EU-China IoT Advisory Group

EU-China Joint White Paper on the Internet of Things

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Abstract :

This paper reflects the outcome of several years of the IoT international cooperation between the EU and China and documents the state-of-the-art on IoT development in both regions and future cooperation avenues.

KEYWORDS:

INTERNET OF THINGS, EU-CHINA COOPERATION, REFERENCE ARCHITECTURES, BUSINESS MODELS, STANDARDS, INTEROPERABILITY, APPLICATION AREAS, TRUST, SECURITY, LARGE SCALE PILOT, MEGAPROJECT, INDUSTRIAL IOT

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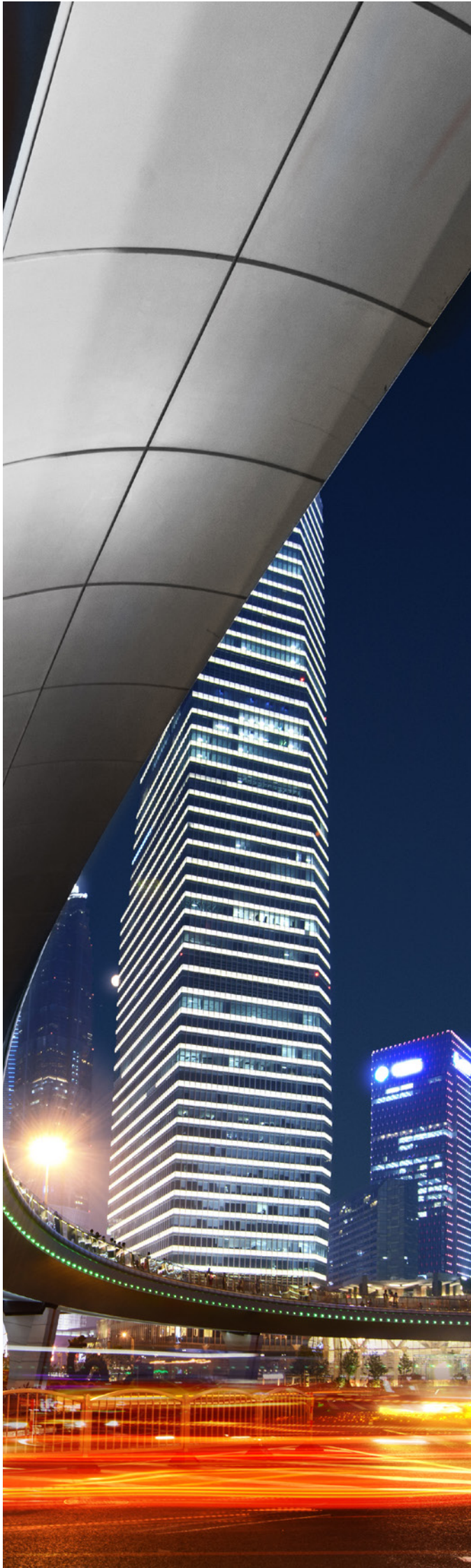


1. The latest development of the IoT in China

1.1 General

In China, the Internet of Things has become an important carrier for strategic information industries and integrated innovation. The central government and local authorities have consistently attached great importance to IoT through the Inter-Ministerial Joint Conference, the ten action plans for IoT development, and the annual special fund for IoT development, giving substantial support to industrial development. As a result, China's IoT development now shows a strong momentum. In 2014, China's IoT industry expanded beyond 620 billion yuan, with a year-on-year growth of 24% . The M2M terminals in China exceeded 73 million units, with a year-on-year growth of 46%, accounting for 30% of the global total. Beijing-Tianjin, Shanghai-Wuxi, Shenzhen-Guangzhou, and Chongqing-Chengdu form the four core industry clusters with unique features and a number of leading enterprises have emerged there. Moreover, IoT third party operation service platforms are rising in traffic, security, health care, IoV, energy-saving, and IoTaaS.

1.2 Policy

China's IoT policies emphasize demonstration and cluster effects, and the policy environment will continue to be improved with top design, organizational mechanisms, think tank support and other fields of activities:

- Planning documents pointing out directions for development of stages: following the 12th Five-Year-Plan for IoT development, China's State Council issued the Guidance on Advancing Orderly and Healthy IoT Development, which further clarified the goals, ideas and areas of focus of China's IoT development.
- Establishment of the Inter-Ministerial Joint Conference system and the Expert Consultation Committee for IoT development: the NDRC, the MIIT, and the MOST coordinated for the top-level design of IoT development and promoted IoT development in China.
- Formulation of ten action plans for IoT development: the plans cover various perspectives, including top-level design, standard development, technology development, application and promotion, industry support, business models, safety and security, supportive measures, laws and regulations, personnel trainings, etc.
- Financial support such as the special fund for IoT development: the annual support directions of the special fund are set against the development demands from key IoT technology R&D projects and IoT systems development projects in key areas during the year. Additionally, annual support measures will be adjusted and optimized.
- The stimulating effect of other guidance documents: the Several Opinions on Promoting Information Consumption to Expand Domestic Demand and the Guiding Opinions on Promoting Healthy Development of Smart City respectively clarified the directions and supporting objectives of future IoT development in hardware and urban management.

Local governments are actively creating the environment for the development of the IoT industry. Many of them have a strong sense of service, and have been promoting IoT industry development by

[1] *CAICT, Calculation data for MIIT*
[2] *GSMA, Global Mobile Economy Report 2015*

offering preferential land and tax concessions, special funds, preferential policies to talents, coordination of an industrial union, and government purchase of services. For example, in recent years, the Shanghai municipal government has supported over 150 IoT R&D technology, industrialization, application and demonstration, and public service platforms. The 300 million yuan supporting fund from the Shanghai municipal government also triggered 5 billion yuan from social investment sources.

1.3 IoT Applications

From a macroscopic perspective, China's IoT application development presents two types: "point focus" and "overall covering".

