrelationships and metadata for efficient retrieval for later use and processing. Storage technologies such NoSQL key-value stores are used to support big data storage with no reliance on relational schema or strong consistency requirements typical of relational database systems. For autonomous IoT applications, the storage can be decentralized, and data is kept at the edge or at the objects that generate it and is not sent up the system.

Abstraction layer

The layer that provides the interfaces and the event and action management through simple rules engine to allow mapping of low level sensor events to high level events and actions, while assuring the basic analytics for data normalization, reformatting, cleansing and simple statistics.

IoT systems scale corporate and global level and require multiple storage systems to accommodate IoT device data and data from traditional enterprise ERP, HRMS, CRM, and other systems. The data abstraction functions are rendering data and its storage in ways that enable developing simpler, performance-enhanced applications. Data abstraction layer processes data and reconcile multiple data formats from different sources, assuring consistent semantics of data across sources, confirming that data is complete to the higher-level application, consolidating data, providing access to multiple data stores through data virtualization, normalizing or de-normalizing and indexing data to provide fast application access, protecting data with appropriate authentication and authorization.

Service layer

The layer that integrates the middleware that sits on top of networks and IoT device streams and provides data management and data analytics are vital functions in IoT systems where large amounts of sensor generated data and events must be logged, stored and processed to generate new insights or events on which business decisions can be taken.

Application layer

Application layer is offering the software platforms that are suited to deliver the key components for implementing various IoT applications that are connecting users, business partners, devices, machines, and enterprise systems with each other and the information interpretation is provided. Software at this layer interacts with the service layer, while the software applications are based on vertical markets, the nature of device data, and business needs. At this layer, many applications are addressed such as mission-critical business applications, ERP, specialized industry solutions, mobile applications, analytic applications that interpret data for business decisions, etc.

Collaboration and processes layer

Enterprise systems and platform and the exchange of data among these platforms. includes people and processes. The layer addresses the processes that involves people, organisations that use applications and associated data for their specific needs or for a range of different purposes, to provide the right data, at the right time, to perform the right thing.

End to end security is address for each layer and as the data is moved across the layers to secure each device or system, provide security for all processes at each level, secure end to end exchange and communication between each layer.

4.3 Research and innovation activities addressing the IoT architectural layers

4.3.1 Physical Layer

ECSEL: Semiconductor process technology and integration actions focusing on introduction of materials, devices and new concepts, in close collaboration with the equipment and materials community, to allow for the diversity of compute infrastructure needed, from high performance, over mobile and edge computing to ultra-low power data processing at IoT node level.

The challenge includes three areas of attention at the transistor level:

- Extensions of the scaled Si technology roadmaps (including FD SOI, FinFET and stacked, Gate-All-Around nanowires, 3D versions),
- Exploration and implementation of devices beyond Si (TunnelFET, III-V, SiGe, Ge, 2D, CNT, ferroelectric, spin-based) and
- Novel device, circuit and systems concepts for optimum Power-Performance-Area-Cost specifications, high energy efficiency and novel paradigms like Neuromorphic and Quantum computing. New memory concepts to support the correct memory hierarchy in the various

applications. Efforts to push new transistor and memory concepts (RRAM, PCRAM, STT-RAM) to the demonstration level in the IoT infrastructure (from server, over edge to nodes). Storage class memory is planned to bridge the gap between DRAM and NAND, IoT applications crystallize the needs for low power embedded devices, cloud and fog computing always need more mass-storage space.

New solutions for energy efficiency on system level in general; new innovations for growing applications addressing lowest power demand for IoT solutions. Multi/many-core processors for new computing architectures, designed from the start with predictability in mind to support emergence of trustable systems for cyber-physical applications. IoT fosters the usage of heterogeneous multicore architectures still poorly addressed at software level (OS, compilers, tools).

FoF/EFFRA: There is an increasing interest on the adoption of new enabling technologies such as smart embedded systems, IoT, low-powered sensors, and M2M integration in manufacturing and maintenance: they can actually enable innovation in factory environment (note – EU funded projects are working on this).

Robotics: Focus on sensor and actuators for assistive robots that need to sense not only the user but obtain information from the ambient and embedded systems around them, either data collected by smart sensors or by other smart devices in the environment. Sensing devices connected to protocols and standards for enhancing exchanging data between multiple devices.

