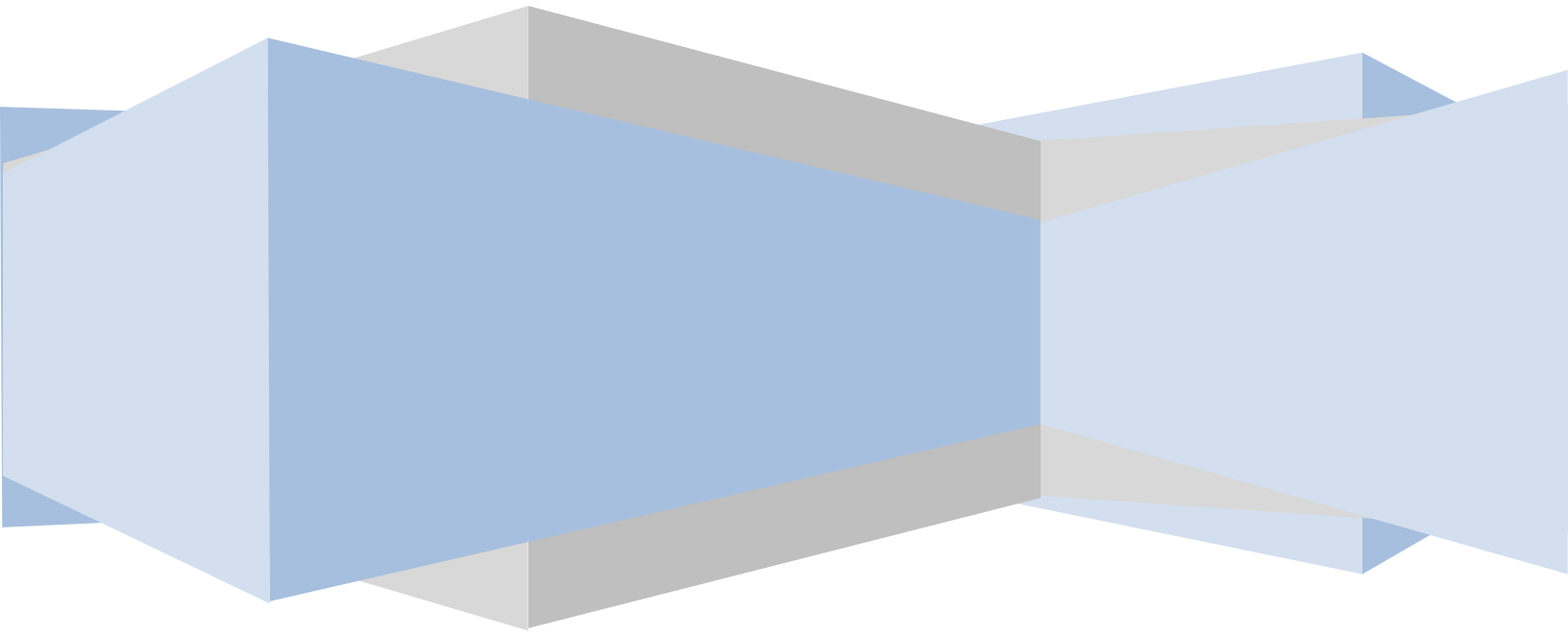
European Commission

Internet of Things
the next revolution

A strategic reflection about a European approach to the Internet of Things

CONNECT Advisory Forum



Internet of Things – the next revolution

A strategic reflection about an European approach to Internet of Things

CONNECT Advisory Forum (CAF)

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Although endorsed by the CONNECT Advisory Forum as a whole this report is the result of a collective reflection of a group of CAF members in which participated Jose Luis Angoso-Gonzalez, Jean-Luc Beylat, Klaus Betz, Jozsef Gyorkos, Martin Curley, Geoff Pegman, Michela Magas, Matthias Jarke, Natali Helberger, Nicolas Demassieux, Stefana Broadbent, Stefanie Lindstaedt, Ole Lehrmann Madsen coordinated by Tatu Koljonen and Wim de Waele