"Point focus" refers to IoT applications in specific industries: CPS (Cyber-Physical-Systems) for mapping links of virtual models to the real world, while IoT is the core of CPS.

- In the field of industrial manufacturing, IoT has been widely applied in intelligent equipment management, environmental real-time monitoring, materials/product tracing and other areas. The applications of CPS will enhance the efficiency of intelligent manufacturing by 20%, cut cost by 20%, and save energy and reduce emissions by 10% .

- In the field of agriculture, IoT cuts the personnel costs of crop cultivation by about 50% and improves the overall economic benefit by about 10%. High precision environmental control in greenhouse facilities can be realized with the help of sensor-based automatic adjustment, and the high-quality green vegetables products cultivated for a high-end customer segment are priced 10 times higher than normal green vegetables .

- In the field of energy conservation and environmental protection, dynamic energy efficiency models can be established based on large data through energy management virtualization, which can precisely locate the peak and valley electricity consumptions and then balance the peak and valley consumptions to save energy and reduce emission. For large industrial parks, the lighting energy reduction alone can be reduced by more than 30% .

"Overall covering" represents platform features of IoT in the field of urban management and consumption management: here IoT is the primary feature of Smart City application systems.

- For more than half of China's smart city projects the main applications cover areas such as public security, transportation, health care, community, environmental protection, underground pipes monitoring, water supply, and education. These applications are based on auto-sensing and data acquisition. With intelligent control serving the core, they target precision management and enhanced services, representing the ability of IoT in comprehensively integrating platform applications.

- In areas such as health care, community, and public safety, public services are able to expand in time and space and enhance convenience of the services with the help of IoT. Mobile health and telemedicine activated medical and health resources provide accessible health care services to the benefit of the people. IoT-enabled smart communities combined with household and elderly care have been powering the innovation of grass-root service models.

- In areas of urban management, pipe network monitoring, and intelligent transportation, the IoT has greatly enriched the urban management instruments and enhanced the urban management capacity. In the field of public security, elevator security management was reshaped through the application of sensing technology, bringing together elevator monitoring, maintenance management, security warning and emergency disposal functions. In the field of urban management, Beijing has realized information monitoring and data analysis of 316 items of daily urban operation from 12 areas such as water, electricity and gas consumption. In transportation, 65% of the buses and nearly 70,000 taxis , passenger cars and dangerous chemicals vehicles in Beijing have been fitted with satellite positioning equipment, and five taxi monitoring centres and rail traffic control centres have been set up for intelligent management of all kinds of transportation.

[3] *GE, Analysis of the economic contribution of the industrial Internet to the United States, 2013*
[4] *The second term of Ten application cases of IoT in Wuxi , 2014*
[5] *CAICT, National IoT survey data, 2014*
[6] *Beijing municipal commission of economy and informatization, open published data, 2014*

1.4 IoT trends and standards

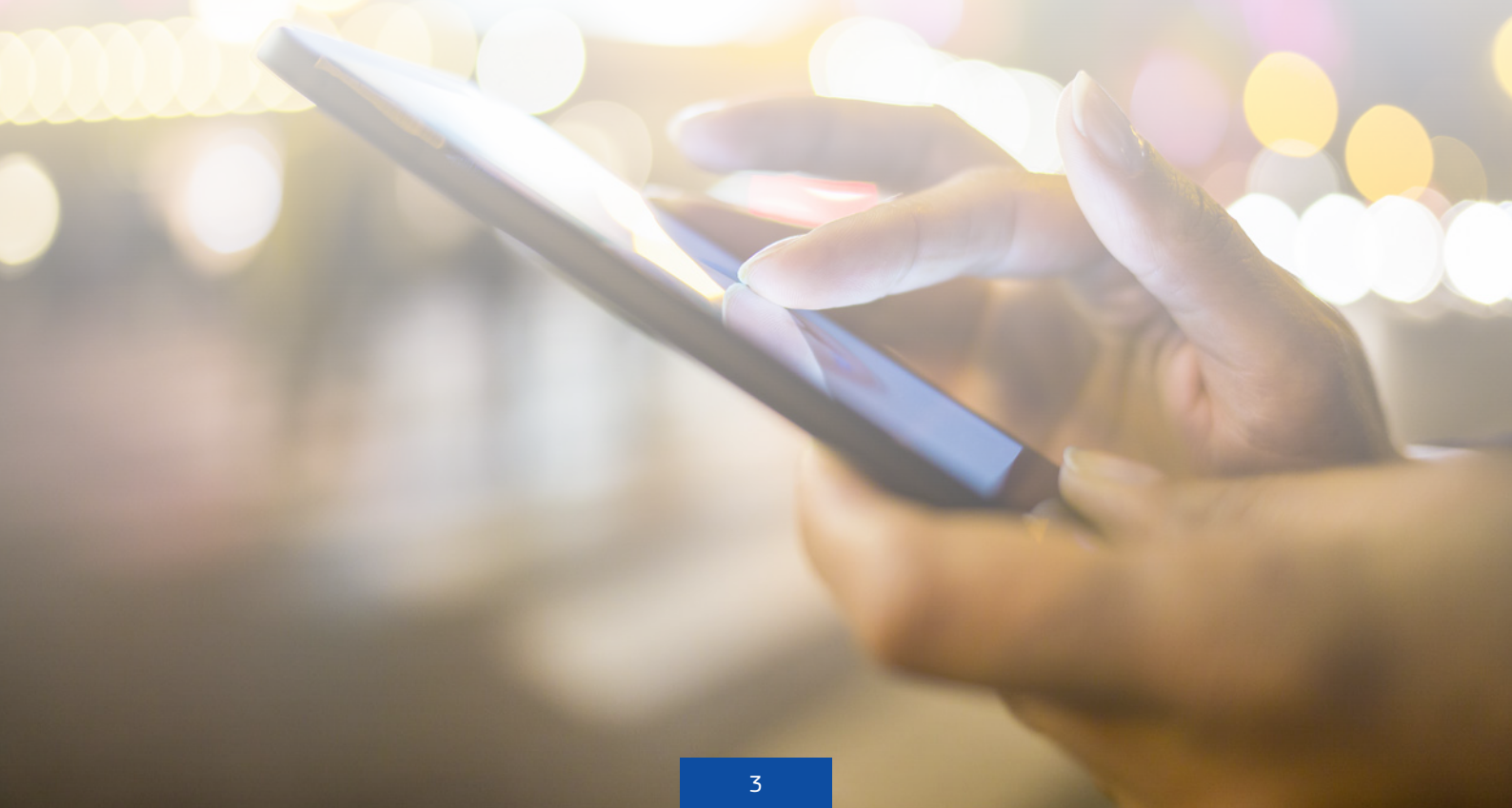
China has acquired important knowledge in network architecture, new types of sensors, M2M and other technologies. The WIA-PA has been applied on a large scale in the oil and electricity areas. The Huawei LTE-M system, which features low power consumption, low cost, low data rate and wide coverage, meets the needs of M2M applications and is now in the experimental stage for business deployment.

