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Link and Evangelize the FI-PPP from Europe to the world for the benefit of FI research and innovation and to the European industry business

D1.1: FI-LINKS technology and business models map

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Abstract	This deliverable provides a map of challenges for Future Internet business and technologies.
Keywords	Cloud, Network, Big data, Internet of Things, Media Internet

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EXECUTIVE SUMMARY

This deliverable introduces the roadmapping methodology used within the FI-LINKS project and, starting from that, it presents the first results achieved as a follow up of the first two internal project workshops dedicated to the roadmapping activities.

In particular, most of this deliverable presents conceptual maps for business and technology challenges. Due to the FI-PPP's main focus and objectives, this version of the roadmap focuses on a set of technologies that are directly relevant to the FIWARE offering: Internet Media, Big Data, Internet of Things, Cloud Computing and Communication Networks. As such, the conceptual maps are not - and do not aim to be - exhaustive, although they highlight the most important challenges that have been identified for the ecosystem associated with the FI-PPP programme, as a result of the FI-LINKS-driven work WP1 has been pursuing in the first part of the project.

The work presented in this document takes also into account the global context and the feedback collected from the international experts invited to the second WP1-dedicated workshop, which has been essential to refine and improve the roadmaps, taking into consideration the global understanding of challenges for the next generation of Internet-based technologies.

Following these initial results, WP1 will proceed with the roadmapping process through the third and fourth workshops, in order to finalize the first year's activities with the release of the consolidated version of the roadmap.

In the next months, we will share the work with a broader audience and present it at different events to collect important feedback from other stakeholders in the Future Internet (FI) landscape for a more comprehensive and sound analysis of the most relevant technology and business factors.

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1 INTRODUCTION

"Innovation distinguishes between a leader and a follower."

Steve Jobs

Looking into the future of technology is fundamental to be able to innovate businesses, regions and nations. The availability of a better technology can lead to a better life for individuals and for the overall society. The road to the realization of a vision about the evolution of a technology is, however, a challenging path that requires an effort going beyond a single individual and a single vision, as it requires an understanding of the world as it is and as it should be.

FI-LINKS has not the ambition to enlighten worldwide researchers and innovators with a revolutionary vision, as it is per se not the main goal of this project; however, the FI-LINKS consortium has the ambition of helping European and international researchers and innovators to better understand what kinds of innovative aspects will be the essential components, in the next 5-10-20 years, of an already revolutionary vision called the *Future Internet*, by providing hints on some of the challenges that lie ahead of us to shape such a vision. The FI-LINKS project runs under the umbrella of the Future Internet Public Private Partnership[1] – FI-PPP – innovation programme. The FI-PPP now reached its third and final phase, where the take-up of FIWARE[2] (the set platform developed within the programme to support Future Internet scenarios) it is expected to occurs. For FIWARE and FI-PPP, this is a crucial moment for looking at the work done, and set the vision for the future to be. FI-LINKS contributes to the analysis of results and the set-up of this vision through the roadmap and linked activities: the engagement of International Future Internet actors to support the roadmap and the engagement of potential international adopters of FIWARE technologies and FI-LINKS roadmap (WP2); the engagement of European regions to establish a local roadmap related to FIWARE technologies (WP3); the wider dissemination to the public of FI-LINKS, and more in general FIWARE, results (WP4).

Several initiatives are currently active around the world that can be gathered under the same concept of a Future Internet (FI); to list a few: the EC Future Internet ICT programme under FP7 in Europe (which spans from future networks to Future Internet Research and Experimentation Infrastructures[3] – FIRE – to the Future Internet Public Private Partnership – FI-PPP – innovation programme); US IGNITE[4] and GENI[5] in US; New-Generation Network[6] (NWGN) in Japan, etc.

Because of these distinct initiatives, the *"Future Internet"* concept may mean different things to different researchers and innovators around the world. In the end, providing a unifying definition is as challenging as forecasting the future. In simple words we can state that *Future Internet is the **evolution** of the Internet as we know it today to enable and support future scenarios both in society and in the business world.*

What will this evolution look like? The aim of the activities pursued by WP1 is exactly the attempt to forecast such evolution. The FI-LINKS consortium believes that the best way to forecast such future is through collective awareness, i.e. through the interaction among people belonging to different culture and expertise background, not only in Europe, but globally. Our main goal is therefore the creation of a roadmap for the Future Internet that:

- Encompasses business and technology aspects and interrelates them;
- Spans from a short-term horizon (up to 2020) to a long-term time horizon (beyond 2020);

[1] http://www.fi-ppp.eu

[2] http://www.fiware.org

[3] http://www.ict-fire.eu

[4] https://us-ignite.org

[5] https://www.geni.net

[6] http://forum.nwgn.jp/english/about/

- Provides a global shared vision of future challenges;
- Defines possible goals for the follow up of research and innovation activities related to FIWARE and FI-PPP.

What is a roadmap? A roadmap is a plan that matches short-term and long-term goals with specific technology solutions to help meet such goals [1]. Developing a roadmap has three major uses [3]:

- It helps reaching consensus about a set of needs and the technology required to satisfy them;
- It provides a mechanism to help forecast technology developments; and
- It provides a framework to help plan and coordinate technology developments.

All these three cases are relevant in the context of FI-PPP, FIWARE and FI-LINKS, as they are crucial in pursuing the following objectives:

- Increase the understanding of business scenarios empowered by FI applications and services;
- Innovate the approaches to the operation of FI infrastructures;
- Strengthen the impact and effectiveness of FI platforms and applications;
- Reinforce the FI impact through new business models based on cross-sector industrial partnerships;
- Establish long-term collaborations on the FI vision with worldwide actors working on FI-related initiatives;
- Support the future growth of the EU industry and economy;
- Facilitate decision-making for the definition of new goals for H2020 related to the FI.

In this deliverable we pave the road toward the achievement of such objectives, by providing an initial map that identifies technology and business challenges for the FI. This first map, rather than going deep into the future challenges, explores their space and provides an initial reference for discussion and validation with worldwide ICT researchers and innovators.

1.1 Motivation: why yet another roadmap?

Several different initiatives have been built worldwide around the FI. Some of them take similar directions, but others focus more on specific aspects such as broadband infrastructures. Furthermore, some adopted a top-down approach, while others a bottom-up one. Nowadays, after more than seven years of worldwide activities, it is time to consolidate the overall picture and build a common understanding of the potential leap ahead.

Such a leap should not only be driven by researchers worldwide, but also supported and promoted by global industry players. To start the exercise leading to draw such a roadmap, we involved three of the key industrial actors that pioneered and contributed to the FI-PPP (namely, TID, ENGINEERING and ORANGE) and a number of international top-notch research institutions leading, or representing (as in the case of US IGNITE and NICT) innovation and research programmes on the FI.

Given the current maturity level of the various FI initiatives, it is important to analyze not only the technological aspects, but also the related business models and implications. The FI-LINK long-term vision for the FI will cover therefore both business and technological aspects.

The roadmapping exercise in FI-LINKS takes into account other recent roadmapping activities, such as:

- Future Internet Assembly Research Roadmap, by FIA [11].
- Engineering Secure Future Internet Services: A Research Manifesto and Agenda from the NESSoS Community, by the NESSoS project [12].
- Future Internet Roadmap, by the ServiceWeb 3.0 project [13].
- Initial Future Internet roadmap and proposals for sustainability, by the INFINITY project, 2012 [14].

- Future Internet Technologies Roadmap for Transport and Mobility, by the Instant Mobility project, 2012 [15].
- Internet of Things Strategic Research Roadmap, by the European Research Cluster on Internet of Things, 2012 [16].
- Landscape and Roadmap of the Future Internet and Smart Cities, by the FIREBALL project, 2009 [17].
- New Generation Network Architecture AKARI Conceptual Design, by NICT, 2009 [18].

A spontaneous question that might arise, considering the availability of these various roadmaps and more, is *"Why do we need yet another roadmap?"*

First of all, *to be effective, roadmaps need to be up-to-date*. In this sense the FI-LINKS work aims at providing the latest perspective on the overall business factors and technological trends that have a crucial role in the FI landscape and its future evolution.

Secondly, the FI-PPP initiative is now entering its third phase, which is a turning point in the path from development to consolidation and uptake of research results into market deployment. In this perspective, the FI-LINKS roadmap aims at providing precious insights into how *further evolution of results achieved so far and sustainable growth for the EU industries having invested - and still investing - in the FI-PPP can be pushed forward effectively*.

Finally, a common vision, such the one WP1 has been working on, is fundamental *to ensure that the next steps within the FI innovation landscape will be globally shared by the key worldwide players and involve not only the current FI leaders, but also new potential early-adopters of next-generation FI technologies.*

2 THE ROADMAP METHODOLOGY

Within FI-LINKS, we decided to adopt a lightweight iterative methodology inspired on the well-established work by Phaal et al [3]. The Phaal et al.'s methodology has been selected for two main reasons: i) differently from other methodology, it provides support for roadmaps related to implementation of R&D programmes (which is in the end the ultimate goal of FI-LINKS) rather than product oriented; ii) the methodology is flexible enough to accommodate the specific needs of FI-LINKS, such as the combination of business and technology vision.

The methodology by Phaal et al [4] is centered on the T-Plan 'fast-start' approach. Phaal and his team developed and applied the T-Plan within a three-year applied research programme, where more than 20 roadmaps were developed in collaboration with a variety of company types in several industry sectors.

The approach is based on two "parts": (i) a standard approach, for supporting product planning, and (ii) a customized approach, which includes guidance on the broader application of the method.

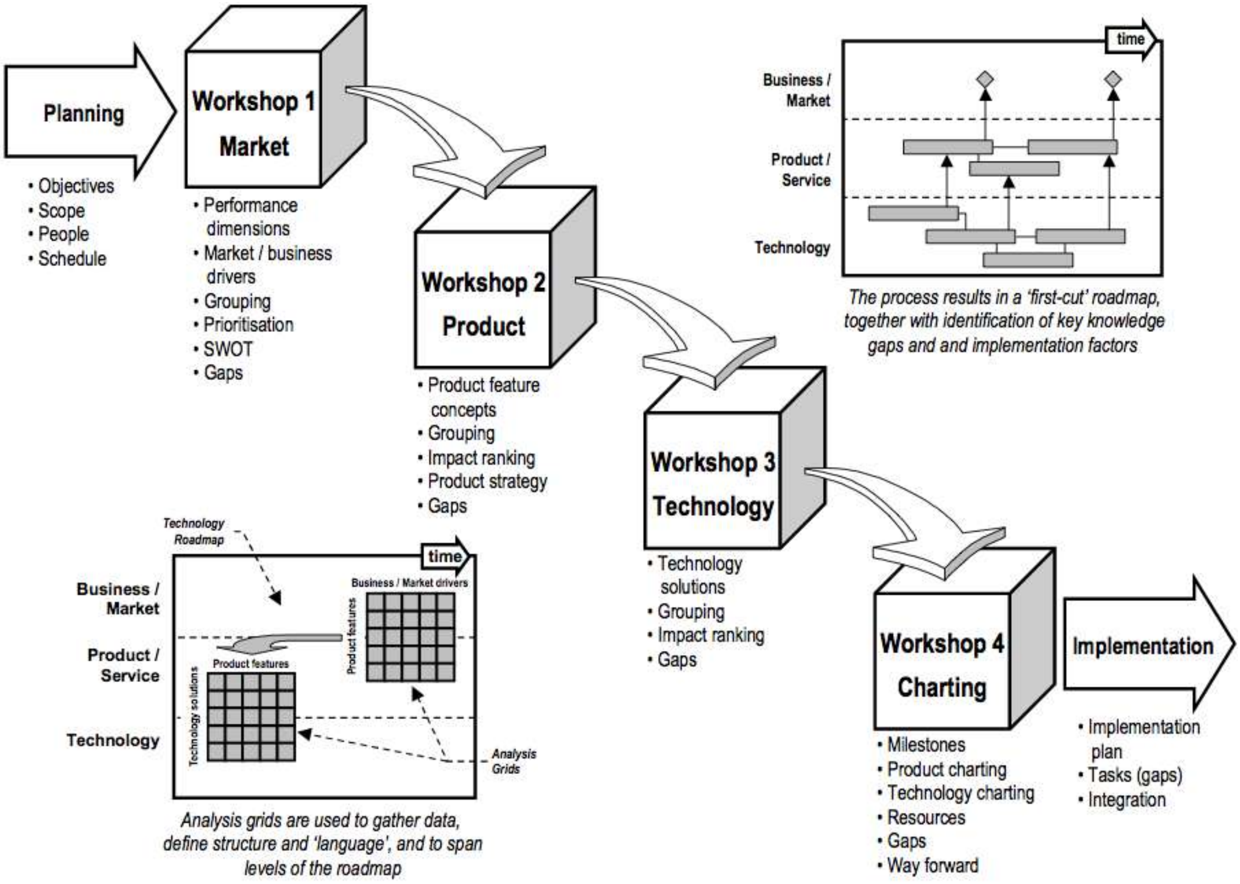


Figure 1: The T-Plan approach by Phaal [4]: standard process steps, showing linked analysis grids.

According to the T-Plan by Phaal [4], a roadmap has different purposes:

1. Product planning
2. Service / capability planning
3. Strategic planning
4. Long-range planning
5. Knowledge asset planning

6. Programme planning
7. Process planning
8. Integration planning

The roadmap under development in FI-LINKS relates mainly with the *Long-range planning* and the *Programme planning* items in the above list. In particular, the *Long-range planning* is described in the part of the T-Plan dealing with "Extending the planning time horizon …. often performed at the sector or national level ('foresight')". The *Programme planning* aspect is described in the part of the T-Plan dealing with "Implementation of strategy and … relates to project planning (for example, R&D programmes)".

Indeed the results of our roadmap should be a *Long-range planning* of FI research and innovation outcomes that support the European Commission in defining their H2020 *Programme planning* on FI innovation.

The key ingredients adopted in FI-LINKS to support and apply the T-Plan methodology are:

- An analysis of existing assets. Assets include: results achieved so far within the FI-PPP programme, such as the FIWARE platform, extensions to the FIWARE platform for specific domains, results of the large trials applying FIWARE technologies and existing roadmaps related to ICT and FI initiatives developed in Europe and worldwide.
- The involvement of FI experts through a series of workshops. These experts will provide their vision on the evolution of FI research and innovation and validate / comment the work done by the FI-LINKS team.

Starting from these key ingredients, the T-Plan methodology was customized as follows.

- **The contributing team**: The roadmapping team is composed by a set of in-house experts - part of the FI-LINKS consortium, listed in Table 1 and a set of external subject matter experts who collaborate with WP1 to steer the development of the roadmap. The external experts, listed in Table 2, may change during the roadmapping process, in line with the specific goals and expertise needed at a given phase.

Internal Expert Name	Expertise Field
Federico Alvarez	Networks and Internet Media
Fabio Antonelli	Internet Media
Federico M. Facca	Cloud Computing and service engineering
Estanislao Fernandez	Big data
Raffaele Giaffreda	Sensor networks and Internet of Things
Jose Gonzales	Networks
Eunah Kim	Internet of Things and Networks
Timo Lahnalampi	Market and business analysis
Elio Salvadori	Networks

Table 1: List of Internal Experts.

- **The schedule**: The roadmapping activity runs over two years (in line with the duration of the FI-LINKS project). The activity is organized to include two release cycles that gradually improve the roadmap with the different feedback and results of the analysis conducted in the 2-year timeframe.
- **The technological scope**: The roadmap will focus on technologies that have been core in the development of the FI-PPP initiative, so as to foster their next round of innovation. Thus, while certain technologies (or their parts) may be relevant (or key) in the overall FI panorama, they are not in the radar of FI-LINKS. For example, we decided to include in the roadmap only "overlapping" challenges on the network side with respect to the 5G PPP domain [5], Following these assumptions, the initial

set of technology areas covered in the FI-LINKS roadmap includes: **Internet Media, Internet of Things, Big Data, Cloud Computing and Networks**[7].

- **The temporal scope**: The initial work on the map differentiates between short-term challenges (that are going to be solved before 2020) and long-term challenges (that are going to be solved beyond 2020).
- **The geographical scope**: The roadmapping exercise conducted in FI-LINKS does not have specific geographical boundaries and it is to be considered generally valid for technological advanced countries. Nevertheless, being defined within the European research context, the map is widely influenced by it. To mitigate the weight of European vision in the roadmapping activity, we involved a number of external experts to pursue the goal of validating it with on-going international actions.

The scope and boundaries described above may change during the lifetime of the project to respond to new needs raised by the participants to the roadmapping exercise and by the other relevant stakeholders of the roadmap (e.g. FI-PPP programme participants, EU industries, European Commission).

Figure 2 presents the customized T-Plan adopted in FI-LINKS. The input planning (presented above) and reference material (e.g. existing roadmaps, market studies, FI-PPP assets, etc.) collected and analyzed upfront have been used as input for the first workshop (that was held on 15th and 16th October 2014 for the first iteration round).

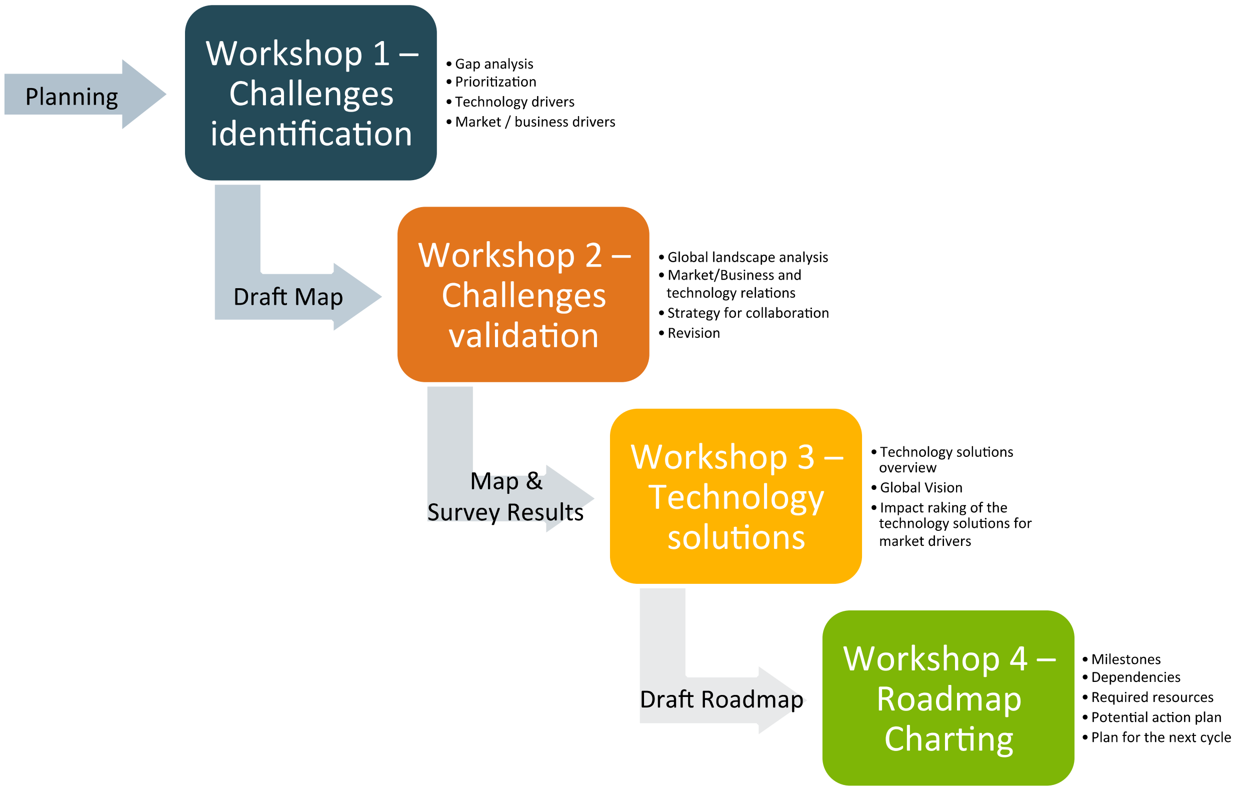


Figure 2: FI-LINKS Customized T-Plan approach.

