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IoT LSP handbook

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Author(s)	L. Pérez-Freire (GRAD), M. Álvarez-Díaz (GRAD), D. Chaves Diéguez (GRAD), R. Muleiro (GRAD), O. Vermesan (SINTEF), R. Bahr (SINTEF), J. Valiño (ATOS), I. Ingardi (ARTS), B. Rowan (BLU), T. Suárez (BLU), L. Manteau (GTO), T. Teixeira (UNP), B. Almeida (UNP), M. Serrano (NUIG)				
Editor	L. Pérez-Freire (GRAD), O. Vermesan (SINTEF), R. Bahr (SINTEF)				
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1. EXECUTIVE SUMMARY

Publishable summary

The term Internet of Things (IoT) has become mainstream and it is quite commonly found nowadays in generalist media and common language. As a consequence, many non-informed readers may have already a rough idea of what the IoT is all about. However, behind the short and catchy acronym the IoT hides a much more complex reality.

The IoT can be understood as a confluence or combination among a variety of technologies (sensors/actuators, connectivity, networking, data processing, virtualization, etc.) that are designed to solve specific needs across a variety of application domains (healthcare, wellbeing, agriculture, transport, industry, wearable applications…).

As in any other technology-related field, there is a large number of specific terms and acronyms related to the IoT that are more or less frequently used among the community working in the field. The combination of technologies and application disciplines makes up for a rich variety of terms and concepts that can range from common 'horizontal' terminology to very specific terms linked to particular application cases or verticals. Obviously, this represents a barrier to the layman that is not well-versed in IoT matters. However, it has become apparent that even for professionals working in the IoT field it is not straightforward to adequately follow documents or presentations coming from IoT work performed in different IoT application domains than their own.

In order to help lower this barrier, and establish a common terminology reference, this document has been designed as a glossary compiling a representative sample of terms of common use across the IoT community in general, and the IoT European Large-Scale Pilot Programme in particular. This document has been conceived as a primary source of reference (certainly, a "handbook") for both IoT experts and non-experts.

Around 250 definitions and acronyms have been compiled in the handbook that covers a wide range of possible IoT dimensions and application fields. For each concept, we have provided its definition as well as some keywords that will allow the reader to properly locate where the concept applies to within the IoT field. Most of the definitions have been extracted from external references, which are as well provided for the interested reader that wants to investigate further.

Considering that the IoT is a living, evolving field just as much as the Large-Scale Pilots are, this handbook must be taken as a tool that the CREATE-IoT project offers to the community that samples the most common terminology used across the IoT European Large-Scale Pilot Programme. Instead of being considered as the ultimate reference on IoT terminology, this handbook should become as a first version of a living document to be taken up, maintained and regularly updated and expanded by the IoT European Large-Scale Pilot Programme community.

Non-publishable information

None. This document is public.

2. INTRODUCTION

2.1 Purpose and target group

As in many other technology-related fields, the vast terminology existing around the IoT may (and does) make it difficult, even for informed readers, to follow adequately many documents and presentations that deal with the matter. To make things worse, sometimes the same term can be used with different meanings or interpretations by two versed professionals working on different dimensions or application domains of the IoT.

The primary purpose of the IoT LSP handbook is to provide a common reference terminology so as to facilitate cross-fertilisation among all projects of the IoT European Large-Scale Pilot Programme.[1] This handbook seeks to establish a common ground for understanding across the seven projects of the Programme, in order to facilitate the exchange of results, experiences, lessons learned, as well as to foster a culture of cooperation among the projects.

The main target group of the IoT LSP handbook is the community working on any of the projects of the IoT European Large-Scale Pilot Programme. We note that the community of professionals involved in the seven projects of the IoT European Large-Scale Pilot Programme is not only formed by experts on IoT technology. Indeed, this community features professionals coming from multiple disciplines (such as public administration, behavioural sciences, arts or law), not to mention the large variety of end-users represented (such as farmers, healthcare professionals or consumers, just to name a few.) Both technologists and non-technologists will benefit from this handbook.

In addition to the IoT European Large-Scale Pilot Programme community, additional target groups that will benefit from this handbook are external readers approaching the activities of the IoT LSP Programme for the first time, and of course, any newcomer to the world of IoT in general.

2.2 Contributions of partners

This handbook is one of the two deliverables coming out of Task 02.01 "IoT architecture approaches and federation of pilots activities". The deliverable has received contributions from eight different partners. All eight partners have contributed with a fair amount of terms falling under their fields of expertise whenever possible.

SINTEF has contributed with the definitions of concepts related to the technology layers of the IoT, the ones related to AI, and IoT applications. In the context of the development of the IoT handbook SINTEF, ensured an efficient interplay of the various elements of the IoT-FA and liaise with relevant initiatives at EU, Member States and international levels in order to align the various definitions.

ATOS has contributed mostly with terms related to the technology layers of the IoT as well as some application domains and supported the alignment with existing European initiatives in which ATOS is already present.

ARTS has contributed mostly with terms related to the IoT design and the human and artistic dimensions of the IoT.

[1] See https://european-iot-pilots.eu/

BLUS has contributed mostly with terms related to business and economic dimension of the IoT as well as some application domains.

GTO has contributed mostly with terms related to the security dimension of the IoT as well as its technology layers.

UNP has contributed mostly with terms related to the technology layers of the IoT.

NUIG has contributed mainly with terms related to the technology layers of the IoT.

GRAD has contributed mainly with terms related to the data plane of the IoT, as well as terms linked to the industrial and agrifood application domains. As lead partner for D02.01, GRADIANT has played the role of editor and coordinator of the deliverable.

2.3 Relations to other activities in the project

Only external sources have been used during the elaboration of this handbook. No inputs have been taken from other activities or work packages of the project.

As explained in Section 2.1, the purpose of this document was primarily to serve the community involved in the IoT European Large-Scale Pilot Programme. Since CREATE-IoT is part of the IoT European Large-Scale Pilot Programme, this document will be useful as the preferred go-to source for IoT-related terminology across all WPs and Tasks of the project.

3. A HANDBOOK TO THE IOT LARGE-SCALE PILOTS PROGRAMME

IoT LSP handbook contains the reference terminology facilitating cross fertilisation among all the Large-Scale Pilots (LSPs) calls, to ensure the use of a common terminology in addressing the technical (protocols, formats, APIs, etc.) and non-technical (business models, testing and validation methodologies, regulatory framework, etc.) issues. This is implemented offline and will be transfer online (i.e. web platform for exchange/community building) during the next phase.

The IoT LSP handbook aims at disseminating knowledge about IoT terminology among the IoT European Large-Scale Pilot Programme projects and IoT stakeholders at large, and at providing easy access to a large range of technical and non-technical IoT. The document is a reference work, including a collection of terms, that is intended to provide ready reference in the field of IoT technologies and applications. The document is designed to be easily consulted and provide quick answers in the IoT area. The IoT LSP handbook addresses will be expanded and revised during the lifetime of the IoT European Large-Scale Pilot Programme.

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5G: The technology designation of the next generation mobile network. Standardization work through ITU-R / IMT-2020 is expected to be completed by 2020, however, it will take several years before "all" expectations are met and widely available (e.g. implementation of frequencies up to 30 GHz). There are high expectations and requirements with respect to speeds, latency and energy efficiency. A very large increase in capacity and much faster internet on mobile phones is expected. The frequency bands are not finally established; however, the EU advisory body Radio Spectrum Policy Group proposes three pioneer frequency bands for fifth generation mobile services: 694-790 MHz, 3.4-3.8 GHz, and 24.25-27.5 GHz [1] [2] [3]. Keywords: *Network Communication Layer.*

A

AAL: See Ambient Assisted Living.

Accountability: The obligation of an individual or organization to account for its activities, to accept responsibility for them, and to disclose their results in a transparent manner. It also includes responsibility for money or other property entrusted to them [4]. Keywords: *Other cross-cutting concepts.*

Active and healthy ageing: Active ageing means helping people stay in charge of their own lives for as long as possible as they age and, where possible, to contribute to the economy and society [5]. Keywords: *Other cross-cutting concepts, Application Layer.*

Adaptive Gateway: A gateway which can adapted to different standards and make it easy to exchange data [6]. Keywords: *Physical Layer.*

Ageing Well: A better quality of life and better health through prolonged independent living; active ageing at work ensuring that older workers can continue to improve and practise their skills; and increased social participation [7]. Keywords: *Other cross-cutting concepts, Application Layer.*

Agile: Agile software development describes a set of values and principles for software development under which requirements and solutions evolve through the collaborative effort of self-organizing cross-functional teams. It advocates adaptive planning, evolutionary

development, early delivery, and continuous improvement as well as encouraging rapid and flexible response to change. These principles support the definition and continuing evolution of many software development methods [8]. Keywords: *Other cross-cutting concepts.*

Agri-food logistics: The economic and commercial activity related to the transportation of agrifood goods to customers. The application of digital technologies such as IoT to agrifood logistics enables the overall logistics operation to be optimized by contributing real-time virtualization, logistics connectivity and logistics intelligence. Keywords: *Application Layer, Farming.*

AI: See Artificial Intelligence.

Ambient assisted living: Ambient Assisted Living (AAL) comprises interoperable concepts, products and services, that combine new information, communication technologies (ICT) and social environments with the aim of improving and increasing quality of life for people of all ages. AAL can best be understood as an age-based assistance system for a healthy and independent life catering to the varying abilities of its users. It also outlines AAL as being primarily concerned with the individual in his or her immediate environment by offering user-friendly interfaces for all sorts of equipment in the home and outside, taking into account that many older people have impairments in vision, hearing, mobility or dexterity [9]. Keywords: *Other cross-cutting concepts, Application Layer, Physical Layer.*

Ambient Intelligence: An emerging discipline that brings intelligence to our everyday environments and makes those environments responsive to us [10]. Keywords: *Application Layer.*

Ambient Localization: Localization is the process of adapting a product to a particular country, market or region [11]. Keywords: *Application Layer.*

Ambient sensing: Ambient sensing refers to the set of devices embedded/hidden in a network using contextual information and enabling the use of artificial intelligence to support people carrying out their day-to-day activities. This concept goes back to the 1990s where these tasks were performed by a combination of consumer electronics, telecommunication protocols and computing. As IoT was booming, devices grew smaller and more powerful, enabling the use of greater amounts of sensing devices and, therefore, data, resulting in the development of the smart home, smart buildings, and the smart office [12]. Keywords: *Application Layer, Sensor, Environmental.*

API**:** See Application Programming Interface.

