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Abstract	In this Deliverable, we extend the considerations performed in D3.2 on interoperability adding the information we were able to gather in the second part of the project. This will be considered as an input to the proposed model and guidelines for interoperability. We added considerations technical and systemic in nature. To facilitate the reader we integrated the text from D3.2 in this report.

Keywords	IoT, China, Europe, Interoperability

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** R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

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EXECUTIVE SUMMARY

This report builds on D3.2 and extends with additional information and consideration on IoT interoperability testing focusing attention on how EU and China markets are developing and racing to innovate and validate their progress.

The digital economy has growing consistently around IoT devices, services and platforms. While this trend is global China benefits from being mostly a greenfield compared to advanced eco-systems such as USA or western Europe. This advantage allows to Chinese IoT providers the luxury of deploying experimental hardware, software and service solutions. As the market grows however there is an urgent need for standards, interoperability and best practice guidelines that are now in the making.

Stemming from the current status in both Europe and China (initiatives, federation projects, standards, platforms, key players, funding, etc.) as reported in D3.2, we add an updated state of interoperability affairs and an analysis on the challenges ahead.

NOTE TO THE READER

The initial part of this report is taken from the deliverable D3.2 prepared within the EU funded project EXCITING as this is the updated version of such report. Sections 5 is however new.

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ABBREVIATIONS

6LowPAN: Ipv6 Low Power Wireless Personal Area Networks
AII: Alliance of Industrial Internet of Things Innovation
AIOTI: Alliance for Internet of Things Innovation
CCSA: China Communications Standards Association
CNGI: China Next Generation Internet
CoAP: Constrained Application Protocol
DLNA: Digital Living Network Alliance
HTTP: Hyper Text Transfer Protocol
ICT: Information and Communications Technology
IoT: Internet of Things
IoT-EPI: IoT-European Platforms Initiative
LSP: Large Scale Pilot
MIIT: Ministry of Industry and Information Technology
MoF: Ministry of Finance
MQTT: MQ Telemetry Transport
OEM: Original Equipment Manufacturers
SME: Small and Medium Enterprises
SDO: Standards Developing Organisation
TCP: Transport Control Protocol
UDP: User Datagram Protocol
UPnP: Universal Plug and play

1 INTRODUCTION: OVERALL APPROACH

1.1 Definition of interoperability

Interoperability must not be confused with compatibility ("the capability of a functional unit to meet the requirements of a specified interface without appreciable modification") and portability ("the capability to be interpreted, understood, or executed on various types of data processing systems without conversion and with little or no modification").

Generally, interoperability is defined as "the ability of a system to work with or use the parts or equipment of another system". It is an essential topic of concern for IoT research and industrial communities. Any coordination with countries all around the world is very important.

A representation of interoperability can be as follows:

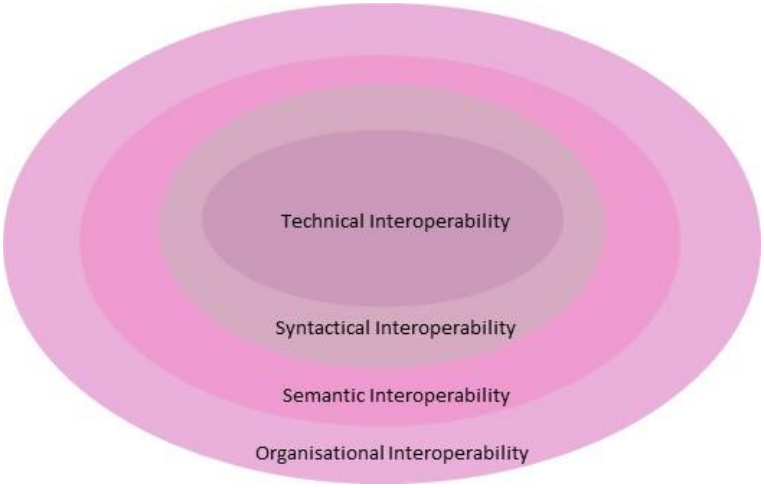

***Figure 1**. Interoperability*

- Technical interoperability is the ability to enable a machine-to-machine communication. It is about especially the protocols and the infrastructure needed.
- Syntactical interoperability is about the definition of the data syntax and encoding.
- Semantic interoperability is about the meaning of the content (the exchanged information has an unambiguous, shared meaning).
- Organisational interoperability is the ability of organisations to effectively communicate and transfer information. It is very linked to a successful technical, syntactical and semantic interoperability.

1.2 General objectives and goals

Interoperability provides advantages throughout the supply chain: users have a much greater choice of products and manufacturers can benefit from the economies of scale that a wider market brings.

The most important challenge in IoT is the enablement of seamless interoperability on a technical and semantic level. Therefore, the IoT requires standards to enable horizontal platforms that are

communicable, operable, and programmable across devices or industry.

Several aspects of interoperability were addressed in the past year such as technical, semantic, syntactic and business interoperability. With the challenges of adding information from big data, there is a particular attention in many SDOs on addressing semantic interoperability.

The objective is to analyse these challenges and requirements and to give a first version of guidelines to operate a successful interoperability.

2 IOT INTEROPERABILITY FRAMEWORK IN EU AND CHINA

2.1 Existing IoT interoperability test activities

Currently, there are many alliances, standards developing organisation, projects and platforms that are active and competing in the IoT field.

2.1.1 In Europe

2.1.1.1 Initiatives

This section describes the main European alliances that have a worldwide impact in the IoT area.