The first workshop was an internal one among the FI-LINKS experts; the workshop started with the reporting on the analysis conducted on collected materials. The analysis discussion led to the identification of a number of challenges - *or drivers* - that have high chances to drive the innovation, either from a technological or market/business perspective; the proposed challenges have then been filtered by importance and mapped into the different technological areas (e.g. Cloud Computing, Big Data, etc.) and the relationships/dependencies across challenges have been analyzed and detailed. Dependencies affect also the timing of challenges (e.g. if

[7] In this deliverable, the term "Networks" corresponds to "Communication Networks".

challenge A is a prerequisite to B, then A should have a shorter timeframe than B). The main outcome of the workshop exercise was a set of conceptual maps presenting: (i) the relations between market drivers and technology drivers; (ii) the sub-challenges for each macro challenge/technology driver; and (iii) the relationships between challenges within the same technology area or across technology areas.

The second workshop was held on 12th November 2014 for the first iteration with external experts. This workshop focused on the validation of the work done. The panel was composed of high-level experts (see the list in Table 2) selected according to the following criteria: their expertise is not targeting a specific technology part of the roadmap; the experts should have a worldwide recognized authority, i.e. they should be affiliated to a leading technology research and/or innovation from a technology advanced country[8].

The workshop started by creating a common understanding about the priorities and the main on-going FI activities in the respective countries. Then, the international/external experts validates and discussed with the internal FI-LINKS experts the draft of the map (outcome of the first workshop) to deepen the analysis of relations between business and technology challenges. The workshop was also the chance to plan for further collaborations related to the roadmapping in the months to come. The outcome has been formulated as a report including a discussion of the global context (summarized in Section 3.2), a revised visual map accompanied by a description of the challenges and hints for the upcoming steps (i.e. the current deliverable).

Expert Name	Affiliation	Nation
Alberto Leon-Garcia, Scientific Director of the NSERC Strategic Network for Smart Applications on Virtual Infrastructures (SAVI)	University of Toronto - http://www.utoronto.ca	Canada
Heeyoung Jung, Chair of Network Working Group at ETRI	Electronics and Telecommunications Research Institute (ETRI) - https://www.etri.re.kr/eng	Korea
Nozomu Nishinaga, Director of NWGN Laboratory at NICT	National Institute of Information and Communication Technology (NICT) - http://www.nict.go.jp/en	Japan
Glenn Ricart, CTO at US Ignite	US Ignite - https://us-ignite.org	USA

Table 2: List of International Experts involved in the 2nd Roadmapping Workshop in the first year of the project.

Following the second workshop, the roadmap is ready to be shared with a wider audience and presented at different events to collect informal feedbacks from other relevant players. To collect more formal responses, the result will also be validated by a wider set of stakeholders through the creation of an online survey. The survey aims at gathering feedback on the released roadmap report. Aspects we will investigate include, for instance, the following: *Are there more technology or market areas - beyond the ones included that are key to the FI-PPP – to be discussed in the roadmap? Are the identified challenges the most relevant ones? Is the identified timeframe associated to these challenges correct? Is any relevant challenge missing? Do the challenges cover all the major need of future business and market drivers?*

In the first iteration, survey participants will be selected from relevant communities in the FI-PPP context. During the second iteration, the group of participants will be extended. Collected feedback will be key input to the third workshop. The third workshop – an internal one (April 2015) – will focus on analysing the survey results and on discussing their application to the roadmap. From the above inputs, the discussion during the workshop will aim at identifying a list of potential technology solutions to the challenges, ranking the solutions according to the market drivers and trying to harmonize the results of such exercise into a summary vision for the roadmap. The outcomes of the workshop will be consolidated in a draft roadmap.

The draft roadmap will be finally discussed with a set of external experts (fourth workshop, planned for Q2

[8] Reference countries identified in the Description of Work and in agreement with the European Commission are: Canada, Korea, Japan and US.

2015). This final workshop will focus on the proposition of a plan to support the enactment of the roadmap in support of the H2020 programme. For each technology and market area, a timeline will be proposed with the expected different achievements (milestones) and possible support instruments (e.g. European Research or Innovation programmes, Industrial programmes, etc.) and an estimation of the required investments will also be given. The result of this activity will be a consolidated version of the roadmap ready to be distributed to EU industries and researchers (June/July 2015).

During the second year of the FI-LINKS project, this process will be repeated to further elaborate the roadmap vision; specific drilling down into selected technologies and business areas might be organized to better explore and asses the roadmap vision according to relevance that might become more clear later on during the project.

2.1 The process behind the technology challenges' map

In this deliverable, a key instrument that the reader will find is a customized version of a conceptual map to highlight challenges within a technology area, their timeline and the existing relations between them. In the following, we shortly describe how the conceptual maps are defined and how to interpret them (basically providing more details about the process described above for the first two workshops).

The 1st workshop was run as follows:

1. For each technology area, the group of internal experts for that area presented the identified challenges, which were then discussed.
2. The challenges identification was based on:
    a. Analysis of existing roadmaps related to the given technology.
    b. Internal experts' vision on the future of the technology area (or Chapter[9]).
3. The Technology Chapter discussion outcomes included:
    a. What are the challenges part of the conceptual map and what should be excluded.
    b. What is the timeline of identified challenges (short-medium term = market, medium-long term = research).
    c. Type of challenge (technological / business).
    d. (if any valid) European relevance / other geographical relevance.
4. The results of the discussion for each technology area were summarized in a conceptual map. Each technology challenges' map includes up to 5 macro challenges and highlights the following information:
    a. Timeline of challenges.
    b. Importance of challenges (mark: 1…5, where 1 ranks the top challenges).
    c. Type of challenge (business/technical).
    d. 2-3 sub-challenges (if any).
5. All experts of the different technology areas discussed cross-relations between the different conceptual maps.
6. The discussion was summarized in a high-level summary conceptual map and in the refinement of the single conceptual maps.

Each circle in the conceptual map represents a high-level challenge (see Figure 3). The colour's scale identifies the timeline of the challenge: a light colour represents a short-term challenge, a dark colour a long term one.

[9] Technology Chapter is the term used in the context of FIWARE. FIWARE Chapters are discussed at this link: http://www.fi-ware.org/our-vision/

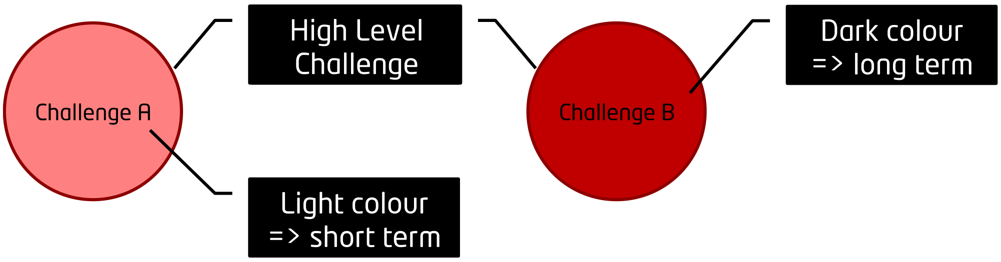


Figure 3: High Level challenges and their timeline representation.

Sub-challenges are represented as smaller bullets connected to the challenge circles (see Figure 4). Also in this case, the colour's scale identifies the timeline of the sub-challenge. Dependences between challenges/sub-challenges are highlighted with dashed lines.

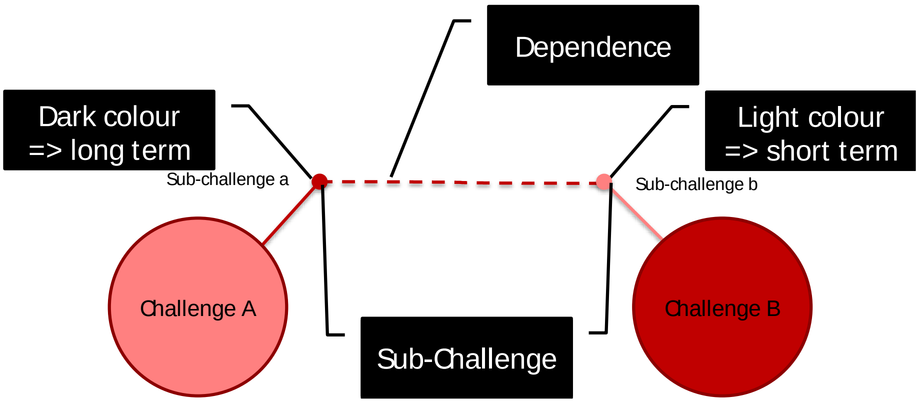


Figure 4: Sub-challenges, and relationships representation.

3 AN OVERVIEW OF CHALLENGES FOR FUTURE INTERNET INNOVATION

As a major result of the process described in Section 2, we developed the conceptual map of challenges for the Future Internet Innovation presented in Figure 5. The map does not aim at being complete. It reflects a number of challenges that by consensus (in the documents analyzed and through the feedback of experts) have been agreed as being of major importance in the context of FI-based innovation according to the currently activities within the FI-PPP context.

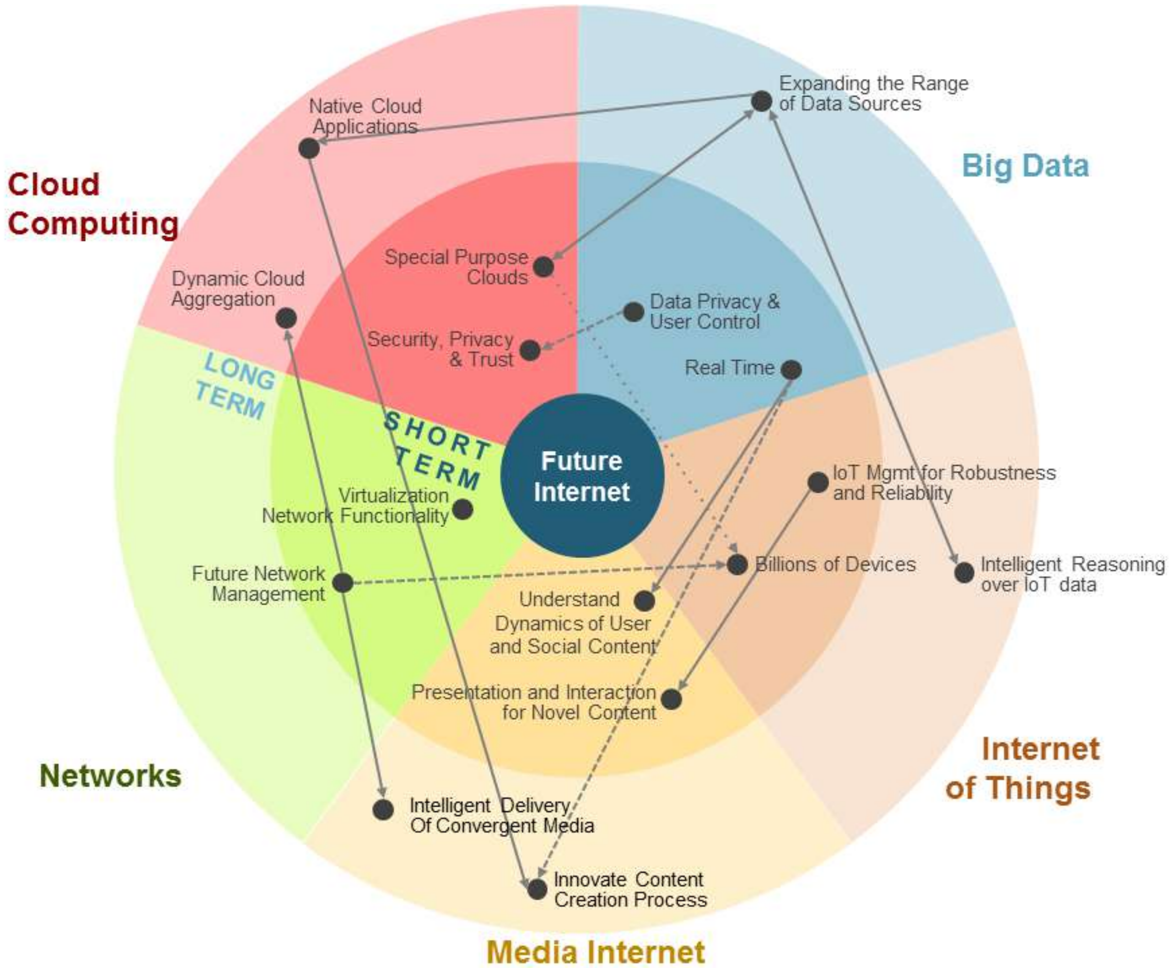


Figure 5: Map of the main challenges for the Future Internet Innovation programme and their relations.

The global map of the FI intends to offer an overall perspective of the core technologies which we believe constitute the base for the FI and the existing relationships among them.

These core technologies include: Media Internet, Internet of Things, Big Data, Cloud Computing and Networks. The map of challenges considers only the elements and aspects which are contributing to the FI in a holistic way and which may have implications on each other (e.g. at the "Networks" domain level we considered the virtualization via SDN and NFV, which have implications for "Cloud Computing" and/or "IoT", but not the research that is done about the physical network layer since, although it may be correlated to bigger capacities and higher speed, it is less connected to new ways of creating distributed Clouds).

The core technological areas, as indicated in the figure above, include a set of challenges. These challenges are the technical macro-challenges for each technological area.

3.1 Organization of the Challenges Map

In this Sub-section, we explain the general relationships among the technical challenges that constitute the FI. What are the parts that compose the map? and what are the relationships between the challenges? Note that only high-level relationships can help understanding the proposed concept of the Future Internet".

We present hereby some relationships between challenges, just to explain the connections. In the technical chapter of this document (Section 5), we will present and explain in more detail the technological challenges and sub-challenges.

1. **Cloud Computing and Big Data.** Data privacy and user control have direct implications for Cloud security and trust. One of the barriers for the development of Cloud Computing for the FI is the development of trust mechanisms and improved security for the data processing and storage in the Cloud. Another direct connection is the use of the Cloud for new uses of Big Data with extended range of data, as for example media analysis or dedicated apps (e.g. in the healthcare domain). This is linked to the need of customized Clouds that can be adapted to specific needs. Going beyond, native Cloud applications can help to better use Big Data as they can provide improved capabilities to the Big Data application: a program that is specifically designed for a Cloud Computing environment as opposed to simply being migrated to the Cloud will provide improved capabilities.
2. **Big Data and Internet of Things.** Another direct connection is the use of Big Data to off-load the computation needs of the Internet of Things (IoT). For example, in a Smart City scenario, the data collected by some given IoT sensors needs appropriate Big Data analysis techniques to allow decision-making concerning that city to be effective, which cannot be computed in the sensors themselves, but instead will have to leverage on a Cloud Computing approach - i.e., offloading computing capacity to the Cloud.
3. **IoT and the Media Internet.** One of the examples of the links between these challenges consists of the techniques for presenting, providing and consuming media content, such as tele-immersion or Augmented Reality-based mechanisms, which can be improved with the deployment of IoT components. These IoT elements can complement and enhance basic data/content through new sensors and associated networks able to capture and provide information that can be elaborated to contribute to the media Internet creation and offering (e.g. with accurate positioning or improved capabilities such as Brain-Computer-Interfaces - BCIs).
4. **IoT and Cloud Computing.** The deployment of IoT components to gather data and links between different "IoT islands" can be enhanced by a Cloud that offloads the computing power and management from the IoT network. Beyond that, the "Cloudification" of IoT will allow for new unforeseen applications that will strength the linkages between those challenges, such as platforms accessing virtualized sensors in the Cloud which can provide developers environments where to program the same app and run in different IoT environments.
5. **IoT and Networks.** There is a clear relationship between IoT and Networks, for the FI. In the future scenarios with billions of interconnected devices (from the deployment of IPv6 or new short-range networks), the capacity of Networks to connect a high density of pervasive and IoT-enhanced devices becomes crucial. Also the type of traffic generated by IoT/M2M communications will have strong implications on the way Networks are designed.
6. **Big Data and Media Internet.** Media analysis and multimedia search are two examples of the possibilities arising from the combination of Big Data in the media Internet. Big Data is opening new opportunities for media processing. Moreover Big Data analysis and mining of social media-content is also another key aspect for the FI.
7. **Networks and Media.** The distribution of media can be enhanced by the provision of lower-latency, higher reliable, improved QoS and increased bandwidth Networks, especially when considering immersive or high quality content beyond 4K.

8. **Cloud and Media.** Cloud and Media, in the cooperative content production and media processing is one of the future directions in both challenges. For instance, the co-creation of video by different users is one of the examples of Cloud use in Media. In addition, the use of Cloud for storing a large amount of content, which can be remotely processed, is another example of the existing relationships.
9. **Cloud and Networks.** Distributed Clouds need reliable and fast connections to act as a federated or unified Cloud so to improve the Quality of Experience of users that will not be affected by the location of Cloud resources used by applications they access.

3.2 The Global Context summary

Note: This is a summary of the information gathered by the FI-LINKS Advisory Board members. More information can be found in the Annexes.

The global context was defined by considering different international regions, which we considered have a similar development when compared to the EU. These regions, as of today, are: US, Japan, Korea and Canada. In addition, the view from Latin America for the FIWARE adoption was also taken into account. This view was given by an expert from Chile who is involved in FI-related activities and coordinates across several Latin American regions/countries.

3.2.1 United States

In the United States, the term “Future Internet” is used sparingly. President Obama’s Administration focuses on “broadband” issues, and the guiding national document from the government is the *National Broadband Plan* (2010). Research funded by the National Science Foundation (NSF) is now focusing on “Cloud” research issues. American corporations often focus on the network management benefits of their solutions and often market with a “**Smart** x” emphasis where “x” can be “cities,” “objects,” “schools,” “planet,” and so forth.

On the infrastructure side, the most visible thrust is gigabit to the end user in a new race triggered by Google Fiber. However, in carrier infrastructure, the emphasis is on improved network management and flexibility through Software-Defined Networking (SDN). Wireless is moving quickly to improve coding efficiency, take advantage of MiMo technologies, and adopting LTE-Advanced so as to keep up with the increasingly phone-centric habits of Americans.

There is a mad scramble for ownership of the application space. Carriers, who do not want to just have the role of bit pipe providers, are rolling out proprietary applications that will provide extra value to their service as well as lock people into that carrier. Phone vendors are stuffing their phones with proprietary apps that hope to be market differentiators. Google believes it can own the application space because of its dominance in data and because it provides some nearly irresistible free services to help collect that data and serve targeted adverts[10]. Apple’s claim on the application space is its integrated hardware/software design and emphasis on usability[11].

The telecommunication policy in the United States is fragmented with several roles being played by local regulatory agencies, the legislative environment in each state. The deployment of national solutions may be constrained by blocking legislation in certain states. In addition, the national government’s Federal Communications Commission (FCC) has been struggling to apply the right amount of regulation on a previously unregulated Internet (c.f. Net Neutrality).

There are several initiatives related with FI in US. They can be divided in several items in order to capture the whole panorama:

- **Infrastructures**: Large network infrastructures that provide access to the Internet can be further divided into:

[10] http://www.google.com/about/company/products/

[11] http://www.apple.com/about/

- Infrastructures owned by corporations (among the most popular: Verizon, AT&T, CenturyLink, Comcast, Sprint, and T-Mobile). AT&T announced in mid-2014 to move its network to SDN for control and management purposes.
- Infrastructures owned by public institutions, such as Internet2 and Regional Optical Networks that provides Advanced Layer 3 services (AL3S), and Advanced Layer 2 services (AL2S). Internet2 has moved to SDN to control its network and it is now offering "virtual networks" that can be programmed by third parties.

- **Gigabit symmetric access**: Companies providing 1Gbps connectivity to users. Available only in a few US cities.
  - Google through its Google Fiber initiative[12].
  - AT&T with its recent 1 Gig Internet initiative[13].
- **Locavore infrastructures**: There are a few national projects (US Ignite, GENI), which are building mini-datacenters in order to make network edges programmable and capable of offering lower latencies services. This transformation is expected to trigger a large set of novel scenarios that will benefit from such ultralow latency.
- **SDN Exchange Points:** This is somehow connected with the locavore infrastructure and it basically targets the set-up of exchange points leveraging on SDN technology to facilitate the interconnection among different datacenters and mini datacenters. For the time being, it is mainly investigated by Universities.
- **Government infrastructure research**:
  - GENI is the primary research testbed for distributed and locavore FI technology, with 55 racks located across the US.
  - Future Internet Architectures: five projects funded by the NSF are exploring novel Internet architectures (i.e., XIA, Mobility First, Named Data Networking, NEBULA and Choicenet).
  - NSF Cloud: two big Cloud-related projects have been launched: CloudLab (a meta-Cloud which incorporates GENI as backbone network to interconnect remote datacenters) and Chamaleon (more focused on HPC technology).
- **FI applications**: there are two major initiatives:
  - US IGNITE: an initiative coordinated by the White House to develop and deploy next-generation applications enabled by FI infrastructures. The goal is to have 60 next-generation applications by 2017 in different sectors and 200 “smart” cities which are deploying these applications on an advanced infrastructure.
  - Global City Teams: The US National Institute of Standards and Technology has recently announced the formation of Global City Teams to leverage the Internet of Things to help create smart Global Cities.