4.3.2 Network Communication Layer

5G: The research in the area of 5G communication technologies [2] addresses the fundamental change is the explosion of IoT involving machine to machine (M2M) communications. IoT implies a much larger number of terminals with a more diverse range of requirements than human-held terminals will ever require. This poses huge technical challenges to many areas of the network. The research focuses on new network control solutions that can effectively handle the authentication, naming, addressing, routing and related functions for such a vast number of terminals. Research on radio systems that provide solutions, which accommodate very low-traffic and low energy terminals as well as high-capacity terminals, plus additional requirements like low delay and localizations, all with high indoor penetration. Terminal technologies development to deliver solutions with a variable combination of requirements at extremely low cost, very low energy, and very small size. The combination of network computing services and internet of things drives a fundamental change in the service model, consisting of the advent of the vertical sectors. Focus on the transformation of the control plane driven by network function virtualization (NFV) and software defined networks (SDN) and the he development in radio and optical technologies. The 5G network development based on a multi-RAT approach, including new developments like millimetre wave, massive MIMO, beam steering and possibly non-orthogonal carriers.

Work on further densification in the form of massive deployment of small-cells which will be connected to the network with efficient, high-throughput and low-latency optical and wireless backhaul links, while adapting the radio access network to the spatial and temporal variations of traffic patterns, will make the paradigm of moving networks essential; through low altitude UAVs (e.g. drones), and terrestrial vehicles, the network access points (base stations) will follow the traffic demand, ensuring maximised capacity and coverage, for both “things” and human-oriented devices.

Research areas for wireless ultra-reliable low-latency device-to-device communication address measurement, modelling and emulation of multi-node communication channels in the targeted 5G frequency bands: due to the fast movement of vehicles and the low height of the antennas the resulting fading process has strong non-stationary properties. Low-latency physical layer modulation formats for low packet error rates at short packet lengths: for reliable communication links, the utilization of all locally available diversity mechanisms (time, frequency, space) is needed.

Research areas for TeraHertz communications such as transceivers, antennas and solid-state circuits supporting Tbps data rates at (sub-)THz bands with an order of magnitude efficiency improvement ready for practical development.

Moreover, the main guideline is to exploit the connectivity paradigm offered by the IoT to support real-time data acquisition. “Manufacturing 2.0 enterprise assets and products of the future will leverage the concept of the IoT where objects (and/or their related transport unit) carry information about themselves, communicate with each other and the world around them, in particular with the relevant Intra factory processes.”

Robotics: Technologies for robots to communicate with each other, with internet based services in the “cloud” and to the IoT around them. Hard real-time communication between different sensors and actuators within one robotic system needs to be automatized and standardized. In view of the increasing complexity of robotics systems, communication protocols and code generation tools are needed, which allow to easily design flexible topologies of sensors and actuators and to automatically generate and configure the code for their communication. Development or adoption of existing of internal communication protocols and offerings of standardised module construction. Address wireless communication protocols, particularly ad-hoc protocols and mobile to mobile systems for robot communication.

ECSEL: Wireless energy transmission concepts for short range applications and concepts for IoT devices to be designed for, or adapted to, the different environments in which they are used with specific requirements for environmental conditions, energy management, communications, etc, in addition to the requirements for sensors and actuators.

FoF/EFRA: Research needed in new software solutions to monitor and improve energy efficiency of products throughout their usage by customers by leveraging new enabling technologies such as smart embedded systems, IoT, low-powered sensors, and M2M integration in manufacturing and maintenance. Integrated data collection about energy consumption at each step of the life cycle and analysis (e.g. autonomous, small, robust, smart embedded devices) through advances in IoT are explored. Research focusing on using advanced sensors and the IoT to transfer product specific data to monitoring logic hosted in cloud infrastructure. Development of usage mark-up language to easily decipher and consume usage patterns of products and of data anonymization techniques such as obfuscation, randomisation, reduction, and perturbation to disassociate customer information from collected data are investigated.

4.3.3 Processing Layer

SPIRE: SPIRE, in its roadmap, presented an overview of the industrial needs and the related research and innovation challenges to go beyond the state-of-the-art. In this context, data processing and related ICT were identified as relevant technologies to enable improved process monitoring and control in process industries.