***Table 1**. IoT European initiatives*

	Description	Activities
IoT- Forum	Member-based organisation.	International dialogue. Organise events and conferences. Develop synergies with and among its members.
AIOTI Alliance for internet of Things Innovation	Non-profit organisation 13 working groups 170 members.	Reports. Develop a dynamic European IoT ecosystem.
IoT-EPI http://iot-epi.eu/	IoT-European Platforms Initiative.	European Initiative addressing IoT platform development. Formed to build a vibrant and sustainable IoT-ecosystem in Europe, maximising the opportunities for platform development, interoperability and information sharing. Its core is composed by seven EU-funded H2020 research and innovation projects: Inter-IoT, BIG IoT, AGILE, symbIoTe, TagItSmart!, VICINITY and bIoTope.

IoT-European Platforms Initiative (IoT-EPI):

The IoT-European Platforms Initiative (IoT-EPI) is described in Figure 2. We have highlighted the important projects that will be described in Table 2.

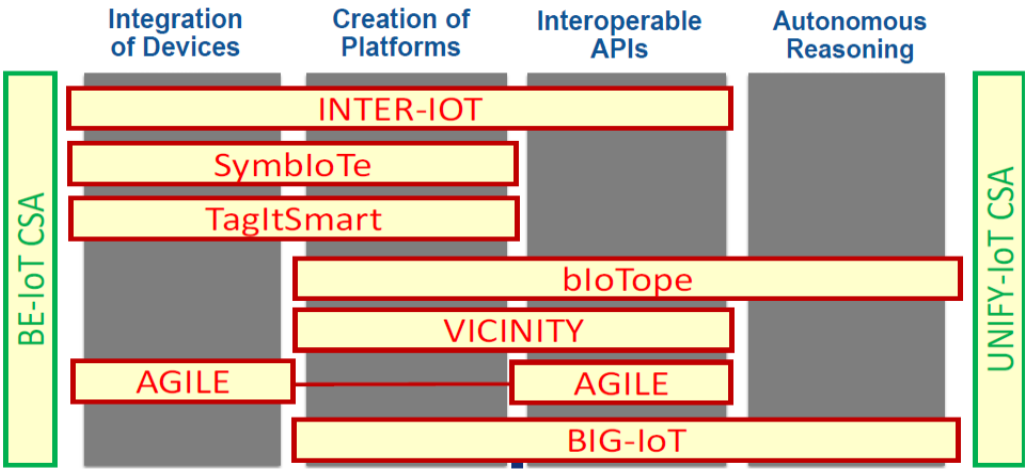

***Figure 2**. IoT-European Platforms Initiative (IoT-EPI) projects*

2.1.1.2 Projects

***Table 2**. IoT projects in Europe*

	Description
Onelab	OneLab is designed to be able to test a variety of diverse networked communication environments, including IoT networks with mobility and sensing capabilities, ad-hoc wireless and wireless broadband access networks, global, public, fixed-line Internet, Cloud and SDN networks. Both wireless and fixed-line emulated environments are available.
Fiesta-IoT	FIESTA-IoT (Federated Interoperable Semantic IoT Testbeds and Applications) The main goal of the FIESTA project is to open new horizons in the development and deployment of IoT applications and experiments. The project operates both at EU and global scale, and it is based on the interconnection and interoperability of diverse IoT platforms and testbeds. FIESTA-IoT is providing a meta-testbed IoT/Cloud infrastructure to enable the submission of experiments over the interconnected/interoperable underlying testbeds. Hence, researchers and engineers will utilise a single-entry point to all FIESTA-IoT EaaS services using a single set of credentials. They will be able to design and execute experiments across a virtualised infrastructure i.e. access the data and resources from multiple testbeds and IoT platforms using a common approach. FIESTA-IoT offers tools i) to design and execute experimental workflows, ii) dynamically discover IoT resources, and iii) access data in a testbed agnostic manner. FIESTA-IoT provides IoT Experiment as a Service atop of a middleware infrastructure that adapts and federates existing IoT platforms and testbeds. This entails the adaptation of the testbeds data to a common FIESTA-IoT ontology (i.e. compliance to common semantics). Necessitating also the provision of a common API standard, to access the testbeds IoT services and thus the wealth of heterogeneous IoT data in them.

Fed4FIRE	Fed4FIRE is an initiative to bring together heterogeneous facilities across Europe so as to target experimentation across the whole Future Internet field i.e., networks, software and services, and IoT. Fed4FIRE federates testbeds, bringing together Cloud, IoT, wireless, wireless mobile, LTE, cognitive radio, 5G, OpenFlow, SDN, NFV and network emulation technologies.
F-interop	F-interop is a European research project which studies and develops online interoperability and performance testing tools as a support to the emerging IoT-related technologies from standardisation to market introduction. It also intends to support research, product development by SME, and standardisation processes. Its aims and objectives are: - to integrate and extend several European testbed federations with a shared "Testbed as a Service". This is done interconnecting three European testbed federations (Fed4FIRE, OneLab, IoT Lab), bringing together over 32 testbeds and 4755 nodes; - to research and develop online testing tools for the Internet of Things. The tools do interoperability, conformance, scalability, Quality of Service (QoS), Quality of Experience (QoE), and Energy efficiency tests; - to support IoT standardisation and enable cooperation with the industry. This will be possible thanks to a close collaboration with standards development organisations (ETSI, OneM2M, IETF and W3C), combined with the research and development of online certification and labelling mechanisms. F-Interop will enable an easier participation of researchers and industries in the standardisation process; - to organise open calls for SMEs and developers, using and enriching the testing platform with additional modules and extensions (additional test tools, tests specifications, etc.). F-Interop works in close collaboration with several standardisation bodies. It directly contributes to three IoT standardisation processes: OneM2M, 6TiSCH (IETF) and the Web of Things (W3C). It also explores the possibility to support and enable new online certification and labelling mechanisms, including the "IPv6 Ready" logo.
IoT Lab.eu	IoT Lab has recently concluded. It unified IoT and crowdsourcing/crowd-sensing testbeds, including smart campus, smart buildings and smart offices testbeds.
SOFIA2	It is a middleware that allows the interoperability of multiple systems and devices, offering a semantic platform to make real world information available to smart applications (Internet of Things). It is multi-language and multi-protocol, enabling the interconnection of heterogeneous devices. It provides publishing and subscription mechanisms, facilitating the orchestration of sensors and actuators in order to monitor and act on the environment. SOFIA2 is one of the several IoT platforms which has the potential to be considered for the interoperability of heterogeneous IoT platforms in this project.
INTER-IoT	The INTER-IoT project aims at the design, implementation and experimentation of an open cross-layer framework, an associated