3.2.2 Japan

The focus of the FI-related initiatives in Japan is primarily on the networks, especially on the New Generation Networks (NWGN) based on the principle of “clean-slate” rather than that of “patching the Internet”. The aim is to create a network that serves as a new social infrastructure with a life span of 50 to 100 years, free from the typical problems (e.g., latency, capacity, etc.) that today’s Internet has.

The following list summarize the challenges tackled by NWGN:

[12] https://fiber.google.com/about/

[13] http://about.att.com/story/att_eyes_100_u_s_cities_and_municipalities_for_its_ultra_fast_fiber_network.html

1. Value Creation Network. The aim is to bring new service innovation in the network, growing beyond services simply offering connections. The issues are the creation of a new value chain for offering services from the user standpoint, and the coexistence of diversifying user needs with sharing of functions for service execution.

2. Trustable Network. The information and communications network is absolutely essential in all social activities of individuals and organizations, and the stability and "trustability" of the network itself are important aspects for maintaining continuous network functions.

3. Ambient/Ubiquitous Network. Environmental problems, food problems, ageing problems, etc. can be raised as social problems closely related to the social life of humanity that are foreseen in the time of the new generation network.

4. "Self-* Network. The network is being used for data transfer like Web and email, and also to transfer sensor data and streaming data, such as voice and video. There is also rapid progress in the diversification of services, such as offering applications and platforms through the network, called PaaS (Platform-as-a-Service). On the other hand, though the accompanying conditions required for services are also diversifying, they are not fully satisfactory, and dramatic problems are foreseen. A network that everyone can use unburdened shall be achieved, which can respond flexibly to the conditions requested by services.

5. Sustainable Network. Information and communications means such as cellular phones, Internet, email, search engines, etc. have already become indispensable infrastructure for the modern society. These information and communications means have been achieved through synergistic effects of breakthrough innovative technologies, especially extra-large capacity (high speed) communication technology typified by optical fibers, Internet technology, mobile telecommunication technology typified by cellular phones, computer technology such as CPUs and memory, etc.

As said, the major focus of Japanese research on FI is on networking aspects. Current major activities can be grouped into five major representative projects:

- **Network Virtualization project**: Both ***wired***, with a testbed active since 2013 that can instantiate fully virtualized networks that can host "clean-slate" Internet architectures on top, and ***wireless***, dealing with service-specific mobile networks targeting quick response in application, higher efficiency in resource utilization, and reduction of signalling messages. This project deals with both Mobile NFV technology and WiFi-based network virtualization.
- **Content-Oriented Networking project (CON)**: This project is targeting the design of a natural communication architecture (along with ICN design concepts) enabling lower response time thanks to in-network caching, efficient network resource saving, one-to-many and many-to-many communications, and better support for mobility.
- **Very Large-scale Information Sharing Network project (PIAX)**: The goal of this project is to establish trustworthy large-scale sensor network construction technologies, that treats the discoveries and information exchanges between huge number of objects (sensors, terminals, etc.) in a wide-area network environment. It is leveraging an open middleware for sensor networking that support huge numbers of objects dynamically appear/disappear on network and change their attributes.
- **Japan-wide Orchestrated Smart/Sensor Environment (JOSE)**: This project leverages on the technology and testbed available through both the NV project and the PIAX project to combine the large number of wireless sensors placed in the real world, SDN capabilities and distributed Cloud resources with the objective of accelerate field trials of "large-scale smart ICT services" essential for building future smart societies.
- **CUTEi (Container-Based Unified Testbed for Information-Centric Networking)**: This project focuses on the creation of a testbed that leverages on the technologies developed via the CON project that facilitate the execution of ICN experiments with LXC (Linux container) technology. Beyond Japanese nodes, it includes also nodes from US, Europe, China, Taiwan and Korea.

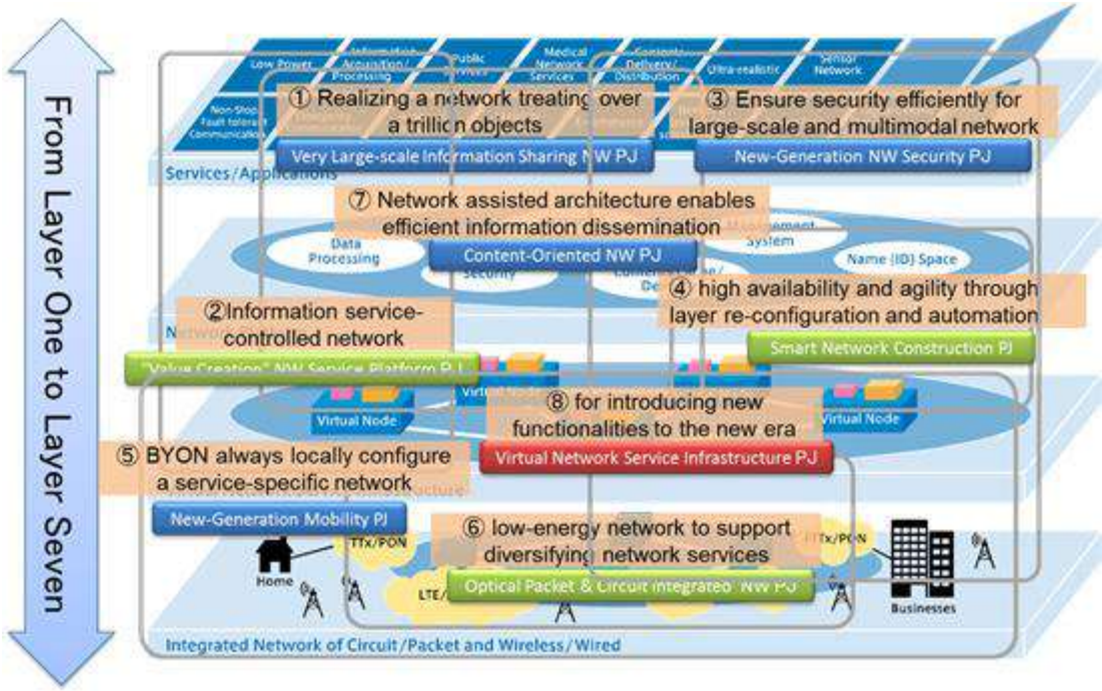


Figure 6: Japan’s strategy for the Future Internet.

3.2.3 Korea

Korea has a very high Internet penetration. According to statistics provided in [25], the Internet penetration and Internet users in Korea was already 84.8 % and 41.6 million, respectively, in December 2013. Note that the Internet penetrations of other major areas are 31.7% in Asia, 68.6% in EU, and 84.9% in North America. Korea is also offering a high speed Internet infrastructure. It is reported that Korea is at the very top for fast broadband, with 77% penetration rate of 10+ Mbps connections. Japan is the second with 54 %, while Sweden and Netherlands are the third and the fourth ones with 45% and 44%, respectively [26].

The well-established Internet infrastructure of Korea is fundamentally changing the people’s daily life. Most Korean enjoys various services over the Internet such as e-government, e-banking, e-shopping, on-line education, and e-games.

FI has become the hottest research topic in Korea since mid-2000. The establishment of the Future Internet Forum Korea (FIF) was the first activity for FI research [27].

The core approaches for FI in Korea can be categorized into two main streams: **architecture-focused** and **testbed-related**. Regarding architectural research, the first official project was launched in 2007. SNU (Seoul National University) led the project and some major Korea universities joined. The main research topics of the project were well-known hot issues in the FI, such as CCN (Content Centric Networking), DTN (Delay Tolerant Networking), multicast, etc. For the testbed-driven research, a new project for experimenting with revolutionary networking architectures was also run under the name of FIRST (Future Internet Research on Sustainable Testbed) in 2009. Core technologies for FIRST were programmability and network virtualization. Since then, many FI related research projects have been performed by several research institutes and universities in Korea. Currently, Identifier (ID) based networking is the representative architectural research and OpenFlow based SDN is the most popular research topic related to testbeds.

The current focus of Korean research on FI is related to two major initiatives:

- **IDNet**, a project dealing with name-based networking which is a follow-up of previous project called MOFI (Mobile Oriented Future Internet). It has mostly to do with ICN technologies and IoT.

- **Smart Internet:** the target of this project is to make the Internet smarter and more flexible using SDN and NFV related technologies. It is the follow-up of FIRST testbed. It includes several projects among them: IRIS (ETRI Recursive SDN controller platform), which is about developing a scalable recursive SDN OpenFlow Controller for carrier-grade network, and a Smart Node platform, an open unified platform to share networking, computing, and storage resources. Smart Internet will have a phase 2, which plans to move the project toward novel services development and commercialization.

3.2.4 Canada

Canada, differently from other countries, has no research and innovation programme dedicated to the FI. Nevertheless, there are important efforts targeting some open Internet challenges such as: naming and addressing scalability, transition to IPv6, routing and multi-homing, and lack of open connectivity. These challenges are not new and they show the slow space at which the current Internet can evolve. Given the absence of a FI framework as such in Canada, in the research arena there is a concern that Canada may be late to embrace the FI.

The major on-going research initiatives in Canada that can be related to FI are:

- **SAVI (Smart Applications on Virtual Infrastructures)** is a *Natural Sciences and Engineering Research Council of Canada* (NSERC) Strategic Network funded project. The project focuses on an application platform for open content and applications marketplace. The idea is to let researchers/developers deploy smart applications on a multi-tier Cloud, leveraging a smart edge based on virtualized wireless access. SAVI includes also a national testbed with 7 nodes.
- **Green Telco Cloud** aims to extend the CANARIE GreenStar Network. It has a strong focus on the virtualization of telco infrastructures and it takes into account the Cloud life cycle and the overall environmental impact, leveraging on workload optimization, energy consumption and GHG emissions minimization.

These major initiatives are complemented by a further set of initiatives, such as the i-Canada Alliance that aims to improve the development of smart applications in different cities and communities across the country.

Finally, the national NREN - CANARIE - has recently launched an accelerator program called DAIR to let innovative SMEs and start-ups leverage on their advanced networking infrastructures to implement next generation applications. Therefore, even though there is no “official Future Internet” framework, these sets of activities that relate to it are in the FI-LINKS radar.

3.2.5 Conclusions

The landscape presented by international experts highlights how, with minor differences, the different countries activating large investments toward Internet innovation and research share a wide set of priorities. In general the trend is to diversify the investments toward two main directions: **advanced infrastructures** (Network, Cloud, Sensor Networks) and **applications** exploiting the capacity of the advanced infrastructures.

Innovation and research on advanced infrastructures is largely pushing the self-* capabilities in the different network layers and largely exploiting the software-defined approach (in networks, datacenters, sensor networks, etc.). Many activities also highlight early experiments toward edge infrastructures (mini datacenters, SDN at the edge) pushed by *connected everywhere* scenarios and environmentally friendly infrastructures (in a holistic and multi-disciplinary approach). In parallel to actions related to “additive” (short-term) technology in the infrastructures, experiments are conducted as well on disruptive (long-term) technologies aiming at changing the Internet architecture to solve the inherent problems of today’s Internet.

In a similar fashion to the FI-PPP programme, different initiatives are starting globally to push crowd sourced innovation for the development of novel “smart” applications that can focus on improving daily life and activities of citizens and companies, based on the innovative capacity provide by advanced Internet-based infrastructures. Such applications strongly build on higher-speed broadband everywhere connectivity, virtualization of infrastructure resources, sensor network and Big Data management solutions on the Cloud.

4 BUSINESS CHALLENGES FOR THE FUTURE INTERNET EVOLUTION

Section 3 introduced the five technological drivers that FI-LINKS has identified as core for FI innovation in Europe. These are: “Media Internet”, Internet of Things”, “Cloud Computing”, “Big Data” and “Networks”. In this Section, we explain the business and market environments for the selected five technology drivers.

In order to identify new business innovative areas of FI-PPP, we analyze the current FI-PPP context including its targeted services and map these to diverse industrial sectors. In a broader perspective, more future oriented, we also identify four Science & Technology areas which will influence FI innovation and new business opportunities: **Bio, Clean Tech, Nano and Neuro**; and describe some of their new potential services/products/innovations/technologies in each Science & Technology area and link them to the current adoption of FI-PPP technologies in these areas.

Overall, the global Telecom and ICT industry market will grow in the future almost 10% per year[14]. The increasing number of smartphone subscriptions is one of the main drivers leading to a huge increase of the data traffic in wireless networks. Ericsson estimates that there will be 6.1 billion smartphone subscriptions (currently 2.7 B) on 2020 and each active subscriber would generate 3.5 GB (current 900 MB) data traffic meaning that the total smartphone traffic would be 17 EB on 2020 (current 2.1 EB). Video (Media Internet) continues to keep the leading position as the most data hungry application[15].

The rising Cloud Computing services are the other main drivers meaning that there will be more requirements for the network speed and reliability. The Cloud Computing market size is expected to grow from $70 M to $241 billion by 2020.

The other main industry growth drivers are increased sensors on the market (Internet of Things, IoT) including e.g. the automotive industry. The integrated GPS and mobile transmitters in the cars can send alert signals in case of traffic accidents already today; in the future similar sensors could be used for communication between cars (without drivers) and for the communication with the traffic monitoring system e.g. to automatically adjust car’s speed to avoid traffic jams and reduce CO2 emission.

Business models will also change. The telecommunications industry is already facing a practical challenge when needing to move from the voice-centric business to the data-centric business. In the future, there will be new types of Service Providers and Virtual Operators in the ecosystem meaning that current large telcos need to adapt to new services to be able to extend their existing data-pipe type of business. Although the technology might be ready for new kinds of mobile services, the missing business models or agreements between Network Operators and Service Providers may slow down the actual service take-off.

4.1 Hype cycle and timeline of emerging science and technologies

New technologies, services, products and their maturity, adoption and time to enter to mass market have been illustrated in a graphical tool called Hype Cycle[16]. The Hype Cycle describes the path that technologies generally take from their initial invention/introduction into the mass market until their eventual maturation into useful components of broader solutions.

[14] http://www.slideshare.net/ashutosh.p/global-telecom-trends-by-2020

[15] Ericsson Mobility Report November 2014: http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-november-2014.pdf

[16] http://en.wikipedia.org/wiki/Hype_cycle

The Hype Cycle consists of the five main phases[17] as depicted in Figure 7:

- **Innovation Trigger** – over 10 years before mass market
    - A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.
- **Peak of Inflated Expectations** – 5-10 years before mass market
    - Early publicity produces a number of success stories - often accompanied by scores of failures. Some companies take action; many do not.
- **Trough of Disillusionment** – 2-5 years before mass market
    - Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
- **Slope of Enlightenment** – less than 2 years before mass market
    - More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
- **Plateau of Productivity** – mass market adoption
    - Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.

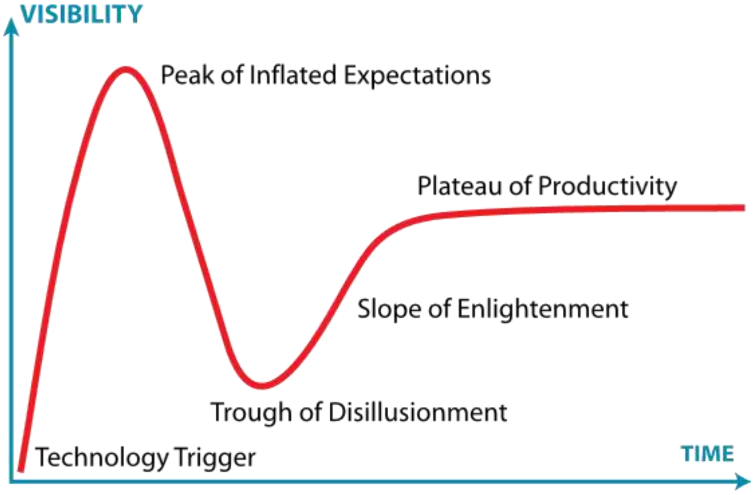


Figure 7: Hype Cycle phases.

It is worth noting that the Hype Cycle focuses on new emerging technologies as they move into mainstream (Plateau of Productivity). In practice, leaving the Hype Cycle does not mean that the technology is being dead; in fact, it may hit a strong period of growth in the mass market when the component prices are low enough and the technology itself is ready for a mass production.

[17] http://en.wikipedia.org/wiki/Hype_cycle

4.1.1 Hype cycle for emerging technologies

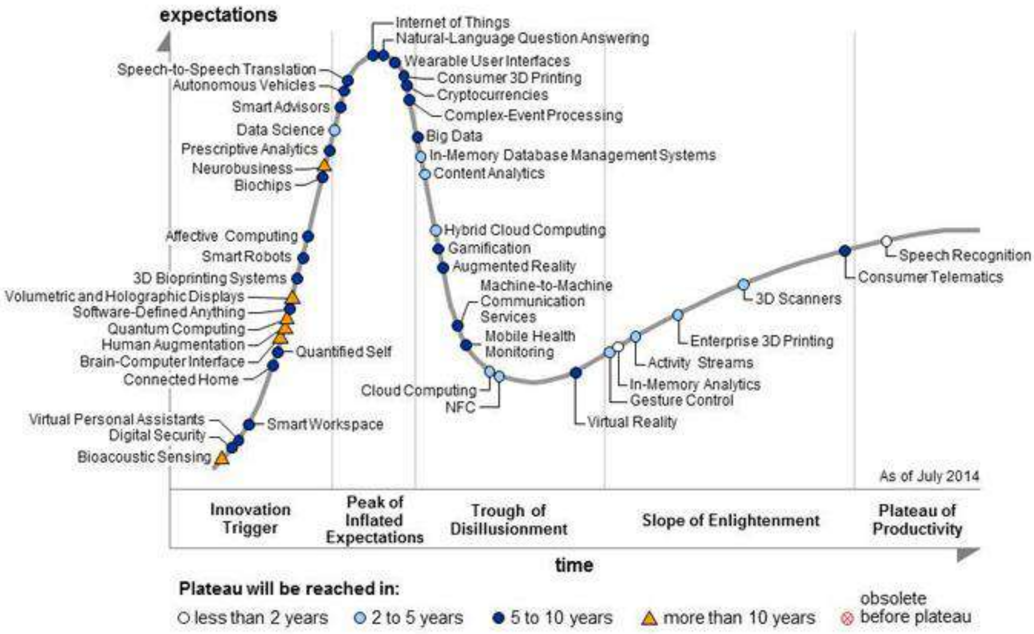


Figure 8: Hype Cycle for Emerging Technologies, 2014.

The IT research and advisory firm Gartner has produced several "Hype Cycles" for Emerging Technologies. In the latest one, published in June 2014, three technology areas described in Section 3 are estimated to enter to mass market during Peak of Inflated Expectations and Trough of Disillusionment phases:

- “Cloud Computing” in 2-5 years,
- “Big Data” in 5-10 years, and
- “Internet of Things” in 5-10 years.

The “Networks” and “Internet Media” are actually already in a Plateau of Productivity phase (mass market adoption) having their own technology evolutions:

- “Networks” moving next from 4G to 5G and having more SW driven functionalities (SDN/NFV), and
- “Media Internet” where e.g. today YouTube HD videos dominate the data consumption in the networks; in the future 3D and 4k video formats will require even higher data speeds and more network and storage capacity.

As innovation triggers, many of multi-sectorial technologies are listed as followings:

- Brain computer interface, Neuro-business, speech to speech translation: Neuroscience and FI are combined and open new and diverse innovative opportunities
- Biochips, 3D Bio-printing systems, Bio-acoustic sensing: BIO, Healthcare and Internet technologies are triggering each other for the business innovations.
- Autonomous vehicles: Automobile manufacturing and ICT (software platform and advanced networks) industries are competing and collaborating for new concepts of transportation.
- Virtual personal assistants: Work environment and healthcare systems are moving to green assisted by advanced network technologies and tools.

These business innovation triggers are refined in Section 4.4.