Application Programming Interface (API): An API is a set of subroutine definitions, protocols, and tools for building application software. In general terms, it is a set of clearly defined methods of communication between various software components. A good API makes it easier to develop a computer program by providing all the building blocks, which are then put together by the programmer. An API may be for a web-based system, operating system, database system, computer hardware or software library [13]. Keywords: *Abstraction Layer.*

Architecture: In reference to information technology, the architecture covers the overall system design and the logical and physical interrelationships between its components. The architecture specifies the HW, SW, access methods and protocols used throughout the system. It is also used as a description of framework and guidelines including development methodologies, modelling tools and organizational structures to build new systems. The architectural framework for the IoT includes descriptions of various IoT domains, definitions of IoT domain abstractions and identification of commonalities between different IoT domains. The IoT architecture will grow in an evolutionary way from a variety of separate contributions. The main challenges for the IoT architecture are the complexity and cooperative work for developing, adopting and maintaining

an effective cross-industry technology reference architecture that will allow for true interoperability and ease of deployment [14] [15] [16]. Keywords: *Other cross-cutting concepts.*

Artificial Intelligence (AI): A term used for technology (devices, machines, systems) that is able to simulate human cognition (intelligence, cognitive computing) such as learning, understanding, reasoning, decision making, and interacting with other devices or humans in a complex environment. Typical applications are related to speech recognition, autonomous vehicles, transmission route optimization, quick decisions/actions based on big and complex data, or simply replacing routine work [14]. Keywords: *Other cross-cutting concepts.*

Artistic practices: A practice is the actual application or use of an idea, belief, or method, as opposed to theories relating to it. Artistic practices, much like engineering and scientific practices, produce knowledge in research processes. David Thomas describes art practice as a way of researching through the practice of making art. Such making is not just doing, but is a complex informed physical, theoretical and intellectual activity where public and private worlds meet. Moreover, artistic practice, as research-in-the making, constitutes a betrayal of prevailing cultural assumptions, an interminable renouncement of normalized research representations in favour of the contingent problematic that emerges during arts practice. The practice of the arts is central in artistic research as it embodies ideas that are given form in the process of making artwork. In this context, there is a field of artistic practice contributing to innovation in ICT technologies. It emerged out of the crossover of several fields of art and science having technology as a common ground. In this intersection, new digital technologies and applications are the main outcome. In its realm, creativity in digital technologies often finds natural ways to direct proof-of-concept. It is exactly here that the field finds its contact points with neighbouring fields of research and practice, namely industrial partners. The achievement of concrete practical outcomes is one of the most important aspects when it comes to technological transfer to society. Artistic practices in technological contexts, such as IoT, are naturally close-to-market as technology is their medium of expression [17] [18] [19] [20]. Keywords: *Other cross-cutting concepts, STARTS.*

Augmented Reality (AR): The real-time view of the real physical world with the ability to add audio-visual effects (unlike virtual reality (VR) which replaces the real world with simulations). These audio-visual effects are virtual means/enhancements integrated with the real-world objects to create added value. Highlighting in the form of graphics, audio or text can be used to catch users' attention and indirectly inform subsequent actions [14]. Keywords: *Other cross-cutting concepts.*

Automation pyramid: General design pattern for creating information and communication infrastructures (ICT) for industry [173]. Keywords: *Other cross-cutting concepts.*

Autonomic computing: The ability of IT infrastructures to adapt to change in a complex environment in accordance with business policies and objectives [174]. Keywords: *Other cross-cutting concepts.*

Autonomous Farming: The increasing maturity of digital and automation technologies is driving an increased offer in autonomous farming machinery. Autonomous farming machinery is able to operate without direct intervention of humans thanks to a combination of technologies such as geolocation, auto-steering, computer vision, Internet of Things, sensing and data analytics, among others [21]. Keywords: *Collaboration and Process Layer, Farming.*

Autonomy: The ability to generate one's own purposes without any instruction from outside [175]. Keywords: *Other cross-cutting concepts.*

Availability: *(i) General:* Characteristic of a resource that is committable, operable, or usable on demand to perform its designated or required function. It is the aggregate of the resource's accessibility, reliability, maintainability, serviceability, and securability. *(ii) Computing:* Percentage of time a computer system is available for use. Formula: Uptime x 100 ÷ (Uptime +

Downtime). *(iii) Quality control:* Ability of an item to perform its designated function, whenever required [22]. Keywords: *Other cross-cutting concepts.*

B

Barcodes: A barcode is an optical and machine-readable form of data used to identify objects. A bar code allows a machine to retrieve a great deal of information about an object as soon as the object is identified through a unique visual code format created by drawing adjacent lines with variable widths and spaces [23]. Keywords: *Physical Layer.*

Benchmarking: Benchmarking is a process by which internal processes and performances are compared directly with recognised best practices as an external standard for comparison and goal setting that promotes learning from others [24]. Keywords: *Other cross-cutting concepts.*

Blue economy: The Blue Economy acknowledges that some aspects of so-called "green living", such as buying organic food and using certain forms of renewable energy, can be economically out of reach for large sections of the population [25]. Keywords: *Other cross-cutting concepts.*

Business ecosystem: An economic community supported by a foundation of interacting organizations and individuals. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders [26]. Keywords: *Other cross-cutting concepts.*

Business models: A business model is the 'description of the rationale of how an organisation creates, delivers and captures value', it is in its essence how a business generates (or plans to generate) a revenue stream that supports the delivery of a value proposition to a client segment [27]. Keywords: *Other cross-cutting concepts.*

C

Certification: Third-party attestation related to products, processes, systems or persons. Note that certification is applicable to all objects of conformity assessment except for conformity assessment bodies themselves, to which accreditation is applicable [176]. Keywords: *Other cross-cutting concepts.*

Circular Economy: An economic model based inter alia on sharing, leasing, reuse, repair, refurbishment and recycling, in an (almost) closed loop, aiming to retain the highest utility and value of products, components and materials at all times, i.e. a model in which waste is seen as a resource and is managed by design [28]. Keywords: *Other cross-cutting concepts.*

Citizen Centric: An adjective applied to e-Government services enabled by information and communication technology that fosters information integration across departmental lines, governmental units, and multi-sector organizations. These services, instead of forcing the user to understand their internal organization and adapt to them, respond to users' needs and behaviours even connecting various departments and increasing both their efficiency and effectiveness [29]. Keywords: *Other cross-cutting concepts, e-Government.*

Cloud Computing: The term Cloud refers to networks hosting an often-large number of users through remote connection enabling a centralized storage of data and collaborative work. They can be categorized into Public (public spaces for users on which companies provide quick access), Private (owned and operated by single companies/users for their particular purposes) and Hybrid (combining a private foundation but also providing public access). Cloud computing involves delivering all kinds of data, applications, multimedia, etc. over the internet through different models of use, namely Software as a Service (SaaS, where companies offer cloud-based

applications able to be connected through users), Infrastructure as a Service (IaaS, on which remote online servers, networking and data centres can be used by customers) and Platform as a Service (PaaS, combining both and, thus, eliminating the need to purchase and maintain hardware, software and hosting). Cloud computing tightly relates to IoT as the straightforward way to direct the huge amount of data collected by sensors/field devices to its destination [30] [31] [32]. Keywords: *Service Layer, Cloud, IaaS, SaaS.*

Co-creation: Value co-creation in IoT platforms ecosystems is addressing activities where customers, end-users, application owners and developers are involved as active participants in the design and development of personalized IoT applications, use cases, products, services, and experiences in IoT-platform ecosystems. In this context, the modernist dichotomy of producers as value creators and consumers as value destroyers is currently losing traction: consumers – or prosumers – exert their power in the marketplace through constructive collective action with other societal actors such as developers, hackers, users, etc. beyond the providers' control. This is common practice, for instance, in the world of Open Source software and hardware where collective effort, social interaction and group influence are all crucial to the development and use of products like Linux or Arduino. Moreover, co-creation in IoT doesn't solely pertain to human-centric design and design-thinking. Artistic thinking is also a key resource. Artists are facilitators of dialogue and are in a privileged position to empower and deepen IoT experiences. An example of a company facilitating co-creative practices in IoT is Little Bits, an open-source kit of electronic modules that snap together with magnets in a way to let anyone – children or rocket engineers – prototype or play [33] [34] [35]. Keywords: *Other cross-cutting concepts, Design, Arts, Experimentation.*

Cognitive IoT (CIoT): In CIoT, cognitive computing technologies are included in the IoT network to add artificial intelligence and signal processing. Physical and virtual objects are interconnected and behave like "thinking agents" (machine learning, decision making) performing tasks with minimum human intervention. CIoT is particularly relevant to handle the big increase in IoT devices expected, and to utilize the huge amounts of data generated [36] [37]. Keywords: *Other cross-cutting concepts.*

Connected Supply Chain

Supply Chain Management is defined as the integration of key business processes from the end-user through to original suppliers that provide products, services, and information and hence add value for customers and other stakeholders. In the context of IoT, a Connected Supply Chain is one that takes advantage of Information Technologies to integrate suppliers/partnering firms in virtual enterprise and supply chain [38]. Keywords: *Application Layer.*

Connectivity: The ability of a computer, program, device, or system to connect with one or more others [39]. Keywords: *Network Communication Layer.*

Consumer awareness: The understanding by an individual of their rights as a consumer concerning available products and services being marketed and sold. The concept involves four categories: safety, choice, information, and the right to be heard [40]. Keywords: *Other cross-cutting concepts.*

Corrective Maintenance: Also called run-to-failure reactive maintenance, corrective maintenance is the simplest maintenance policy where machine interventions (repairs) are only performed when a failure in operation occurs [16]. Keywords: *Other cross-cutting concepts, Industry.*

CPS: Cyber-Physical Systems (CPS) are integrations of computation, networking, and physical processes [41]. Keywords: *Abstraction Layer.*

Creation: Creation is the action or process of bringing something into existence. Creation often describes the act of producing something for the first time and is, in this connotation, often

linked to artistic creation. Artistic creation can bring resourceful insights in the process of building lively, user-centred and trustworthy IoT systems for broader adoption. David Bohm (1927-1992) advocated for dialogue among disciplines as the core of creativity. The arts are more about creation than creativity. However, artists can play a crucial role as catalysts of innovation in IoT by enabling an open dialogue with society in general and thereby fostering its process of uptake. Results of art and technology research projects are in their majority intend to take the form of proof of concept – they are creations. Knowledge is materialized in concrete applications which, very often, including usability testing in their early stages. This is one of the reasons why many artists have been at the origin of new technologies. The example of the Berlin-based company ART+COM is key. The company created the Terravision system in 1994 that many consider to be the prequel to Google Earth. It can be said that the artistic origin of one of the most successful worldwide on-line platforms lies in Europe, but was commercially explored elsewhere. More recently, Eduardo Miranda has developed the new bio- musical computer which potential s will certainly take some time to be unveiled [35] [19]. Keywords: *Other cross-cutting concepts, Innovation, Prototype, STARTS.*