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More information about the CONNECT Advisory Forum is available at the Digital Agenda web site of the European Commission - http://ec.europa.eu/digital-agenda/en/connect-advisory-forum

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What is IoT about

Internet of Things (IoT) is a set of products, services and processes that virtualizes the real-world things for digital processing. The outcome of IoT is a digital representation of the real world that can interact with digital systems and applications and is susceptible to internet business models. Depending on the instance, the digital representation of the real world can be very simple or extremely complex, very local or globally orchestrated. The sources of information can be anything from tags, sensors, embedded systems, existing databases to human agencies. An essential ingredient is scalable connectivity, locally and globally.

Vision

IoT promises to be one of the most disruptive technological revolutions since the advent of the Internet: projections indicate that more than 50 billion humans and objects will be connected to the Internet by 2020.

IoT is principally about attaching varying amounts of identity, interaction and inference to objects. Identity can be e.g. tags, shapes and forms or IP addresses. Interaction includes acting, sensing and physical connectivity. The connectivity is not just between devices, but also between materials, spaces, phenomena, human actions, concepts, processes, data repositories etc. Embedded systems play a major role in facilitating those interactions. Varying amount of inference is used to refine the data into information. That can be turned into new applications and services via cloud computing and big data analytics and other digital means.

As electronics has taken over more and more functions in a wide variety of technical systems, e.g. in manufacturing plants, medical equipment, power supply systems, aircrafts, and cars, but also in home appliances like washing machines and refrigerators the “things” become “smart things”. Smart things are delivering sophisticated and enriched information that can be provided to a higher level system to build sophisticated services and applications on top by connecting them via smart communication. Former “things” take on new functionality, turning them into sensors and actuators. These devices are able to run smart applications (e.g. sensors in a fridge can turn the fridge into a smart device), receive and collect data about ‘things’ (e.g. the content of the fridge, but also temperature, weather forecast, user behaviour, home automation). heart rate).

Furthermore IoT is a cornerstone for the development of smart and sustainable cities and smart and sustainable infrastructure in general. Therefore IoT technologies will have to operate in a multitude of industrial domains including, but definitely not limited to the consumer/IT/tele communications domains. This results in highly complex systems that are increasingly powerful and comprehensively networked.

IMPORTANCE FOR EUROPE

IoT operates both at the level of the individual user and at the level of the invisible systems and processes that support and enable society, government and industry. These processes include b2b, b2c, c2c (citizen to citizen), c2g (citizen to government) communications and transactions. Depending on the application, these processes can take place within a global matrix of mutually interchangeable, multidirectional dialogues and exchanges; they can also operate on a local or even hyper-local level, namely in the realms of a private home, a car, the human body etc. In so doing, IoT can challenge fundamental conceptions about the distinction between public/private, offline/online, tangible/intangible, ownership/control, which has to be taken into account also in policies and legislation.

Europe is in an excellent position to become a global leader in IoT. The main strengths of European ICT are in business-to-business software and services (although with strong USA competition), embedded systems (including automotive and aeronautics), and in particular in applying ICT in complex system level solutions in various industrial and societal domains. Leveraging 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 and will strengthen Europe's position against the USA and Asia.