4.1.2 Timeline of Emerging Science and Technology

Beside the Gartner's yearly Hype Cycle, the Imperial College London has created a more futuristic Timeline of Emerging Science & Technology map that covers five key Science & Technology areas: **Digital, Bio, Nano, Neuro and Clean Tech (Green Tech)**. The timeline describes technologies, trends and big ideas what is currently happening, what's probably going to happen and what could possibly happen:

- "Present", which includes services, products or technologies which are available now or in the near future (2014-2015) with at least 1000 working examples where appropriate;
- "Probable" is the second zone and it is defined to cover timeframe 2015-2030; and
- "Possible" is the third zone defined as being potentially available from 2030 onwards[18].

By using both the Gartner's *Hype Cycle for Emerging Technologies* and the Imperial College's *Timeline of Emerging Science and Technology*, which both complement to each other and have some common identified elements, we describe in each science & technical area with some selected potential future services, products, technologies, trends and big ideas, and link them to current FI-PPP usage areas and to the selected technology areas in the following Sections.

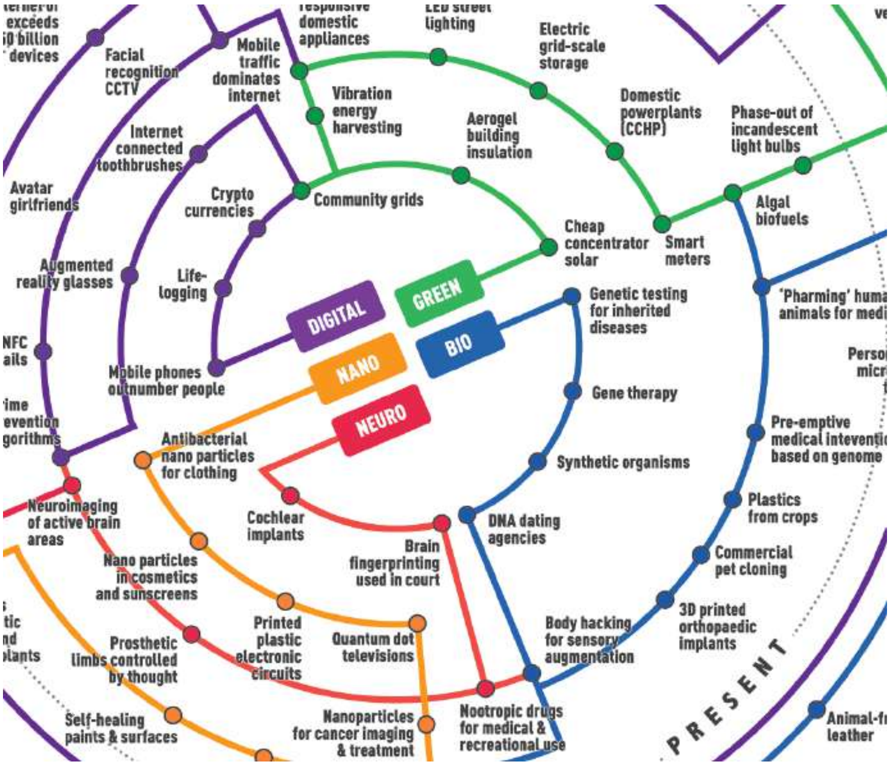


Figure 9: Timeline of Emerging Science and Technology.

4.2 The selected technical drivers of FI and their market estimation

In this Section, we explain the business and market environments for the selected five technology drivers of FI: Internet of Things, Big Data, Cloud Computing, Network virtualization, and Internet Media (connected media).

[18] http://www.imperialtechforesight.com/future-visions/87/vision/timeline-of-emerging-science-and-technology.html

4.2.1 Internet of Things

The Internet of Things market, which comprises sensors embedded, e.g. in the connected cars, smart homes, and wearables, excluding PCs, tablets and smartphones, will grow up to 50 billion devices units installed in 2020 according to Cisco[19] and Ericsson[20]. The global IT research companies like Gartner, IHS Global Insight, ABI research and IDC, as well as the specialized IoT research firm Harbor Research, have made lower forecasts from 32 billion to 18 billion devices on the market in 2020. On the revenue side the five market research companies: IDC, Visiongain, Harbor Research, Markets&Markets and Gartner, have estimated the market potential in 2020 to be between $300 billion (Gartner) and $7 trillion (IDC). Big differences can be explained, e.g. with the market value starting point differences in 2014 and then differences with the market growth figures between 2014-2020: e.g. Gartner 50% and IDC 200%.

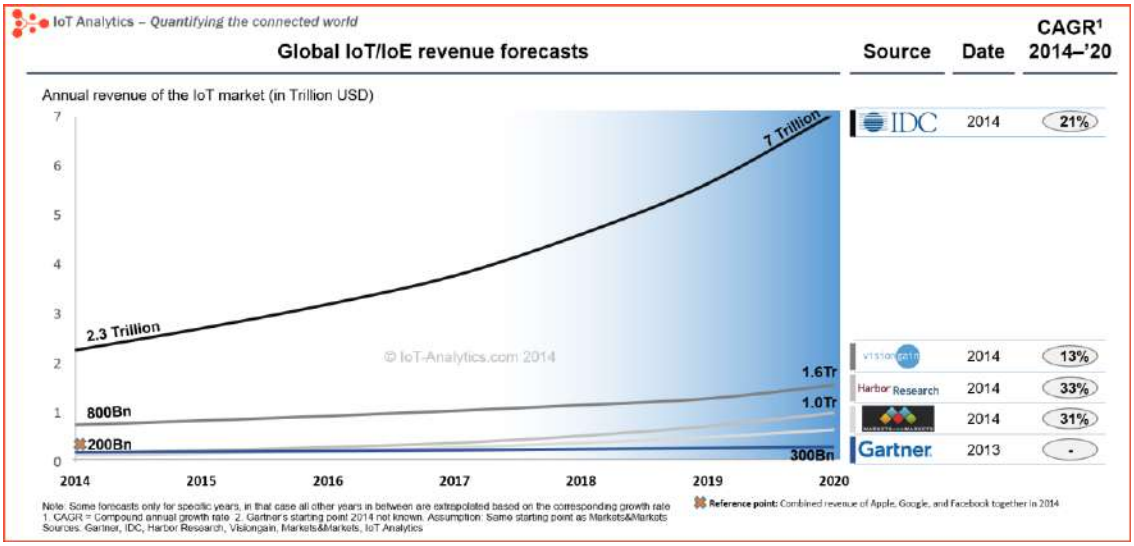


Figure 10: Global IoT/IoE revenue forecasts.

4.2.2 Big Data

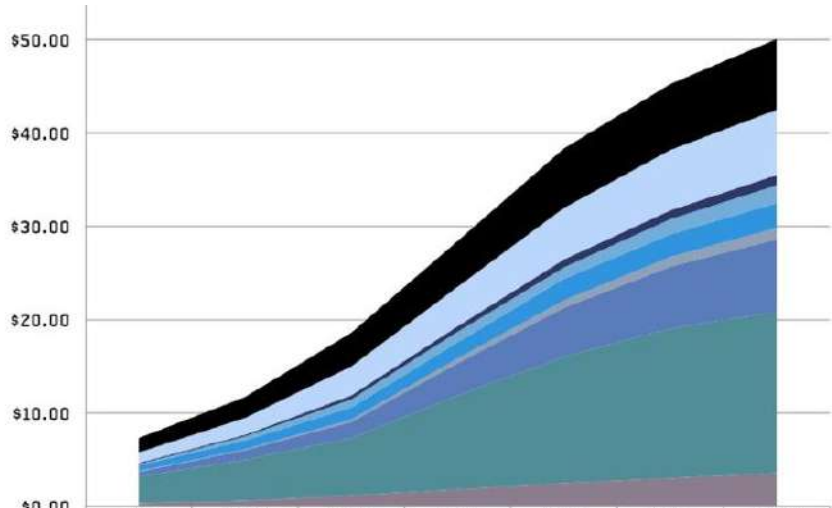
Big Data originally emerged as a term to describe datasets whose size is beyond the ability of traditional databases to capture, store, manage and analyze. However, the scope of the term has significantly expanded over the years. Big Data not only refers to the size of the data itself but also to a set of technologies that contribute to capture, store, manage and analyze large and variable collections of data to solve complex problems.

The Big Data market is projected to grow to $50 billion in 2017 according to Wikibon[21]. Below is a graphic from the study, illustrating Wikibon's Big Data market forecast broken down by market component through 2017. The professional services dominate the overall revenue in 2017 with $17 billion share, followed by Apps & Analytics and Compute with $8 billion share.

[19] Cisco: The IoT - http://www.cisco.com/web/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf

[20] Vision 2020 - 50 Billion Connected Devices – Ericsson: http://www.slideshare.net/EricssonFrance/vision-2020-50-billion-connected-devices-ericsson

[21] http://wikibon.org/wiki/v/Big_Data_Vendor_Revenue_and_Market_Forecast_2013-2017



	2011	2012	2013	2014	2015	2016	2017
Compute	$1.53	$2.29	$3.65	$4.92	$6.40	$7.10	$7.60
Storage	$1.10	$1.75	$3.09	$4.20	$5.50	$6.40	$6.95
Networking	$0.15	$0.23	$0.42	$0.65	$0.85	$1.01	$1.15
Infrastructure Software	$0.14	$0.44	$0.83	$1.08	$1.25	$1.60	$1.90
SQL	$0.62	$0.88	$1.31	$1.75	$2.25	$2.45	$2.70
NoSQL	$0.07	$0.13	$0.29	$0.50	$0.80	$1.00	$1.20
Apps & Analytics	$0.52	$0.99	$1.69	$3.45	$5.29	$6.65	$7.75
Professional Services	$2.80	$4.42	$6.15	$10.10	$13.50	$16.00	$17.20
Cloud	$0.36	$0.62	$1.19	$1.82	$2.52	$3.05	$3.65

Figure 11: Big Data market forecast by sub-type 2011-2017.

According to Gartner, Big Data is biggest in the media and communications industries, where 39% of organizations have already made Big Data investments followed by 34% in banking. Gartner also estimates that the transportation, healthcare, and insurance industries are expected to invest the most in Big Data solutions over the next couple of years.

4.2.3 Cloud Computing

Cloud Computing provides computing resources from remote networked servers to allow centralized data storage and online access to computer services or resources. Clouds can be classified as public, private or hybrid[22]. The value of the public Cloud market is expected to reach at least $191 billion by 2020, according to a report from Forrester Research[23]. In the analysis the Software-as-a-Service (SaaS) alone is predicted to be about 70% of the total market in 2020, followed by Infrastructure-as-a-Service (IaaS) / Platform-as-a-Service (PaaS) with 20% market share and Cloud business services taking the remaining 10%.

[22] National Institute of Standards and Technology

[23] http://blogs.forrester.com/james_staten/14-04-24-cloud_computing_enters_its_second_stage_hypergrowth_ensues

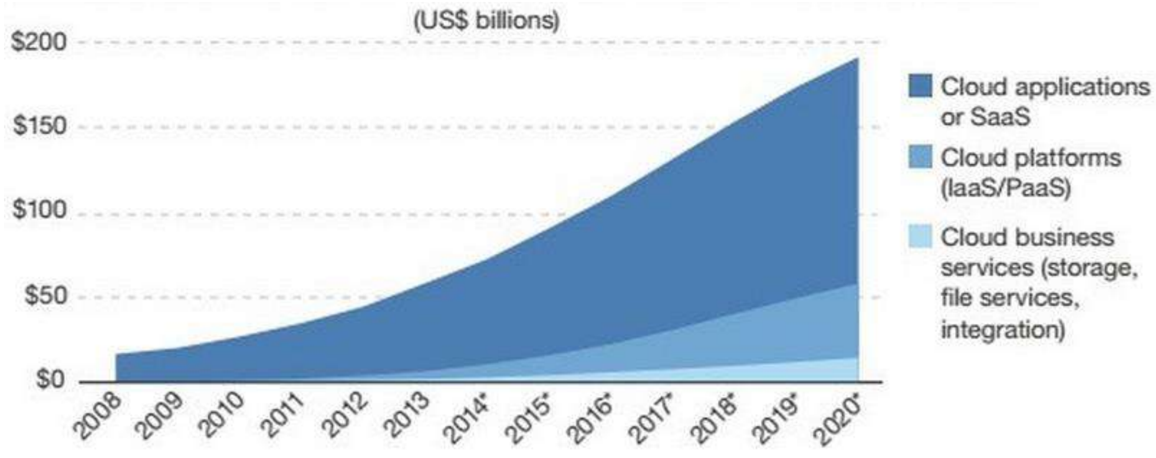


Figure 12: Cloud market size forecast 2008-2020.

4.2.4 Networks

Ericsson presented in their 2014 Capital Markets Day that the global Networks market potential on 2017 will be $250-270 billion whereas the Telecom Services will continue to keep the highest part of the total revenue although the Support Solutions is growing faster[24].

Figure 13: Networks Market outlook.

The Networks Equipment includes hardware and software for the Key segments: Radio, Core and Transmission components. Software Defined Networking (SDN) and Virtualized Network Functions (VNFs), which belong to the *Key segments* in Figure 13, have been hot topics for the telecommunications industry during the past 2-3 years. A big change from hardware to software is really taking place now in the network technology: Infonetics Research estimates that the SDN and NFV market will grow from $500 Million in 2013 to $11 billion in 2018.

4.2.5 Media Internet

The Media Internet covers a wide set of industry sectors such as social media, broadcasting (e.g., online broadcasting, IPTV), Internet publishing of books, music and video, mobile communication, electronic games, online education, etc. Due to this diversity, it is hard to predict the market size as a single area of technologies. Among diverse Media market areas, social media, IPTV, games and e-learning are important business areas

[24] http://www.ericsson.com/ericsson/investors/events/2014/capital-markets-day-presentations.shtml

that FI-PPP use cases cover. The following sub-sections explain major market trends and market analysis of these four business areas.

Social media

Gartner expects the number of social media users will continue to increase at a moderate pace. "New revenue opportunities will exist in social media, but no new services will be able to bring significant fresh revenue to social media by 2016," said Ms. Gupta from Gartner[25]. *"The biggest impact of growth in social media is on the advertisers. In the short and medium terms, social media sites should deploy data analytic techniques that interrogate social networks to give marketers a more accurate picture of trends about consumers' needs and preferences on a customized basis. In the meantime, however, they should also continue to exploit other channels of revenue like mobile advertising and social commerce."* Gartner analysts also said that social media sites will continue to incorporate gaming techniques on their networks, driven by the monetization opportunities that it presents. The sale of virtual goods will remain the primary source of revenue.

Growing user numbers will make advertising and communication on social networking sites a far more attractive proposition for brands. This will see the revenue of social networking sites increase and it is forecast that total global revenue of social networking sites will hit $30.1 billion by 2017 based on Social Networking and Social Media: 2013[26].

IPTV

Covering 138 countries, the number of homes paying for IPTV will rocket to 191 Million by the end of 2020; more than double the 90 Million recorded at the end of 2013 according to a report from Digital TV Research[27]. The Global IPTV Forecasts report forecasts that IPTV penetration will exceed 11% of TV households by 2020, and IPTV revenues (from subscriptions and on-demand movies and TV shows) will grow to $26.2 billion by 2020, up from $16.0 billion in 2013. This report says that from the 101 million subscribers to be added between 2013 and 2020, 69 Million will be in the Asia Pacific region – or 68% of the new subscribers. Asia Pacific will account for 61% of global pay IPTV subscribers by 2020, its share of the global total will increase to 30% by 2020, but North America will remain the revenue leader by taking 34% of the 2020 total (down from a 46% share in 2010).

Games

According to the report from Newzoo, the global games market is going to reach $102.9 billion by 2017 from $81.5 billion in 2014[28]. According to the report, mobile and online gaming has the most rapid growth due to greater online access in emerging markets and cheaper smart devices. Already Apples revenues from gaming are almost identical to Nintendo ($2.4 billion) in the gaming markets outside the US and the West which are making the biggest gains. The report says "*we predict that mobile gaming will secure over a quarter (27%) of the global games market by the end of 2014, yielding revenues in excess of $21 billion. What is more astounding is that in the course of 2015, monthly mobile game revenues will surpass those generated by TV and handheld consoles combined. Full year console revenue will end up just marginally ahead of smartphone and tablet gaming: $26.4 billion vs. $26.3 billion."*

e-Learning

According to the report from Docebo, e-learning market revenues should reach some $51.5 billion by 2016[29]. The report says that The Cloud is changing the way Organizations, Employees and partners interact and collaborate, and the adoption of the SaaS model is playing a pivotal role in helping to increase the size of the

[25] http://www.gartner.com/newsroom/id/2092217

[26] http://www.generatorresearch.com/report/social-networking-and-social-media-2013

[27] Global IPTV forecasts, July 2014, Digital TV Research

[28] http://www.newzoo.com, http://www.proelios.com/report-predictions-for-the-global-games-market-2013-2017

[29] e-Learning Market Trends and Forecast 2014 - 2016, Docebo, https://www.docebo.com/landing/contactform/elearning-market-trends-and-forecast-2014-2016-docebo-report.pdf

E-Learning market. Market acceptance of E-Learning has resulted in its increased use for both large and small companies. SaaS/ Cloud E-Learning solutions are particularly suitable for Organizations ranging from SMEs to large institutions. This report also says that the new frontier to address is the trend towards Bring Your Own Device (BYOD). These seem to be being used to help their owners perform work activities including formal training, both in and out of the workplace. Smartphones are the most common examples of these devices but employees often also use their tablets or laptops in the workplace.

Total E-Learning Market
(LMS + Packaged Content + Other Services)

	2013	2016
Total	**40.605**	**51.172**
North America	23.800	27.100
Western Europe	6.800	8.100
Eastern Europe	729	1.200
Asia	7.100	11.500
Middle East	443	560
Africa	333	512
Latin America	1.400	2.200

Table 3: E-learning market prediction by regions - from Docebo report.

4.3 Future Internet in the FI-PPP

The FI-PPP aims to significantly advance the implementation and uptake of a European-scale market for smart infrastructures that allows innovative applications and services to be offered in a most rapid and effective way leading to significant socio-economic benefits. It provides European industries with opportunities to bring together over 150 European private and public sector organizations from diverse vertical market-segments such as transport, energy, content and media, logistics, mobility, food, safety and security, work environments and health.

4.3.1 FI in multi-sectorial businesses

Revolution and evolution of the FI have a pivotal role in influencing how other business sectors and our society overall is evolving. To enable such multi-sectorial services taking advantage of the advanced Future Internet technologies, the FI-PPP provides an open standard platform named FIWARE[30], which provides a rich library of Generic Enablers (GEs) of important FI features such as IoT, Big Data, Clouds, virtual networks, etc.. The open service platform, FIWARE, runs on the federated FI infrastructure characterized by the advanced open stack based Clouds. The modular based GEs and the open Cloud infrastructure allow a large community of developers to build different business models and lead to business innovation. As the Figure 14 presents, FI-PPP covers diverse areas of industries with support of FIWARE technologies that implement innovative Future Internet technologies.

[30] http://www.fiware.org/

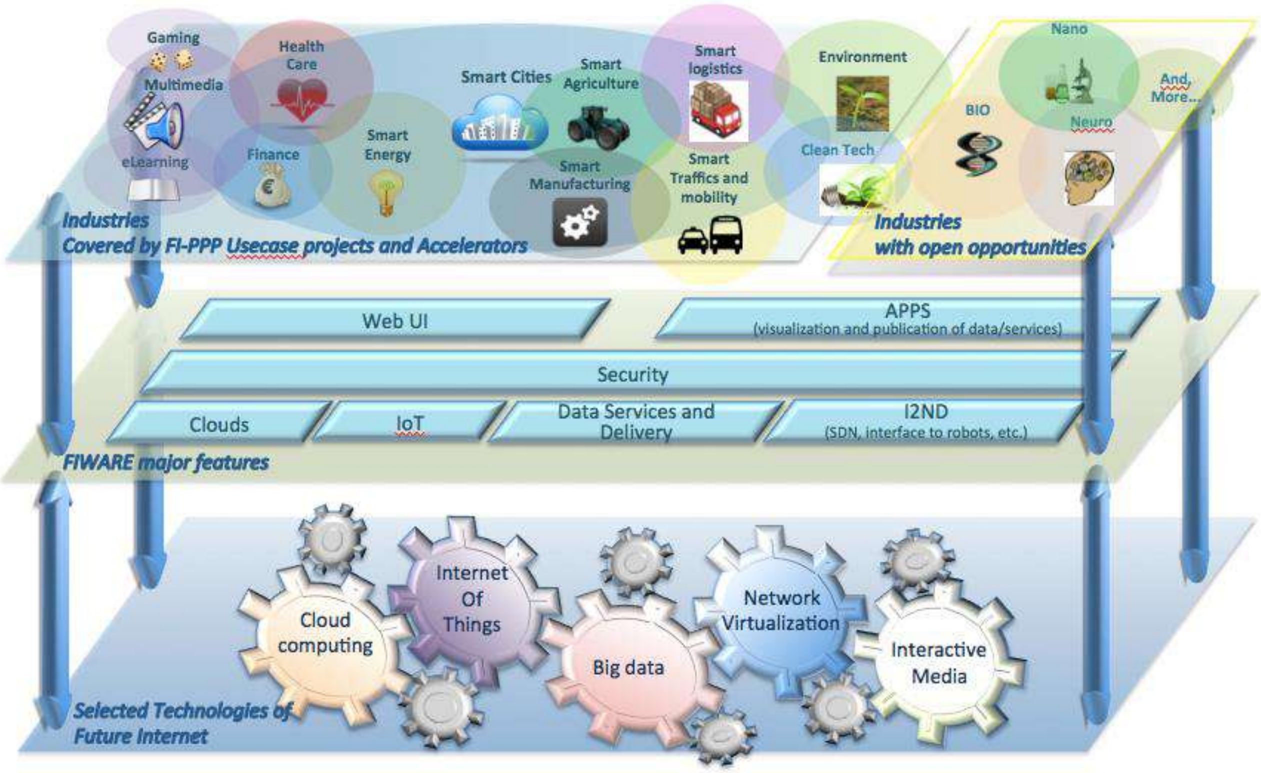


Figure 14: Multi-sectorial business opportunities in FI-PPP.