	methodology, and a set of tools to enable voluntary interoperability among heterogeneous Internet of Things (IoT) platforms. The project will enable effective and efficient development of adaptive and smart IoT applications and services. It will work with several heterogeneous IoT platforms, spanning single and/or multiple application domains. The developed framework will be tested in two application domains: port transportations and logistics, and mobile health. Additionally, it will be also validated in a cross-domain use case.
BIG IoT	The objective of BIG IoT (Bridging the Interoperability Gap of the Internet of Things) is not to develop yet another IoT platform, as several other projects already do. Instead, it will establish interoperability by defining a unified Web API for IoT platforms: the BIG IoT API. This Web API is aligned with the standards currently developed by the W3C Web of Things group. The project approaches the existing interoperability gap based on (1) a common Web interface, called the BIG IoT API, (2) a semantic description of resources and services, as well as (3) a marketplace as the core driver of the ecosystem. This has to provide functionalities such as authentication, discovery and charging. The BIG IoT API will be designed as an open community process and the project consortium will engage with current standardisation initiatives to receive inputs and deliver contributions. As part of the project, 8 smart object platforms will implement BIG IoT API. Hence, allowing a real and widespread exploitation of their data and application heritage. The BIG IoT Marketplace will allow different IoT providers to easily offer and monetise accesses to their resources as well as IoT consumers to discover and use them.
VICINITY	The objective of VICINITY is to build and demonstrate a device and standard agnostic platform for IoT infrastructures that will offer "Interoperability as a Service". It will rely on a decentralised and user-centric approach that offer a complete transparency across vertical domains while retaining full control of the ownership and distribution of data.
bIoTope	The bIoTope platform aims to enable IoT product and service providers to develop and deploy IoT solutions utilising heterogeneous information and services together with multiple systems (OpenIoT, FIWARE, city dashboards, etc.). Based on recent IoT standards, as O-MI (Open Messaging Interface) and O-DF (Open Data Format), bIoTope applies an “Everything as a Service” concept to enable a rapid development of new IoT systems and a reduction of development costs.
UNIFY-IoT	UNIFY-IoT is the “working partner” of the Alliance for Internet of Things Innovation (AIOTI) and the Internet of Things European Research Cluster (IERC) by coordinating and supporting the activities on innovation ecosystems, IoT standardisation, Policy Issues, Research and Innovation. UNIFY-IoT project is part of the IoT-EPI initiative. Get all news, events and developments from IoT-EPI projects on the initiative’s website. Project objectives are to stimulate and support the collaboration between IoT projects and potential platforms. The support aims to sustain the whole IoT ecosystem. It focuses on complementary actions, e.g. fostering and accelerating the acceptance of IoT technology, as well as on the means to understand and overcome the obstacles to the IoT deployment and value creation.

2.1.1.3 IoT Platforms

IoT platforms are emerging to simplify devices and connectivity management and application enablement.

According to « https://www.xipi.eu/Infrastructures », there are nine dedicated IoT platforms in Europe.

***Table 3**. IoT platforms in Europe*

	Country	Description
Fit – Future Internet of Things	France	FIT is a large-scale testbed for testing performance, interoperability, and security. It uses nine sites across France, including Paris, Grenoble, Lille, Strasbourg, and Lyon. It is part of the OneLab federation.
CROSS-TEC LABORATORY of ENEA TECHNOPOLE in Bologna	Italy	CROSS-TECH structure is composed by two main infrastructures: 1- Testbed environment for standard compliance and for networked enterprises interoperability; 2- Lab for prototyping, 3D design and production technologies as a support to the designed based goods. Notice that while the laboratory is actually running, the testbed is not fully developed, yet.
Fraunhofer FOKUS SmartTV Lab	Germany	The Lab offers a comprehensive test and development environment for cutting-edge, hybrid TV technologies and devices. Including brand new TV formats, interactive content, HbbTV and cross-platform applications. Fraunhofer FOKUS Smart TV Lab provides support for both application and content providers, as well as CE manufacturers. Thus, they allow their customers to test and validate their solutions against standards (HbbTV, CE-HTML) in regard to interoperability.
Open Overlay Lab (UPC)	Spain	Open Overlay Lab offers a running overlay network for experiments. The experimental network spans over 20 countries with about 200 nodes and is managed by UPC.
PerformNetworks	Spain	PerformNetworks is a FIRE+ experimental platform. Its main goal is to offer a realistic experimentation environment able to deal with LTE, LTE-A and future networks. The testbed is based on commercial off-the-shelf solutions (both in the radio and core

		network), software defined radio equipment and conformance testing equipment. It offers a wide range of possibilities like covering pilots, interoperability, performance evaluation, QoS, QoE and more. PerformNetworks is operated by the MORSE research group at the Universidad de Málaga.
ETOMIC SONoMA	Hungary	SONoMA is a common and extensible network measurement platform. It proposes an alternative to define and perform distributed network experiments. This SOA based approach aims to significantly decrease the required time and effort for network experiment implementation.
Wisebe hobnet-crowdsourcing	Switzerland	It offers a large IoT devices heterogeneity by providing support for testbed federation.
smartSantander Testbed	Spain	It provides a set of Smart City facilities through large-scale deployments of sensor networks. Applications and services can be developed on the top of it. Furthermore, Sunrise is a federation of sensor network testbeds that provides monitoring and exploration of the marine environments. In particular, they support experimentation in terms of the underwater Internet of Things.
Intel Intelligent Systems Framework		Intel Intelligent Systems Framework is a set of interoperable solutions to address, connect, manage, and secure devices in a consistent and scalable manner. ISF provides solutions that allow smart objects to Connect, Share and Drive value from the Data. The Intelligent Systems Framework permits OEMs to shift their investments from achieving interoperability to unlocking the value of data. ISF allows faster-time-to-Market, since it enables innovative services (due to the exploitation of the unlocked value of the data), and lower development and deployment costs. Intel and its ecosystem partners supply the components to address connectivity, manageability, and security. The aforementioned components, as well include software and middleware from Wind River and McAfee. ISF is a product which can be considered as an interoperability device-to-device layer.