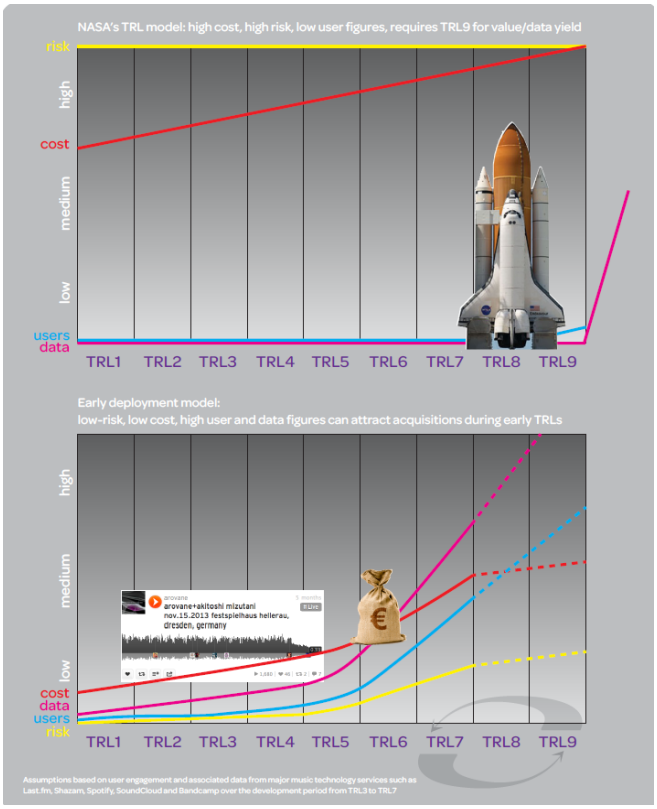
Over the past two decades, European companies, in particular SMEs in traditional engineering and production sectors have endeavoured – sometimes with great success – to adapt their business models and human resources to the new requirements of embedded software and modern IT-based engineering tools. This process, which is far from completed is now overlaid with the advent of the Internet of Things that some call the fourth industrial revolution ("Industry 4.0", or Smart Industry). This development completely changes the opportunities and threats for all these companies, irrespective of their size. Opportunities include optimization across individual devices and enterprises, traceability of products, remote maintenance as well as new Internet-based product-accompanying services. Threats include additional network-based security risks for company IP, and market entry of large players often monopolistic who enter industrial domains such as fashion, home automation or automotive from the Internet side. It will be crucial for European competitiveness and industrial future to strengthen the innovativeness and companies of not just the "pure" ICT industries but also software- and network-intensive "user industries" especially at the SME level.

THE GAME CHANGERS

Hyper-scalability

Digitalization changes the industry dynamics, especially in terms of how businesses scale (= positive marginal return with respect to resources). New “hyper-scalable” businesses based on digital services and digital products have emerged, where the marginal return increases according to Metcalfe’s law. Initial examples are from gaming and entertainment, but with IoT making the real world susceptible to digital tools and ways, the new industry dynamics will eventually find its way to realm of traditional businesses and whole society. The winner is the one who gets most users and takes it all in terms of profit. Therefore it is necessary to have a fair share of European winners and strong local clusters to help them initially succeed and monetize the success in local jobs and economic growth. While technology is an important enabler, the really disruptive effect results from the hyper-scalability effect of "data" applications – where adoption by user communities (being these individual users, business users or even larger communities – e.g. industrial applications) is the determining factor for success.

While the current Internet already has made inroads into the lives of denizens and also that of businesses and organizations, this penetration will increase in scope and depth due to IoT. Not only will new application fields be opened up, but also the penetration of processes, environments and actions by ICT will increase. The range of “things” that will be sensed, tracked, and manipulated through IoT will truly be overwhelming. It will span from microscopic and even sub-microscopic entities (bacteria, nanobots, etc.) to macroscopic objects. The digital shadows, the data, of these “things turned into devices”, will be – like real shadows - quite different compared to its original, and might be manipulated depending on the context. For instance, while for a shipping company whole containers usually constitute the finest scale of granularity and thus “things”, the individual pieces of products in such a container constitute “things” for the receiving retailer and also the end-customer. This entire container with contents will be creating and receiving data and possibilities for applications which we have not even imagined at this moment.



Market Adoption Readiness Levels

There is a major distinction between ICT applications which can drive the EU economy quickly and competitively in the global market, and the traditional techno-centric discourse which largely relies on the risk management concept of Technology Readiness Levels (TRLs). The TRL model is driven by the degree of maturity requested from technology and is particularly suited to its original context, as developed by NASA in the 1980s. The NASA model typically deals with high-risk technologies, carries high development costs, is aimed at few end users, and yields important user data only after final deployment.