4.3.2 FI-PPP Use Case and Accelerator Projects

As shown in Figure 14, large areas of industries have joined the FI-PPP framework bringing to their business more innovative pathways. More than 1000 SMEs and Web Entrepreneurs from diverse industries are creating innovation ecosystems within the FI-PPP context. The following table summarizes the FI-PPP Phase I and Phase II so called Use Case projects and Phase III Accelerators (i.e., projects designed to encourage and fund the development of FI services enabled by FIWARE and the open Cloud infrastructure that is provided). It should be underlined that the Phase III Accelerators are now in the phase of collecting innovative ideas emerged with the proposals for the 1st Open Calls wave. In this perspective, the coverage of services offered by FIWARE is expected to be extended and embrace a wider variety of business services and domains.

Sector	FI-PPP projects	Covered services/applications
 Note: other sectors are connected to the Smart Cities scenarios. Here the focus is on services related to city infrastructure and citizens' living condition.	Outsmart Safecity FI-C3 CEEDTech EuropeanPioneers IMPACT INCENSe FrontierCities SOUL-FI SpeedUP!	• Smart city infrastructure - waste management - water and sewage - sustainable transport - street lighting and smart meters, etc. - Smart territories - Public safety service - smart city guides; - smart city platforms; smart city services • Care & well-being - smart home - indoor position

Sector	FI-PPP projects	Covered services/applications
Smart Energy	FINSENY FINESCE SOUL-FI INCENSe Finodex CEEDTech SpeedUP!	• Smart utilities - virtual power plants - electric vehicle grid - home energy management - building energy management - energy grid management
Smart Transport	Instant mobility FrontierCities Soul-FI Finodex Finish	• Smart mobility - Increased Citizen Smart Mobility Awareness • Sustainable mobility
Smart logistics	Finest FIspace Finish	• Business-to-Business (B2B) software platform • Smart-agri-logistics with virtualization, connectivity, and logistics intelligence • 3D printing technologies for logistics
Smart Manufacture	FITMAN FABulous CEEDTech FInish	• Smart factory - safe & healthy workplace - Cloud manufacturing - mobile workforce • Digital factory - product lifecycle management - training service - As-designed vs. As-built Interoperability • Virtual factory - Collaboration valorization - Networked Business Innovation - Collaborative Production • 3D printing technologies for designing and manufacturing
Smart Agriculture	SmartAgriFood FIspace FRACTALS Finish SpeedUP!	• Smart farming with sensors and traceability • Smart-food awareness (transparency of data and knowledge representation)
Health Care BIO	FISTAR FICHe FI-C3 Finodex FI-ADOPT	• Interactive online health care • Medicament supply chain • Virtualization of operating theatre environments and real-time data integration • healthy behaviour and wellbeing shaping
Multimedia Gaming	FI-CONTENT FI-CONTENT2 European Pioneers FI-C3 IMPACT CreatiFI FABulous	• Media and Contents - Social connected TV - multimedia augmented reality - transmedia/cross-media devices - personalized connected media • Pervasive gaming • 3D printing technologies for content based service • social-cultural integration • mobility based service models in media and contents

Sector	FI-PPP projects	Covered services/applications
Environment BIO	ENVIROFI	• Observation of environment - marine asset - biodiversity - personalized info. on air pollutants
eLearning	FI-CONTENT SOUL-FI IMPACT FI-ADOPT EuropeanPioneers	• Corporate and citizen's learning/training • Mobility based service models in education

Table 4: FI-PPP Use Cases and Accelerator projects and their service areas.

As the table shows, large sets of services and applications are tested and testing under the FI-PPP Programme. More innovative services and applications will emerge via the Phase III Accelerators.

4.4 Important technologies influencing FI business innovation

From the Section 4.3, we learned that the current FI-PPP program includes diverse multi-sectorial services and applications. Still, there are widely open opportunities on new business using FI. Particularly, we identified four important science & technical areas which will have high impact on FI business innovation: Nano, Clean Tech, BIO, Neuro. Some exampled applications and services of these areas are shown in the Figure 15.

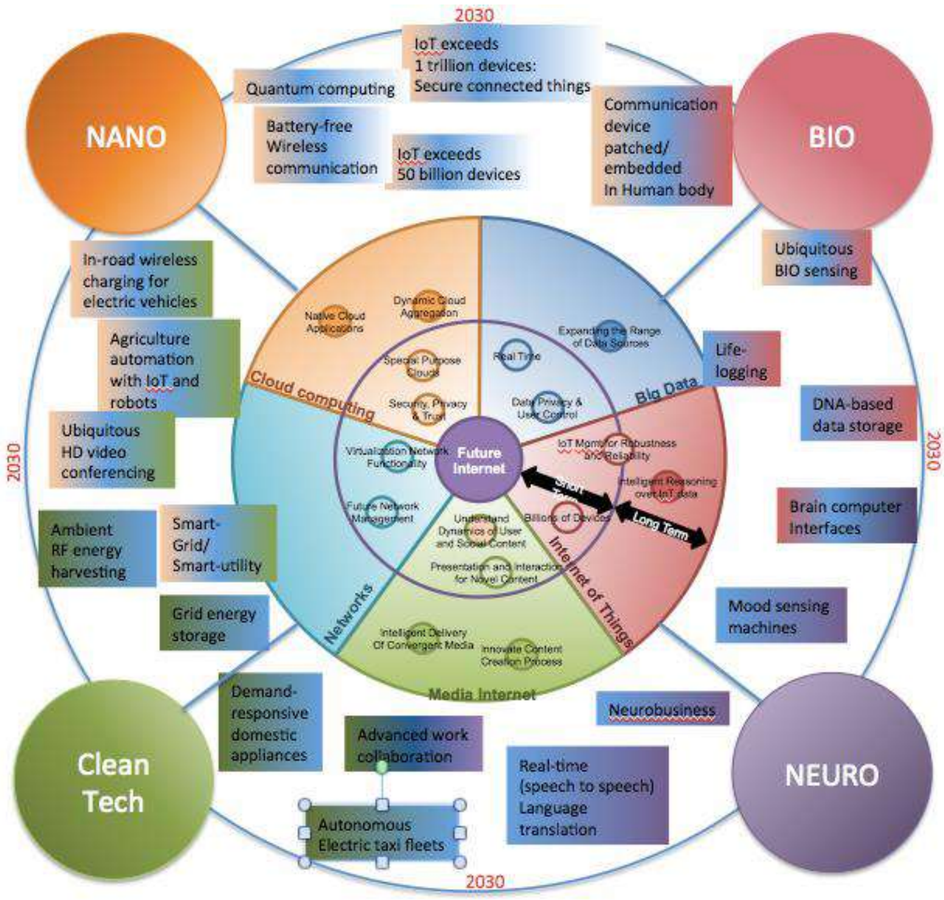


Figure 15: Important technologies influencing FI business innovation.

4.4.1 Clean Tech

Worldwide, the clean technology market is worth more than €2 trillion a year, and it is expected to more than double (€4 trillion) in size by the mid-2020s according to new research commissioned by the German government[31].

The green economy takes important role in the market innovation characterized by innovation-oriented, ecological and participatory growth. There are strong driving forces in the clean tech industries such as demographic change, urbanization, globalization, scarcity of resources and the challenge of climate change. These will ensure a transformation toward a green economy. Greater energy and materials efficiency gives the economy in general strategic benefits in light of international competition. Wide area of industries and services are included in this category, e.g., Smart grid, smart utility, electric vehicles, e-administration, remote work collaboration, video conferencing, etc.

FI technologies are essential to realize the clean tech vision and, at the same time, the network requirements for these social movements are also strongly influencing the direction of the network developments including IoT, virtualized networks, Clouds systems, etc. Diverse area of services and applications are included in this area, and energy aware solutions and providing connectivity for heterogeneous environment/products/solutions are challenging FI technologies.

In the following we provide short descriptions of a few examples selected from Figure 15:

- Smart grid/Smart utility: -2020
  - A modernized electrical and utility grid that uses analogue or digital information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.
  - The technologies are already demonstrated in the real market, but there are still remaining issues to solve both in technology (e.g., standards communication protocols for heterogeneous devices) and regulation (e.g., pricing policies).
- Grid energy storage: -2020
  - The methods used to store electricity on a large scale within an electrical power grid.
  - Extended to the Smart grid issues and networks should be a platform for trading and exchanging electricity.
- Demand-responsive domestic appliances: - 2020
  - Domestic appliances that change in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.
  - Connected to home automation, Machine to Machine communications (among domestic appliances) and mobile/wireless communications (end-users and domestic appliances) should be provided with robust and secure network technologies.
- Ambient RF energy harvesting: - 2030
  - RF energy is currently broadcasted from billions of radio transmitters around the world, including mobile telephones, handheld radios, mobile base stations, and television/ radio broadcast stations. The ability to harvest RF energy, from ambient or dedicated sources, enables wireless charging of low-power devices and has resulting benefits to product design, usability, and reliability. Battery-based systems can be trickled charged to eliminate battery

[31] http://cleantechnica.com/2012/09/17/global-cleantech-market-expected-to-expand-to-e4-trillion-by-2020s-germany-to-capitalize/

replacement or extend the operating life of systems using disposable batteries. Battery-free devices can be designed to operate upon demand or when sufficient charge is accumulated. In both cases, these devices can be free of connectors, cables, and battery access panels, and have freedom of placement and mobility during charging and usage.
    - It will have high impact on spreading connected things in IoT.
- In-road wireless charging for electric vehicles: -2030
    - Batteries of electric vehicles charge wirelessly with no need to plug in to charge, it's a breakthrough that should speed up the widespread adoption of electric vehicles.
    - It will influence both wireless technologies and use of electric vehicles.
- Autonomous electric taxi fleet: -2030
    - An autonomous vehicle capable of fulfilling the transportation capabilities of a traditional car. As an autonomous vehicle, it is capable of sensing its environment and navigating without human input.
    - Robotic cars exist mainly as prototypes and demonstration systems.
    - Both of hardware and software parts of sensors and automobile service platform with their communication mechanisms are all challenged to prompt the use of autonomous vehicle in real life.
- Agriculture automation with IoT and smart robots: - 2025
    - Using ICT technologies, agricultural and rural development can be significantly improved the efficiency. Sensors, robots and following network technologies are used in the wide areas of agricultural industries from crop cultivation, water management and fertilizer application to post-harvest handling. It can be extended to transport of food products, packaging, food preservation, food processing/value addition, quality management, food safety, food storage and food marketing.
    - The sensor nodes must be robust and provide reliable technologies in outdoor environment even with harsh weather. Big Data and Clouds technologies should provide accurate, complete and concise information, and the user interface should be easy and user-friendly.

The movement of the clean tech using Internet technologies often brings competition and cooperation between industries which have not been expected to be related before. For example, the realization of smart car needs softwarization of vehicles and Machine to Machine communications, and it brings competition and cooperation between car manufacturer and software developing companies.

There are some regulation issues particularly in Smart grid and Smart utility for using the natural monopoly products and services. Legal frameworks must set the rules for tariffs based on regulated, incentive based costs for the electricity grid itself (where a market based merchant investment is not introduced), and for ancillary services where market based approaches are not used. This includes the questions which stakeholders shall pay for which parts of the costs based on which rules.

4.4.2 BIO

Based on UN Convention on Biological Diversity, Art. 2[32], biotechnology is any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use". One stream of future network study also takes biology to build algorithms in networks and computing (e.g., bio-inspired network algorithms that can autonomously judge changes in the situation and environment and communicate flexibly). New trends of healthcare systems are creating with the convergence

[32] http://www.cbd.int/convention/articles/default.shtml?a=cbd-02

of ICT and BIO in biomedical engineering area that the application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g. diagnostic or therapeutic).

Research and Markets has estimated (2013) that the global BIO (Bio medical, Biopharmaceutical) market, valued $200 billion in 2013, is further projected to reach $498 billion by 2020, growing at 13.5% Compound Annual Growth Rate (CAGR) between 2010 and 2020[33].

The followings are short description of a few examples selected from Figure 15:

- Lifelogging: -2015
    - Lifelogging is the process of tracking personal data generated by our own activities. Lifelogging tracks personal activity data like exercising, sleeping, and eating.
    - Social media is serving as a method to track lifelogs by providing accumulated records of a year or so.
    - A lot of smartphone apps support lifelogs. Especially, fitness tracking apps are widely used.
    - Wearable gadgets like smart watches which are worn throughout the day, with various sensors to capture data - and apps to help make use of them also serve lifelogging.
    - Although technologies for lifelogging are not new, services and products related to lifelogging continue to develop. Privacy issues need to be solved.
- Ubiquitous BIO sensing: 2015 - 2030
    - A biosensor is made up of a transducer and a biological element. A biological component that acts as the sensor and the biological response is converted into an electrical signal by the transducer.
    - Bio-sensing for personalized health monitoring via increasing availability of small, diverse, robust, high fidelity sensors can be used to extended e-health services.
    - It is noted that there are controversial discussions on Bio-ICT convergence technologies related to risk and privacy issues.
- Communication device embedded in the human body: 2030 -
    - Comfortable sensors that are worn on the body - possibly hidden into clothing, attached to the body as intelligent patches, or even, in the extreme case, implanted. Sensors that measure body parameters and send them wirelessly to a base station and from there on to the hospital.
    - Tattooed circuits in human body: video tattoos making video presentation possible (1st RFID tattoos 2014).
    - People suffering from chronic diseases, or elderly people that need watching, could be monitored from their homes. Automated home monitoring systems transfer the data to the hospital; and for patients, they could be monitored without leaving their homes, permanently and comfortably. To enable this scenario, secured IoT data transmission (issues on IoT, Networks and Clouds) and ultra-low biomedical signal processing (processing algorithm and Big Data handling) should be supported.
    - It is noted that there are controversial discussions on Bio-ICT convergence technologies related to risk and privacy issues.
- DNA based data storage: 2030 -
    - Digital data stored in the strings of DNA - demonstrating the feasibility of using DNA as a long-term, data-dense storage medium for massive amounts of information.
    - With current progress of the research, one gram of DNA can store 700 terabytes of data. It will

[33] http://www.researchandmarkets.com/research/mrzjdp/biopharmaceuticals

get rid of storage problems and will change the business of data center and many other ICT technologies and services.

4.4.3 Nano technology

This term includes extremely thin films, tiny but powerful microprocessors, long-life batteries, nanosensors. These are all from nanotechnology that is throwing the doors open to a hyper-tech era in which electronics and ICT are going to become ubiquitous. Nanoelectronics are paving the way to miniaturized supercomputers and bringing about the development of pervasive computing all the way down to the so-called ‘smart dust’. It is already generating ultrafast semiconductors and microprocessors, not to mention low voltage and high brightness displays.

Using nanotechnology and nanoscale materials, more sensitive, specific, and adaptable sensors can be built that is expected to impact multiple sectors of the economy, including the healthcare, pharmaceutical, agricultural, food, environmental, consumer products, and defence sectors that contributes ubiquitous connected things. Nanotechnology can now realistically look forward to a much longed-for quantum computing breakthrough.

The followings are short description of a few examples selected from Figure 15:

- Quantum computer: 2030 and beyond
    - A quantum computer is a computation system that makes direct use of quantum-mechanical phenomena, such as superposition and entanglement, to perform operations on data Quantum computers are different from digital computers based on transistors. Whereas digital computers require data to be encoded into binary digits (bits), quantum computation uses qubits (quantum bits), which can be in superposition of states.
    - Large-scale quantum computers will be able to solve certain problems much more quickly than any classical computer and may unlock the doors of ICT to infinity.
- Battery free wireless communication: 2020
    - The new communication technique, which the researchers call "ambient backscatter," takes advantage of the TV and cellular transmissions that already surround us around the clock. Two devices communicate with each other by reflecting the existing signals to exchange information. Researchers (University of Washington) built small, battery-free devices with antennas that can detect, harness and reflect a TV signal, which then is picked up by other similar devices.
    - The technology could enable a network of devices and sensors to communicate with no power source or human attention needed.
- Ubiquitous Biosensing: 2015 - 2030
    - It is an example that nano technology is used for biology and ICT convergence.
    - A biosensor is made up of a transducer and a biological element. A biological component that acts as the sensor and the biological response is converted into an electrical signal by the transducer.
    - Bio-sensing for personalized health monitoring via increasing availability of small, diverse, robust, high fidelity sensors can be used to extended e-health services.
    - It is noted that there are controversial discussions on Bio-ICT convergence technologies related to risk and privacy issues.
- Communication device patched/embedded in the human body: 2030 and beyond
    - It is an example that nano-technology is used for biology and ICT convergence.
    - Comfortable sensors that are worn on the body - possibly hidden into clothing, attached to the body as intelligent patches, or even, in the extreme case, implanted. Sensors that measure body

parameters and send them wirelessly to a base station and from there on to the hospital.

- Tattooed circuits in human body: video tattoos making video presentation possible (1st RFID tattoos 2014).
- People suffering from chronic diseases, or elderly people that need watching, could be monitored from their homes. Automated home monitoring systems transfer the data to the hospital; and for patients, they could be monitored without leaving their homes, permanently and comfortably. To enable this scenario, secured IoT data transmission (issues on IoT, Networks and Clouds) and ultra-low biomedical signal processing (processing algorithm and Big Data handling) should be supported.
- It is noted that there are controversial discussions on Bio-ICT convergence technologies related to risk and privacy issues.

4.4.4 Neuroscience

Neuroscience that deals with the structure or function of the nervous system and brain has great impact on the innovation of ICT and the FI. Understanding the brain's computing paradigm could lead to a paradigm shift in current models of computing. New interfacing with pervasive ICT might become possible. Brain inspired cognitive chips may create machines which are capable of emulating human cognition (neuro-morphic computing). In 2013, Gartner has chosen to feature the relationship between humans and machines as a key theme due to the increased hype around smart machines, cognitive computing and the Internet of Things. Analysts believe that the relationship is being redefined through emerging technologies, narrowing the divide between humans and machines.

The followings are short description of a few examples selected from Figure 15:

- Mood sensing machines: -2015
  - Being able to automatically quantify such an intangible and personal given as someone's mood - a combination of personality traits, situational and emotional influencers - is important to understand an audience's actions and intents, and to optimize computer to human interaction.
  - It can be used to enrich e-health care systems for sick and disabled people combined with features of the FI. Overall, it will advance human interface with pervasive connected things.
- Neurobusiness - 2015 and beyond
  - The capability of applying neuroscience insights to improve outcomes in customer and other business decision situations.
  - Neurobusiness is applying in diverse ICT business areas including improvement of decision-making methodologies of online collaborative tools, e-learning systems and e-commerce.
- Real-time (speech to speech) Language translation and ubiquitous e-learning: - 2030
  - Research in real-time translation is focused on developing efficient applications for different devices that use the spoken language in a global context. Mobile, Internet and international communication.
  - The technology can break language barriers and can be used ubiquitous learning assisted by Internet and mobile technologies.
- Brain computer interfaces for gaming, robotic and device control, etc. : 2015 - 2030
  - The brain computer interface aims at controlling electronic and mechanical devices only by means of modulation of people's cerebral activity.
  - The application of brain computer interface brings a new generation of ICT devices and tools powered by the ability of being guided by people's cerebral activity.