2.1.1.4 The IoT European Large-Scale Pilot Programme

Under the H2020 programme, the European Commission is currently co-funding five IoT Large-Scale Pilots. The IoT European Large-Scale Pilot Programme, consisting in a financial contribution of €100 million from the EU, started in January 2017 and covers the following areas:

- Smart living environments for ageing well (ACTIVAGE)
- Smart Farming and Food Security (IoF2020)
- Wearables for smart ecosystems (MONICA)
- Reference zones in EU cities (SYNCRHONICITY)
- Autonomous vehicles in a connected environment (AUTOPILOT)

The coordination of these projects is supported by two additional projects, U4IoT and CREATE-IoT. A detailed description about these LSP Programmes is given in the deliverable D4.1 [1] of this project.

Through the selected IoT Large-Scale Pilots, the EU seeks to support the testing and experimentation of new IoT related technologies. These Pilots are expected to accelerate the standards setting across different business sectors boosting further the IoT technology. Privacy and security, business models, usability as well as other legal and social challenges, are also important factors that the EU's Large-Scale Pilots are trying to tackle.

2.1.1.5 Standards

As we introduced before, AIOTI includes 13 working groups [2], as reported in the following Figure:

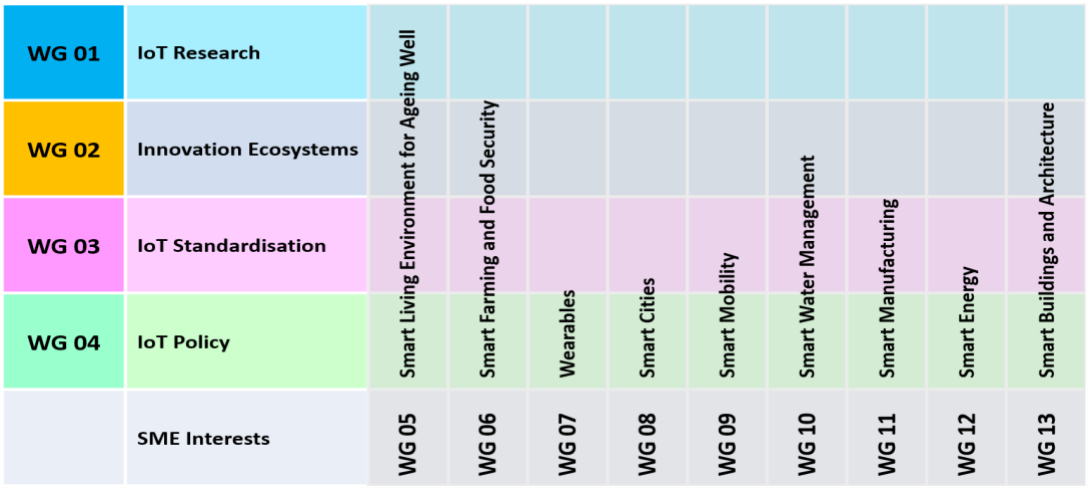

***Figure 3**. AIOTI Structure*

WG 03 in AIOTI identifies and, where appropriate, makes recommendations to address existing IoT standards. It analyses gaps in standardisation, developing strategies and use cases aiming for:

- The consolidation of architectural frameworks, reference architectures, and architectural styles in the IoT space;
- The (semantic) interoperability;
- The personal data & personal data protection to the various categories of stakeholders in the IoT space.

To better understand how to develop those strategies, an overview of the IoT standards is needed. Standards are needed for interoperability both within and between domains. The interoperability ensures cooperation between the engaged domains, being more oriented towards a proper "Internet of Things". The most important standards are described in this part (for more details D3.1.1 describes the harmonisation of standards for IoT technologies):

- **ETSI** [http://www.etsi.org/] Initiative: (European Telecommunications Standards Institute) It produces globally applicable standards for ICT, including fixed, mobile, radio, converged broadcast and internet technologies.
- **IETF** [http://www.ietf.org/] (Internet Engineering Task Force): The mission of IETF is enhance the Internet. That is done by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet itself. The IETF Mission Statement is documented in RFC 3935. The IETF has an IoT directorate to deal with IoT specificities. The ETSI Standards Association addresses the organisational interoperability.
- **IEC International Electro Technical Commission**: It covers all the electro-technical aspects, from plugs, wires, voltage levels to automation, control and management. Various protocols are supported, such as: IEC61850, IEC 61968/61970 (CIM), XMPP, DLMS/COSEM, OPC-UA. The IEC Standards Association addresses the syntactical, technical, and semantic interoperability.
- **OneM2M** [http://www.OneM2M.org/]: The purpose and goal of OneM2M is the development of technical specifications that have to address the need for a common M2M Service Layer. The Service Layer should be easily embedded within various hardware and software. Furthermore, it has to rely upon the myriad of connected devices in the field of M2M application servers worldwide. A critical objective of OneM2M is to attract and actively involve organisations from M2M-related business domains such as: telematics and intelligent transportation, healthcare, utilities, industrial automation, smart homes, etc. The OneM2M Standards Association addresses the syntactical, technical, and semantic interoperability.
- **IEEE Standards Association**: Its mission is the advancement of technology for the benefit of the humanity. It perpetrates that by providing a globally open, inclusive and transparent environment for market relevant, voluntary consensus standardisation. The various standards of the IEEE Association address all the different levels of interoperability.
- **3GPP** (3rd Generation Partnership Project) [http://www.3gpp.org/]: The project covers cellular telecommunications network technologies, including radio accesses, the core transport networks, and service capabilities, like codecs, security, QoS, etc. providing a complete system specification. 3GPP specifications and studies are contribution-driven. The member companies (originating from its Organisational Partners) give the contributions, they are organised into Working Groups and Technical Specification Groups.
- **OASIS**: It is a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society. OASIS promotes industry consensus and produces worldwide standards for security, IoT, cloud computing, energy, content technologies, emergency management and other areas. OASIS describes IoT as (OASIS, "Open Protocols," 2014): "System where the Internet is connected to the physical world via ubiquitous sensors." OASIS describes the ubiquity of sensors as existing in "every mobile, every auto, every door, every room, every part, on every parts list, every sensor in every device in every bed, chair or bracelet in every home, office, building or hospital room in every city and village on Earth."