Critical approach to IoT: To think out-of-the-box is a well-known objective in innovation processes. Artists, however, are more interested in getting rid of the box. It is this disruptive approach that is seen as fundamental to create a critical approach to technological developments. In this context, the integration of artists in technological research processes can be instrumental for the attribution of meaning to new technologies. A solid critical approach is fundamental for competitiveness based on knowledge and creativity. The critical approach is one of the main differential elements between artists and designers. An artist involved in a technological challenge would go deeper in the analysis of the challenge, with a critical eye. On the other hand, a designer would be driven by finding a solution - problem solving. An example of artistic critical approach in IoT is the work of artist James Brindle who is trying to build his own self-driving car and has published all the code developed in pursuit of the DIY self-driving car via this link https://github.com/stml/austeer. Brindle says "Self-driving cars bring together a bunch of really interesting technologies - such as machine vision and intelligence - with crucial social issues such as the atomization and changing nature of labour, the shift of power to corporate elites and Silicon Valley, and the quasi-religious faith in computation as the only framework for the production of truth - and hence, ethics and social justice. The attempt to build my own car is a process of understanding how the dominant narratives of these technologies are produced, and could be changed" [42] [19] [43]. Keywords: *Other cross-cutting concepts, STARTS, Designers, Innovation.*

Cyber physical systems: Cyber-physical systems are combinations of intelligent physical components, objects and systems with embedded computing and storage possibilities, which get connected through networks and are the enablers of the smart factory concept of Industry 4.0 in the scope of the Internet of Things, Data and Services scope, with a focus on processes [44]. Keywords: *Other cross-cutting concepts.*

D

Data access: Ability to make use of the data in an information system resource. Data access refers to a user's ability to access or retrieve data stored within a database or other repository. Users who have data access can store, retrieve, move or manipulate stored data, which can be stored on a wide range of hard drives and external devices [45]. Keywords: *Other cross-cutting concepts.*

Data Analytics: Data analytics comprises the needed operations needed to be performed so as to extract valuable information out of data, including discovery, interpretation and modelling. It makes full use of mathematical/statistical algorithms combined with performance and programming techniques. Data analytics is often tied to Big Data. In this respect, IoT is a key

enabler for data analytics, as IoT devices produce huge amounts of information that can susceptible to be used to generate models, studying patterns, feed intelligent decision systems and more, etc. [46] [47]. Keywords: *Abstraction Layer, Data, Analytics.*

Data ownership: Under EU law, personal data can only be gathered legally under strict conditions and, for a legitimate purpose. Furthermore, persons or organisations that collect and manage your personal information must protect it from misuse and must respect certain rights of the data's owners which are guaranteed by EU law. [48]**.** Keywords: *Other cross-cutting concepts.*

Data protection: Under EU law, personal data can only be gathered legally under strict conditions, for a legitimate purpose. Furthermore, persons or organisations which collect and manage your personal information must protect it from misuse and must respect certain rights of the data owners which are guaranteed by EU law [49]. Keywords: *Other cross-cutting concepts.*

Data security: Data security refers to the protection of information by using appropriate technical measures that shall be taken against unauthorised or unlawful access or processing, and against accidental loss, destruction, or damage [50]. Keywords: *Other cross-cutting concepts.*

Data-Driven Farming: The use of big data and contextual analysis to support decision making with the aim of reaching increasing productivity and profitability through precision agriculture. Keywords: *Other cross-cutting concepts, Application Layer, Physical Layer, Processing Layer.*

Decision Support System (DSS): A computer-based information system that supports business or organizational decision-making activities. DSSs serve the management, operations, and planning levels of an organization (usually mid- or/and upper management) and help people make decisions about problems that may be rapidly changing and not easily specified in advance, i.e. unstructured and semi-structured decision problems. Decision support systems can be either fully computerized, human-powered or a combination of both. [51]. Keywords: *Application Layer.*

Deep learning: Deep learning mimics human neural pathways to analyse unstructured data, providing multiple outputs/decisions through layered abstraction and pattern recognition [52]. Keywords: *Abstraction Layer, Application Layer, Processing Layer*

DEI**:** See Digitising European Industry.

Demand-driven Farming: A farming operation that is driven by the demand that the farm experiences (or foresees) from successive stages in the supply chain (food processors, businesses, consumers). Demand-driven farming is facilitated by the combination of technologies such as IoT or (predictive) data analytics. [16]. Keywords: *Application Layer, Farming.*

Devices: Mechanical, electrical, or electronic contrivance with a specific purpose. [177]. Keywords: *Physical Layer.*

Device Management: Device management refers to the process of monitoring the implementation, operation and maintenance of physical or virtual devices. IoT device management implies a set of operations including provisioning and authentication, configuration and control, monitoring and diagnosis, software updates and maintenance [53]. Keywords: *Application Layer, Security, Authentication, Management.*

Digital: Digital describes electronic technology that generates, stores, and processes data in terms of two states: positive and non-positive [54]. Keywords: *Processing Layer.*

Digital assistants: Applications that perform digital tasks for the user using speech recognition and natural language processing, e.g. Siri, Alexis. Keywords: *Service Layer, Application Layer, Processing Layer.*

Digital Automation: See Smart Manufacturing.

Digital economy: The sum of all economic activity that relies upon or produces internet-enabled technologies like e-commerce, cloud computing, artificial intelligence and the Internet of Things [55]. Keywords: *Collaboration and Process Layer*.

Digital Industrial Platforms: A Digital Industrial Platform integrates (data from) various functions implemented by different technologies via clearly specified interfaces and makes data available for use by applications. Digital Industrial Platforms bring together different technologies, applications and services. They open up data from e.g. the machines, products and operators on a shop floor, make it accessible to e.g. monitoring and control applications, may provide open interfaces that allow third-parties to develop applications on top, and connect different stakeholders, such as users and application developers [56]. Keywords: *Abstraction Layer*.

Digital Innovation: Digital innovation is the application of new technologies to existing business problems or practices. The unique properties of digital technology enable new types of innovation processes that are distinctly different from the analogue innovation processes of the Industrial Era [57]. Keywords: *Other cross-cutting concepts.*

Digital Manufacturing: See Smart Manufacturing.

Digital Platforms: Digital platforms are the base upon which an increasing number of connection-based activities – marketplace, social, and political - are being organized. If the Industrial Revolution was organized around the factory, today's changes are organized around platforms and algorithms applied to enormous databases running in the cloud [58]. Keywords: *Other cross-cutting concepts.*

Digital rights management: Digital rights management (DRM) is access-control technology used by manufacturers, publishers, and copyright holders to limit the use of digital devices or information. It describes the technology that prevents unauthorized distribution and use of content, media, or devices [59]. Keywords: *Other cross-cutting concepts.*

Digital Single Market: A Digital Single Market is one in which the free movement of persons, services and capital is ensured and where the individuals and businesses can seamlessly access and exercise online activities under conditions of fair competition, and a high level of consumer and personal data protection, irrespective of their nationality or place of residence [60]. Keywords: *Other cross-cutting concepts, Policy.*

Digitising European Industry (DEI): The DEI Strategy was launched in April 2016 by the European Commission as an articulated set of measures to help European industry, SMEs, researchers and public authorities make the most of digital technologies such as IoT [61]. Keywords: *Other cross-cutting concepts, Industry, Policy.*

DSM: See Digital Single Market.

E

Edge computing: Edge computing is a way to optimize cloud computing systems by using edge device computational capabilities to run analytic/knowledge generation functions and, thus, reducing the processes performed on the cloud. Locating this data processing near the data sources also allows a reduction of the bandwidth as only relevant aggregated information is transferred. The application of edge computing to IoT might be the solution to the current concern about not having enough resources at cloud level to process the overall data being reported by IoT devices. Nevertheless, there are some barriers to overcome to reach a truly functional IoT edge computing network, such as the potential unavailability of devices due to its often used wireless link or the scheduling/coordination problems that may arise when deploying it at large scale [62]. Keywords: *Network Communication Layer, Cloud, Edge, Devices.*

Embedded systems: Embedded systems are dedicated mini-computers serving as parts of a larger mechanical, electrical or communications system. They often suffer from real-time and/or computing capabilities constraints. These systems include hardware and mechanical parts and are commonly used as monitoring and control devices for a plethora of applications. IoT disrupted the way embedded systems were traditionally conceived as they require very strict miniaturization, communication and processing capabilities. This disruption touches upon not just hardware design for embedded systems, but also software programming models and Operating System design [63] [64]. Keywords: *Physical Layer, Things, Devices, Hardware.*

Enabling network: The organization of communication between various devices in applications such as smart grids, smart meters, smart houses, smart healthcare systems, smart industries, etc. [65]. Keywords: *Network Communication Layer.*

End-to-end security: *(i)* Safeguarding information in a secure telecommunication system by cryptographic or protected distribution system means from point of origin to point of destination. *(ii)* Safeguarding information in an information system from point of origin to point of destination [66]. Keywords: *Other cross-cutting concepts, Security Layer.*

Ethics: Ethics refers to universally- or socially-accepted norms and behaviours. Ethics are concerned with what is good for the individual and society and the associated behaviours and actions [67]. Keywords: *Other cross-cutting concepts.*

European Platforms Initiative (EPI): See IoT European Platforms Initiative (IoT-EPI).

Experience Readiness Level: The Experience Readiness Level (ERL) measures the capability of IoT systems to trigger experiences, a measure that steps away from the modernist ideal of the «perfect object» and embraces the potential of a thriving, dynamic exchange between technology and art to empower the spectator and deepen his or her experience. The ERL is a complimentary approach to Technology Readiness Level (TRL), Market Readiness Level (MRL) and Production Readiness Level (PRL). Kevin Ashton in 1999 coined the term IoT, and understood it as an evolution of the Internet whereby "we empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory". Nowadays, we understand the power of the hyper-connected society is about empowering citizens, not computers. A shift of attention from labs and drawing boards to involving existing and new communities at an early stage of IoT development is fostered and advocated. If the goal is the adoption of IoT by masses in full confidence, it's important we stop thinking about IoT as objects and start thinking of IoT as triggers for better lives. The Experience Readiness Level (ERL) is a new notion that introduces the focus on 'better lives' and moves the attention from the production to the consumption of IoT [68] [69]. Keywords: *Other cross-cutting concepts, Consumer.*

F

Farming: The activity or business of raising crops or livestock [70]. Keywords: *Other cross-cutting concepts.*

Federation of platforms: An approach to enterprise architecture that allows interoperability and information-sharing between semi-autonomous business units [71]. Keywords: *Collaboration and Process Layer.*

Fog computing: Fog computing refers to a mechanism similar to edge computing, but using one or more end devices acting as gateways/data-processing units performing substantial storage, control, configuration, measurement and management activities for a given number of associated end devices and, therefore, reducing the cloud processing needs [72]. Keywords: *Network Communication Layer, Cloud, Edge, Devices.*

Food Security: Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life [73]. Keywords: *Other cross-cutting concepts, Farming, Agrifood.*

Food supply chains: The processes and participating organisations through which food reaches the consumer from the farm of origin, it includes farmers, processors, distributors, retailers and consumers [74]. Keywords: *Other cross-cutting concepts.*

Food Traceability: Ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution [75]. Keywords: *Other cross-cutting concepts, Agrifood.*

Framework: In general, a framework is a real or conceptual structure intended to serve as a support or guide for the building of something that expands the structure into something useful [76]. Keywords: *Abstraction Layer.*

FTC: The Federal Trade Commission is an independent agency of the United States of America that has jurisdiction to enhance consumer welfare and protect competition in broad sectors of the economy [77]. Keywords: *Other cross-cutting concepts.*

Functional Ink: Functional printing means the additive printing of electronic components and circuits on a carrier material such as paper or foil [178]. Keywords: *Physical Layer.*

G

Governance: 'Governance' refers to the rules, processes and behaviour that affect the way in which powers are exercised, particularly in regard to openness, participation, accountability, effectiveness and coherence. IoT governance refers to the development and application by Governments, the private sector and civil society of shared principles, norms, rules, decision-making procedures, and programmes that shape the evolution and use of the Internet of Things in a direction that addresses policy concerns and ensures that the maximum benefits are reaped [78]. Keywords: *Other cross-cutting concepts.*

H

H2M**:** See Human-to-Machine communication.