4.4.5 Mapping with Technical challenges

The following table illustrates the mapping of identified technical challenges reported in Section 3 including the selected areas for the new business opportunities and their services and applications.

Science areas	Business challenges	Applications/services/products	FI-PPP application/usage areas (need to be checked)	Interactive media	Understand Dynamics of User and Social Content	Presentation and Interaction for Novel Content	Intelligent Delivery Of Convergent Media	Innovate Content Creation Process	Network Virtualization	Virtualization Network Functionality	Future Network Management	Big data	Data Privacy & User Control	Real Time	Expanding the Range of Data Sources	Internet of Things	Billions of Devices	IoT Mgmt for Robustness and Reliability	Intelligent Reasoning over IoT data	Cloud computing	Security, Privacy & Trust	Special Purpose Clouds	Dynamic Cloud Aggregation	Native Cloud Applications
BIO	- The population getting older - Next-Generation Genomics, data Collection and data analysis - Secure data transfer & analysis created by the medical devices (sensors/M2M) and other digital health technologies	Lifelogging	e-Health; Networked media including gaming	X	X				X		X	X	X	X	X	X	X		X	X	X	X		
		Ubiquitous BIO sensing							X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
		Communication device embedded in the human body		X		X	X		X			X	X		X	X	X	X	X	X	X		X	X
		DNA based data storage		X	X				X	X		X			X					X	X	X	X	X
Clean tech	- Demographic change -> transformation towards a green economy - Greater energy and materials efficiency - applying to wide industries such as Smart grid, smart utility, electric vehicles, e-administration, remote work collaboration, video conferencing, etc.	Smart grid/smart utility	Smart Cities; Smart Agriculture; Environment; Smart Energy; Smart Traffics and mobility						X		X					X		X	X	X	X	X		
		Grid energy storage														X			X	X		X		
		Demand-responsive domestic appliances		X	X							X		X						X	X	X		
		Ambient RF energy harvesting		X	X				X		X													
		In-road wireless charging for electric vehicles							X	X		X				X		X	X	X		X		
		Energy-aware self-organising networks							X	X										X	X	X		
		Autonomous electric taxi fleet							X		X					X		X		X	X	X	X	
NEURO	- Mobile network usage change from speech to data -> new business models - brain understanding is applied to end-user applications	Mood sensing machines	Networked media including gaming; e-Health; Smart Cities; eLearning									X		X		X		X	X					
		Real-time Language translation										X		X	X	X			X					
		Brain computer interfaces for gaming		X			X	X				X								X	X	X	X	X
		Extreme 3D video, virtual reality and gaming applications		X		X	X					X												
NANO	- miniaturized supercomputer and new materials > new products and new business opportunities - smart dust: IoT exceeds 50 billion devices: 2020	Quantuml computing	e-Health; Smart Manufacturing; Smart Traffics and mobility; Smart Agriculture						X	X	X													
		Battery free wireless communication							X	X						X	X	X	X					
		Ubiquitous BIO sensing							X	X	X	X	X			X	X	X	X	X	X	X		
		Communication device embedded in the human body							X	X		X	X			X	X	X	X	X	X	X		
		agriculture automation with IoT and robots							X	X	X					X	X	X	X					

5 TECHNOLOGICAL CHALLENGES FOR THE FUTURE INTERNET EVOLUTION

This section discusses in details the technological challenges identified for each technological area introduced in Section 3.

5.1 Media Internet

Social media and media services are changing the way people communicate, interact and act as enablers for new ways of collaboration, socialization and innovation. Grounding on a networked society, these new paradigms of interaction and collaboration are opening new opportunities both from social and business perspectives: allowing us to share our experiences and knowledge in a more personalized, contextualized and direct way, letting us to become direct creators of content and services, offering creative industries new ways and new tools to express designers creativity, helping companies in the engagement of target audience and in the analysis of their social impact. The following sub-section summarizes the main challenges that Media Internet has to face in the short and long term perspectives in order to enable, sustain and advance the above mentioned opportunities.

The analysis here reported is the results of the outcomes of an evaluation done together with subject matter experts and takes into consideration relevant roadmapping analysis already published in the recent years, with focus on media domain such as, in particular:

- Future Media Internet Research Challenges and the Road Ahead, Future Media Internet-Task Force – Whitepaper from NextMedia, Apr 2010;
- Position Paper on Future Research Directions - Opportunities for an Innovative Europe, NEM Sept 2011;
- Co-creating the Future – InfoComm Technology Roadmap 2012, Public Report of IDA – Singapore.

5.1.1 Conceptual map and challenges

In order to foster new opportunities capable to boost individual and social creativity, innovation and productivity in the Media Internet domain, a set of macro-challenges need to be addressed, and in particular:

- On the **Content** side (creation, presentation, interaction):
    - The creation of **novel forms of content** enabling an improved user experience, from both *presentation* and *interaction* perspectives (*short–medium term challenge*);
    - The availability of tools and environments **innovating** the **content creation process**, from a technical perspective (making easier the access, search, retrieval, sharing of relevant content, lowering technical barriers for content creation and production) and from a creativity perspective (fostering individual creativity and the co-creation process) (*medium–long term challenge*);
- On the Social Media side:
    - Achieve an improved **understanding** of opportunities that arise from **social media** that can help organizations to engage the community more effectively and gain useful insights to improve their services or business models (*short-medium term challenge*);
- In relation to Infrastructures:
    - On the **networking** and **content delivery infrastructure**, improve scalability of content delivery in an adaptive way in order to cope with the different consumption and interaction contexts (*medium-long term challenge*).

These macro-challenges are summarized in the conceptual map represented below, where specific sub-challenges and main relevant relationships among them are also depicted.

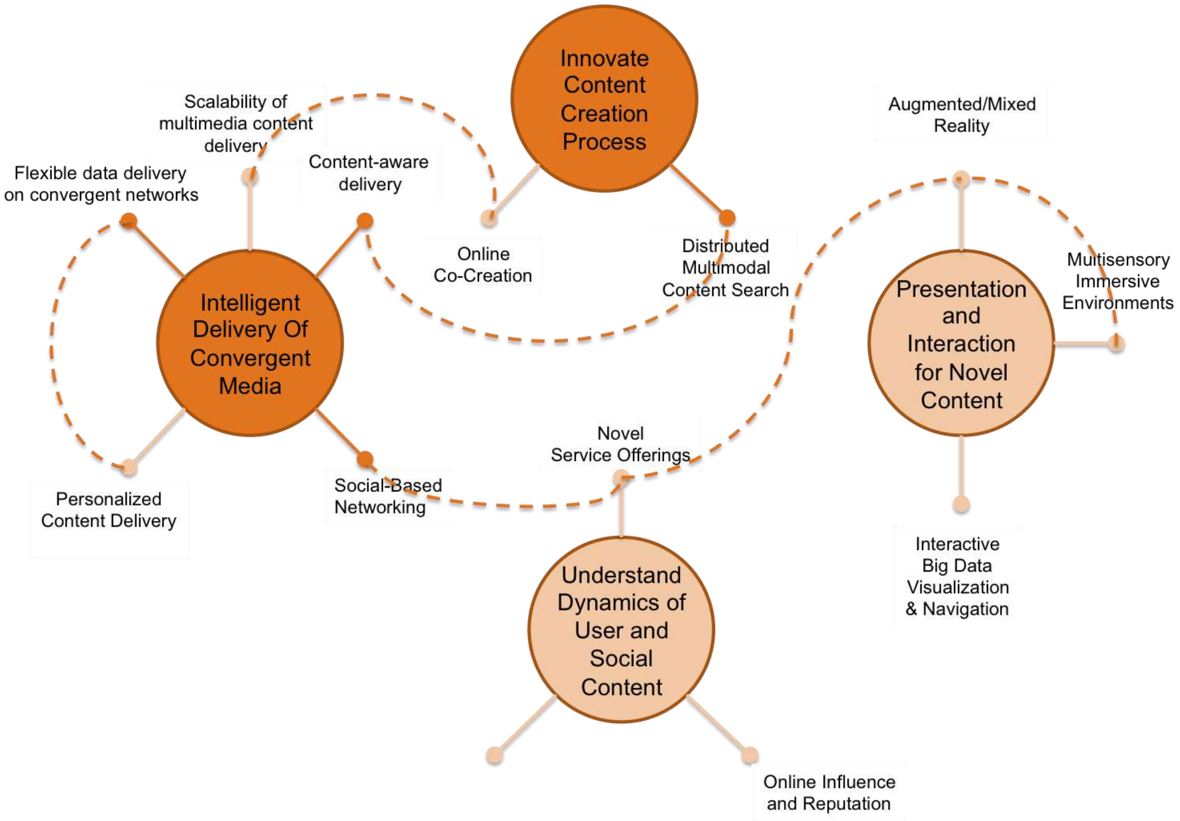


Figure 16: Media Internet's challenges conceptual map.

Here follows a short description of each of the identified sub-challenges and their motivations.

Presentation and Interaction for Novel Content:

- *Mixed (Augmented/Virtual) Reality*. Even if relevant technologies (displays and software platforms) are still on the market from many years, there is a huge space for improvements in usability and applicability in many different domains (from entertainment to manufacturing, medical, engineering just to mention a few); A/V reality can enable new forms of immersive access and interaction with content seamlessly mixing real and virtual world.
- *Multisensory immersive environments*. The search for new media experiences can be greatly addressed by combining multisensory technologies with immersive technologies that can enable new ways of interaction among people and with the real world, especially in home environment and in co-located scenarios, where people may virtually interact at distance with the same efficiency and ease than face to face. Even if many mechanisms have been studied and tested (gesture recognition, multisensory immersive experiences, integration of physical and virtual spaces, etc.), they are still in a technology validation phase.
- *Interactive Big Data Visualization & Navigation.* While the amount of available information at our disposal is massively growing at the same time this trend makes for us significantly more difficult to analyze and explore it. The application of interactive and scalable visualizations can help to leverage on our visual perception capabilities for gaining an improved, personalized and interactive Big Data analysis, supporting the understanding, navigation and editing of large data sets.

Innovation in Content Creation Process:

- *Online co-creation.* The availability of ICT tools capable to support the process of collaborative content ideation, design and creation can enable a faster, easier, less costly and more effective results: multiple different stakeholders actively involved in the ideation and design can radically change conventional user-designer relationships, opening to new forms of collaboration, such as, for example, among clients and companies.
- *Distributed Multimodal Content Search.* The massive amount of content available on the Internet, distributed in heterogeneous repositories poses limitations in the capabilities of processing, indexing and retrieving relevant content for users; there is the need for personalized and user-centric mechanisms that will allow the delivery of content matching user's interests. This requires the development of more homogeneous, efficient, multimodal, intuitive cross-search capabilities.

Understand Dynamics of User and Social Content:

- *Novel Service Offerings.* As social media evolves, more services will be created to meet the needs of niche groups, new service offerings exploiting new dynamics and practices of social content sharing. Many of these services already exist (such as, for example, social casting, citizen journalism, social gaming, collaborative storytelling) but new service offerings are expected to appear as social media will integrate even more in our every day's life.
- *Social Media Management, Analytics and Marketing.* Social media management systems are becoming a key tool for companies to monitor conversations and people's opinions across different social media channels and to coordinate the engagement on these platforms, together with the need to analyze, understand and control the effects of interactions and associations among people, about topics, ideas, products and services. Tools and platforms capable to assist companies in decision making and in the delivery of targeted and personalized content and services to stakeholders are key enablers for a successful social media strategy.
- *Online Social Influence and Reputation*. Social influence of individuals has become a social "currency" which marketers can leverage for marketing and advertising, or individuals can exploit for their own purposes. The need for understanding and measuring social influence and management of online reputation, for understanding online people's sentiment are topics that need to be further investigated and enforced in order to allow companies to manage a trustful and effective interaction with their stakeholders.

Intelligent Delivery of Convergent Media:

- *Scalability of multimedia content delivery.* The increasing demand for high quality content delivery in different network and user's conditions (from different devices, different networks, with strict requirements in terms of throughput, delay, packet loss, etc.) imposes on one side to maximize the availability of delivery resources but also to identify optimization strategies for the best usage of available resources where infrastructural constraints exist. New strategies for scalable streaming and optimization of information flows can dramatically increase network transmission capabilities; adding intelligence in the network nodes can make possible the development of novel advanced communication system architectures and transmission models.
- *Flexible data delivery on convergent networks*. Strategies for content delivery should be flexible and capable to address content delivery according to the specific QoE requirements imposed by ubiquitous multi-device access of convergent services (from massive high quality delivery of high definition content to very low latency delivery of interactive augmented reality/immersive applications);
- *Personalized Content delivery*. Content delivery has to be indeed adaptable to user context and preferences at terminal, network and service level for achieving improvements in QoS/QoE, (user profiling, service recommendations are key building blocks in this perspective);
- *Content-aware delivery:* Media content delivery should become core part of network delivery capabilities, where network resources are allocated on the basis of content requirements, through open federated in-network caching and replication mechanisms;

- *Social-based networking.* New paradigms of social content delivery can be investigated and addressed in order to improve social content sharing and social interaction.

5.1.2 Links to other technology chapters

Media Internet challenges are strictly related and dependent on the specific challenges belonging to all other technology chapters described in this document. In particular, the impact of future network evolutions and network virtualization capabilities represent key resources for enabling a scalable, context-aware, intelligent media content delivery and enablers for an effective user-content interaction. Special purpose Clouds can be tailored to virtualize and scale media computing services as well as enabling content creation and co-creation in the Cloud. Big Data analysis on social media and for distributed media content indexing and analysis is another relevant link. Interactive Big Data visualizations and navigation can be beneficial both for Big Data analysis but also for Internet of Things data visualization, offering novel user interfaces for data analysis and interaction. In addition, specifically to the Internet of Things chapter, augmented and virtual reality technologies can enable a new medium and paradigm for users to interact with real world.

5.2 Internet of Things – IoT

In this Section, we introduce the roadmap challenges to the FI, which will come from IoT-based applications and services. In this particular context we take for granted the assumption that there will be billions of connected "things" by 2020. Ensuring mere connectivity for that many devices has its own set of implications, managing them to ensure dependable and robust services will bring more challenges and, longer term, interpreting IoT harvested data will also need to be duly tackled in the FI as illustrated more in detail in this Section.

In terms of reference material, all contents of this chapter have been aligned / shaped by the strategic research agenda of the IERC Cluster[34].

5.2.1 Conceptual map and challenges

As mentioned in the introduction, three macro-challenges have been identified as a suitable means to convey the main challenges for the FI, derived from the evolution of IoT.

The first one relates to the already ongoing trend of having more and more devices and more generically "objects / things" connected to the Internet. Forecasts vary in numbers according to who made the predictions and what those predictions entailed. There is however no disagreement on the fact that we will have billions of connected objects by 2020. The sheer scale of connected devices and the type of traffic these generate (compared to human's devices) will have substantial implications on the current Internet as we know it today.

Managing objects and ensuring the data they produce can be reliably accessed to sustain dependable services is part of the next macro-challenge identified. We currently have many IoT services that are already being used. However these are mostly "best effort" services due to the nature of the resources involved (end devices that get out of coverage, out of battery, jammed through interference etc.).

Getting billions of objects duly connected and managing to create a reliable monitoring / actuating substrate only partially caters for the challenges ahead, as these cannot be complete without considering how to handle the huge amount of data produced and how to transform these into useful and actionable knowledge. This is indeed the most difficult of the macro-challenges ahead given it is about intelligent reasoning over the data IoT will produce. The difficulty of this challenge lies in the lack of general purpose machine-learning based solutions that can be re-used to address the wide variety of situations in which similar IoT services and applications could be applied.

[34] http://www.internet-of-things-research.eu

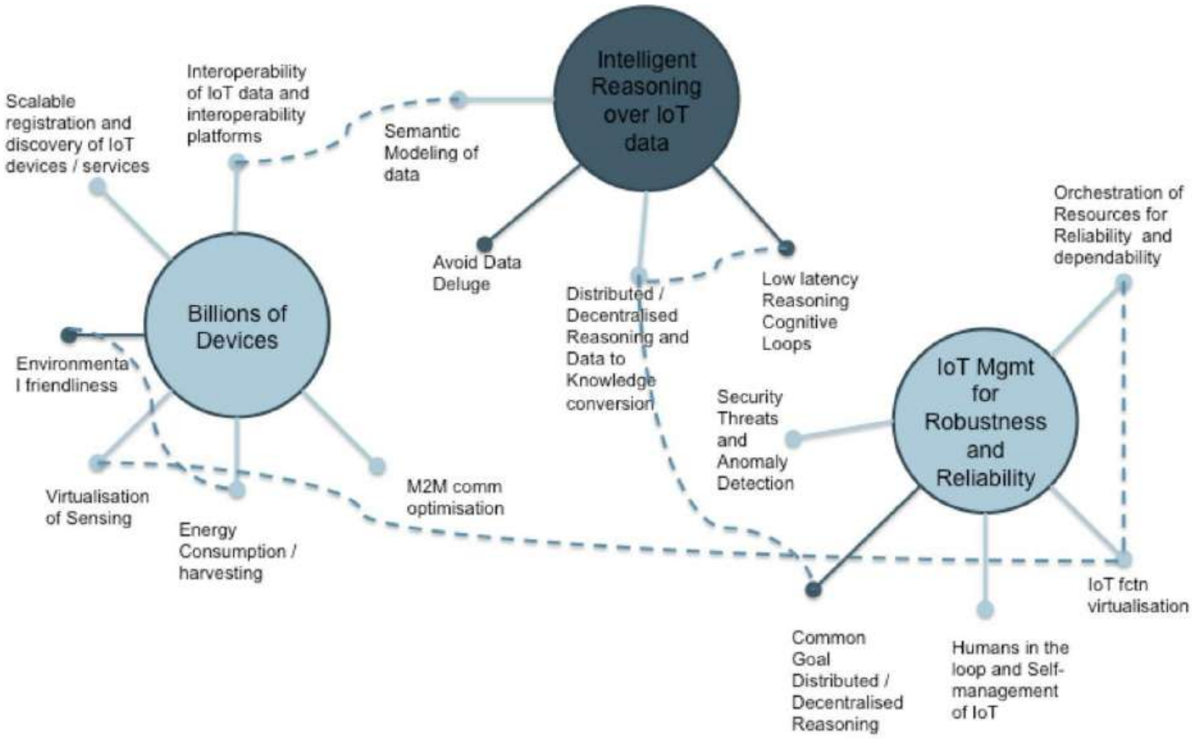


Figure 17: Internet of Things' challenges conceptual map.

Billions of devices:

- *Scalable registration and discovery of IoT devices / services*. As more and more devices get connected, the challenge becomes finding them in a context-aware way. Semantic enrichment of objects description is poised to play a role in facilitating the automated discovery of suitable objects for the purposes of the various applications.
- *Interoperability of IoT data and interoperability platforms*. Besides the common aspects of underlying technologies that have enabled short-range connectivity and the miniaturization of devices that have paved the way towards the success of IoT, current applications have been evolving as a collection of vertical silos often deployed with different standards. To fully unlock the potential of having billions of connected objects, cross-use of data across application domains will be needed. Solutions that foster interoperability and reduce barriers between application silos will therefore have a strong role to play.
- *Virtualization of sensing*. Following on the need to foster interoperability, virtualization of objects will also be needed to separate real and resource-constrained objects from their virtual counterparts in order to minimizing energy consumption, facilitate interaction with applications as well as address the challenges of scalability and those of empowering single objects with flexible added resources from the “wired and resource intensive world”.
- *M2M communication optimization*. Connected objects have communication requirements that can be substantially different from devices like computers or smart-phones. Short-lived communications in huge numbers and energy consideration will require redesign of communication protocols, especially for the wireless part to minimize the overheads associated with exchanging data between objects and their corresponding clients / gateways.
- *Energy consumption / harvesting*. To ensure long duration and usefulness of connected objects, given also limitations of battery evolution compared to processing power and spectrum efficiency, it will be essential to design hardware and systems that can operate for long time without need for battery replacement / recharging. Integration of energy harvesting techniques also falls in this category.
- *Environmental friendliness*. Billions of devices lasting up to 5-10 years but very often replaced much earlier means a lot of waste produced after these devices are no longer operational. Choice of fully

recyclable materials fostering sustainability of IoT will be more and more important, especially after the many IoT deployments will produce sustained need of hardware and services and differentiation between vendors will start including these environmental friendliness factors.