ICT applications require development which considers adequate business models, user engagement, and societal aspects. This implies that new models are needed as guidelines particularly for EU Innovation Actions. One of the proposed models is the "Market Adoption Readiness Levels" (MARLs). In addition to the technology readiness levels parameter, this model requires the assessment of three further value parameters: users (numbers of potential early adopters and values associated with feedback loops), data (potential quantity and value of data generated by the system and user interactions at each stage of the process) and the level of risk (assessment of benefits or adverse impacts of the technology on early adopters and the society as a whole in various stages of the process). This MARLs model is strongly motivated by the disruptive nature of IoT, but is used more widely. It also focusses on the fact that those who capture most users earliest in the life time of a product development have a fundamental advantage.

For example, many creative applications are extremely low on risk, cheap to run, easy to understand and can get millions of early adopters, even as experimental proofs-of-concept. Examples from the music industry include Last.fm, Shazam, Spotify, SoundCloud and Bandcamp. For a potential investor, a large number of early adopters, and the related substantial datasets, have often proven to be sufficient incentives for investment and acquisition in early stages of development (traditionally classified as TRL3 to TRL7). In the creative applications sector therefore, the market is extremely agile, with development of applications being cheap and typically low risk, and great potential of investment and acquisitions through clearly demonstrable social and economic benefits in early stages.

In addition to this, the agile nature of the digital market and the relatively cheap deployment of competitive applications requires active development and evolution of technologies via constant innovation and new iterations of products and systems. It is essential that the product constantly evolves, or else it will lose out to competition. It is important therefore to focus primarily on early deployment in order to maximize on the creative engagement with the tools by early adopter and creative content maker communities. This ensures the potential for growth through feedback loops and iterative stages of active development, and capitalizes on collaboration and agile and adaptive innovation for maximum market competitiveness.

Maximize the effect of Metcalfe's law

Metcalfe's law states that the value of a telecommunications network is proportional to the square of the number of connected users of the system. Metcalfe's law characterizes many of the network effects of communication technologies and networks such as the Internet, social networking, and the World Wide Web. In the IoT context, it may be used to explain the actual capability of system to serve an increasing amount of users, which in many digital services will hyper-scale i.e. the service works increasingly better the more users there are. In hyper-scalable business logic we have used Metcalfe's laws to explain the increasing returns of businesses based on such services. This aspect needs to be fully exploited to maximize the effect of the IoT. It also implies in many business organizations a re-definition of their business model putting more emphasis on the user attention, instigation and involvement. Many companies like the elevator maker Kone and the sports watch maker Suunto have raised the user and user communities, or tribes, on a major role in their product development and actual products and services.

Trust and individual/societal adoption

IoT extends the provision of services and applications, but also the collection of personal data and more generally privacy-sensitive information (including metadata), far into the personal or even intimate areas, namely in the realms of a private home, a car or even the human body. This can have many advantages for individuals, but also result in more invasive, persuasive and insensitive applications and data collections. Accordingly, value sensitive and trustworthy design of IoT devices is paramount for their broader adoption. One challenge in this context is to govern information flows in a way that is compatible with expectations of privacy, security and autonomy. At the same time it is important to ensure that individual and social adoption does not result in a new social divide between 'smarter' and less smart households.

THE SYSTEMIC PERSPECTIVE

Creating European winners

In hyper-scalable business, global natural monopolies will emerge in smaller and smaller pieces of innovation. Europe needs to ensure two things: 1) fair share of global winners and 2) way to turn those successes in the jobs and economic growth for Europe. The history shows that the winners can be both big companies as well as start-ups, but the competition is global. In other words Europe needs to offer the best conditions worldwide for competitive, innovative and market-ready IoT solutions.

Europe has to strengthen the IoT sector

Europe has to strengthen its core industries by supporting IoT technologies. Europe has to avoid a situation where core European industrial activities such as industry automation, factory/process automation, generation and distribution of renewable energies (Smart Grid), as

well as the development and production of enhanced environmental technologies, cars, air planes, etc. have to rely on solutions delivered by non-European companies. Especially for IoT, Europe needs a strong high-tech sector that is world-leading in IoT technology and supports the traditional European industry in the transition into the digital era, where everything is connected. This transition requires new types of organization, new business models, new services, new development methodologies, optimization of the whole digital engineering tool landscape for the whole production chain. Organizations, methodologies and business models have to be fundamentally scrutinized.