- In the area of network structure, the release of the international standard ITU-T Y.2068 led by CAICT was completed in 2015. The Wuxi IoT Industry Research Institute and the China Electronics Standardization Institute under the MIIT jointly promoted the approval of the ISO/IEC 30141 project, and have also proposed a consistent system decomposition model and an open standard design framework. The China Electronics Technology Group Corporation invested in network architecture development and a more advanced general architecture of the web.

- In the area of MEMS sensors, China's sensor enterprises grasped the new needs and technologies of MEMS sensors, and have developed core technologies such as the MEMS acceleration meter technology, the MEMS sensor chip development and production test technology based on proprietary thermal detection method, the 5 million pixel CMOS image sensor based on back lighting technology, the CMOS-MEMS process and the wafer level integrated package process. The first pilot-scale production line for the complete MEMS process has been built and the manufactured systems have been widely used in security monitoring, automotive electronics, consumer electronics and other fields.

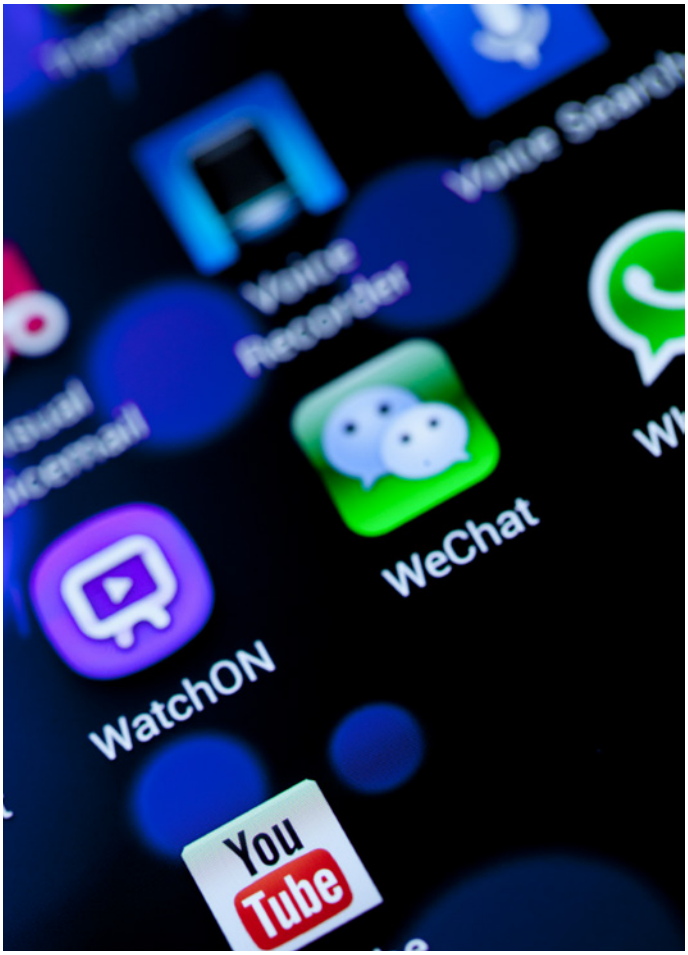
- For M2M network platforms, both China Mobile and China Telecom are vigorously promoting the construction of M2M platforms. At present, both provide full network operation support and have launched a range of IoT products in transportation, health care, environmental protection, logistics, water supply and other fields. Studies on the optimization of the existing networks and the M2M narrowband networks represent the current focus of activity. China will continue to promote standardization work for network optimization, including terminal triggering, low power consumption and wide coverage, as well as network congestion. Huawei and other device manufacturers have been carrying out research and development on narrowband M2M business supporting technologies, and have promoted the standardization of the narrowband network.

" Chinese internet enterprises have emerged as the most dynamic actors in the development of IoT, and have been strongly influencing the patterns, models and industrial ecological system of China's IoT development. "



1.5 The internet and the reconstruction of the industrial ecology

Chinese enterprises have demonstrated strong innovation ability in application services and business models. With the mobile internet extending to IoT in recent years, Chinese internet enterprises have emerged as the most dynamic actors in the development of IoT, and have been strongly influencing the patterns, models and industrial ecological system of China's IoT development. Major Chinese internet companies have entered the field of IoT through wearable intelligent terminals, smart home, mobile health care, IoV, security, and other businesses, and have made rapid development in some of these areas. On one hand, IoT applications can expand to be national-level applications in no time by virtue of mobile internet portals and the large user scale. For example the Wechat platform can communicate with home appliances, toys, routers, wearable devices, sports equipment and other types of smart devices, and interconnects between intelligent devices and hundreds of millions of Wechat users. In less than one year, the Wechat hardware platform has attracted more than 2,400 hardware vendors, activated 25 million devices, and accumulated more than 10 million Werun-Wechat users. On the other hand, mobile APPs have become the data aggregation centres and feedback nodes for IoT. The anti-lost devices for children are integrated with a Bluetooth function, indicating children's distance from their parents, an alarm function when children are being beyond safe distance of their parents, and a four-fold location function, allowing parents to know the locations of their children at any time from a mobile app. The Qihu 360kid anti-lost devices sold 500,000 units in only three months and experienced quick iterative upgrades to the third generation.