Each application in the IoT is recommended to use standards based on well-known organisation (e.g. ETSI, IEEE, W3C, OneM2M, ITU-T, ISI, etc.) For that reason, it is necessary to map the standards to

the protocols provided for the different layers in the ISO communication, as proposed by the AIOTI (given in Figure 4 provided by the W03). As more real-world applications will be operated on top of standardised IoT infrastructure, this needs to be considered in future IoT standards.

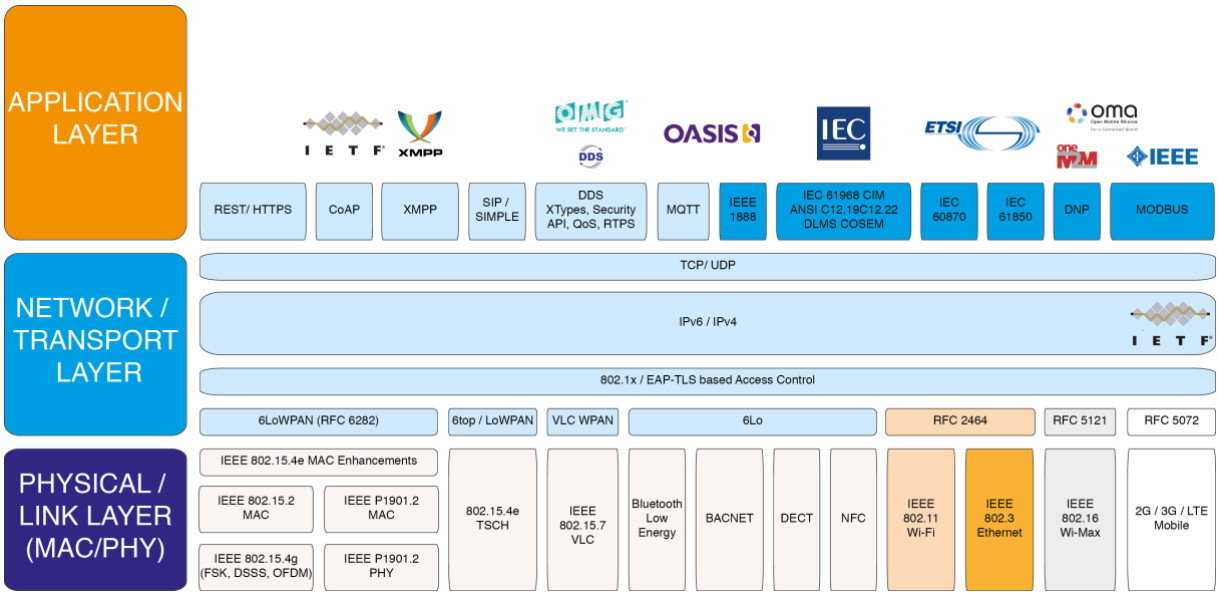

***Figure 4**. Mapping of the different standards to the protocol layer stacks*

2.1.2 In China

IoT activities have a great importance in China, too. In the following, a description of the initiatives and the projects is given.

2.1.2.1 Initiatives

Here now follows, a description of the organisational structures:

***Table 4**. IoT Initiatives in China*

	Description	Activities
CCSA China Communications Standards Association	It is a non-profit organisation, comprising: - 11 Technical Committees (TCs) - 9 Special Task Groups (STGs) - operators, internet service providers, manufacturers, standardisation and R&D institutes, design units, universities, societies, etc. CCSA is a partner of both 3GPP	CCSA is the main working platform for the development of ICT industry and national standards in China.

	and OneM2M.	
AII Alliance of Industrial Internet of Things Innovation	Is an open, cross-sector, non-profit and social organisation	AII is working on a platform to ensure communication and cooperation for technology and standards. Their goal is the construction of a technology and standard oriented framework for the industry. They also care about the development of the key technical standards. Furthermore, AII promotes their standards to establish them as national or industry standards. Encouraging also the international cooperation of the standards for the industrial internet.

2.1.2.2 Testbeds

In the following table, a description of eight testbeds in China is given.

***Table 5**. IoT testbeds in China*

	Description
China Telecom	China Telecom is a core network of the CNGI project with heavy investments in IoT infrastructure in China. It aims to have nationwide narrow-band IoT (NB-IoT) coverage and has already released the enterprise standard "NB-IoT equipment v1.0". This standard includes ITS, logistics, security monitoring, public utilities, intelligent manufacturing, modern agriculture, smart street lighting, video monitoring, intelligent financial POS information, waste management, smart manhole covers, and auto-parking. Over 400 NB-IoT base stations have already been installed covering the entire city of Yingtan in Jiangxi province.
China Mobile	China Mobile is a core network of the CNGI project and runs the OneNET open cloud platform which offers PaaS and SaaS. It offers a variety of network access protocols and accesses to networked devices, smart homes, smart cars, and wearable devices. China Mobile offers intelligent parking including online parking queries, online booking, reverse searches, and online payments. They have conducted NB-IoT and eMTC trials in Hangzhou, Shanghai, Guangzhou, and Fuzhou and now have 5000 stations. As of 2015, they have over 65 million IoT terminals registered with China Mobile.