IoT Management for Robustness and Reliability:

- *Security threats and anomaly detection*. This is a cross-cutting issue as it relates not only to the security of radio communications, but also to the security of IoT-generated data to ensure good levels of trust and privacy. On this front not only solutions that address these issues are needed but also solutions that at a management level can detect attacks and contain them.
- *Orchestration of resources for reliability and dependability*. This challenge relates to the ability of assessing dependencies between sensing, networking and computing resources and how these components contribute to the QoE and reliability of the end-to-end application being supported. Issue of dependability becomes important if one has to leverage on the advantages of the IoT also within mission critical systems and / or simply more dependable services.
- *IoT function virtualization*. The IoT functionality is currently solely supported by ad-hoc hardware (i.e. communication of sensed-data, domain/sensor specific gateways etc.). IoT function virtualization will be opening-up new opportunities where hardware ownership will not be necessarily a requirement for producing IoT services.
- *Common goal distributed / decentralized reasoning*. As IoT functionality gets virtualized and distributed besides orchestrating the use of resources there will also be need to coordinate decision-making and achieve conflict resolution for the actuators that are involved in achieving a common goal.

Intelligent reasoning over IoT data:

- *Semantic modeling of data.* As more and more data gets collected through IoT devices, to ensure a more automated selection of the appropriate end devices to be associated with IoT services and applications, IoT data will have to be modeled according to given structures and properly annotated. Semantics help in this respect; so this challenge is part of the broader data interoperability problem though it encompasses besides “finding” the right data also the ability of fostering automated translation between data structures in different ontology domains.
- *Avoid data deluge*. This challenge is about the ability of processing data close to the place where it is generated or on its way to the requesting application in order to avoid unnecessary use of network resources, as well as reduce the amount of data that have to be processed for analytics purposes. It includes challenges like data aggregation, stream processing, CEP etc.
- *Distributed / decentralized reasoning and data to knowledge conversion*. While the previous challenge is about why we should avoid data deluge, at least with IoT generated data, this challenge is about how this has to be achieved. With IoT set to become the underlying monitoring fabric of future smart-x applications and with trends suggesting we will soon have more devices than we can dedicate attention to, getting data across to applications will have to be better managed on the end-to-end delivery path, introducing new ways for distributed data interpretation which accounts for the locality of data, the need to compress it to meet application requirements (i.e. latency, quality etc.) and network capacity.
- *Low latency reasoning cognitive loops*. This challenge relates to the IoT evolving towards becoming able to support very low-latency reasoning loops. This involves the ability to instantiate data processing instances dynamically and close to data sources, besides addressing redesign of communication protocols for speed.
- *Humans in the loop and self-management of IoT*. The rapidly increasing number of connected objects will not be met by a similarly progress in humans ability to set them up, configure them, manage them etc. this element of the roadmap relates to the need of solutions that will ensure devices can be fully operational with simple and little involvement of the users, if need be.

5.2.2 Links to other technology chapters

The envisaged relationships between the various challenges are illustrated in the picture. These are probably the most obvious and self-explanatory ones besides being a matter open to different interpretations according to the perspective one takes at doing the analysis. Rather than trying to go too deep in the analysis of "intra-technology-chapter" relationships, we will at this point rather give a brief overview on the implication of above-illustrated IoT challenges to the other technologies chapters of this document.

With IoT currently positioned at the top of the Gartner hype cycle (the so called "peak of expectations"), the challenge for all the businesses that plan to draw on the wide uptake of this technology, is to ensure the "through of disillusionment" is somewhat reduced and the market remains sustained. To achieve this objective one must focus on adoption and on user-friendliness, ensuring the technology can deliver what it has promised to a large set of users (i.e. well beyond "early adopters") without too many glitches. Addressing the above-identified challenges has a lot to do with this. Moreover, the relatively slow advances in battery technologies compared to evolution of computing capabilities means that wireless IoT devices will always be more resource constrained than their wired counterparts. Virtualization techniques empower wireless devices by adding "always-on" functionality on the "wired side" of the network and breaking functionality from hardware ownership. This is aligned to pushing functionality to the edge of the network, which is going to be key and in this respect and the advances in both flexible networking and Cloud Computing technologies are indeed going to be needed enablers as they give flexibility to modulate at a higher level of granularity the usage of resources end-to-end, helping fulfil diverse requirements (quality, latency, processing speed etc.).

Relationship to the other technology chapters such as media and data are a bit less relevant and explicit. While this is easy to understand for the media chapter given the rather low bit-rate nature of IoT, for the data chapter IoT will certainly contribute to the data management challenges of FI. For the reasons explained above however, rather than having huge amounts of data transferred to data analytics servers, we foresee that processing and filtering IoT sensed *data* into meaningful *knowledge* will happen in a more distributed way and over time as data gets collected.

5.3 Big Data

When reading the specialized media as well as the reports from the most prestigious analyst's agencies, there seem to be consensus on the fact that Big Data has reached as of 2014 the "Peak of Inflated Expectations" according to Gartner's Hype Cycle.

At this point investment in Big Data is heavily increasing in different industries. According to Gartner [22] the industries that have most actively invested in big Data so far (around half of the respondents' companies) are Comms/Media, Healthcare and Transportation. In addition companies from the following industries have higher expectations to invest in the next 1-2 years: Insurance and Utilities.

However there are some indicators that the technology may be entering the "Trough of Disillusionment" zone of the Gartner's Hype Cycle. In fact most of the Big Data deployments are in experimental phase yet, with many companies keeping their usual analytics tools and just using the Big Data tools in an exploratory fashion. In addition one of the main challenges for companies is determining how to get value from Big Data. It is clear that Big Data technologies have a great potential to generate valuable insights for the companies, but these need to know first what to "ask" to the Big Data platforms and how to apply the received insights to create new business models, products and services, or enhance the existing ones.

5.3.1 Conceptual map and challenges

Taking into consideration the aforementioned and sources the following Sections analyze some technological trends around Big Data, which have been of course the focus of many efforts in the last years but whose enhancement may capture a good part of the work around Big Data over the next few years.

These challenges and the relationship between them are shown in Figure 18.

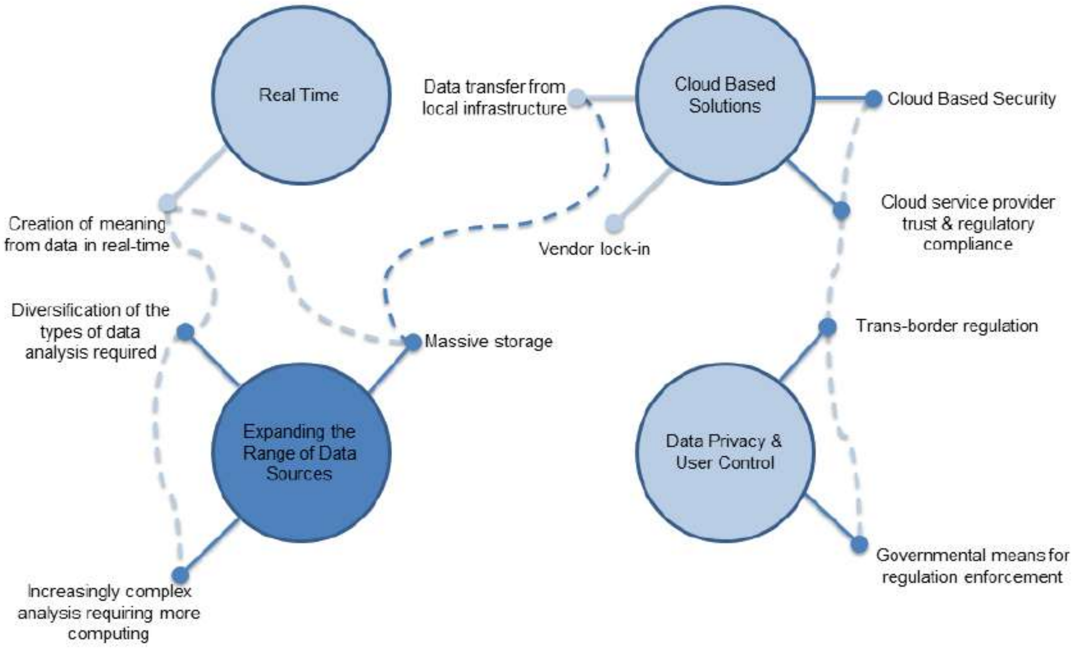


Figure 18: Big Data's challenges conceptual map.

The following paragraphs discuss the challenges and its accompanying sub-challenges in detail.

Real Time

It is hard to say what real-time is when it comes to Big Data, but in general the term near-real-time seems more appropriate. It heavily depends on the specific application. For instance traffic management may be demanding shorter response times than a retail business, as the former may be used to dynamically adjust the traffic lights cycles, whereas the latter may be used to adjust prices on a daily basis. Furthermore Big Data solutions applied to stocks market may present real-time requirements orders of magnitudes more demanding than the previous two examples.

We can though say that the range of seconds or even a few minutes can be named as real-time for most of the applications, as opposed to traditional analytics that perform batch processing, which could be produce results one or a few days later. Thus under the term “real time” in the scope of Big Data we refer to producing insights shortly after the data were received and thus allowing the consumer of the insights to react promptly and steer the system in a meaningful and profitable manner for the business. Usually this means that data needs to be analyzed as it arrives rather than storing it and then retrieving it to analyze it.

One of the core components technologies of Big Data are the parallel processing technologies. Map&Reduce, proposed by Google[35] back in 2004, which were key in the development of the Big Data area. In fact the Hadoop ecosystem is relying on this technique.

However other emerging technologies seem to be aiming at reaching a much greater speed than Map&Reduce, for instance Spark[36], which claims to “run programs up to 100x faster than Hadoop MapReduce in memory, or 10x faster on disk”, or Storm[37], which “makes it easy to reliably process unbounded streams of data, doing for realtime processing what Hadoop did for batch processing”.

This challenge embeds the following sub-challenges:

[35] http://research.google.com/archive/mapreduce.html

[36] http://spark.apache.org/

[37] http://storm.apache.org/

- *Creation of meaning from data in real-time*. This refers to the actual need to not only collect, process and store data in real-time, but to provide meaningful results after heavy processing usable in the fields of application as well.

Cloud-based solutions

The investment to deploy and run a Big Data on-premise solution is usually a deterrent factor for companies interested in exploring the Big Data potential, but not certain on whether it will bring a significant advantage for their business. In this context Cloud-based Big Data solutions, offered following the SaaS (Software-as-a-Service) paradigm may be key to lower the barriers to entry to Big Data.

Cloud-based business analytics systems enable companies to quickly benefit from Big Data solutions without high upfront investment and without the need of highly specialized staff on this technology. Thus they may be especially useful for small/medium companies or even for large companies that want to test this technology before making large investments.

There are, though, relevant challenges associated to this kind of deployments. One of the most relevant is transferring the data in a quick and cost-effective fashion. As the source data may usually reside in the company's IT systems it is a challenge to transfer it to the Cloud-based analytics system for their analysis. Also, ensuring high standards of privacy and security for the data is key to enrol security-concerned companies. Another deterrent for this kind of solutions is the capability to migrate to an on-premise solution at a later point, which may be challenging if the source data is just stored in the Cloud and needs to be migrated at the transition.

Amazon, which is a leader in Cloud services, is also a reference for Cloud-based Big Data analytics.

For this challenge we identified the following sub-challenges:

- *Data transfer from local infrastructure*. Stepping up from a local infrastructure to a scalable and reliable Cloud-based solution implies transferring a massive amount of information before the new system is ready to operate
- *Vendor lock-in*. Finding an open strategy to ensure that systems operate on standards and customers can avoid being captive of their initial provider
- *Cloud Based Security*. Either by nature or by mere size, the data stored in Cloud-based systems needs to be protected in order to ensure integrity, conformity to privacy rules, etc.
- *Cloud service provider trust & regulatory compliance*. Technical means are needed that enable the validation of regulatory compliance and allow customers to verify the integrity of the data being stored and processed

Expanding the range of data sources

So far deployed Big Data solutions take textual information as the main source for the analysis. Textual information may be structured or non-structured and may have a huge variety of formats and origins (e.g. financial transactions, social media posts, email messages, Web navigation interactions, traffic statistics, etc.).

On the other hand other types of contents are rather un-explored as source data for Big Data analysis, for instance video and audio content.

Video automatic analysis to extract insights opens the door to a new range of applications, that would have required human supervision or that would have not been possible at all.

One of the challenges associated to video analytics is the huge amount of data linked to video signals. Two different approaches can be followed to perform the analysis of these signals, namely edge-based systems and central-based systems. The former approach is based on the analysis of the visual information at the origin of the data (e.g. at the camera itself) whereas the latter implies transferring the video signal for analysis to a central system.

Audio is another source of data whose analysis can help to obtain very useful insights. Areas where audio analysis is especially relevant are for instance the security and intelligence or the customer care centers. In this later case, being able to react during the course of a call to maximize customer's satisfaction or to identify suitable cross-selling actions can bring substantial benefits for the business.

For this challenge we highlighted the following sub-challenges:

- *Diversification of the types of data analysis required*. As new sources of information are added to Big Data systems, new types of analysis are required, e.g. media processing, such as video recordings, audio, pictures...
- *Increasingly complex analysis requiring more computing*. The new types of information will not only require new algorithmic but will probably be more demanding in terms of storage and computing
- *Massive storage*. New sources will be added to the system faster than the new algorithms are developed, tested and executed, which will imply storing and ever-increasing amount of information

Data Privacy and User Control

Although Big Data analysis seems to have a huge potential for enterprises it is a source of distrust for many individuals and organizations. Many end users may see their privacy is eroded when they realize that certain companies use personal information (e.g. collected via Web cookies, activity in social networks, etc.) for their own interests. A typical example is finding personalized Web ads recurrently in various Web pages after having looked for an article at an on-line store some days or even months before.

Although some measures are being taken by regulators in this context, e.g. EU directive on Wcookies, there seem to be a demand for a greater control by the user on the information they consciously or unconsciously generate. To this regard, control tools offered by the companies that control / analyze user data, will be certainly welcome by final users and will increase the level of trust towards those companies.

For this challenge we highlighted the following sub-challenges:

- *Anonymization*. providing the technological tools that allow effective anonymization and efficient against reverse engineering (de-anonymization)
- *Trans-border regulation*. ICT deployments, specially Cloud-based, are global and span over several countries in which there might be subtle changes in regulation
- *Governmental means for regulation enforcement*. national and supranational authorities might require tools and means that enable them to validate compliance to regulatory requirements

5.3.2 Links to other technology chapters

The challenges herein described impose additional requirements to other technology chapters being discussed. Most notably in the challenges in the Cloud Computing chapter:

- **Data Privacy & User Control** directly impacts the requirements in **Security, Privacy and Trust** challenges
- Both **Real Time** & **Cloud Based Solutions** carry on implications to **Special Purpose Clouds**

In addition, being able to create near **Real Time** systems heavily depends on the solutions to challenges in the Networks Section.

5.4 Cloud Computing

Cloud Computing, according to a widely shared definition by NIST [20] refers to a model for self-management of computing resource (e.g., networks, servers, storage, applications, and services) that enables ubiquitous, convenient, on-demand network access to a shared pool of such resources. This technology traces its roots into Mainframes (‘50) and Computing Grids (‘90). The first public available platform for Cloud Computing appeared in 2006 with the introduction of Amazon EC2[38], which provided access and self-provisioning of virtualized resources within Amazon Data Centers. Since then, Cloud Computing is more and more adopted by the industry spanning different sectors (e.g. retail, telecommunication, banking, manufacturing, …) and several commercial and open source solutions are available. Cloud Computing is often seen as a solution for reducing

[38] http://aws.amazon.com/ec2/

costs related to management of ICT infrastructures and services (CAPEX savings), but its introduction, beyond that, supported different innovative scenarios such as: new business model (e.g. pay-per-use for online services like SAP Business One), higher service automation (e.g. automation behind ebay services), millions users' social networks (e.g. Facebook), etc.

This active engagement of industries in the field is reflected in different standardization activities (e.g. TOSCA[39], OCCI[40]) and Open Source solutions (e.g. OpenStack[41], Cloudfoundry[42]). Industries backing such initiatives include: HP, IBM, SAP, Telefonica and others.

In the next sub-section we highlight the challenges we identified for the evolution of Cloud Computing technologies. Such challenges have been identified through analysis of different documents on technology road map and status of the art analysis related to Cloud Computing and through the discussion with subject matter experts. The study of documents included analysis of Standardization Roadmaps (e.g. the NIST roadmap [20]), Industrial public roadmaps (e.g. the Oracle Roadmap for Cloud Computing [19]), European Research and Innovation Roadmaps [21] and Innovation roadmaps produced by other industrialized countries (e.g. the roadmap by Singapore Innovation agency [23]).

5.4.1 Conceptual map and challenges

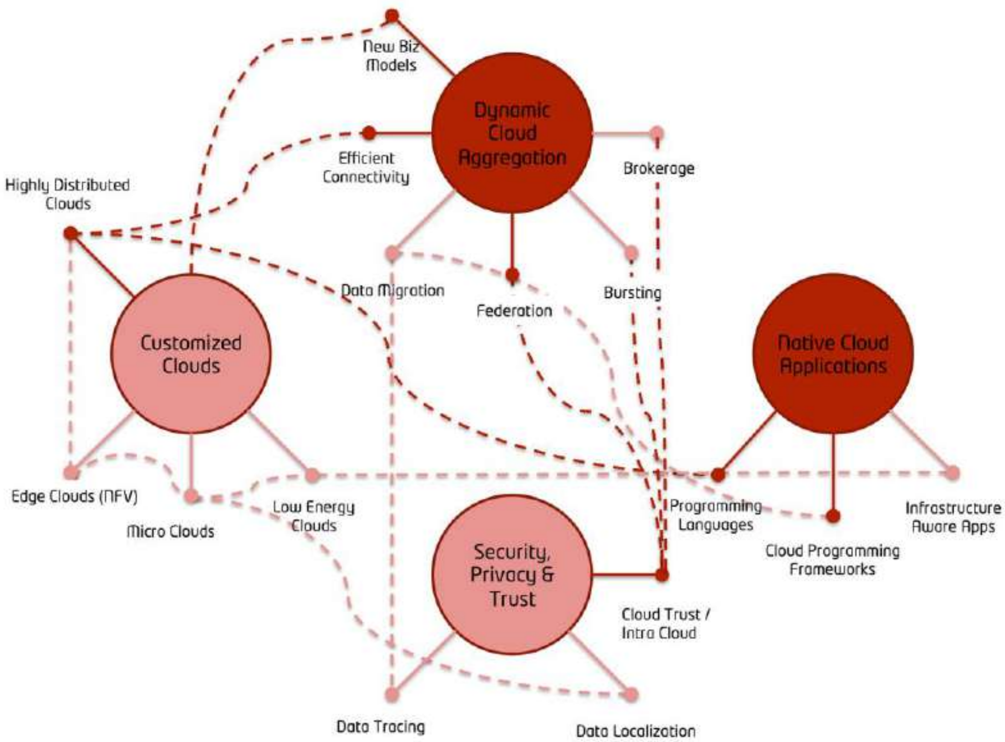


Figure 19: Cloud Computing's challenges conceptual map.

The Future Internet Public Private Partnership (FI-PPP) and the European Community invested several millions in the past few years to support the evolution and innovation of Cloud Computing technology. Starting from that, we analyzed the current status of affairs in the European Research and Innovation framework as regard to Cloud Computing and we have identified a number of challenges that are relevant for the EU Agenda, by taking into account application of Cloud Computing solutions in the markets relevant for the EU context in the Horizon 2020 timeframe. EU Markets considered relevant include the Telco domain targeted as well by the 5G Infrastructure PPP [5], another Research & Innovation initiatives supported by EC.