" Major Chinese internet companies have entered the field of IoT through wearable intelligent terminals, smart home, mobile health care, IoV, security, and other businesses, and have made rapid development in some of these areas."

2. Latest development of the Internet of Things in the EU

2.1 General

In the EU the Internet of Things (IoT) is now widely recognised as the next step of disruptive digital innovation. With the IoT, any physical and virtual object can become connected to other objects and to the internet, creating a fabric of connectivity between things and between humans and things. Recently, there has been an increasing consensus that the IoT is gathering pace and unleashing a very disruptive potential. The IoT is therefore at the core of the digitisation process of the economy and society and an essential building block for the Digital Single Market. IoT initiatives are gathering pace, with a series of announcements in the past months, from Germany's Industrie 4.0 to the UK's IoT initiative, to France's 'objets connectés' and Spain's smart city initiative, just to mention a few.

2.2 Policy

Europe's IoT innovation policy is about value creation and fresh thinking, with activities in:

- the monitoring of innovation performance and of the uptake of innovation in order to identify developments that require a policy intervention,
- the development of policies to foster the broad commercialization of innovation by EU industry (e.g. public procurement of innovation or design),
- the development and coordination of policies to accelerate the uptake of advanced manufacturing technologies and other cross-cutting innovations with a view to modernizing the EU's industrial base.

" The Internet of Things is a key growth area for the European Member States."

The Internet of Things is a key growth area for the European Member States. In particular, industry is focussing on exploiting the innovation potential domestically and abroad. Organising co-operation at different levels, co-ordinating national or European policies, establishing networking teams and increasing the mobility of individuals and ideas are therefore requirements resulting from the development of modern research in a global environment.

In this respect, an IoT Focus Area (FA) will be established in the coming two years as part of the European Commission's R&I programme Horizon 2020, with the implementation of large-scale IoT pilots starting in 2016. It will lead not only to technology validation, but also to business models and standards validation. It is a unique approach where for the first time the "technology push" (the supply side) will be joined with the "market pull" (the demand side).

In order to achieve a Single Market for the Internet of Things, where any device can plug and connect, actions are planned at various levels such as free flow of data for the IoT, guidelines for the application of the new European General Data Protection Regulation, support for IoT standards and interoperability, and development of a telecom framework conducive to an IoT single market.

In the light of the European Digital Agenda, Europe is also willing to establish stronger links between science, technology and art. The future will be different in the way we create, perceive, communicate and earn our living. The nano-, cogno- and biosciences will reveal new secrets and give new stimulating ideas for IoT applications. New interfaces and communication networks, connected with sensors, actuators and smart objects of the Internet of Things will transfer us into the era of a hyper-connected society. The need for innovation in today's information and experience economy transforms the role of culture and creativity in our society. They are now regarded as one of the prime sources of innovation and of competitive advantage for companies and industries as well as for cities, regions and nations.

2.3 IoT and innovation in industry

> According to Gartner, nearly five billion "things" will be connected by 2015, reaching 25 billion by 2020. A recent study by IDC-TXT for the European Commission estimates that the IoT market (hardware, software and services) in Europe will exceed one trillion EUR by 2020.

The key activity of the European Commission on the Future Internet [https://www.fi-ppp.eu/] has significant influence on the development of the Internet of Things. The Future Internet Public-Private Partnership (FI-PPP) is a European 400M EUR programme for internet innovation. It is aimed at accelerating the development and adoption of Future Internet technologies in Europe, advancing the European market for smart infrastructures and increasing the effectiveness of business processes through the internet. It follows an industry-driven, user-oriented approach that combines R&D on network and communication technologies, devices, software, service and media technologies and their experimentation and validation in real application contexts. It brings together the demand and supply sides, and it involves users early into the research lifecycle. The platform technologies will be used and validated by many actors, in particular by small and medium-sized companies and public administrations.

Alongside these technology- and business-driven developments, the European Commission has leveraged industry uptake through the Alliance for Internet of Things Innovation (AIOTI) [http://www.aioti.eu/]. The launch of the AIOTI in early 2015 provides a platform for industry-driven cross-sector developments, and serves to support the dialogue and interaction among the various IoT players. The overall goal of the establishment of the AIOTI is the creation of a dynamic European IoT ecosystem to unleash the potential of the IoT. The AIOTI will assist the European Commission in the preparation of future IoT research as well as innovation and standardisation policies.

In addition, the Internet of Things International Forum (IoT Forum) aims at the development of a worldwide interoperable Internet of Things, addressing technology barriers, business and societal challenges to create the conditions for a truly worldwide IoT ecosystem and market. It does this through promoting international dialogue and cooperation on the Internet of Things between diverse actors from industry, research and government and across sectors.

Despite rapid technological development in many areas – particularly in health and business – research on the social impact of the IoT is still quite sparse. Most work has focused on identifying potential business benefits, and apart from privacy, much less is known about the current and future impact of the IoT on society more generally, for example as we start to interact with the city-wide IoT systems of so-called 'smart cities'. Furthermore, much discussion of the IoT is conducted at a high level of abstraction, or in very general and ill-defined contexts. However, we cannot discuss the social aspects of the IoT without focusing on particular contexts of use, whether these might be monitoring medical conditions, controlling household appliances, or environmental sensing. What might hold true for IoT systems and technologies in the retail sector won't necessarily be true for IoT systems in home automation – and what is true in terms of electricity generation and distribution will not necessarily be true in vehicles and public transport systems.