China Unicom	China Unicom is a core network of the CNGI project and will launch NB-IoT LSPs in at least six cities for testing purposes. Their IoT-service platform and NB-IoT private network is supporting smart cities construction, smart meters, smart parking, environmental monitoring, and intelligent manufacturing in Shanghai. Over 3000 base stations are being built in 2017.
State Grid	State Grid will experience IPv6-sensors deployment with a minimum transmission speed of 250kbps. That will permit power transmission monitoring and, with the help of Mobile IP technology, power line monitoring together with mobile meter reading.
Yingtan Smart City	Yingtan Smart City has built a global coverage of NB-IoT business network, with 135 NB-IoT base stations. Several IoT business have been deployed, including smart cities management, smart street lights, smart parking, smart logistics and smart agriculture.
IoT Platform in BUPT	The IoT platform in BUPT includes both an Android-based gateway and Cloud service. It is an open platform - easy to extend to new scenarios - supports RESTful architecture and heterogeneous devices (IP and non-IP), and represents data in XML/JSON. An example of its use is the smart classroom where it is possible to control the lights and environmental controls as well as to monitor the number of students and what devices they have with them. New functions can easily be added while old functions can easily be updated. Cloud-computing allows for the possibility of Big Data Analysis too.
IoT Testing Platform in Southeast University	The IoT testing platform includes 200 sensor nodes. The users are able to remotely control nodes (both malicious and legitimate), realis and the base stations for testing purposes. The protocols to be tested can be downloaded remotely as well. The performance metrics include throughput, loss rate, delay, average path, average energy consumption and scalability of network, etc.
Mobike	Mobike is created by Beijing Mobike Technology Co., Ltd., which is a fully station-less bicycle-sharing system currently deployed in Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Ningbo, Xiamen, Foshan, Zhuhai and Wuhan. It is the world's largest bicycle operator, and recently made Shanghai the world's largest bike-share city. Mobike works with China mobile, Vodafone, Ericsson, Qualcomm, and Huawei to create a seamless mobile networking system. It is also the first one to use NB-IoT in the real case.

2.1.3 Analysis of interoperability requirements

In order to reach the IoT interoperability, the key idea is to consider it across those important layers of the hardware/software stack:

- ➔ Networking layer

- Device layer
- Middleware and service layer
- Data and semantic layer

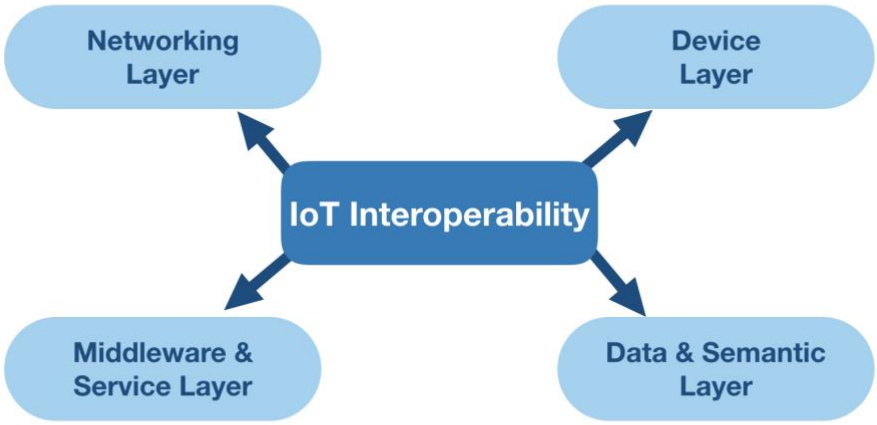

***Figure 5**. IoT Interoperability layers*

2.1.3.1 Networking Layer

As noticeable from the aforesaid, platforms are heterogeneous, multi-vendors, multi-services and largely distributed. As a consequence, the risk of non-interoperability increases. Thus, it is vital to guarantee that network components will interoperate to fully unleash the value of the Internet of Things. Interoperability is having interworking standards with less complexity and must be achieved amongst the various element of the IoT.

At networking layer different protocols can be used, e.g. 6LowPAN, TCP/HTTP, UDP/CoAP. Communication between real objects and the gateway can be based on universal plug and play (UPnP) or DLNA. The use of buses on MQTT protocol can also be used to implement asynchronous communications between entities. The most promising is IPv6 with its version for constrained devices, 6LoWPAN, even though its adoption is slow.

2.1.3.2 Device Layer

The unification, convergence and accessibility of the platforms require D2D (device to device) communication. Different communication protocols are used at device layer, each device has to be defined, standardised and certified (Wi-Fi Alliance, WiMAX).

2.1.3.3 Middleware and Service Layer

The middleware provides general and specific abstractions to help IoT systems to build up. It should be

able to receive data from multiple types of sensors and support the semantic modelling. To acceleration of the development of new services with other standards, inevitably requires a common access API library. For instance, the API provided by the onePOWER platform, are more generic, ensuring more flexibility. To facilitate the application implementation, and thus to support the uptake of the standard, the API bindings for relevant programming languages should be defined as part of the standard.

2.1.3.4 Data and Semantic Layer

Semantic interoperability can be achieved through commonly agreed information models (e.g., defined with ontologies) of the terms used as part of the interfaces and exchanged data.