Standards and interoperability

IoT technological implementation should ideally rely on a commonly agreed basis e.g. via standardization. The international standards are needed to avoid regional fragmentation and allow worldwide use of products and solutions. Also the standardisation of a reference architecture model for IoT is needed to achieve the goal of compatibility and interoperability across industrial domains – without, however, compromising on security. This reference architecture model (like the ones proposed by European research project IoT-A, FI-WARE and Smart M3) will be the base for domain specific refinements and extensions addressing notably common open platform / backbone that supports the needed communication, data capturing services and can be shared by multiple providers of data-centered services / applications. . For IoT standardization, it is of utmost importance to have relevant players from all industrial domains involved. IoT standards which are only defined from the viewpoint of a single domain (i.e. telecommunications or consumer domain) will not match the needs and requirements of other domains and lead to silo solutions which will contradict the IoT goal of compatibility and interoperability across industrial domains.

Law and policy as a key enabler of IoT innovation

This involves many notably legal and regulatory issues. The concept of single digital market in Europe is far from being realized. IoT applications and services can have many societal benefits, by making our society more effective, greener, healthier, safer, smarter, convenient etc, but they are often blocked by the legal and regulatory framework still in place in one or more EU Member States of EU. 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. A clear regulatory framework covering these aspects will provide guidance for standardization and solution development. The regulatory framework shall focus on requirements, liability and accountability and shall not select or prefer certain solutions and standards.

Related developments dealing with big data, cloud and human agency

These three aspects are closely related. To put it in a schematic form, the sensors create data in massive amounts which need specific Big Data analytics to extract usable knowledge. This data can be made available easily and on a big scale using cloud technologies. Most of the data is generated by sensors or machines and will be processed by machines without human interaction therefore it is important to take the humanistic, ethical and societal aspects into consideration.

How to transfer this to reality?

The watchword is "Implementing massively and widely" by designing spearhead / flagship projects with a challenge-based approach of cross-sectorial nature. In this approach two kinds of projects are put forward to support a faster uptake of the IoT applications namely, on the one hand, the Spearhead/ Lighthouse/ Flagship Projects which define massive thematic ground-breaking directions and bring a number of key players together from the point of view of business, technology, legal and ethical aspects, user groups and the sectors of society involved. The target is to define a project to be developed in the next 2-5 years with a very clear but challenging objectives. On the other hand there are the IoT Competence Centres which are the one-stop-shop for the IoT development e.g. for SMEs to find the technology, the development processes, and test beds. These Competence Centres could also play a role in disseminating the knowledge of the IoT application creation processes by organising workshops, seminars, master classes. Entrepreneurship and innovative SMEs are playing an important role in this transition process. Moreover, the potential of a pan European ecosystem shall be discovered between IoT solution providers and application developers. Whenever appropriate it is advised to exploit the added value of national initiatives and their contribution to the realization of a European strategy.

RECOMMENDATIONS

The Game Changers

Maximising the effect of Metcalfe's law, Market Adoption Readiness Levels and Disruptive Innovation

User and product-centred approach: In defining the projects, more emphasis should be put on early engagement, feedback loops and community building of the users of the final product that the projects have in mind. The idea is that the projects should be defined from a user perspective with a foreseen impact (e.g. business or societal). These types of projects should balance competences and domain knowledge from the humanities, social sciences, business and technology and include end users as participants.

Disruptive innovation support: We should become better at picking up innovation when it is hot and passing it on when we are at our best. The recommendation is to encourage a group of projects to break from the waterfall model and create innovation eco-systems that are reactive and proactive.

Business Creation and IoT Value Chains

Stimulate business model creation: Study opportunities for IoT-based Business Creation and respective IoT value chains, by funding projects which analyse IoT business models and clarify value chains, and by accelerating the transfer of research results into business e.g. via intensifying the link between research and EIT ICT labs activities.