High Performance Computing (HPC): HPC refers to the use of aggregated computing power for handling computation- and data-intensive tasks [79]. Keywords: *Other cross-cutting concepts, Processing Layer.*

HMI**:** See Human-Machine Interfaces.

Holistic innovation: Europe strongly relies on innovation to compete globally and to make human activities more sustainable and our society more inclusive. It is not about technology as such but about a better life for all of us. To achieve that, industry and technology have to think in a more holistic way to conceive radically novel products, services and processes that are also putting the human at the centre. Despite this imperative to work across boundaries and silos, Europe is still addressing innovation without fully engaging the creative forces that lie at the crossover of the arts – and, more generally, culture - science, and technology. In technology, Europe has historically focused its attention on R&D and standardization in technology. This led to initial successes e.g. in mobile telephony (Nokia and the GSM standard). Today, however, focusing only on technology is trapping us in incremental innovation. In a situation of saturated and over-engineered European economies, change is considered as being risky and innovation often remains bound to an already existing logic. Holistic innovation happens when one overcomes stereotypes on the technology and culture divide that are an impediment to engaging

in cross-border R&I and to unleashing creative forces [80] [81]. Keywords: *Other cross-cutting concepts, Silos, Cross-Border.*

HPC**:** See High Performance Computing.

Human-centred IoT: It is commonly recognised that IoT has the potential to drastically improve our personal lives, our work places and our industrial / manufacturing efficiencies and capabilities. There is, however, a concern that IoT may lead to alienation because of objects capable of 'talking' to one other and to lose sight of human preferences. One of the main challenges for the implementation of IoT is to develop a human-centred IoT, an ecosystem where citizens aren't forced to compliance and data share data while losing sight of their agency capacity for agency, but can instead trust that the IoT systems around them operate according to understood principles and guarantees for their integrity, privacy and security whilst allowing room for fantasy and appropriation. A human- centred IoT would imply an environment where IoT will empower people and not transform them into hostages of technology. Always being connected to the things around us has the potential to lead to more surveillance or more profiling by public authorities and private entities. More generally, without appropriate legal, technical and organisational safeguards, the IoT may facilitate the emergence of a de-humanised world, where machines enforce rules stringently, reduce humans' freedom, and room for fantasy, and contact among them by make steps to controlling their behaviour. Director-General Roberto Viola also recently expressed this position: "The Next Generation Internet must be built for the humans respecting our European values" [82]. Keywords: *Other cross-cutting concepts, Human, Empower, Trust.*

Human-centred production: Human-centred production is an innovative technology that can efficiently utilize human and material resources in order to secure production locations [83]. Keywords: *Application Layer.*

Human-Machine interface (HMI): The user interface of a mechanical system, a vehicle or an industrial installation [84]. Keywords: *Application Layer.*

Human-to-Machine (H2M) communication: H2M communication is an important development within IoT for applications like remote health monitoring and activity tracking. In vivo or in vitro devices (implantable, swallow able or wearable) collect sensor data and use a wireless interface for transmitting the data. The recipient could be the health care system (physician, nurse, etc.). See also Machine-to-Human (M2H) communication. Keywords: *Other cross-cutting concepts.*

Hybridity: Hybrid arts is a contemporary art movement in which artists work with frontier areas of science and emerging technologies. Artists work with fields such as biology, robotics, physical sciences, experimental interface technologies (such as speech, gesture, and face recognition), artificial intelligence, information visualization, and many others. They address the research in many ways such as undertaking new research agendas, visualizing results in new ways, or critiquing the social implications of the research. A 'hybrid creative' is a transdisciplinary practitioner owning specific technical skills that may enable one to expertly and fluently navigate the specifics of the fields or ICT as well as the arts. Hybridity of competences of practitioners allows a hybrid creative to simultaneously or alternately approach a circumstance in a problem-solving mode, design thinking, and/or in a critical approach mode, artistic thinking. [85] [19]. Keywords: *Other cross-cutting concepts, STARTS, Innovation, Research.*

Hyper-connected Society: A society where anyone and anything is connected regardless of time and place. All humans and physical objects do (or have the possibility to) communicate with each other through a communication network [86]. Keywords: *Other cross-cutting concepts.*

Hyperconnectivity: Hyperconnectivity means that anyone or anything is connected anytime and anywhere. All humans and physical objects should (or have the possibility to) communicate with each other through a communication network [86]. Keywords: *Other cross-cutting concepts.*

I

ICT Art Connect: ICT Art Connect is the name of a study of the European Commission that revealed new evidence for the integration of the Arts as an essential and fruitful component within research and innovation in ICT. ARTSHARE, along with imec, the coordinating organism of the Flemish Government for ICT research, carried out the study ICT ART CONNECT: Activities Linking ICT and Art: Past Experience - Future Activities, and created a map of institutions and individuals engaged in artistic practices within ICT research projects in Europe and worldwide. Because of the study, the European Commission launched the STARTS programme: Innovation at the nexus of Science, Technology and the Arts. ICT Art Connect concept is no longer used in the European context and has been replaced by STARTS [19]. Keywords: *Other cross-cutting concepts, STARTS, Innovation.*

Independent living: Independent living is the daily demonstration of human rights-based disability policies. Independent living is possible through the combination of various environmental and individual factors that allow disabled people to have control over their own lives. This includes the opportunity to make real choices and decisions regarding where to live, with whom to live and how to live. Services must be available, accessible to all and provided on the basis of equal opportunity, free and informed consent, and allowing disabled people flexibility in their daily lives. Independent living requires the built environment, transport and information to be accessible as well as the availability of technical aids, access to personal assistance and/or community-based services. It is necessary to point out that independent living is for all disabled persons, regardless of gender, age and the level of their support needs [87]. Keywords: *Other cross-cutting concepts.*

Industrial Internet of Things (IIoT): The IIoT is a subset of the IoT, where edge devices, processing units and networks interact with their environments to generate data to improve processes. It also, and describes the IoT when used across various several types of industrial sectors, (manufacturing, logistics, energy, etc.) [88] [89]. Keywords: *Other cross-cutting concepts.*

Industry 4.0: Industry 4.0 is the naming provided to the current automation trend for manufacturing in which cyber-physical systems, IoT and Cloud computing combine together. It is also referred to as smart manufacturing. It is the next expected industrial revolution, preceded by the mechanization and steam power (1st revolution), the electrical mass production assembly line (2nd revolution) and computer automation (3rd revolution). In this complex new process, cyber-physical systems monitor real processes, creating a virtual copy of the real world and making decentralized decisions. IoT is used to permit communicate these cyber-physical systems to communicate with other systems and humans, in a way that they can jointly collaborate in real- time. All relevant data is centralized and exploited in cloud computing services, optimizing the maintenance and decision taking procedures [90] [91]. Keywords: *Other cross-cutting concepts, Industry, Revolution.*

Information technology (IT): IT is the application of computers to store, operate, communicate, gather and manipulate information, in the business context. It is often regarded as a branch of Information and Control Technologies (ICT). It is often used as a synonym for computer networks, although it covers a wider spectrum of technologies, such as television and cellular communications, among others, including IoT and wireless sensor devices, and others. Alternatively, a set of tools, processes, and methodologies and associated equipment employed to collect, process and present information [92]. Keywords: *Other cross-cutting concepts, ICT.*

Infrastructure: Infrastructure is the foundation or framework that supports a system or organization [93]. Keywords: *Abstraction Layer.*

Innovation: The traditional definition of innovation is the launch of a new product or version new species of an already known product, application of new methods of production or sales of a product (not yet proven in the industry), opening of a new market (the market for which a branch of the industry was not yet represented), acquiring of new sources of supply of raw material or semi-finished goods, or a new industry structure such as the creation or destruction of a monopoly position. A more up-to-date definition can refer to the successful implementation (as evidenced by the market introduction) of an idea that provides a novel solution to a problem [94]. Keywords: *Other cross-cutting concepts.*

Innovation Ecosystems: While a concrete definition has not been decided, we propose that an innovation ecosystem refers to the interdependent agencies and agents (e.g. universities, corporates, start-ups, public bodies) that drive the innovation process from conception to market which involving cooperation and competition. [95]**.** Keywords: *Other cross-cutting concepts.*

Internet of Autonomous Things (IoAT): IoAT refers to bring devices (things), including artificial intelligence and machine learning, being brought into the physical environment as autonomous entities, moving and interacting with humans and other devices without human intervention. IoAT includes topics like mastering varied surroundings, device identification, dynamic discoverability, context- based cognitive network integration, and seamless platform integration. Examples of IoAT applications are autonomous vehicles and self-navigating drones. Sometimes the expression Autonomous Internet of Things (A-IoT) is used for IoAT [88] [96]. Keywords: *Other cross-cutting concepts.*

Internet of Buildings (IoB): An application domain of IoT, where information from multiple intelligent building management systems are gathered and integrated by IoB, for optimising the behaviour of individual buildings as part of a larger information system. The edge devices are important components for value creation through data collection, exchange and processing [88]. Keywords: *Other cross-cutting concepts.*

Internet of Energy (IoE): A dynamic energy network infrastructure including energy cloud storage based on standard and interoperable communication protocols that interconnect the energy network with the Internet allowing units of energy (locally generated, stored, and forwarded) to be dispatched bidirectionally when and where it is needed. The related information/data and financial transactions follows the energy flows thus implementing the necessary information exchange together with the energy and financial transfers. Internet of Energy refers to the current trend among followed by energy producers and distribution grid operators of upgrading and automating electricity infrastructures to adapt the to the new decentralized and customer- centred model pushed by renewable energies, the new role of prosumers and the adoption of novel communication and data processing technologies. IoT plays a key role on this new Internet of Energy concept. IoT devices will be put in place on all value chain parts, including monitoring devices for energy plants (allowing optimal operation and maintenance for the generation), automating and controlling devices on the grid (smartening the distribution grid) and real-time monitoring on customer side (enabling real-time bi-directional communication with users) [97] [223] [224]. Keywords: *Application Layer, Energy.*