That is why, it is recommended to use standardised models and message format for representing data. In fact, when interworking nodes, residing in two different service provider domains, exchange messages, the data format and payload data size of the messages must be interoperable and conform to the one used by each service provider. Therefore, a negotiation process regarding data format or data size should be considered essential.

2.2 Available funding for IoT interop projects

In Europe:

From the Work Programme Leadership in Enabling and Industrial Technologies by Information and Communication Technologies:

IoT is supported for 2014 – 2015 in ICT30 - 2015 Internet of Things and Platforms for Connected Smart Objects:

- ICT30.a : 48 M€.
- ICT30.b :1 M€.

IoT is supported for 2016 – 2017 for ICT-04-2017: Smart Anything Everywhere Initiative with 26.5 M€

IoT is supported for 2018 – 2020 for ICT-27-2018-2020: Internet of Things with 1.5 M€

In China:

The key IoT players in China are Huawei, the largest and leading player in IoT and the most active application and implementation areas at the moment are:

- Wuxi – Leading IoT spot
- Shenzhen

By 2015, IoT industry in China has reached 750 billion RMB (€101 billion) with 29.3% year-on-year growth rate – account 31% of total global volume.

By 2020, the overall IoT industry in China may reach 1.8 trillion RMB (€ 243.5 billion).

A series of policies and action plans have been released since March 2011 when the "12th Five Year Plan on IoT" to boost the IoT development in China was officially released.

The original plan covers 9 key development sectors: smart industries, smart agriculture, smart logistics, smart traffic, smart grid, smart environmental protection, smart security, smart healthcare, and smart home.

In April 2011, MoF and MIIT jointly released the special funding for IoT development. During 2011 to

2014, there were projects funded 110, 149, 122 and 101 respectively.

The funding accumulatively was over 2 billion RMB in the 4 years. Each project could be funded 3 ~ 5 million RMB.

In 2013, several Chinese ministries jointly committed and published "IoT Development Special Action Plans (2013-2015)" which included specific 10 Action Plans. Within the series of supporting policies and action plans, there were Pilots of national IoT key application demonstration projects and areas, during 2014-2016.

3 ANALYSIS OF THE INTEROPERABILITY SITUATION BETWEEN CHINA AND EU

3.1 Definition of the strengths of the Chinese and EU models

3.1.1 Situation in China

Recently, China's IoT application development (explained in [5]) has been widely applied in many fields and areas such as:

- The industrial manufacturing, to reduce the cost, save energy and reduce emissions;
- The agriculture, to reduce the personnel costs and improve the overall economic benefits;
- The energy conservation and environment protection especially for large industrial parks;
- The health care, community and public safety, public services are able to expand in time and space;
- The urban management, pipe network monitoring and intelligent transportation;
- The network structure (the release of the international standard IUT-T Y.2086 led by CAICT was completed in 2015).

The Huawei LTE-M system, which features low power consumption, low cost, low data rate and wide coverage, meets the needs of M2M applications and is now in the experimental stage for business deployment. Both China Mobile and China Telecom are vigorously promoting the construction of M2M platforms. At present, both provide full network operation support and have launched a range of IoT products in transportation, health care, environmental protection, logistics, water supply and other fields. Studies on the optimisation of the existing networks and the M2M narrowband networks represent the current focus of activity. China is promoting standardisation work for network optimisation, including terminal triggering, low power consumption and wide coverage, as well as network congestion.

The Chinese government attaches importance to the IPv4 addresses shortage, towards which the international attention gravitates, and the transition from IPv4 to IPv6 has become consensus. The Chinese government and research institutions devote a lot of effort to broad research and in-depth practice, aiming at the realisation of an advanced deployment as soon as possible. In addition, they are racing to control the commanding heights, before large-scale IPv6 industrialisation overtaking the competitors.

In accordance with the National Strategically Emerging Industries Development Planning in the 13th Five-Year Plan and the National Information Planning in the 13th Five-Year Plan, to facilitate the healthy development of the new generation of information technology, China will increase its investments in information infrastructure construction. During the 13th Five-Year Plan, new generation Internet and other network infrastructure will be deployed and applied in succession. That will give a great impetus to the development of IPv6.

Generally, IPv6 is gaining momentum in its deployment in China. However, due to various objective reasons, even though government bodies have given high support, the progress of its promotion and penetration have not lived up to expectation, yet, with relatively few applications in the industrial Internet. It has to be noticed that the reason of the slowness of the deployment, snatches the opportunities for solving the IP addresses distribution for IoT development and accelerates the transition to IPv6 with true efforts to enable the policy implementation.

3.1.2 Situation in the EU

Europe is in an excellent position to become a global leader in IoT as stated by the European Commission [6]. The main strengths of the European ICT are in business-to-business software and services, embedded systems and in particular in the application of ICT to complex system level solutions in various industrial and societal domains. Leveraging on traditional European industrial and social system strengths by augmenting solutions with ICT in e.g. Smart Grids, transportation and logistics, cyber-physical systems, eHealth, active & healthy aging, and digital inclusion is necessary for European industry.

3.2 Potential challenges related to the integration of EU/Chinese test platforms

The cyber security for IoT has become a new challenge that we must pay close attention to. At present, there are an increasing number of IoT devices that have loopholes, covering a wider and broader range. That is true for sensors, cameras and other parts, up to the whole industrial chain control including manufacturing, operation, maintenance and logistics. All of those need strict security regulation and control. In case of negligence, interruption might happen to key services.

Therefore, in the process of IoT industrialisation, technicians should underline the study of secure coding and secure design. At the same time, we call on the government bodies to formulate relevant policies and standards to prevent any vulnerabilities that might become sitting ducks for IoT attacks.