PENTA: The EUREKA cluster PENTA is addressing a wide value chain of “micro- and nanoelectronics components and systems”. This obviously also includes the processing layer of IoT systems with hardware design and implementation, including embedded software.

ITEA: The EUREKA cluster ITEA focusses in its program on all aspects of “software intensive systems”. As this includes embedded system, some processing aspects can be included in ITEA projects.

Robotics: Modelling and Knowledge Engineering for system development with the extension of object modelling through computer vision through other forms of sensing (infrared, tactile), database of typical motion and interaction patterns during care processes, format that allow care personnel to verify correctness of learnt models. Research to address areas from ontological learning to phylogenetic and social learning. Formal methods for knowledge integration also on a collaborative way with other robots (internet of things for problem solving). Complete description of mechatronic behaviour by merging mechanical and electrical modelling methods with computer science modelling methods - 100% virtual validation of the system. Address the generalised, neutral task and resource modelling- Resource programming automatically achieved based on resource and task characteristics and the robots integrated into IoT and making use of big data methods and semantic web technology (Industry 4.0).

ECSEL: The analysis of the big data produced by billions of entities (sensors, people and organisations) is challenges for the IoT that requires data science experts that can extract relevant information and patterns while preserving user privacy and security. Address the issues of data, combined with machine-learning techniques, that have a major positive impact on the efficiency of industrial production. Address the cyber-physical systems integrated in IoT applications to deal with hard real-time constraints, energy management, data access and storage, dynamic reconfiguration, application deployment, reliability and security of the data and processes. Connectivity enables functions and functionalities to be performed at all levels, such as distributed computing, edge-computing or fog computing. The developments allow the seamless integration of the Internet of Things (IoT) concept with applications to Internet of Energy (IoE), Internet of Buildings (IoB) and Internet of Vehicles (IoV), etc. The key challenges are: energy efficiency, by all possible means: avoiding unnecessary data communications (e.g. by processing

data to extract the useful information where it is captured), pushing for new innovative architectures and protocols, holistic optimisation. New silicon technologies, new non-volatile storage technologies (which can change the existing storage paradigm), photonics, adaptive voltage and frequency control, 3D interconnect, energy-aware operating systems and middleware, data placement and retrieving, application development and so on will be required to harmoniously cooperate in order to further increase energy efficiency.

Ensuring Quality of the Service (QoS) dependability including real-time is a major challenge that worsens with the emergence of many/multi-core systems. The solution covers real heterogeneous parallel processors, new memory architectures and chains, the development of parallel oriented programming languages and design methods, as well as software architectures and setting up respective education. Edge computing that due to connectivity functions, computing capabilities are shared/exist outside the physical device and processed in the ‘Cloud’. Deploying Cloud-dependent services (software running on the device or outside as well as software applications not embedded in the product) to provide latency, QoS, and increased the security.

4.3.4 Storage Layer

The storage layer will be covered by several different entities,

ECSEL and PENTA: In the common SRA of both ECSEL and PENTA one of the chapters is devoted to R&D&I on “Computing and Storage”. Similarly, the ITEA program, supporting “software intensive systems” includes projects that address storage and retrieval of data (structured in databases).

Robotics: Address the unstructured and unknown environments that assistive robots are likely to face through processing carried out in the cloud (i.e. the recognition of novel objects, or advice about strategies or decision making that may involve clinical judgement that cannot be pre-programmed or the interpretation of social context.

Complex interpretation of interaction tasks processed and stored in the cloud where their drivers and enablers can be collated from a wider range of experience than any one robot may encounter. Establishing standards for these high level cognitive and social interactions will be critical to their wide spread enhancement of assistive robots. Interacting between products by different manufacturers will be critical to wide adoption and deployment.

4.3.5 Abstraction Layer

FoF/EFFRA: Association focus is also on solution that ensures interoperability (standardisation, protocols, data and information models) between objects and systems operating in the shop floor. Key Challenges: semantic interoperability. Research on the use of advances in IoT and product traceability to devise identifiers to map unique product IDs to corresponding service offerings, develop transactional models for customers to purchase and consume after-sales services, and add semantic search functionality to correlate product, after-sales services to third party added-value services. The mobile servicing cockpit to be integrated with backend enterprise systems for inventory and asset tracking and offer intuitive mobile UIs for customers to visualise and browse the entire range of available service offerings for products.