There are essentially four levels of maturity in the development of new business models from and for the IoT:

- Connected Products – enhancing an existing product with a digital embedded capability, e.g. fitbit.
- Optimised business – saving costs by optimising processes through sensor data.
- Transforming Business Models – e.g. from products to services.
- Interconnection effects – e.g. big data, smart city, etc.

THE INTERNET OF THINGS REQUIRES A MINDSET SHIFT
Because you'll create and capture value differently.

		TRADITIONAL PRODUCT MINDSET	INTERNET OF THINGS MINDSET
VALUE CREATION	Customer needs	Solve for existing needs and lifestyle in a reactive manner	Address real-time and emergent needs in a predictive manner
	Offering	Stand alone product that becomes obsolete over time	Product refreshes through over-the-air updates and has synergy value
	Role of data	Single point data is used for future product requirements	Information convergence creates the experience for current products and enables services
VALUE CAPTURE	Path to profit	Sell the next product or device	Enable recurring revenue
	Control points	Potentially includes commodity advantages, IP ownership, & brand	Adds personalization and context; network effects between products
	Capability development	Leverage core competencies, existing resources & processes	Understand how other ecosystem partners make money

SOURCE SMART DESIGN HBR.ORG

" All sectors like transport or home automation have distinct requirements for IoT systems, but also many communalities such as identification, interoperability and security."

2.4 Internet of Things trends and standards

Technology

A number of technology trends are merging with efforts developing the Internet of Things in Europe. The key question is to merge the Internet of Things into the internet to seamlessly offer IoT services in future internet ecosystems. Several key technologies are integral to this effort:

PLATFORMS: A large number of highly distributed and heterogeneous devices in the IoT need to be interconnected and be able to communicate in different scenarios autonomously. This implies that providing interoperability among the 'things' in the IoT is one of the most fundamental requirements to support object addressing, tracking, and discovery as well as information representation, storage, and exchange. The suite of technologies developed in the Semantic Web, such as ontologies, semantic annotation, linked data and semantic Web services, can be used as principal solutions for the purpose of realising the IoT.

BIG DATA: Big data is characterised by 'four Vs': volume, variety, velocity and veracity. Big data comes in large amounts (volume), is a mixture of structured and unstructured information (variety), arrives at (often real-time) speed (velocity) and can be of uncertain provenance (veracity). Such information is unsuitable for processing using traditional SQL-queried relational database management systems (RDBMSs), which is why a constellation of alternative tools for distributed data processing systems, plus various NoSQL databases and a range of business intelligence platforms, have evolved to service this market. IoT and big data are intimately connected: billions of internet-connected 'things' generate massive amounts of data.

CLOUD COMPUTING: Public and hybrid cloud and mobile-based platform technologies are providing companies with an easy way of connecting traditional enterprise-based information systems to both private and public IoT-enabled devices. This capability allows enterprises to quickly and economically build Internet of Things-based sense and response systems that can scale up or down based on changes in the environment and transaction level. Cloud-based developer services provide developers with the ability to quickly and easily extend an internet-connected device such as a sensor or controller into the cloud, build an application alongside the device to collect the data and send real-time insights back to the developer's business. At the same time, developers can quickly build mobile apps that act as remote controls to connected devices.

SEMANTIC TECHNOLOGIES: In dealing with large volumes of distributed and heterogeneous IoT data, issues related to interoperability, automation, and data analytics will require common description and data representation frameworks and machine-readable and machine-interpretable data descriptions. Applying semantic technologies to the IoT promotes interoperability among various resources and data providers and consumers, and facilitates effective data access and integration, resource discovery, semantic reasoning, and knowledge extraction. Data annotations and semantic descriptions can be used at different levels, and semantic annotations can be applied to various resources in the IoT.

5G: IoT will only be fully realized when data and information flow freely between different systems, geographies, vendors and industries, providing highly integrated end-to-end solutions. The main difference between what we experience today and this vision is that future solutions will only take relevant components, or IoT building blocks, from a complex ecosystem of data, services, platforms, vendors and industries in a fast, dynamic and efficient way to produce the information we need. This is when the IoT generation reaches maturity, and where 5G becomes a fundamental enabler, providing the much required flexibility in connectivity and the core tools needed to enable communication between bespoke and standardized IoT building blocks.

" The key question is to merge the Internet of Things into the internet to seamlessly offer IoT services in future internet ecosystems."

Standards

Standards are needed for interoperability both within and between domains. Within a domain, standards can provide cost efficient realizations of solutions, and a domain here can mean even a specific organization or enterprise realizing an IoT. Between domains, the interoperability ensures cooperation between the engaged domains and is oriented towards a more globalized Internet of Things.

> There is a need to consider the life-cycle process in which standardization is one activity. Significant attention is given to the "pre-selection" of standards through collaborative research, but focus should also be given to regulation, legislation, interoperability and certification as other activities in the same lifecycle. For IoT, this is of particular importance.