4 PRELIMINARY OPPORTUNITIES AND GUIDELINES FOR INTEGRATION BETWEEN EU AND CHINA

4.1 Proposed model

4.1.1 Standards and Policy

Regarding interoperability, IoT technological implementations should ideally rely on a commonly agreed basis. So, international standards are needed to allow worldwide use of products and solutions. The standardisation of a reference architecture model for IoT is also needed to achieve the goal of compatibility and interoperability across industrial domains. This reference architecture model (like the one proposed by the European research project FI-WARE) will be the base of domain specific refinements and extensions. Thus, it will be possible to mainly address common open platforms that support the needed communication and data capturing services. This way those can be shared by multiple application providers.

For IoT standardization, it is of huge importance to have relevant players from all the most important industrial domains involved. Those IoT standards defined from the viewpoint of a single domain (i.e. telecommunications domain) will not match the needs and requirements of other domains. Hence, leading to contradicting solutions for the IoT goal of interoperability across industrial domains.

We encourage the development of international standards, innovation cooperation, research and publications. This will act as a reference and will push enterprises even individuals to participate in cooperative projects between EU and China.

4.1.2 Technical cooperation

Encourage twinning activities between China and Europe by carrying out technical cooperation in strategic sectors on key product development. This can be done exchanging technical staff and industry researchers, to make a full profit of the knowledge of both the regions.

4.1.3 Legal and policy

This includes all the legal and regulatory aspects. The single digital market is an objective that can be realised. IoT services can have many societal benefits but they are often blocked by the regulatory framework still in place. A balanced view between the benefits of new technological developments and associated risks and potential issues is needed. Trust, security and privacy are important aspects of IoT which have to be guaranteed in order to achieve wide acceptance in the society, as are consumer protection, autonomy, functioning competition and choice.

4.2 Action plan

As a first step, we will organise workshops with some interop projects (F-interop, Fed4FIRE), where we can discuss further some good IoT interoperability practices. In such events, we can profit from experiences in both the research and the industry fields. We will focus our attention on the data interoperability and the protocols/standards challenges. Many other issues will be tackled: e.g. How to build a reference model and IoT architectural framework? How to encourage the technical and standards cooperation?

5 FINAL REMARKS AND TAKE-HOMES

5.1 IoT Interoperability paradigms

The Chinese markets and the European markets are driven by different forces and styles of operations. European industry takes an approach that is traditionally "standards first":

- In Europe A great value is given to standards and interoperability and this results in large capital and human investments to create the necessary technology and consensus to build standards. Products are then a result of such process. This approach leads to create technology that is founded on solid grounds and has the potential to last for long.
- Chinese Industries still value the standardization process and respect it however thy enjoy the luxury of an extra-large market that pushes for the "product first" approach. This is closer to the paradigm adopted in the US thanks to its vibrant start-up eco-system. The introduction of new standards usually happens once the market has already some products deployment.

The IoT arena has shown to behave similarly with Telecom Operators, and Application Providers on the hunt for market-share.

Specifically, the Chinese market is evolving more and more towards NB-IoT solutions as they are ready to deploy and can reach the market quickly. This is achieved through strong and close cooperation between equipment manufacturer and telecom operators. And a strong support from the government in the creation of the market through field trials [7] as well as actual deployments of IoT platforms focused on providing scalability and rapid service development such as Connectivity Enablement Platform deployed by China Mobile and Huawei to build an IoT eco-system [8].

European players are very interested in the potentially 8-billion object Chinese market and they are trying to follow on the same approach. Specifically, Ericsson was initially able to enter the Chinese market through China Mobile for its device connectivity platform used in 24 countries globally.

5.2 A new road for Interoperability

The pressure to be first on the market and enjoy the competitive advantage of locking the customers has forced some European network operators to change their approach to interoperability. The key idea is to be in the market while the necessary standardization and legal framework steps are taken. It is of paramount importance for operators such Vodafone to keep the IoT market share or possibily conquer new one. This approach has opened a new path towards interoperability in IoT. Vodafone for example set-up the "Interoperability Development Testing (IODT)" The process aims at increase the interoperability of Vodafone NB-IoT platform. The IODT process requires manufacturers involved with the VODAFONE NB-IoT deployment to ensure the equipment is interoperable and able to work as one.

CONCLUSION

Interoperability is a key concern for the future IoT market in both China and Europe. While both markets recognize the importance of strong interoperability guidelines, best practices and testing models, the Chinese market due to its size and vibrant start-up like eco-system is still in a phase of trial-and error that privileges the time-to-market over lengthy standardization and interoperability testing processes.

Between 2017 and beginning of 2019 as the IoT market is greatly increased and demanding customer-oriented applications have been introduced (i.e. MoBike, Lime Electric Scooters, Vodafone GPS Tracking for vehicles, etc) we witnessed few interesting phenomena:

- the appetite for interoperable systems has grown.
- NB-IoT is becoming the leader for IoT applications GLOBALLY with china leading the market (due to its size).

Network operators and application providers, are becoming the key drivers in the interoperability and standardization arenas. They have the urgent need to avoid lock-in from technology vendors. The China Mobile(s) and Vodafone(s) of the world have understood that is in their best interest to being able to switch platform provider according to the market changes and new innovation. They are therefore pushing interoperability by:

- Stepping up the interoperability tests and processes for new platform acquisitions [10]
- Creating Interoperability test labs that reproduce in-the-wild scenarios [11], [12]
- Supporting cross-border standardization actions.

Compared to the traditional standard-first approach used for instance in the creation of GSM and then LTE standards the IoT stakeholders privilege a market-first approach that has been traditionally used by Internet technology companies. Companies in the front-end of the IoT eco-systems, such as telecom operators or service-providers have learnt the lesson from past successes and failures and they have understood the importance of interoperability for the market long-term sustainability. This has resulted in a set of cross border market driven actions towards interoperability testing and standardization driven by network operators or end-user service providers. This approach is very strong in China and USA and it appears to be also growing in the European market with Vodafone acting as leader.

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