SPIRE: few EU funded SPIRE projects are exploiting IoT solutions supporting interoperability.

ECSEL: Programming a network or system of computing systems (as is done in data centers, and between mobile devices and sensing devices in IoT applications) where an application is, in fact, the result of more or less coordinated interdependent programs interacting with each other and distributed onto different systems and programmed with different approaches.

SPIRE: few EU funded SPIRE projects are exploiting IoT solutions supporting interoperability.

4.3.6 Service Layer

EIP-AGRI: From the point of view of the EIP-AGRI community, the IoT Service Layer can be seen as a primary stage where agricultural actors (for example, farmers) can *consume* the data generated by the IoT system(s) available to them. Key technology challenges: *data compatibility*, *platform interoperability*, *semantic interoperability*, *data management* and *data access control* (security, privacy).

BDVA: Big Data technologies *consume* data provided by the lower IoT layers (as well as from other data/information sources apart from IoT) in order to process it, analyse it and generate useful knowledge or insights ready to be turned into value by the Application Layer. Key technology challenge: *semantic interoperability*.

FoF/EFFRA: In its roadmap, the association clearly highlights a main need to address interoperability issues within different factory processes by research and standardization of interfaces. Moreover, EFFRA identified as relevant solution the development of IoT-based device integration middleware, inherently scalable and distributed. Such solution should also support self-configuration capabilities, limiting the manual intervention of involved factory stakeholders. Key technology challenges: platform interoperability, semantic interoperability.

The focus on the development of IoT ‐ based device integration middleware that are scalable and distributed in nature and do not require manual intervention to register and configure multiple shop floor resources having the same generic specifications. This would improve productivity across shop floors by reducing configuration time and provide an automated way to control different facets of the shop floor. Future research is needed in the development of a dynamic object‐ oriented model to represent classes and instances of real‐ world resources as well as semantics representations to model intangible assets on the shop floor. These should be coupled with the development of SOA‐ based distributed middleware with dynamic code deployment functionality and intuitive UI that give holistic views of resource layouts on the shop floor and configurations to the decision‐ makers. The semantic models that are holistic in nature and able to represent all levels of production functions and equipment. For real‐ time data acquisition, the connectivity paradigm offered by the IoT should be exploited and complemented with mobile decision‐ making apps that will assist plant managers in getting a holistic overview of KPIs computed on collected data.

SPIRE: note – few EU funded SPIRE projects are exploiting IoT solutions supporting interoperability.

4.3.7 Application Layer

EIP-AGRI: From the point of view of the EIP-AGRI community, the Application Layer is the main interface between EIP-AGRI stakeholders and the IoT. In this sense, the EIP-AGRI represents an *IoT end-user community*. Key technology challenges: *platform interoperability*, *application interoperability*, *semantic interoperability*.

BDVA: At the Application Layer, IoT plays here the role of *consumer* of what is provided by Big Data. Big Data technologies can digest the data-turned-knowledge generated from lower IoT layers (and other data/information sources apart from IoT) and convert it into useful or actionable knowledge by means of software-based decision support tools and applications that are usually tuned or specifically designed for a given vertical. Key technology challenges: *platform interoperability*, *application interoperability*, *semantic interoperability*.

FoF/EFFRA: "Future research should use advances in IoT and product traceability to devise identifiers to map unique product IDs to corresponding service offerings, develop transactional models for customers to purchase and consume after sales services, and add semantic search functionality to correlate product, after sales services to third party added value services."

IoT‐ based continuous data collection from real‐ world resources (i.e. assets, devices, products) from the field and along the value chain in conjunction with appropriate simulation and data analytics tools to identify deviations between expected and actual results allowing early management of factory and production issues.

EIP-SmartCities: Address reference architecture into which standards can fit that enable interoperability between city systems and entities at many levels. New standards for Smart Cities to be developed swiftly with full consultation and agreement from relevant stakeholders, and with the principle of adoption/adaption of existing materials. These include: internet protocols (IPv6), data formats (jpeg, xml), radio frequency identification (RFID) tags, and building energy performance standards.