Internet of Health (IoH): An IoT application domain within the healthcare sector. The IoH concept refers to a large-scale system for reliable communication, information exchange and interaction possibilities facilitating more efficient, affordable and better-quality healthcare, together with enhanced patient experience and engagement. For instance, through improved or new remote health- monitoring and activity- tracking methods; diagnostics, treatment and medication methods; and patient flow, record-keep journaling and administrative methods. New communication, health and welfare technologies provide new services regardless of geographic localisation. A careful balance between data access and sharing of information are required to ensure security and privacy. [16] [98]**.** Keywords: *Other cross-cutting concepts.*

Internet of Mobile Things (IoMT): This is an application domain where mobile devices (things) are included in the IoT network/system. These mobile devices are characterized by increasing diversity and number, which challenge device identification, dynamic discoverability, context based cognitive network integration, and seamless platform integration. Some general examples of mobile devices today are sensors/actuators embedded in smartphones, smartwatches and cameras. To avoid misunderstandings, we mention that the abbreviation IoMT is also used for Internet of Medical Things [88] [99]. Keywords: *Other cross-cutting concepts.*

Internet of Robotic Things (IoRT): A concept that incorporate robotics aspects into the IoT landscape to provide advanced robotic capabilities, where intelligent devices (robotic things) are able to monitor events, collect sensor data from different sources, and use distributed intelligence to determine best solutions before effectuating an action on objects in the physical world. See also Robotic things [88] [100] [101]. Keywords: *Other cross-cutting concepts.*

Internet of Things (IoT): IoT is "A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network". ITU-T has formulated the following definition: "Internet of things (IoT): A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies. *Note 1*: Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled. *Note 2*: From a broader perspective, the IoT can be perceived as a vision with technological and societal implications [102] [103]. Keywords: *Other cross-cutting concepts, Things, Applications, Cloud.*

Internet of Vehicles (IoV): The IoV concept refers to connected vehicles in a large-scale distributed system for reliable dynamic communication and information exchange facilitating smart mobility and transport, through traffic management, information services, environmental protection, road safety, assisted/autonomous driving, etc. The communication network includes both mobile internet communication, inter-vehicle/infrastructure communication, and intra-vehicle communication, as well as storage, artificial intelligence, learning, sensing, and decision-making capabilities [88] [100] [101]. Keywords: *Other cross-cutting concepts.*

Interoperability: Interoperability is a characteristic of a product or system, whose interfaces are perfectly able, to work with other products or systems, at present or future, in either implementation or access, without any restrictions [104]. Keywords: *Other cross-cutting concepts.*

IoB**:** See Internet of Buildings.

IoE**:** See Internet of Energy.

IoH: See Internet of Health.

IoRT: See Internet of Robotic Things.

IoT: See Internet of Things.

IoT Applications: Applications that run in an IoT system.

IoT Data: Data is the real value offered by IoT. Most business models for IoT are based on how to exploit and extract value out of the data being posted by deployed IoT devices in the field. In this data-driven scenario, it is critical to conduct measurements properly. The phenomenon/device monitored should be carefully selected to assure its relevance. Moreover, the accuracy of the measurement should also be guaranteed so as to avoid misleading information and, therefore, decisions. These decisions should drive data processing and

analytics. A business strategy for IoT should consider how to exploit data through analysis [105] [106]. Keywords: *Storage Layer, Data, Analytics.*

IoT Devices: IoT devices range from large, industrial sensing devices to tiny implants or from high-demanding video-surveillance devices to low-rate pulse sensors. They all have in common that they are deployed to serve a business/industry/particular need and are able to remotely report data. In terms of communication capabilities, they can use short-range radio interfaces (usually being grouped towards a high-end device acting as gateway to the Internet), long-range radio interfaces (such as LPWAN, cellular, etc.) or even wired communication links. They can also be classified as just data-posting devices (unicast communication link) or actuators (accepting external commands and, thus, using bidirectional communication links) [105] [106]. Keywords: *Physical Layer, Things, Hardware.*

IoT Ecosystem: Solutions comprising large heterogeneous systems of systems, solving challenges across application verticals. In these ecosystems, IoT acts as an essential driver for optimization, innovation, competitiveness and business based on enabling technologies and collaboration among various stakeholders. It increases the value creation through exchange of information between multiple domains while maintaining privacy and security. Complementary architecture for seamless IoT integration is important to ensure interoperability. Open technologies and platforms are preferable [16] [88]. Keywords: *Other cross-cutting concepts.*

IoT European Large-Scale Pilots (IoT-LSPs): The IoT European Large-Scale Pilots Programme in Horizon 2020's work programme 2016-2017, includes IoT-LSP projects addressing the IoT applications based on European relevance, technology readiness and socio-economic interest in Europe. (ACTIVAGE, MONICA, IoF2020, AUTOPILOT, SYNCHRONICITY, U4IoT, and CREATE-IoT). The IoT-LSPs involve stakeholders from supply side to demand side, and contain all the technological and innovation elements and tasks related to the use, application and deployment, as well as development of technology, testing and integration activities. The pilot projects are also accompanied by coordination and support actions to ensure smooth and efficient cooperation and management of the various activities of the Focus Area (FA) as well as to support cross- fertilisation of the various pilot projects for technological and validation issues of common interest across the various use cases. The European Large-Scale Pilots Programme website is available https://european-iot-pilots.eu/. See also Large-Scale Pilot (LSP) [107] [108]. Keywords: *Other cross-cutting concepts.*

IoT European Platforms Initiative (IoT-EPI): A European initiative for IoT platform development, interoperability and information-sharing, founded by the EU to build a vibrant and sustainable IoT ecosystem in Europe. Seven leading research and innovation projects (AGILE, bIoTope, BIG IoT, Inter-IoT, symbIoTe, TagItSmart!, VICINITY) supported by two coordination and support action projects Be-IoT and UNIFY-IoT make their technology accessible to third parties. In addition, a strong support and funding structure in the form of open calls and workshops fosters further collaboration. Their website is available on http://iot-epi.eu/. See also IoT European Platforms Initiative (IoT-EPI) [109]. Keywords: *Other cross-cutting concepts.*

IoT Operating Systems: As IoT hardware providers peaked over the past few years, so did IoT Operating Systems (OS) seeing, as they are sometimes tied to a particular platform. There are also some commonly used alternatives, being Linux-based OS being the most used alternative these nowadays. IoT OSs are often tied to particular device needs, t. Therefore, there is not a single approach but multiple options that can be considered depending on the application. Determining if real-time performance is needed, memory size, catching capabilities or CPU processing requirements, level of required security, hardware constraints, and shaping the communication/networking needs are decisive aspects to take into account when choosing the IoT OS [105] [106]. Keywords: *Physical Layer, OS, Software, Real-Time.*

IoT Platforms: IoT Platforms refer to online management tools for IoT devices, often combining multiple applications such as device management, security, data analytics and visualization tools. IoT platforms range from hardware vendor operated (tied to a particular IoT device), network operated (tied to a particular communication network provider) and system integrator operated (offering interoperability approaches) [105] [106]. Keywords: *Service Layer, Platform, Cloud, Data.*

IoT Policy: AIs a document that provides a comprehensive guide to help an organization promote the development of the IoT and/or deal with the complex issues related to that development [110]. Keywords: *Other cross-cutting concepts.*

IoT Standardization: IoT standardization can be divided into four categories: Platform, Connectivity, Business Model and Killer Applications [111]. Keywords: *Other cross-cutting concepts.*

IoT Standards: Standard model to perform common IoT-backend tasks [111]. Keywords: *Application Layer.*

IoT Standards Landscape: Support of a large variety of applications departing from existing silos and the generation of healthy ecosystems [112]. Keywords: *Other cross-cutting concepts.*

IoT technology: It brings together two evolving technologies: wireless connectivity and smart sensors [113]. Keywords: *Other cross-cutting concepts.*

IoT Trust: Trust management plays an important role in IoT for reliable data fusion and mining, qualified services with context-awareness, and enhanced user privacy and information security. It helps people overcome perceptions of uncertainty and risk and engages in user acceptance and consumption of IoT services and applications [114]. Keywords: *Other cross-cutting concepts.*

IoV: See Internet of Vehicles.

IT: See Information Technology.

K

Key Enabling Technologies (KET): KETs are a group of six technologies that have a wide range of product applications such as developing low carbon energy technologies, improving energy and resource efficiency, and creating new medical products. They have huge potential to fuel economic growth and provide jobs [179]. Keywords: *Other cross-cutting concepts.*

Key Performance Indicator (KPI): A KPI is a high-level metric that measures the performance of a company, business unit, project, process or system that aligns with the organisational strategy or the desired outcomes of the process or system in question [115]. Keywords: *Other cross-cutting concepts.*

KPI: See Key Performance Indicator.

L

Legislation: A law or set of laws suggested by a government and made official by a parliament [116]. Keywords: *Other cross-cutting concepts.*

Liability: Product liability is the area of law in which manufacturers, distributors, suppliers, retailers, and others who make products available to the public are held responsible for the injuries those products cause [180]. Keywords: *Other cross-cutting concepts.*

Lifecycle Management: Activities related to the follow-up and supervision of the evolution of a system, product, service, project, or other human-made entity from conception through retirement [181]. Keywords: *Other cross-cutting concepts.*

Long-Range Wide Area Network (LoRaWAN): The wireless LoRaWAN technology for long-range radio, low power, and low data rate IoT applications are based on spread spectrum chipsets from Semtech Corporation, but promoted by the non-profit association LoRa Alliance. Typical characteristics are distances of up to 20 km, battery- powered end-nodes of up to 10 years' lifetime, and data rates ranging from 0.3 kbps to 50 kbps in the 869 and 900 MHz ISM bands. Switching between LoRa chirp spread spectrum (CSS) and frequency-shift keying (FSK) modulation are facilitated. The network server hosts the system intelligence and complexity (e.g., duplicate packets elimination, acknowledgement scheduling, data rate adapting). All connections are bidirectional, support multicast operation, and forms a star of stars topology. To serve different applications, the end-nodes are classified in three different classes, which trade off communication latency versus power consumption. Class A is the most energy efficient, and is implemented in all end-nodes. Classes B and C are optional and must be class- A- compatible. A spreading factor (SF) is used to increase the network capacity. A higher SF gives longer communication range, but also implies decreased data rate and increased energy consumption. For frequent data sampling, LoRa systems use an SF as small as possible to limit the airtime, which requires end-nodes located closer to the gateways [117] [118]. Keywords: *Network Communication Layer.*

LPWAN: LPWAN stands for Low Power Wide Area Network, and refers to the type of wireless network designed to allow long- range communications at low- bit rates, which is especially interesting for the vast great majority of IoT devices. It is also specifically designed for low-power devices, in contrast with other wireless wide- area networks such as cellular networks, requiring more expensive and power- demanding radio modules, as they allow high- throughput rates. LPWAN technologies can be used to create private networks or a service provided by a third party, eliminating, thus, the need for gateway deployments seeing, as IoT devices can connect directly connect to the network. LPWAN technologies have appeared in the recent past and, evolving into a reality nowadays. The most commonly LPWAN networks/technologies used in Europe, currently are SigFox and LoRa, although NB-IoT is also a promising alternative [119] [117]. Keywords: *Network Communication Layer, Communications, Wireless, Long-range.*

LSP: See IoT Large Scale Pilot Program.