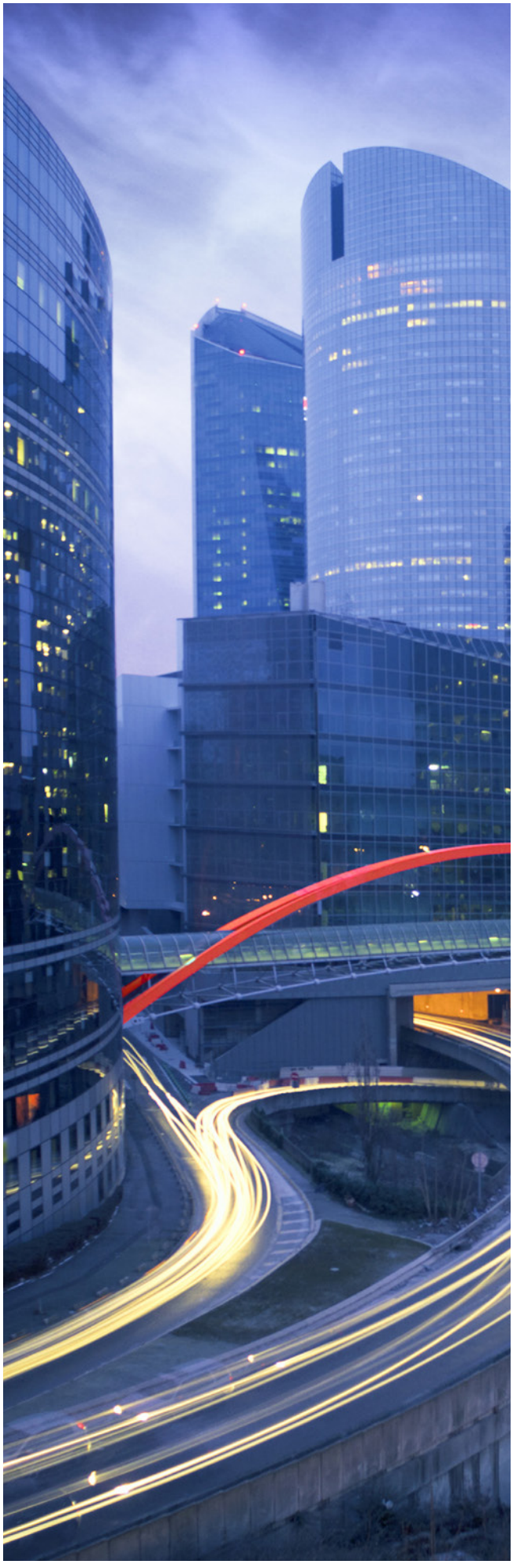
A complexity with IoT comes from the fact that IoT intends to support a number of different applications covering a wide array of disciplines that are not part of the ICT domain. Requirements in these different disciplines can often come from legislation or regulatory activities. As a result, policy making can have a direct requirement for supporting IoT standards to be developed. It would therefore be beneficial to develop a wider approach to standardization and include emerging or on-going policymaking in target application areas, and thus be prepared for its potential impact on IoT-related standardization.

2.5 Demand driven IoT deployment

The present challenge in Europe is to foster the deployment of IoT solutions through smart combination of advanced IoT technologies across the value chain, and to demonstrate and implement IoT applications at scale. In this respect several European Member States have been advancing on the integration across the value chain (components, devices, networks, middleware, service platforms, application functions) and their operation at large scale to respond to real needs of end-users (public authorities, citizens and business). Overall, Europe values less a technology push and focuses more on an end-user and societal perspective, and the evolution of society. Given the innovation potential in areas such as autonomous driving and e-Health, it is expected that legislation, rules and even infrastructures might need to be adapted for wide implementation and full efficiency gain.

IoT is also part of governmental activities for supporting the combination between creative communities and ICT technologies.

Creative people and artists are today regarded as one of the prime sources of innovation and of competitive advantage for companies, industries, and regions. A strong alliance between technology, design, and business is a pre-requisite for achieving the next generation of high-yielding IoT innovations.



3. Common challenges

3.1 General

Although industry, service providers and end-users gain rapid benefits through IoT, many actors are still facing common challenges. The IoT will not develop without cross-cutting approaches. By focusing on vertical applications, there is a risk of reinforcing silos and preventing innovation across areas. Only through the horizontal support and real-time awareness of the IoT, a more powerful and disruptive innovation can be delivered, cutting across verticals.

3.2 Business models and new ways of cooperation

The recent discourse on the IoT has emphasized the need for IoT ecosystems from the business perspective. However, many IoT actors, including administrations, still apply a more traditional thinking when designing new products and services, whereas there will be no true and wide-ranging innovation without cooperation. In order to deliver comprehensive IoT solutions, cooperation among potential competitors or with new partners entering the field of IoT is important as one single entity cannot provide all components of a solution. Moreover, in an era of constant evolution, proactive and mutually beneficial relationships with customers, suppliers, and even competitors are necessary.

3.3 Interoperability

At a basic level, the Internet of Things is connectivity between people, processes and things and one of the central-most challenges 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, regardless of make, model, manufacturer, or industry. The vision is that connectivity between people, processes, and things works no matter what device, software, interface and data are used. 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.

3.4 Technical environment

The Internet of Things domain will encompass an extremely wide range of technologies. At present, a large number of proprietary or semi-closed solutions to address specific problems have emerged, leading to fragmented solutions usually dedicated to a single application. In order to facilitate the emergence of cross-cutting IoT applications and eco-systems, to prevent the risk of silos and lock-in, and to facilitate innovation, open IoT architectures, platforms and standards should be supported.

3.5 Trust

The development of IoT may also raise privacy concerns since smart objects will collect more and new kinds of data, including personal data, and exchange data automatically, which may lead to a perception of loss of control by citizens. IoT may further provoke ethical questions pertaining in particular to individuals' autonomy, accountability for objects behaviour, or the precautionary principle. Recent examples of objects being hacked have shown that the development of IoT and its integration into systems enabling key economic and societal activities may raise security and resilience issues, which may require further organizational measures.

3.6 Societal environment

The Internet of Things is about to transform just everything – business, manufacturing, services, quality of life, and social interaction because globally connected smart devices and linked applications will not only create a world of smart physical and virtual objects, but also a new way for human and machine intelligence to interact. Smart devices and even implants that gather data and applications that perform statistical data mining raise ethical questions if human behaviour should be monitored at all times. Without appropriate training on IoT, some users could also be left behind and may not entirely benefit from a knowledgeable use of the IoT. A further aspect is the combination of IoT and art in the context of a novel research and innovation strategy that strongly links science, technology and social innovation.