4.3.8 Collaboration and Processes Layer

EIP-AGRI: Technology investments in the farming domain are done typically with a long-term mindset, and therefore it is common that state-of-the-art technology operates (collaborates) with other more aged, legacy systems, platforms or applications. Key technology challenges in this layer: *platform interoperability*, *semantic interoperability*, *security and data access control*.

BDVA: Big Data tools and solutions typically deal with inputs from multiple systems, data sources, platforms or enterprise domains. At the same time, they typically provide insights o decision-support recommendations whose effect ranges across different systems, organizational structures or processes, and even end-user communities. Key technology challenges: *platform interoperability*, *semantic interoperability*, *security and data access control*.

FoF/EFRA: Manufacturing 2.0 enterprise assets and products of the future will leverage the concept of the IoT where objects (and/or their related transport unit) carry information about themselves, communicate with each other and the world around them, in particular with the relevant intra‐ factory processes. In order to harness the potential of connected objects and perform meaningful data analytics, future research should bridge the gap between different abstractions of objects operating at the shop floor level, business systems level, and at the level of supply networks.

On the shop floor level, the need for research and standardisation of interfaces includes both mechanical (types of load carriers in relation to standardised types of pallets and, beyond them, to common means of intra‐ factory transportation like mobile machinery) and digital (programming languages, I/O protocols I/O devices in relation to common information carriers like bar codes, RFIDs and others) interfaces. Address the cooperating objects that carry their own servicing and maintenance information, thereby facilitating faster fault resolution and triggering repair operations. Furthermore, scalable tracking and tracing of production orders, assets, products and personnel across different organisations, semantic modelling and description of IoT resources, and business process modelling of data and interactions of IoT resources and capturing non‐ deterministic and unpredictable behaviour at run‐ time should be researched.

ECSO: As part of ECSO's main objective to support all types of initiatives or projects that aim to develop, promote, encourage European cybersecurity, it particularly aims to "foster and protect from cyber threats the growth of the European Digital Single Market (DSM)" [7]. As stated by the European Commission "strengthening the EU's cybersecurity industry will allow European businesses to seize these opportunities and reinforce trust of citizens and businesses in the digital world, contributing to the goals of the Digital Single Market Strategy" [8].

ECSO was launched as a key initiative in the endeavour of boosting industrial capabilities in Europe and of delivering both the DSM and EU Cybersecurity Strategies. In order to meet its strategic goals, it contemplates ICT infrastructures as one of its major areas of interest (where IoT is an emerging area where cybersecurity offering needs to match specific needs) and brings together a wide variety of stakeholders such as large companies, SMEs and Start-ups, research centres, universities, end-users, operators, clusters and association as well as European Member State’s local, regional and national administrations, and countries part of the EEA, EFTA and associated to H2020.

ECSO creates a cyber pillar for cyber security trustworthy innovation and further supports this in H2020 by providing reports and information beyond the state of the art of cybersecurity and future trending topics in order to support the definition of future research topics of EU projects, and with the additional goal to support piloting for validation and stakeholder involvement. One of this fields of expertise is IoT cybersecurity, which has been identified as basis for the growth of the DSM.

The security, privacy and trust objectives of ECSO are transversal across all ICT infrastructures and application domains-verticals (e.g. ICT Infrastructure, Smart Grids, Smart Buildings and Smart Cities, etc.), which were identified as critical for the DSM. Similarly CREATE-IoT addresses the same horizontal aims as ECSO, however, focused on the domain of IoT, and importantly also overlap in vertical domains such as Smart Cities and Health Care pilots coordinated by CREATE-IoT. There is therefore great potential for mutual collaboration between both initiatives on privacy and security by design recommendations (which can be expected to become more prevalent and can be effectively communicated and materialized with a basis on certification as a key enabler); a security architecture for IoT application, network and subsystem levels; standardization; certification and trust labels (including marking of IoT devices with security labels to generate trust into connected IoT devices towards citizens, end users and businesses); and creation of common security building blocks (e.g. building trustworthy IoT frameworks is identified as a desired outcome of some research challenges of ECSO’s SRIA) that are applicable to the IoT application domain. Furthermore, ECSO has also identified AIOTI as relevant initiative for establishing links. The recent proposal for a Regulation from the European Commission to set up an EU-wide Certification framework for ICT Security products is a major development to be followed both from ECSO and IoT initiatives [9][10].