M

M2H**:** See Machine-to-Human communication.

M2M**:** See Machine-to-Machine.

Machine Learning (ML): Machine learning is an application of artificial intelligence (AI) that gives systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it learn for themselves [120] [225]. Keywords: *Collaboration and Process Layer.*

Machine-to-Human (M2H) communication: The concept of letting the machines interact with humans based on either voice or gestures is called machine-to-human interaction. See also Human-to-Machine communication [121]. Keywords: *Abstraction Layer.*

Machine-to-Machine (M2M): Machine- to- machine communications refers to such communications involving just devices (without human intervention) and using any means of communication channels, including wireless. It constitutes a subset of use cases covered by the whole spectrum of IoT cases, as they also include devices triggered or operated by humans.

M2M was built from the seed of current IoT and industry 4.0 technology, with networks of machines relaying information back to a central computing system in charge of analysing the information. Currently, those systems evolved into the current usage of M2M to allow systems of networks to transmitting data to personal appliances [122]. Keywords: *Network Communication Layer, Things, Communications.*

Manufacturing Digitisation**:** See Smart Manufacturing.

Market: Markets for technology refer to "transactions for the use, diffusion and creation of knowledge and technology". They are places where the technology seller (supply side) meets the technology buyer (demand side). Markets for technology can be characterised along several dimensions, including (i) their purpose, which may be to circulate existing technologies (e.g IP marketplace), or to produce or co-produce new technologies (e.g. based on bilateral contracts); and (ii) the type of technology transactions. Technology transactions can take different forms, from pure licensing or sale of well-defined intellectual property, to complicated collaborative agreements that may include the development of the technology or its realization [182]. Keywords: *Other cross-cutting concepts*

Market Adoption Readiness Levels (MARL): A new approach proposed (AIOTI WG2 Innovation Ecosystem community) for measuring the impact of early adopter models. This approach poses the increase of TRL as one out of four factors to achieving innovation instead of being the only one. This is a promising starting point for a holistic approach to digital transformation of the EU industry. Such an approach is mostly targeting consumer-centric and creative industries and needs substantial improvements and extensions to be applied to the manufacturing domain. So far, the four factors/levels in this approach are defined as follows: (i) Level of risk, (ii) Number of potential early adopters, (iii) Potential to yield data from early adoption, and (iv) The technology readiness [16]. Keywords: *Other cross-cutting concepts.*

Mass customization: Mass customization is a production process that combines elements of mass production with those of bespoke tailoring. Products are adapted to meet a customer's individual needs so no two items are the same. It can also be defined as the production of personalized or tailored goods or services to meet consumers' diverse and changing needs at near mass production prices. Enabled by technologies such as computerization, internet, product modularization, and lean production, it portends the ultimate stage in market segmentation where every customer can have exactly what he or she wants [123] [124]. Keywords: *Other cross-cutting concepts, Physical Layer.*

Middleware: Middleware is a distributed software layer that sits above the network operating system and below the application layer and abstracts the heterogeneity of the underlying environment [183]. Keywords: *Other cross-cutting concepts.*

MIMO: Multiple Input Multiple Output technology uses multiple antennae to make use of reflected signals to provide gains in channel robustness and throughput [125]. Keywords: *Network Communication Layer.*

ML**:** See Machine Learning.

Mobile edge computing: A concept that enables information technology service environments and cloud computing capabilities at the edge of the radio access networks/cellular networks. Implementing the relevant applications nearby or at the base stations and thereby performing the processing tasks closer to the users, enables fast and flexible deployment of new context-based applications and services for the users. At the same time, it will relieve traffic in the telecommunications network. MEC is a network infrastructure component for blockchain since the replication of blocks via devices can be implemented at the edge and enables IoT applications to deliver real-time context-based mobile moments to the users. The technical standards are being developed by ETSI. See also Edge computing [126] [16]. Keywords: *Network Communication Layer.*

N

Narrow Band IoT: Narrow Band IoT is a LPWAN radio technology standard developed by 3GPP to enable the connection of low-power IoT devices to the cellular network telecommunication bands. NB-IoT specification was frozen at Release 13 of 3GPP specification (LTE-Advanced Pro) in June 2016. It focuses on indoor coverage enabling long-life battery-powered device applications while increasing the number of connected devices [127] [128]. Keywords: *Network Communication Layer, Communications, Cellular, Long-range.*

Natural Language Processing (NLP): A field of computer science, artificial intelligence and computational linguistics concerned with the interactions between computers and human (natural) languages and, in particular, concerned with programming computers to fruitfully process large natural language corpora whether written or spoken. NLP is an area of research and application that explores how computers can be used to understand and manipulate natural language text or speech to do useful things [129]. Keywords: *Other cross-cutting concepts.*

NB-IoT: See Narrow Band IoT.

Near Field Communication (NFC): Standards-based short-range wireless connectivity technology that makes life easier and more convenient for consumers around the world by making it simpler to make transactions, exchange digital content, and connect electronic devices. NFC complements many popular consumer level wireless technologies, by utilizing the key elements in existing standards for contactless card technology (ISO/IEC 14443 A&B and JIS-X 6319-4) [222]. Keywords: *Wireless communication.*

Network: Computer networking is the practice of interfacing two or more computing devices with each other for the purpose of sharing data [130]. Keywords: *Network Communication Layer.*

Network Functions Virtualization (NFV): An initiative to virtualize the network services. NFV is way to reduce cost and accelerate service deployment for network operators by decoupling functions like a firewall or encryption from dedicated hardware and moving them to virtual servers [131] [184]. Keywords: *Network Communication Layer.*

Neural Networks: An information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information [132]. Keywords: *Processing Layer.*

Next Generation Networks (NGN): Next Generation Networks are packet-based networks that use IP to transport the various types of traffic (voice, video, data and signalling) [133]. Keywords: *Network Communication Layer.*

NFC**:** See Near Field Communication.

NFV: See Network Function Virtualization.

NGN**:** See Next Generation Networks.

NLP**:** See Natural Language Processing.

O

Open Data: Open data is data that can be freely used, re-used and redistributed by anyone subject only, at most, to the requirement to attribute and share alike [134] [135]. Keywords: *Other cross-cutting concepts.*

Operation technology (OT): Hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise [14]. Keywords: *Service Layer.*

OT: See Operation Technology.

Outcome-based Agricultural Services: Agricultural services that are able to deliver not only pure agricultural produces and products, but also quantifiable results that matter to their customers such as crop yield, energy saved, machine uptime, and carbon footprint. Such outcome-based services are possible thanks to the use of technology such as IoT which permits the ability to monitor and control farm processes [16]. Keywords: *Other cross-cutting concepts, Farming.*

P

Paradigm: A paradigm is a standard, perspective, or set of ideas. A paradigm is a way of looking at something [136]. Keywords: *Other cross-cutting concepts.*

Personalized Nutrition: Personalized nutrition can be defined as developing unique nutrition guidelines for each individual. Precision nutrition seeks to develop effective approaches based on the combination of an individual's genetic, environmental and lifestyle factors [137]. Keywords: *Other cross-cutting concepts.*

Pervasive: Spreading or spread throughout [138]. Keywords: *Other cross-cutting concepts.*

Physical: Physical refers to tangible objects that are perceived through the senses. Within IoT it refers to the hardware like sensors, devices and networking gear. Keywords: *Physical Layer.*

Platforms: A platform is a specific combination of hardware and operating system and/or compiler. See also IoT Platforms [139]. Keywords: *Abstraction Layer.*

Policy and regulations: Technology policy is a form of 'active industrial policy', and effectively argues, based on the empirical facts of technological development as observed across various societies, industries and time periods, that markets rarely decide industrial fortunes in and of their own and state-intervention or support is required to overcome standard cases of market-failure (which may include, for example, under-funding of Research & Development in highly competitive markets) [185]. Keywords: *Other cross-cutting concepts.*

Policy on IoT: A document that provides a comprehensive guide to helping an organization promote the development of IoT and/or deal with the complex issues related to that development. [140]. Keywords: *Other cross-cutting concepts.*

Precision Agriculture: Precision Agriculture is a whole-farm management approach using information technology, satellite positioning (GNSS) data, remote sensing and proximal data gathering. These technologies have the goal of optimising returns on inputs whilst potentially reducing environmental impacts [141]. Keywords: *Other cross-cutting concepts.*

Precision farming: Precision farming is farm management at a level that allows inputs to be tailored to variable conditions across short distances in a single field [142]. Keywords: *Other cross-cutting concepts.*

Predictive Maintenance: Also called condition-based maintenance, predictive maintenance is a maintenance policy that sets out the regular monitoring of machine and equipment conditions to better understand their operating condition and thus be able to schedule maintenance interventions only when they are really needed. Maintenance interventions are programmed in real-time avoiding unforeseen downtime and their related negative implications. The integration of digital technologies such as IoT in machinery and equipment facilitates predictive maintenance [16]. Keywords: *Other cross-cutting concepts, Industry.*

Preventive Maintenance: Time-driven maintenance policy that seeks to correctly predict the optimal times of maintenance interventions in order to anticipate the failure of complex systems.

Preventive maintenance results in maintenance interventions scheduled based on the mean-time-to-failure statistic [16]. Keywords: *Other cross-cutting concepts, Industry.*

Printed Circuit: A circuit for electronic apparatus made by depositing conductive material in continuous paths from terminal to terminal on an insulating surface [186]. Keywords: *Physical Layer.*

Privacy: Privacy refers to a person's right to control access to his or her personal data and be free from intrusion, misuse or disclosure by third parties. This definition extends the right of a person to control what is and isn't available on the internet. In the United States of America, privacy is used to refer to Data Protection [143]. Keywords: *Other cross-cutting concepts.*

Privacy-by-default: Obligation under Art. 25 of the GDPR - By default, only personal data that are essential to the stated purpose of each process shall be processed and that personal data are not made accessible without the individual's intervention to an indefinite number of natural persons [144].

Privacy-by-design: Obligation under Art.25 of the GDPR - Privacy should be taken into account throughout the entire engineering process from the earliest design stages to the operation of the productive system i.e. that data protection safeguards (also known as Privacy Enhancing Technologies (PETs)) should be built into products and services from the earliest stage of development [145].