4. Development of the Internet of Things in the future

4.1 Towards a hyper-connected society

With the explosive growth in IoT devices, everything will all be connected, combining the world with virtual data. The internet industry is the prototype of the interconnection of everything. With all products and services connected to the internet, the world will become full of smart devices and smart services that form the future new intelligent ecosystem's world. Intel predicts that by 2020, up to 50 trillion devices will be connected, which will be the basic realization of the interconnection of all things. All Internet of Things will redefine things, people, processes, and data and make the data more accurate, more relevant, and more comprehensive. Cisco expects the interconnection of all things in the next 10 years will create a value of $1.44 trillion. China has an estimated 336 million active M2M connections – more than 50% of the global market.

4.2 Massive and secure IoT deployments enabled by the coming 5G technology

Today, mobile technologies (e.g. LTE) cannot guarantee enough security for future IoT application and do not support the massive deployments envisaged with the IoT either. An example is automated vehicles, which would require new communication technology that is not available today. Therefore, for future secure and massive IoT deployment, the community is looking for new radio technology called "5G" which would meet those requirements. According to ITU IMT Vision, 5G applications will have different demands and requirements in terms of traffic capacity, user data rates, mobility coverage, massive number of devices, latency, spectrum and bandwidth flexibility, etc. The three categories of main uses are Extreme or Extended Mobile Broadband, Mission-critical Machine Type Communication and Massive machine communication. The availability of 5G technology will certainly boost the IoT deployment in a number of critical domains and contribute to a generic IoT connectivity.

4.3 Benefits from other technology fields

From a pure technology perspective, IoT will certainly benefit from more basic research oriented fields, such as nano engineering, biological engineering and cognitive sciences. Results from these research areas and corresponding technologies will make IoT objects and terminal products smaller, and networking in a more intelligent way. At the same time new breakthroughs for IoT are expected in sensors and actuators, networking, energy harvesting, interfaces, information processing and autonomous behaviour. Whereas some basic technologies like robotics and artificial intelligence still need some time for market readiness, new interfaces can be expected rather soon.

" Chinese internet enterprises and European technology providers and integrators have emerged as the most dynamic actors in the development of IoT. "

4.4 The fusion of IoT, big data, cloud computing and generic connectivity

Over the last years, the Internet of Things has moved from being a futuristic vision to an increasing market reality. However, the integration and federation of IoT with big data and cloud, having all three diverging principles, remains a key challenge. The exploitation of big data, being obtained from remote sensing, actuation, the Web and social media crawling, enables the creation of distributed intelligence as key service towards attractive IoT services.

The next generation of IoT will be much more interwoven with big data and cloud computing, supported by a more generic connectivity across all network technologies. Large-scale IoT data analytics and complex event processing through big data, trans-regional federated infrastructures enabling edge and local computing, more sophisticated platform integrations (device, data, storage, service, connection) are just examples of what can be expected.

4.5 Automated vehicles in a connected environment

It is clear that the application of IoT in automated vehicles in a connected environment holds a great potential. We will see a deployment of safe, highly and fully automated vehicles in various representative use case scenarios, exploiting local and distributed information and intelligence. Core technologies include reliable and real-time platforms managing mixed criticality car services, advanced sensors and internet information sources around which value-added apps will be constructed, efficient navigation and improved decision-making technology, interconnectivity between vehicles, and vehicle to infrastructure communication. These evolutions are expected to be supported by an open service platform which may have access to all in-vehicle information sources and to surround information, in view of providing value-added apps, e.g. intelligent maintenance. Key barriers to the deployment of such vehicles and ecosystems touch upon e.g. the robustness of the vehicle service platform, how to keep users sufficiently attentive, the overall user acceptance, as well as economic, ethical, legal and regulatory issues.

"However, the integration and federation of IoT with big data and cloud, having all three diverging principles, remains a key challenge."

4.6 E-Health and smart living environments for ageing well

Socio-economic and demographic developments but also the availability of new technologies will fundamentally change the way healthcare is delivered. The IoT will enable more and more healthcare related devices and allow for subsequent virtualization of care. Typical examples for fast developing IoT driven technologies in the e-Health domain are robotics, smart pharmaceuticals, wearables and tagging and tracking. One focus is now more on the integration of different devices during surgery in operating theatres and the integration of data from different smart pharmaceuticals. A very important trend is the so-called precision medicine or personalized medicine, which is seeking to integrate data from a multitude of sources in order to enable the treatment of people based on their individual profile, rather than statistical models.

Gartner predicts that in 2022 the number of smart home devices in the general family of developed countries will exceed 500 units, the annual growth rate of the car industry networking equipment will be as high as 95%, helping us to achieve smart life and smart travel. For example the smart home system Fibaro can control 95% of home appliances. The user will achieve home appliances control through language, gestures and mobile intelligent terminal sensing. In this context, solutions like an implantable chip can collect human blood glucose, blood pressure, and other health information, but also trigger action. The future may even help us restoring memory loss caused by brain insufficiency.

4.7 Smart farming and food safety

The implementation of precision agriculture has become possible thanks to the development of sophisticated sensors, robots and sensor networks combined with procedures to link mapped variables to appropriate farming management actions. Those sensors, either wired or wireless, integrated into an IoT system, gather all the individual data needed for monitoring, control and treatment on farms located in a particular region. Such future Internet of Things scenarios would bring data management to a new level by establishing interactions between the concerned objects, help them exchange information in efficient ways and enable them to execute autonomously appropriate interventions in different agricultural sub-sectors (e.g. arable crops, livestock, vegetable and fruit production) and their associated post-production value chain through to the consumer. The introduction of the IoT scenario would allow monitoring and control of plant and animal products during the whole life cycle from farm to fork. It should thereby also help farmers' decision making with regard to the use of inputs and management processes.

"A very important trend is the so-called precision medicine or personalized medicine, which is seeking to integrate data from a multitude of sources in order to enable the treatment of people based on their individual profile, rather than statistical models."