5. COORDINATION PLAN

5.1 Phased approach

As indicated in section 2.1.4 the coordination plan consists of five phases, as further elaborated below.

5.1.1 Inventory phase

A document study of the publicly accessible SRIA documents will yield in short IoT-focused summaries to be provided for each of the 20 SRIA documents of the different entities identified.

5.1.2 Interview phase

Live interviews will be conducted with key representatives of reports and reports will be included

5.1.3 Consolidation phase

clustering of the various findings per entity, from both the document study and the interview conducted, combined with general impressions

5.1.4 Feedback and Alignment phase

Feedback is provided as consultancy to the stakeholders in the form a written report of the combined findings, including recommendations how to better align to the European IoT landscape and how to use more consistent terminology

Such feedback document will be addressing several aspects, including:

- The position in the IoT landscape
- The scope of IoT coverage
- Thw alignment with other IoT actors in the landscape
- The usage of IoT terminology and its semantics (nomenclature)

5.1.5 Reporting phase

The overall conclusions of this study will be reported in de final deliverable D04.05.

6. CONCLUSIONS

6.1 Conclusion

Several aspects can be concluded for the EU research and innovation activities overall plan.

6.1.1 Stakeholders

This EU research and innovation activity has identified as much as 20 relevant stakeholder groups that are more-or-less related to IoT-related research in Europe.

6.1.2 SRIA documents

For each of the relevant stakeholder groups the Strategic Research and Innovation Agenda documents have been identified and an inventory will be made of the IoT-related content.

6.1.3 Investigation

For each of the SRIA documents identified an investigation will be done: next to the document study a personal interview will be carried out.

6.1.4 Reporting

For each of the entities addressed, a feedback document with be provided containing recommendations how to improve the alignment within the IoT landscape, on the scope of IoT coverage and on the usage of preferred IoT terminology and its semantics.

7. REFERENCES

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7.1 Internet WEB-links

The table below contains the WEB-links to the entities home page and SRIA document:

Table 3: Internet references

#	"PPP" entity	Name / Scope	WEB-Link
1	ECSEL	Electronics Components and Systems	www.ecsel.eu
2	Artemis-IA	CyberPhysical Systems	https://artemis-ia.eu
3	AENEAS	AENEAS Association	https://aeneas-office.org
4	Eposes	Smart Systems	https://www.smart-systems-integration.org

5	ITEA	Software Intensive systems	www.itea3.org
6	PENTA	Micro and nanoelectronics enabled systems and applications	www.penta-eureka.eu
7	BDVA	Big Data Value	www.bdva.eu
8	CyberSecurity PPP & ECSO	European Cyber Security Organisation (ECSO)	https://www.ecs-org.eu/
9	RRI-SSH	Responsible Research and Innovation (RRI) and Social Sciences and Humanities (SSH)	https://european-iot-pilots.eu/u4iot/
10	FoF / EFFRA	Factories of the Future	http://ec.europa.eu/research/industrial_technologies/factories-of-the-future_en.html http://www.effra.eu/
11	5G-PPP	5G networking	https://5g-ppp.eu/
12	SPIRE	Scalable and Unified Platform for Real World IoT Services with Feature Interaction	https://www.spire2030.eu/
13	EIP AHA	Active Healthy Ageing	https://ec.europa.eu/eip/ageing/home_en
14	EIP SmartCities	Smart Cities	http://ec.europa.eu/eip/smartcities/
15	EIP Agri	Agri & Food	https://ec.europa.eu/eip/agriculture/
16	Robotics PPP	Robotics	https://www.eu-robotics.net/ppp/
17	IoT-EPI	European Platforms Initiative (cluster of EU-funded projects)	http://iot-epi.eu/
18	Autonomous Transport FA	Autonomous Transport Focus Area	http://www.ertrac.org
19	FIRE	Future Internet Research & Experimentation	https://www.ict-fire.eu/
20	AIOTI	Association of IoT Industry	https://aioti.eu/