Interoperability in the IoT domain: It is not clear yet what are the business models that drive interoperability and who will benefit/lose from a connected internet of things and who will benefit/lose from building silos.

Open industry collaboration and cooperation: EU money should be spent also on novel and radical system concepts that break the current business ecosystem with early market experiments in an Internet economy way.

IoT systems will need to meet stakeholder aspirations over entire value chains (example: information security and traceability over entire logistic chains). New models of collaboration and cooperation enabling cross-value-chain approaches are needed.

Cross-Sector Partnerships Support: Fund industrial cross-domain partnerships (ICT and non-ICT) for application of IoT architecture frameworks to the creation of use-case-specific IoT profiles in a range of application domains, for platform development (based on IoT architecture frameworks), and for proof-of-concept activities. For efficiency reasons, this could very well be done by bringing together national initiatives in selected domains; a starting point could be the domain of industry automation, which is addressed by Industry 4.0 in Germany and similar activities in other European countries.

Cumulating the domain specific IoT knowledge in Europe: The best position in the IoT value chain is the knowledge owners' position. It should be in European hands at least in case of European IoT knowledge.

Outreach campaign to equip IoT stakeholders with skills and entrepreneurial capacity to fully exploit the potential of IoT.

Involvement of VC investors in the early stages of the IoT value chain creation.

The Systemic Perspective

Standardisation and IoT Open Platforms and Interoperability

The standardisation (horizontally and vertically) should keep pace with the requirements and evolution in the area of IoT. Such standards assure Interoperability in the IoT domain.

There is need for standards in the areas of

- **Cross domain architectural frameworks for IoT**, e.g. developing Traffic Control systems for Smart Cities requires the suitable combination of Traffic Optimization systems optimizing the overall throughput while awarding strict priority to emergency services / police where and when needed. Re-use results of EU-funded research activities such as IoT-A and FI-WARE.
- **Semantic interoperability** between data from different domains enabling integrated cross domain services, the example above also requires standardization of data over the whole value chain. Use results from European research projects like HyperCAT and Smart M3

In addition to this there is a need for a concrete implementation of an IoT platform.

- The spearhead projects need to result in IoT platforms which can become the basis of application development. The centres working on these topics could work as open innovation motors generating output which is available to the industry (or industry partners taking part in a consortium). Another target of such a consortium could be to generate spin-offs in that area.
- Reuse and extension of existing standards which fit the needs of IoT: IEEE for Communication topics and an architecture framework for IoT, IETF for Internet Protocols, W3C for Semantic technologies, IEC for vertical / domains-specific applications.

Legal and Regulatory environment

Regulatory and legal aspects should be enabling factors for a successful exploitation of IoT and job creation in Europe. To this end, it is necessary to Analyse the current European regulatory situation with respect to IoT relevant topics, and

- Propose regulatory modifications, where needed, to enable optimal IoT development in Europe.
- Ethical and normative values should be taken into account from an early stage on in the development process, in order to produce IoT products and services that are attractive for businesses, consumers and society.
- A sustainable legal framework that facilitates innovation while ensuring fairness and a high level of user protection, protection of fundamental rights & trust is a critical competitive factor. Europe can have a front runner position here and even export its regulation.

IoT creates new challenges for the existing legal framework. Attention is needed for the question of how the future legal framework can address these challenges and at the same time play a role in facilitating innovation in IoT, by providing common benchmarks, defining essential ground rules and generating trust.

How to put all this in reality?

Network of Pilots: **Spearhead Projects (vertical or horizontal applications)** and **Strong local clusters of trust with Competence Centres (horizontal dissemination)**

Design **ground-breaking (spearhead) projects** bringing together a number of key players addressing the business perspective, the technological dimension, the legal and ethical aspects and mobilising user communities and societal groups concerned.

The goal is to design projects that will be developed in the next 2-5 years with very clear but challenging objectives. Judged on a case-per-case basis, these can include vertical domains for which non-ICT (i.e. vertical) and ICT stakeholders have already intensively cooperated in previous or currently running projects & initiatives such that a mutual understanding has been achieved already to some extent. We suggest to have one Spearhead project per each of the seven societal challenge of H2020.