As result of the process we identified four major challenges in the field of Cloud Computing, presented in

[39] https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=tosca
[40] http://occi-wg.org
[41] http://www.openstack.org
[42] http://www.cloudfoundry.org/

Figure 19:

- **Dynamic Cloud Aggregation** (medium-long term): This challenge refers to the general ability of composing and migrating resources across different Cloud platforms. In the current market, different providers offer more and more platforms and each providers include different offers. This plethora of offers opens different opportunities for Cloud-based business, but at the same time is making more and more complex the composition of resources from different providers and/or the migration of applications and data from one provider to another.
- **Native Cloud Applications** (medium-long term): While the usage of Cloud solutions (i.e. IaaS, PaaS or SaaS) is becoming more and more frequent for any type of applications, developers are still often using a traditional approach to develop applications that are hosted in the Cloud. This limits the benefits of Cloud adoptions in the development of applications. This challenge addresses the needs for solutions that facilitates the development of Cloud-native applications and their interaction with the Cloud infrastructures (at any level: IaaS, PaaS and SaaS).
- **Customized Clouds** (short-medium term): This challenge relates to the fact that Cloud is becoming adopted by different sectors and each sector is raising new requirements. While traditional Cloud infrastructure are perfect to host normal Web applications and services, adoption by new markets of Cloud solutions is demanding for more customized solution to the specific market. For example, more and more often we see rendering occurring in the Cloud, this requires Cloud infrastructures able to support GPU virtualization.
- **Security, Privacy & Trust** (short-medium term): This is the Achilles' heel of public Cloud offering adoption: most of the blocking issues for companies and users are related to security, privacy and trust issues. Of course, if you cannot trust a resource, you are not willing to use it for any vital activity.

In the following we identify, for each challenge, the most important sub-challenges identified in the conceptual mapping exercise.

Dynamic Cloud Aggregation

- *Data Migration*. The migration between different providers (or Cloud technology) of users virtual appliances characterize as a vendor lock-in problem. This challenge requires for standard for migration of data (and services) that maximize the interoperability between the different providers' offers. The problem cannot be simply solved by virtual machine snapshotting (first because not every application or data in the Cloud is in a VM), secondly because this may consume a large amount of data beyond the transfer capacity of available network.
- *Efficient Connectivity*. In the global context were we are living, applications are not serving just a customer in a single location and are not localized just in a single location for different reasons (e.g. legislation or performance requirements). This implies – regardless that the applications are hosted by the same provider or different provider – that applications are more and more globally distributed. This demands for more efficient communication among the components of the application (to avoid issues such as latency), but also more efficient Internet connectivity across Cloud resources able to cope with needs of users.
- *Federation*. While on the technical level different automated solutions are available, due to the self-provisioning principle of Cloud Computing, managing and ensuring proper quality of service in a federated environment is still a challenging. Moreover, it is often the case that such federations are needed for short amount of time in order to fulfill a specific need (e.g. complete my limited Cloud capacity for a given customer). The ability to master in a more automated fashion federation of Cloud resources is fundamental, and this requires for adequate protocols of resource negotiation and easier compatibility and interoperability among Cloud solutions.
- *Bursting*. Even though the concept is quite well known, scaling out resources from your private infrastructure to another (supposedly public) infrastructure is yet a very complex scenario. First it implies that applications are able to support auto-scaling and benefit from it (i.e. they are Cloud native), secondly it requires ability to orchestrate and make seamless resources that are hosted in different

context. The road to automate this process, especially across infrastructure based on different monitoring and management mechanisms is still an open challenge.

- *New business models.* The availability on the market of new Cloud-based offering is radically changing also way software are charged to users. Recently, the larger introduction of PaaS offering (e.g. IBM BlueMix[43]) caused many software vendors to embrace the SaaS offering for PaaS using a pay per use model. The users are more and more combining themselves offers from different providers to be able to create the perfect platform for their needs. Business models of cross vendors collaboration to facilitate and stimulate this take-up are still largely unexplored.

Native Cloud Applications

- *Cloud programming frameworks.* While the development of applications is moving more and more toward the Cloud, programming frameworks (e.g. Ruby-on-Rails, Django) are still not offering any Cloud specific feature that allow for simplifying the development of applications that benefit from Cloud service model (e.g. low cost high availability). Programming frameworks are not automating the interaction of applications with the underlying resources, thus leaving the entire decision making on resource usage logic to ad-hoc developments or external frameworks (e.g. PaaS Manager types of solutions). External solutions may not be aware of the resource need of the application such as the application itself, leading to unwanted scale in or scale out behaviors.

- *Programming languages.* The discussion above is valid as well for lower level abstractions than programming frameworks. Programming languages themselves may abstract Cloud functionalities in a transparent way to the developer: e.g., writing to a local or to a Cloud file system may be handled without the developer changing any line of code; the memory assigned to the virtual machine may be increased when the software fills the memory heap.

- *Infrastructure aware apps.* Regardless the availability of native programming languages or frameworks for the Cloud, a number of infrastructure aware applications are starting to appear. For example, Hadoop is complemented with self-management solutions that are able to scale the cluster up or down. This trend will definitively increase and the challenge will be to make applications aware of more aspects of the infrastructure, beyond the simple management of “memory” and “CPU”, and include, for example awareness of status of network and availability of bandwidth at a given point in time.

Customized Clouds

- *Highly distributed Clouds*. Current Clouds are in their nature centralized, since they are hosted in a datacenter. This does not correspond to the requirements of several scenarios, such as low latency distribution of video content and localized network function deployment. The Cloud is designed to host applications and services that are distributed in principles, but mostly there is no distribution and resources are managed transparently only within a single datacenter. Following the requirements of different industrial scenarios, as the one mentioned above, different solutions that will enable the management of infrastructure where computation will be highly distributed will be more and more common.

- *Edge Clouds.* The edge of the network is the place where provider resources can be located closer to the user. The ability to deploy applications close to the edge will significantly decrease the data volume that must be moved, the consequent traffic, and the distance the data must go, thereby reducing transmission costs, shrinking latency, and improving quality of service (QoS). Also security may benefit, given that data transfer between the edge and core network can be secured through encryption. Edge computing poses new requirements to Cloud technologies that span from the management stack to the underlying cluster of servers. Telco themselves are facing this challenge, for example for the virtualization of network functions in the edge of their network.

- *Low energy Clouds*. Environmental sustainability is a major challenge for the modern society. Datacenters and Clouds cannot escape this challenge. Nowadays different holistic approaches are applied to reduce energy consumption in the data centers. The expansion of the adoption of Cloud-

[43] http://www-01.ibm.com/software/bluemix/

based solutions in new contexts (such as Edge Clouds, or more disruptively Cloud anywhere – including your car), will push further the needs for lowering energy consumption. The problem may be tackled, for example by adopting ultra-low power CPUs. Such CPUs, nevertheless, are not the most suitable ones for virtualization, thus better ways of employing them within a Cloud management model are needed. As it is already occurring, Cloud solutions will decouple from the traditional virtualization concept to embrace alternative technologies (e.g. containers, bare-metal, library operating systems, etc.).

- *Micro Clouds.* On the one side, different organizations are unable to move data onto the Coud due to insufficient bandwidth, latency, location-specific processing needs, Big Data, security, or compliance reasons. On the other, they cannot afford in house datacenters to host a private Cloud. This requires for cost-effectively Cloud solutions that allows organizations to realize the benefits of Cloud Computing as they create new insights from their premises by moving computations and analytics to where the data resides, dynamically and intelligently.

Security, Privacy & Trust

- *Data Tracing.* More and more data are hosted in the Cloud. For trust and privacy reason it is very important for each users that any action related to their data – if needed – may be traceable. Who accessed the data?, What happened to the data in a given moment?, Where was the data located?, etc. Especially in European context, data privacy is very restrictive and it is important that Cloud solutions are able to ensure that legal requirements regarding data privacy are respected. Facilitating the traceability of data in the Cloud, for this reason, is fundamental.
- *Data Localization.* In most of the cases, users adopting a Cloud service to host their data (beyond a self-provisioned resource in a given datacenter) do not have any information about where their data is hosted: when using Dropbox or Google Drive, users are clueless. In several scenarios, this is not acceptable, e.g. due to legislation, and users fallbacks on localized solutions that may not give them the advantages of public Cloud adoption.
- *Cloud Trust.* Improving trust towards Public Clouds and more in general Cloud technologies is a fundamental step to facilitate its adoption. More, the present landscape that shows more and more the usage of Cloud resources belonging to different providers to build applications satisfying the users' needs, poses the challenge of defining, modeling and measuring the trust among Cloud providers. This, given that most of the operation related to Cloud resource aggregation are occurring in automated fashion, should be as much as possible automated as well.

5.4.2 Links to other technology chapters

Most of the challenges cited in the previous Section respond to concrete requirements of other technology areas currently adopting Cloud Computing. For example, challenges related to security, privacy and trust in the Cloud are very important for the Big Data technologies. Support for edge computing or other similar challenges are fundamental for Network, Internet of Things and Internet Media. For instance Cloudification of IoT is one of the next big things and will require customized Cloud copying with IoT needs. On the other side, many of the challenges in the field of Cloud, such as efficient connectivity poses challenges to new network virtualization technologies such as Software-defined networks.

5.5 Network

Both **Software Defined Networks (SDN)** and **Network Function Virtualization (NFV)** are the two main technological trends that industry manufacturers, telecommunication operators and service providers around the globe are currently moving toward. Worldwide service providers that control over 51% of global telecom CAPEX believe that SDN and NFV are a fundamental change in telecom network architecture that will deliver benefits in new services and revenue, operational efficiency, and CAPEX savings [6], [7].

Relevant industrial players such as Ericsson and Alcatel-Lucent are actively involved in the technical dissemination of both technologies [8], [9]. In addition, several meaningful standardization bodies are deemed as closest to network service definition and provision, for instance the ETSI's Industry Specification Group for NFV [10].

This Section will assess those top drivers that are required to accomplish the adoption and operation of SDN and NFV-based architectures in a short-medium term.

5.5.1 Conceptual map and challenges

Taking into consideration the fundamental changes in the evolution of network architectures from a FI perspective, these will be founded to cope with **three major challenges**. Obviously, there are other aspects to consider where plenty of effort shall be destined, such as the radio network architecture and the convergence beyond last mile. Nonetheless, this document, and the forthcoming network-driven roadmaps (D1.2 and D1.3), will only cover those drivers with a direct influence in the FI-PPP goals. To evaluate a full-fledged assessment of Future Networks in its multiple areas, the **5G Infrastructure PPP** [5] is within the priorities for Europe in the context of Horizon 2020.

The three major challenges to be analyzed here are:

- Virtualization of Network Functionality (short-medium term);
- Future Network Management (short-medium term); and
- Software Defined Infrastructures.

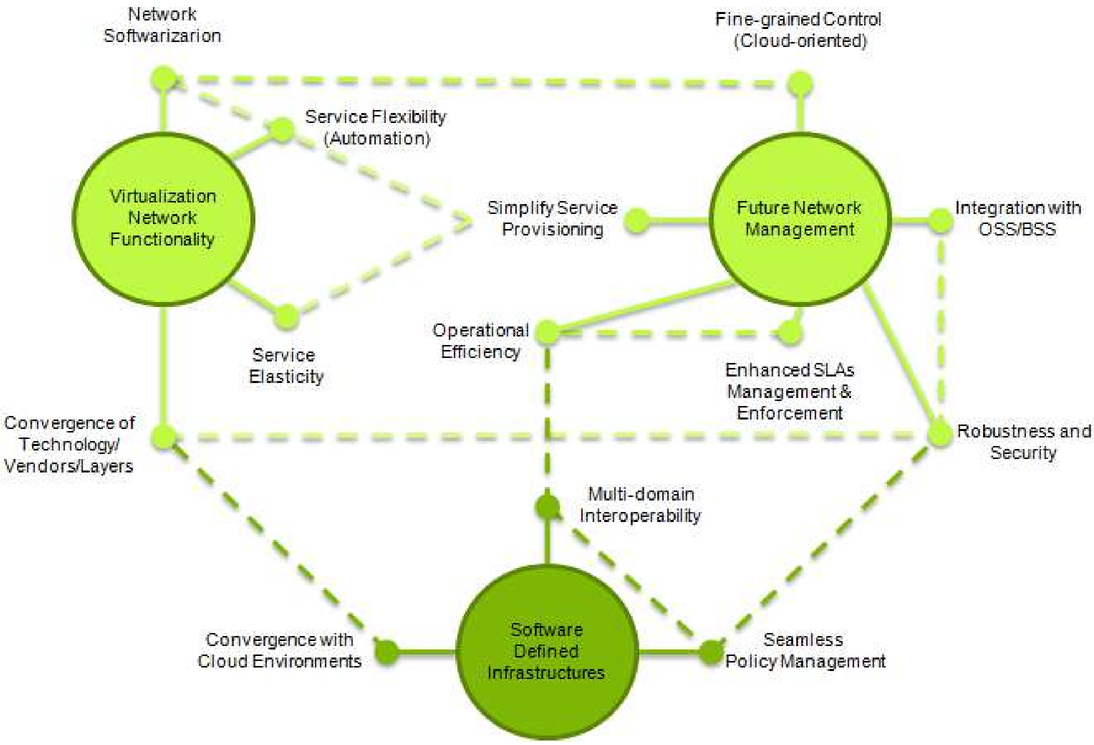


Figure 20: Network's challenges conceptual map.

The three major challenges we analyzed hereby, whose interconnections are displayed in the figure above, are:

- **Virtualization of Network Functionality** (short-medium term): This will offer a new way to design, deploy and utilize network services. With the virtualization of network-oriented functions traditionally implemented in dedicated hardware, by leveraging on Cloud technologies, network operators expect to achieve greater agility and accelerate new service deployments;
- **Future Network Management** (short-medium term): The innovations that both NFV and SDN will bring to network architectures require addressing the challenge to operate these technical initiatives in

a proper and flexible manner, overcoming operational integration and high costs of managing the closed and proprietary appliances presently deployed throughout telecom networks; and

- **Software Defined Infrastructures** (medium-long term): Considering the consolidation of the two previous aspects in a shorter period of time (by 2020), the evolution of architectures in terms of management and service provision cannot be constrained to an isolated network paradigm. The likely convergence with Cloud-based environments leads us to contemplate the concept of "Software Defined Infrastructures", where computing and network-based resources will be handled uniformly by interoperable multi-domain infrastructures.

From each one of these top strategic drivers, there are some sub-challenges to assess, especially due to the boundaries that they share (as it is depicted in the map above).

Virtualization of Network Functionality

- *Network Softwarization*. Both in SDN and NFV the role of the software becomes crucial to the detriment of hardware specific equipment in the management and operation of networks. To provide a network API that can be used by applications to obtain network state or information, or move functionality into software are key features to enable the whole ecosystem.
- *Service Flexibility*. Introduction of virtualized networking and Cloud technologies to adopt tools similar to those used by the information technology (IT) industry to automate many aspects of operations and management. Such degree of automation will enable service providers to meet the needs of the market through faster service introduction, automated scaling of resources up and down to meet changing demands, and the ability to continuously optimize resource allocation based on the results of sophisticated analytics-based algorithms.
- *Service Elasticity*. In the NFV environment, VNFs are created, adjusted and destroyed in real time on demand. Networks must be capable of being reconfigured rapidly to achieve the elasticity needed to optimize the pooled resources in the dynamic NFV environment. In general, NFV will require datacenter infrastructure designed specifically to support massively scalable VPNs.
- *Convergence of Technology/Vendors/Layers*. Today, several vendors design products that combine software, hardware and networking in a single bundle. The product meets specific performance, reliability and availability targets directly associated with service level agreements (SLAs). The challenge is to define a unified interface which clearly decouples the software instances from the underlying hardware aspects, as represented by virtual machines and their hypervisors.

Future Network Management

- *Fine-grained Control*. The control plane in software-defined networks works in conjunction with Cloud management systems in order to dynamically configure network elements to adapt to changing resource usage. This unified control layer controls the datacenter and network as an integrated entity. Granular policy management is required that can be assigned to services and flow, but decoupled from the physical infrastructure.
- *Simplify Service Provisioning.* Deploying a new service in a large-scale network is a long and arduous process. By automating the management and orchestration of the network, time to market for configuration changes for new service rollout will be significantly reduced. Targeted service introduction based on geography or customer sets is possible. Services can be rapidly scaled up/down as required. In addition, service velocity is improved by provisioning remotely in software without any site visits required to install new hardware.
- *Integration with OSS/BSS (Operating Support Systems/Business Support Systems)*. In the traditional model, OSS are specific to a network technology and form the funnel through which all operations and maintenance actions flow. Service providers will have different operations teams for the physical infrastructure and for the virtualized software layer, which will have a significant impact on the way they operate. In addition, it must co-exist with network operators' legacy network equipment.
- *Robustness and Security.* Due to the dispersion of VMs that belong to a VNF across datacenters, and

due to migration of VMs for optimization or maintenance purposes, the physical perimeters of network functions become blurred, making it practically impossible to manually define and manage security zones. In addition, hardware, hypervisors, VNFs and Cloud resource control solutions may be provided by different vendors, increasing the risk of security holes due to mismatched assumptions and expectations.

- *Enhanced SLAs Management & Enforcement.* Many network services within telecommunications infrastructure have strict requirements for latency, reliability and availability.
- *Operational Efficiency*. The ever-increasing volumes of data traffic create a growing challenge. Network performance is a key factor in customer satisfaction since operators need to meet rising expectations. Guaranteeing end-to-end service performance is crucial. Therefore, it is required new systems for monitoring, analyzing and managing to shift from reliability and availability per network element to end-to-end service availability.

Software Defined Infrastructures

- *Convergence with Cloud Environments*. The virtualization of network capabilities will allow the infrastructure administrators to manage resources independently whether they are computational or network-based. This convergence will be feasible thanks to the robust integration that will take place among technology, vendors and multiple layers. Hence, there will not be need for differentiating specific Cloud environments destined to cover network functionalities.
- *Multi-domain interoperability*. End-to-end services spanning multiple domains are available nowadays. However, these services are performed under concrete conditions and triggered by a control entity. Future network services need to be interoperable independently from the domain, which will imply the definition and integration of standard mechanisms. This crosswise homogeneity will allow service providers to offer a broader catalogue of services, managed in a more efficient way.
- *Seamless Policy Management*. This aspect is closely coupled with the previous one. The more interoperable the multiple domains are, the more transparent they will be managed in terms of policies. Today, each single network administrator applies those policies that better fit the objectives of the specific infrastructure. With a cross-domain management, policies will be able to be applied in a more homogeneous, safe and robust manner.

5.5.2 Links to other technology chapters

Apart from the Big Data chapter, where the links with network services are not straightforward, the challenges on network-driven strategies must take into account the rest of identified technical chapters and vice versa. The evolution of network services and management cannot be agnostic to the rest of the domains where network architectures play such an important role. As it has been already described in Section 3, the convergence between network and Cloud domains will be a reality in the longer term thanks to the virtualization of services. In addition, the enhancement in the management of Future networks, enabling more efficient, secure and reliable connections, will boost both media and IoT-driven services.

6 CONCLUSIONS

In this deliverable, we presented the conceptual maps for business and technologies challenges related to the European Future Internet innovation initiatives (such as the FI-PPP) we designed following the first two workshops of the roadmapping process. The workshops have been organized with the key support of WP2, that engaged of International Experts and WP3, that engaged the European regions interested in FIWARE adoption and its roadmap. The maps are not - and do not aim to be - complete, but they highlights the most important challenges that have been identified as result of the analysis process of the ecosystem connected to the FI-PPP programme. The definition of the maps took into account the global context and the feedback gathered from the international experts invited in the second workshop: this allowed us to refine and improve these maps, by taking into account the global understanding of challenges for next generation Internet-based technologies.

Following up on this activity, we will refine and enhance the roadmapping process in view of the third and fourth workshops that will contribute to finalize the first year’s project activities of WP1with the release of the first consolidated version of the roadmap.

Within the next months, we will be sharing the FI-LINKS work with a wider audience and present it at different events so as to collect informal feedback. To then collect more formal and specific responses, we will also create an online survey to gather input on the released map report. In this first iteration, survey participants will be selected from relevant community in the FI-PPP. During the second iteration, the participants will also be from the outside FI-PPP landscape. Collected feedbacks are key input to the third workshop that will focus on the elaboration of the collected input for the release of a first draft of the roadmap. The draft will then be discussed at the forth workshop with external experts and finally consolidated for the broad audience.

These upcoming activities will run in close collaboration with WP2 and WP3, as regard the feedback collection from external international and EU regional players under the umbrella of the FIWARE Mundus initiative. The FIWARE Mundus initiative, lead by FI-LINKS, supports the global engagement of Future Internet players around FIWARE achievements. In this respect, through the leadership of WP4, FIWARE Mundus, will become – in the second phase of the roadmapping – the reference channel to engage external experts to FIWARE community to gather feedbacks on FI-LINKS roadmap.

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