4.8 Industrial Internet of Things

The automation and management of asset-intensive enterprises will be transformed by the rise of the IoT, Industry 4.0 and similar initiatives, or simply Industrial Internet. Compared with the internet revolution, many product and asset management solutions have laboured under high costs and poor connectivity and performance or simply a lack of “internet thinking”. This is now changing. New high-performance systems that can support both internet and cloud connectivity as well as predictive asset management are reaching the market. New cloud computing models, analytics, and aggregation technologies enable broader and low cost application of analytics across these much more transparent assets. These developments have the potential to radically transform products, channels, and company business models. This will create disruptions in the business and opportunities for all types of organizations – OEMs, technology suppliers, system integrators, and global consultancies.

4.9 Focused zones in smart cities

There are no doubt major developments of applications for smart cities. One trend and challenge will be to have focused zones in smart cities using IoT beneficially.

For instance, building on the past results and achievements in some cities in Europe, some innovative deployment will likely cover a series of cities to operate as reference zones for showcasing and experimenting new citizen-centred IoT services. Starting from users’ expressed preferences and needs, these cities will experiment and test similar new services and solutions, also through the involvement of creativity hubs such as fab-labs, co-working spaces, and gather experience at scale and evaluate citizens’ acceptability and endorsement. It will enable SMEs to use open demonstrators to test innovative new services. This includes advanced solutions for traditional services’ provisioning e.g. water management but also solutions that are at the edge of authorised business practices or regulation (ex: sharing of electricity, autonomous vehicles) and thus require dedicated testing zones.

4.10 Retail

China’s retail sector is expanding rapidly as consumers become more prosperous. To make shopping easier and more secure, retailers are increasingly adopting point of sale terminals that use M2M connectivity to process “chip and Pin” credit and debit card transactions. While dial-up landline technologies have traditionally been used by point of sale terminals, the public switched telephone network has limited reach and there is a growing demand for wireless PoS terminals that enable consumers to enter their Pin anywhere on a retailer or restaurateur’s premises. It is also expected that the IoT will be used to enhance the customer experience and thus put additional challenges on retail such as virtual configuration, fast and full real-time delivery information and dynamic configuration of goods and services.

" China’s retail sector is expanding rapidly as consumers become more prosperous."

5. EU-China cooperation proposal

5.1 Policy level cooperation

Encourage and actively promote research and innovation cooperation, and publication of results. Improve the EU-China cooperation policy and mechanisms in scientific research and innovation from a strategic and operational perspective, for elaborating policy recommendations. Encourage enterprises, institutions, and individuals on both sides to actively participate in cooperation projects and to form a long-term cooperation mechanism between the EU and China. At a later stage, and given that conditions are right in terms of fully reciprocal access to each other's RDI programmes, joint undertakings and calls will be considered as a further step.

> The mechanism should be installed on two levels: governmental level and project level, preferably on a larger scale. For the first mechanism, policies should be investigated on both sides and provide input for the yearly EU-China ICT Dialogue. For the second mechanism, a wider scope of beneficiaries shall be considered including IoT Large Scale Pilots and Megaprojects.

5.2 Technical cooperation

Carry out twinning activities between IoT Large Scale Pilots and Megaprojects on IoT key technologies such as the Internet of Things architectures, test beds and platforms, semantic and technical interoperability, thus making full use of the knowledgebase and advantages of both regions. Encourage enterprises to carry out technical cooperation in strategic sectors on key product development, which can help each of the parties involved to break through technical bottlenecks and promote the process of high-tech industrialization on a reciprocal basis. Expertise can be enhanced and cultivated through short, medium and long-term exchanges of PhD and post doctorial students, faculty staff, industry researchers. This should also be considered for entire institutes and companies.

5.3 Standards cooperation

Encourage EU-China mutual support and jointly push the development of international standards for the IoT business layer, in the activities of international standardisation organizations such as OneM2M, ETSI, CEN/ISO, IEEE, ITEF and ITU-T. A joint position paper on EU-China Internet of Things standardisation mapping including recommendations should be elaborated, which can thus provide a reference for the future EU-China standards cooperation. This should also include a consideration of domain specific standards which could be done in conjunction with large scale projects as mentioned in 5.1.

5.4 Market cooperation

Strengthen EU-China information exchange and cooperation between the technology innovation strategic alliance of the IoT industry in China and Alliance for IoT Innovation in the EU to establish an effective market supply and demand platform for European and Chinese enterprises, which can expand bilateral industrial research and innovation activities.

Joint market analyses of potential applications of IoT in diverse fields are needed to instate confidence. Mutual studies on topics related to IoT large scale projects could be a means of providing this confidence.

" Improve the EU-China IoT cooperation in science and innovation from a strategic and operational perspective. "

6. Conclusion

In order to jointly promote the IoT development and deployment, the EU and China have set up the EU-China IoT Advisory Group in 2011, which has been endorsed by the EU-China Dialogue on Information Technology, Telecommunications and Informatization, established between MIIT and DG CONNECT. By now, ten EU-China IoT Advisory Group meetings have been held, ranging from information sharing to joint white paper publication and industrial collaborative platforms. The EU-China IoT Advisory Group has already carried out joint research on IoT architecture, identification and semantic, released the “Position Paper on Internet-of-Things Architecture”, the “EU-China Joint White Paper on Internet-of-Things Identification”, and targets to publish a new white paper “EU-China Joint White Paper on Semantic”. In parallel, the EU-China IoT Advisory Group aims to promote industrial cooperation, IoT test beds and IoT Large Scale Pilot twinning. Connected and Automated Vehicles, e-Health, Smart Cities and Smart Agriculture are regarded as specific cooperation areas, in addition to the future hot topic of Industrial IoT.

Finally, we would also like to point out that we are living in a world of global challenges – economic crisis, hunger, poverty, climate change, pollution, shortage of resources, etc. Both the EU and China are fully aware of this and intend to leverage their global IoT leadership positions by addressing these challenges jointly. IoT is one of the key technology approaches that will drive a new evolutionary jump in technological and societal advancement, allowing us to contribute to address these problems through innovative solutions.

" The EU-China IoT Advisory Group aims to support political and industrial cooperation, IoT test beds and strategic IoT Large Scale Pilot twinning. "

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