The **Competence Centre** idea leads to the concept of the one-stop-shop for the IoT development e.g. for an SME to find the technology, the development processes, and the test beds. These Competence Centres could also play a role in disseminating the knowledge of the IoT application creation processes by organising workshops, seminars, master classes.

As a first step a clear view needs to be developed for which sets of **IoT topics** a Competence Centre is required. Amongst these topics the following should be considered: Web-based System Synthesis, Data Grid, Device Auto-Connect & Operation, Network Function Provisioning & Management, Massively Distributed Systems, IoT Security.

IoT platforms: **Towards compatible infrastructures supporting communication, object management and data exchange services**.

Focus on European IoT platform(s): Today most players in the IoT business develop their own IoT platforms. This significantly slows down the speed of innovation for IoT application development and adoption of IoT technologies compared to a scenario where Europe focuses on few (Open-Source) IoT platforms on which innovative players (e.g. start-ups) can immediately develop their applications.

IoT Architectural Framework: An architecture framework (reference model, reference architecture + guidance of how to apply them) is needed that fosters the reuse of architectural principles and the reuse of system modules and concepts. A reference model provides a coherent ontology and semantic for describing and analysing IoT use cases and IoT systems. Reference Architecture provides high-level advice on how to build IoT systems that meet IoT-stakeholder concerns and expectations. The guidance of how to apply both also answers the question of how to tackle qualitative system requirements while, at the same time, avoiding architecture and system divergence. Use the reference architecture model of European research projects IoT-A and FI-WARE and semantic interoperability solutions European research projects like HyperCAT and Smart M3.

Scenarios: Relying more and more on technological solutions brings about risks that we

	do not understand. Companies, governments and users are unaware of security breaches or sometimes even hide them out of fear of backlashes, losing face or plain ignorance. We need to rapidly learn from experience in dealing with the digitisation of everything. This recommendation is to establish projects which challenge digital infrastructures, their security and robustness against malicious attacks thus ”hacking the World for a better World”.
Other IoT components: **Smart IoT, Smart objects, cyber-physical systems and embedded hardware**	
	Smart Data approach: Position Europe as the driver for mastering the huge amount of IoT data by developing and driving an “information-centric” approach. The information-centric approach is characterized by decentralized information creation from the raw data making the things in the IoT smart. Since the information generation in this approach is done closer to the process, it fosters easier contextualization and use of pre-knowledge that is not readily available in the cloud. The data we are processing is machine-generated, and therefore quite different from the user-generated data. Access to data is not sufficient, but requires deep domain know-how to generate customer value out of this data. The domain know-how is a decisive competitive edge that allows us to pursue a unique approach: “Smart Data” (generation of information from the raw data already on the things supported by domain and device know-how) rather than “Big data” (sending all raw data into the cloud and generation of information from these raw data only in the cloud). **More funding to the maker community:** Making devices and hardware is about 49% of the value of the IoT- another 49% is the app/service wrap and 2% is connectivity and maintenance. It is still important to keep being involved in the makers community at a global scale.
SME Partnerships	
	Stimulate approaches where **SMEs and new innovative companies** are considered equal partners with other stakeholders in **IoT ecosystems**. The system ownership will change so that instead of one company the ownerships will be distributed as responsibilities for all participating organisations and individuals. Enable use of testbeds for SMEs. There are different infrastructures at this moment available for IoT testing (network testbeds, home labs, manufacturing labs). These testbeds should be made more standardised and user friendly (e.g. FED4FIRE project). One of the elements which could be simplified to ensure the use of these testbeds is the financing of projects using these testbeds as an external service. On the other side, especially for the horizontal knowledge dissemination to SMEs it is recommended to finance small projects (a few person months of work, 50-100K projects). These small projects for SMEs can result in tangible outcomes fast. Improve the condition for entrepreneurs and SMEs in Europe e.g. the lack of early- stage investment which is a major factor contributing to a big gap in commercialisation of R&D results.