Proactive Maintenance: In opposition to corrective (reactive) maintenance, proactive maintenance seeks to detect and correct the root cause aberrations of failure (unstable operating conditions that will lead to actual failure unless they are corrected) [146]. Keywords: *Other cross-cutting concepts.*

Production Systems: A manufacturing subsystem that includes all functions required to design, produce, distribute, and service a manufactured product [147]. Keywords: *Application Layer.*

Programme: A plan of activities to be done or things to be achieved [148]. Keywords: *Other cross-cutting concepts.*

Prosumer: In the 1980 book, The Third Wave, futurologist Alvin Toffler coined the term "prosumer" when he predicted that the role of producers and consumers would begin to blur and merge. George Ritzer and Nathan Jurgenson, in a widely-cited article, claim that prosumption has become a salient characteristic of Web 2.0. Prosumers create value for companies without receiving wages. Sparked by technology and led by global consumer culture's dominance, 21st-century consumption has been radically transformed; co-creation and prosumption being some of its most representative examples. The prosumer actively works to produce the services and goods they buy and consume. For example: self-check-outs at the supermarket, the DIY furniture of Ikea, or online order and delivery services such as E-bay or Amazon. In fact, with the huge help of the Internet, most prosumption is happening in the online world. The most common example is Wikipedia where the users can generate, edit, update and comment on articles. Nevertheless, it is not enough to create stimulating contexts and environments for consumers to take an active role. For prosumption to be integrated in technological development in IoT at a significant level, commitment of prosumers is key. Commitment is a limited resource in a context where "consumer fatigue" – consumers frustrated by technological solutions that they no longer understand and whose utility they no longer perceive – is an encompassing trend in consumer research [149] [150] [151] [152]. Keywords: *Other cross-cutting concepts.*

Q

QoS**:** See Quality of Service.

QR codes: A QR code is a type of matrix (or bi-dimensional, BiDi) barcodes. Barcodes are machine-readable, optical labels including relevant information about the object to which it is attached. A QR code can encode its information using four different and standardized modes, namely kanji, alphanumeric, numeric and byte/binary, although extensions can also be used. QR codes are specifically designed for cameras to read. It is commonly presented as small black squares arranged in a square grid on a white background. QR codes are especially interesting for IoT as they enable device identification and interaction with other devices or human users [153]. Keywords: *Physical Layer, Image, Code.*

Quality of Service (QoS): Quality of Service refers to the measurement of the performance, usually observed user-side, of services such as telephony, cloud, computer or IoT networks. This assessment includes several aspects such as latency, error rate, throughput and availability. Quality of Service is relevant to any IoT network whose applications are oriented toward interactions with humans. They should perceive smooth communication and critical or real-time operations where delays and error rates should be minimized [106]. Keywords: *Network Communication Layer, Communications, Quality, User-experience.*

R

RAMI: RAMI 4.0 stands for Reference Architectural Model Industrie 4.0. RAMI 4.0 is a service-oriented architecture that combines all elements and IT components using a layer and life cycle model. RAMI 4.0 breaks down complex processes into easy-to-grasp packages along three dimensions: hierarchy levels (related to the systems, machines and products present in the factory), the product life cycle and a layered architecture [154]. Keywords: *Service Layer.*

Reasonable: Reasonable refers mainly to the licensing rates. According to some, a reasonable licensing rate is a rate charged on licenses which would not result in an unreasonable aggregate rate if all licensees were charged a similar rate [187]. Keywords: *Other cross-cutting concepts.*

Reference Architecture Model: A reference model that provides an architectural template solution for a particular domain. Concerning IoT, there is a need to standardize a reference architecture model in order to support the interoperability in IoT. In this context, the IoT platforms are the highest, most generalized layer of intelligence and user interface that ties together connected devices and web-based services. They collectively define a reference architecture model for IoT. A wide range of technologies, communication protocols, layers, dimensions and standards are taken into consideration. An example of a reference architecture model initiative is Industrie 4.0 (RAMI). See also Architecture and Industrie 4.0 [155] [86]. Keywords: *Other cross-cutting concepts.*

Regulations

Regulations can refer to either specific European Law or a more general description. In European Law, a regulation is a legal act adopted by the European institutions and are legally binding with immediate application in all member states providing homogenous application of EU law across states. Generally, a regulation is the application of a set of standards, norms and/or responsibilities overseen by an external body (i.e. government) or internally (e.g. industry body)to ensure the maintenance of quality or proper functioning of a product, service or market and to support consistency across jurisdictions [156] [157]. Keywords: *Other cross-cutting concepts.*

Research: Systematic investigative process employed to increase or revise current knowledge by discovering new facts. It is divided into two general categories: *(i)* Basic research is inquiry aimed at increasing scientific knowledge. *(ii)* Applied research is effort aimed at using basic research for solving problems or developing new processes, products, or techniques [188]**.** Keywords: *Other cross-cutting concepts.*

Resource virtualization: Resource virtualization consists in either partitioning a single physical resource into multiple virtual resources or aggregating multiple physical resources into one virtual resource [189]. Keywords: *Abstraction Layer*.

RFID: RFID stands for Radio Frequency identification and refers to a system of storing and retrieving data wirelessly using tags, smart cards or RFID transponders. It uses electromagnetic fields to identify tags attached to objects which should be brought into proximity of a reader with a typical coverage of a couple of centimetres. Tags can be passive (unpowered and just readable when close enough) or active (battery powered and with extended coverage). RFID is commonly embedded into IoT applications and deployments as an easy way to identify devices and/or interact with humans [158] [159]. Keywords: *Physical Layer, Communications, Short-range, Tags.*

Risk: Potential that a given threat will exploit vulnerabilities of an asset or group of assets to cause loss or damage to the assets [190]. Keywords: *Other cross-cutting concepts.*

Robotics: Branch of science that deals with making and using robots [191]. Keywords: *Other cross-cutting concepts.*

Robotic Things**:** See Internet of Robotic Things (IoRT).

S

Safety: In IT systems, it refers to functional safety (in the physical not digital dimensions) [192]. Keywords: *Other cross-cutting concepts.*

SDN**:** See Software Defined Network.

Security: Property of an IT system by which confidentiality, integrity, availability, accountability, authenticity, and reliability are achieved [193]. Keywords: *Other cross-cutting concepts.*

Security-by-design: The capability of an ICT product to protect information and data so that unauthorised persons or systems cannot read or modify them and authorised persons or systems are not denied access to them [194]. Keywords: *Other cross-cutting concepts.*

Self-healing: Self-healing can be defined as the property that enables a system to perceive that it is not operating correctly and, without (or with) human intervention, make the necessary adjustments to restore itself to normality [195]. Keywords: *Other cross-cutting concepts.*

Self-optimizing: The conceivable development of information technology will enable mechatronic systems with inherent partial intelligence. We call this kind of systems self-optimizing [196]. Keywords: *Other cross-cutting concepts.*

Self-protecting: Self-protecting software systems are a class of autonomic systems capable of detecting and mitigating security threats at runtime [197]. Keywords: *Other cross-cutting concepts.*

Services: Services are intangible products provided to a customer or user enabling them to achieve a task or goal. Keywords: *Other cross-cutting concepts.*

Silver economy: Existing and emerging economic opportunities associated with the growing public and consumer expenditure related to population ageing and the specific needs of the population over 50 [160]. Keywords: *Other cross-cutting concepts.*

Smart Buildings: Smart building encompass many things, but, the primary goal is the use of building technology systems to enable enhanced services and the efficient operation of a building for the betterment of its occupants and building management. The main drivers of smart buildings are the positive financial impacts of integrated system, energy conservation, greater

systems functionality, and the continuing evolution of technology [198]. Keywords: *Other cross-cutting concepts.*

Smart City: Smart city refers to those cities integrating Information Technologies together with IoT technology to gather and monitor data from its assets (including hospitals, power plants, transportation systems, local information systems and water supply networks) and citizens. The data gathered is used to optimize the services being monitored and enhance quality of life for all citizens [161]. Keywords: *Application Layer, Applications, Cities, Verticals.*

Smart Clothing: Life simulation system which has perception and feedback of clothing. Smart clothing can sense changes in internal and external environmental conditions, as well as make real-time or near-time self-report feedback [199]. Keywords: *Other cross-cutting concepts.*

Smart Energy: Smart energy system is defined as an approach in which smart electricity, thermal and gas grids are combined and coordinated to identify synergies between them in order to achieve and optimal solution for each individual sector as well as for the overall energy system [200]. Keywords: *Other cross-cutting concepts.*

Smart Environments: Any space where ubiquitous technology informs the learning process in an unobtrusive, social or collaborative manner [201]. Keywords: *Other cross-cutting concepts.*

Smart Farming: Smart Farming techniques help produce more food from fewer resources, including soil, water, fertilisers, pesticides and human effort. Predictive analytics helps improve yields, reduce crop diseases and optimise resource utilisation. Smart farming concept brings together researches, farms and industry to produce food smarter [202]. Keywords: *Other cross-cutting concepts.*

Smart Health: The technology that leads to better diagnostic tools, better treatment for patients, and devices that improve the quality of life for anyone and everyone [203]. Keywords: *Other cross-cutting concepts.*

Smart Homes: Smart Home technology has become the popular name for the integration of telematics into the electrical installation of the home [204]. Keywords: *Application Layer.*

Smart living: Smart living refers to improving quality of life by transforming environments to become more intelligent and adaptable to users [205]. Keywords: *Application Layer.*

Smart living environments: A physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network [206]. Keywords: *Application Layer.*

Smart Manufacturing: Smart manufacturing is a broad category of manufacturing with the goal of optimizing concept generation, production, and product transaction. While manufacturing can be defined as the multi-phase process of creating a product out of raw materials, smart manufacturing is a subset that employs computer control and high levels of adaptability. Smart manufacturing aims to take advantage of advanced information and manufacturing technologies to enable flexibility in physical processes to address a dynamic and global market. There is increased workforce training for taking advantage of the increased flexibility of this technology instead of the specific tasks that are customary in traditional manufacturing [162]. Keywords: *Application Layer, Industry.*

Smart Mobility: Technology that enables Intelligent Transport Systems to create highly efficient, uninterrupted and reliable transportation networks with the goal to build sustainable infrastructure for future generations [207]. Keywords: *Other cross-cutting concepts.*

Smart Objects: A smart object is an item equipped with a form of sensor or actuator, a tiny microprocessor, a communication device, and a power source [208]. Keywords: *Physical Layer.*

Smart water management: Utility system for water supply which is characterized by the use of communication networks and the control of grid components and loads [209]. Keywords: *Other cross-cutting concepts.*

Social Innovation: Social innovations are new ideas that meet social needs, create social relationships and form new collaborations. A considerable number of technology-based artworks, transformed into products and services, were conceived to be products from conception; not necessarily due to potential commercial reasons but instead were designed so as to have an impact on society. In this context, social innovation is a relevant aspect in IoT. Projects such as the open hardware platform Arduino show how artistic practice can lie at the basis of later technological developments with a tangible economic and societal impact. They have a concrete impact on the growth and jobs objective by enabling more people to experiment with open source digital technology. This exponentiates the probability of the creation of new products and services and contributes to socially-driven innovation processes which distinguish the EU from other players in the global market [163] [19]. Keywords: *Other cross-cutting concepts, SOCENT, Impact, Innovation.*

Software Defined Network: Novel network paradigm that separates each network services from its point of attachment to the network, creating a far more dynamic, flexible, automated, and manageable architecture. It is an emerging architecture that is dynamic, manageable, cost-effective, and adaptable, making it ideal for the high-bandwidth, dynamic nature of today's applications [210]. Keywords: *Network Communication Layer*.

Standard: A technical standard is an established norm or requirement in regard to technical systems. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes and practices. In addition, a custom, convention, company product, corporate standard, etc. that becomes generally accepted and dominant is often called a de facto standard [164]. Keywords: *Other cross-cutting concepts.*

Standardisation**:** See Standard.

STARTS: The European Commission has launched a new initiative, (S+T)*ARTS=STARTS - innovation at the nexus of Science, Technology and the ARTS. STARTS funds and encourages collaboration of the Arts with Technology by, for instance, including artists in H2020. The mission of STARTS is to bring artists into innovation. An innovation that is much more than the sum of its parts and goes well beyond: Holistic Innovation. In fact, in order to create value for citizens, industry has to think more holistically about technologies and services that put the human in the centre. Indeed, digital transformation of industry and society is already naturally uniting science and engineering with design and artistic approaches. This can be seen in many areas where art and technology naturally collaborate like in urban development or in new media like virtual and augmented reality. In this context, the Arts gain prominence as catalysts for an efficient conversion of S&T knowledge into radical novel products, services, and processes [165]. Keywords: *Other cross-cutting concepts, Arts, Innovation, Creativity.*

Swarm intelligence (SI): This concept can be looked at as a subfield of artificial intelligence (AI) and is based on collective behaviour and interaction of decentralized and self-organized systems inspired by nature ("swarm of individuals"). With enhanced SI, IoT objects are capable of cooperating and sharing resources efficiently (by a set of algorithms). This allows for solving numerous IoT optimization challenges, which are otherwise difficult to implement due to the large resources required. Examples of IoT applications may be optimization of node localization, signal coverage, and transmission route [16]. Keywords: *Other cross-cutting concepts.*

Swarm technologies: The technologies that provide swarm intelligence (SI). The swarm technologies needed are related to the applications. Together with the artificial intelligence, robotics, and machine learning; the swarm technologies are the technologies that will provide the next phase of development of IoT applications [16]. Keywords: *Other cross-cutting concepts.*

Systems of systems: Combination of systems (being individually composed of interacting elements) organized to achieve one or more stated purposes. *Note 1*: A system may be considered as a product and/or as the services it provides. *Note 2*: In practice, the interpretation of its meaning is frequently clarified by the use of an associative noun, e.g. aircraft system [211]. Keywords: *Collaboration and Process Layer.*

T

Technology: Technology is a body of knowledge devoted to creating tools, processing actions and extracting of materials [212]. Keywords: *Other cross-cutting concepts.*

Technology Readiness Level (TRL): A tool for describing the maturity of a technology. The scale ranges from level 1 to level 9, where each level characterises the technology development progress, from idea to product. The European Commission defines the nine Technology Readiness Levels as follows: TRL 1: Basic principles observed, TRL 2: Technology concept formulated, TRL 3: Experimental proof of concept, TRL 4: Technology validated in lab, TRL 5: Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies), TRL 6: Technology demonstrated in relevant environment, (industrially relevant environment in the case of key enabling technologies), TRL 7: System prototype demonstration in operational environment, TRL 8: System complete and qualified, and TRL 9: Actual system proven in operational environment, (competitive manufacturing in the case of key enabling technologies; or in space) [166]. Keywords: *Other cross-cutting concepts.*

Test beds: An execution environment configured for testing. May consist of specific hardware, OS, network topology, configuration of the product under test, other application or system software, etc. The Test Plan for a project should enumerate the test beds to be used [213]. Keywords: *Other cross-cutting concepts.*

Things: A thing, in the Internet of Things, can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low - or any other natural or man-made object that can be assigned an IP address and provided with the ability to transfer data over a network [214]. Keywords: *Physical Layer.*

Transdisciplinary: Transdisciplinary Research is defined as research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem. Transdisciplinarity requires for creating a unity of intellectual frameworks beyond the disciplinary perspectives, whilst interdisciplinarity integrates knowledge and methods from different disciplines using a real synthesis of approaches. Transdisciplinarity can also be found in the arts and humanities. For example, the Planetary Collegium seeks "the development of transdisciplinary discourse in the convergence of art, science, technology and consciousness research [167]. Keywords: *Other cross-cutting concepts, Holistic, Research, Innovation.*

Transparent: Network transparency is the situation in which an operating system or other service allows a user to access a resource (such as an application program or data) without the user needing to know, and usually not being aware of, whether the resource is located on the local machine (i.e., the computer which the user is currently using) or on a remote machine (i.e., a computer elsewhere on the network) [215]**.** Keywords: *Network Communication Layer.*

Trust: Relationship between two elements, a set of activities and a security policy in which element x trusts element y if and only if x has confidence that y will behave in a well-defined way (with respect to the activities) that does not violate the given security policy [216]. Keywords: *Collaboration and Process Layer.*

Trust Management: Trust-management systems provide applications with a standard interface for getting answers to such questions, and provide users with a standard language for writing the policies and credentials that control what is allowed and what isn't [217]. Keywords: *Collaboration and Process Layer.*

Trusted IoT: The development of standards for trust, privacy and end-to-end security for the Internet of Things [218]. Keywords: *Other cross-cutting concepts.*

Trustworthy: Trustworthiness is the demonstrated ability of the trustee to perform a specified action while adhering to a set of stated principles (integrity) and acting in the best interest of the trustor (benevolence) [219]. Keywords: *Other cross-cutting concepts.*

U

Urban Farming: The growing of crops and raising of livestock within an urban environment for consumption within the local area. Activities include, among others, balcony, rooftop and back garden growing, community gardens, allotment gardening and animal grazing on commons. [168]. Keywords: *Other cross-cutting concepts.*

V

Value Chain: The value chain refers to all the activities, from receipt of raw materials to post-sales support that together create and increase the value of a product [169]. Keywords: *Other cross-cutting concepts.*

Value Network: The collection of upstream suppliers, downstream channels to market, and ancillary providers that support a common business model within an industry. When would-be disruptors enter into existing value networks, they must adapt their business models to conform to the value network and therefore fail at disruption because they become co-opted [170]. Keywords: *Other cross-cutting concepts.*

Vehicle-to-Infrastructure (V2I) communication: Two-way wireless transmission of information (data) between vehicles and the roadside infrastructure, e.g. embedded equipment in traffic signs/lights. The main components are the on-board unit, roadside equipment and reliable communication channel. V2I communication facilitates local (or regional) traffic coordination. Information on traffic and road conditions can be used to inform, warn or redirect vehicles to a given area. Information from the vehicles can also be collected and redistributed to ensure traffic safety, avoid traffic congestion, improve traffic flow and environment, collect road toll, etc. Interconnectivity between vehicles and the infrastructure play an important role in intelligent transportation systems (ITS) and autonomous driving. High-speed environments and reliable real-time information are important issues for the V2I communication network. Examples on relevant standards are ETSI ITS-G5, IEEE 802.11p, IEEE 1609, and SAE J2735.

Vehicle-to-Vehicle (V2V) communication: The wireless transmission of information (data) between vehicles. V2V communication facilitates exchange of information and early warnings/control to ensure traffic safety, avoid traffic congestion, improve traffic flow and environment, etc. Interconnectivity between vehicles plays an important role in autonomous driving. High-speed environments and reliable real-time information are important issues for the V2V ad-hoc communication network, also referred to as VANETs (vehicular ad-hoc networks) or IVC (inter-vehicle communication). Examples on relevant standards are ETSI ITS-G5, IEEE 802.11p, IEEE 1609, and SAE J2735

Virtual: Representation of an asset in the cyberspace. NOTE: In this context, currency can be defined as either a medium of exchange or a property that has value in a specific environment, such as a video game or a financial trading simulation exercise [220]. Keywords: *Other cross-cutting concepts.*

Virtual Food Chains: The digital representation (virtual) of a supply chain, enabled by the use of digital technologies such as IoT. The use of virtual food chains enables the application of virtual chain management techniques such as advanced remote planning, re-planning, monitoring and control of the different elements and processes involved across the chain [16]. Keywords: *Collaboration and Process Layer, Agrifood.*

Virtual Manufacturing: A virtual manufacturing system is a computer system that can produce similar information concerning manufacturing system structure, states and behaviours as one can observe in the real manufacturing systems it represents [221]. Keywords: *Processing Layer.*

Virtual Reality (VR): Virtual Reality provides a computer-generated 3D environment that surrounds a user and responds to that individual's actions in a natural way, usually through immersive head-mounted displays and head tracking. Gloves providing hand-tracking and haptic (touch sensitive) feedback may be used as well. Room-based systems provide a 3D experience for multiple participants; however, they are more limited in their interaction capabilities [14]. Keywords: *Application Layer, Physical Layer.*

Virtualisation: The process of changing something that exists in reality into a virtual version. The abstraction of information technology (IT) resources that masks the physical nature and boundaries of those resources from resource users. An IT resource can be servers, clients, storage, networks, applications or operating systems. Essentially, any IT building block can potentially be abstracted from resource users [116] [14]. Keywords: *Other cross-cutting concepts.*

W

Wearables: Wearable refers to all electronic devices able to be worn on the human body using implants or through the use of clothing and accessories. They are often designed to track activity and/or health-related measurements. They are IoT devices optimized to be ultra-low cost, size and power. They are thought to constantly interact with the user [171]. Keywords: *Physical Layer, Things, Hardware, Miniaturization.*

Wellness: The optimal state of health of individuals and groups. There are two focal concerns: the realization of the fullest potential of an individual physically, psychologically, socially, spiritually and economically; and the fulfilment of one's expected role in the family, community, place of worship, workplace and other settings [172]. *Keywords: Other cross-cutting concepts.*

4. CONCLUSIONS

The present deliverable compiles a glossary of about 250 terms related to the activities undertaken across the seven projects of the IoT Large Scale Pilots Programme. This handbook has been designed as a contribution that the CREATE-IoT project provides to the community of the IoT Large Scale Pilots Programme with the goal to facilitate a common terminology ground as basis for cross-fertilization among all projects of the Programme.

This deliverable has not been conceived as an input to any specific WP or Task of the CREATE-IoT project. Rather, this handbook will be considered by the whole consortium members as a tool to help harmonize the terminology used during the project's lifetime and across all WPs, Tasks and deliverables produced until the end of the project.

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