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Authors	Federico M. Facca, Jose Gonzalez, Federico Alvarez, Estanislao Fernandez, Eunah Kim, Timo Lahnalampi, Fabio Antonelli, Raffaele Giaffreda, Eduardo Fulla
Reviewers	Martin Potts, Monique Calisti

Abstract	This deliverable documents the first version of the FI-LINKS Roadmap on Future Internet technologies in relation to FI-PPP and FIWARE.
Keywords	Cloud, Network, Big Data, Internet of Things, Media Internet



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EXECUTIVE SUMMARY

Looking into the future of technology is fundamental to be able to innovate the society we know today. The evolution of 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.

Far from aiming at enlightening the world about the future of technology, FI-LINKS intends to help European and international researchers and innovators to better understand what will be the essential components, in the next 5-10-20 years, of an already revolutionary vision called the *Future Internet*. What is the Future Internet? In simple words we can state that the *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.*

In this document, which is an update and enhancement of the technology and business map presented in FI-LINKS D1.1, both European and global Future Internet activities are contextualized them in the FIWARE scope. Thus, while the roadmap starts from a broader vision and covers aspects beyond FIWARE itself, the major focus - especially in term of follow up actions - is given to FIWARE-relevant developments.

The roadmap focuses 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 Future Internet panorama, they are not within the radar of FI-LINKS. 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. The work on the roadmap differentiates between short-term challenges (timeframe from 2015 to 2020) and long-term challenges (timeframe from 2020 to 2030+).

The audience or main stakeholders targeted by this document are the FIWARE developers' community, which needs to envision the evolution of the technology; the EC DG Innovation officers, who need to plan for further strategies around - and beyond - FIWARE; and the FIWARE adopters' community, which needs to understand what may be the future steps of the technology they are using today.

This document was produced by the members of FI-LINKS (experts in each of the chapters) and external advisors. In line with the goal of supporting the FIWARE programme, the following version of the roadmap (May 2016) will increasingly focus on FIWARE related business and technology targets.

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1 INTRODUCTION

“The best way to predict the future is to invent it.”

Alan Kay

Looking into the future of technology is fundamental to be able to innovate the society we know today. The evolution of 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.

Far from aiming at enlightening the world about the future of technology, FI-LINKS intends to help European and international researchers and innovators to better understand what will be the essential components, in the next 5-10-20 years, of an already revolutionary vision called the *Future Internet*. What is the Future Internet? 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.*

In the deliverable D1.1 “FI-LINKS technology and business models map-0”, we proposed hints about some of the challenges that lie ahead of us to shape the Future Internet vision in-line with the Future Internet Public Private Partnership¹ – FI-PPP –, under which umbrella the FI-LINKS project is funded. In this deliverable we progress from those results to provide a roadmap of technology solutions that will help in the resolution of the challenges identified so as to provide a guide for the evolution of the Future Internet within FIWARE² - a platform to develop Future Internet applications created within the FI-PPP initiative. Readers not familiar with FIWARE can find an introduction to it in Appendix A.

FI-LINKS contributes to the take-up of FIWARE by looking at the work done, and setting a vision for the future, 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 the 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 generally) the FIWARE, results (WP4).

As introduced earlier, the result of the exercise elaborated within the context of deliverable D1.1 is a map of challenges and their relationships, spanning from the business (economical) domains to the technology empowering the Future Internet. Such challenges provide an interesting set of problems to be solved to enable innovative scenarios of the adoption of Future Internet technologies, e.g. *how can I handle billions of connected devices?* While challenges pertain to a number of major technological areas, they are intrinsically related to other challenges e.g. *how the network can handle billions of devices?* While the scope of deliverable D1.1 was to formulate such questions, i.e. identify the challenges, the scope of this deliverable is to propose a path of technological achievements able to provide an answer to such questions.

In the previous deliverable - D1.1 “FI-LINKS technology and business models map [9] – we saw how 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 Infrastructures³ – FIRE – to the Future Internet Public Private Partnership – FI-PPP – innovation programme); US IGNITE⁴ and GENI⁵ in US; New-Generation Network⁶ (NWGN) in Japan, etc.

Albeit the different initiatives highlighted in D1.1 may focus on different aspects, they are all aligned in the

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/>

vision of the evolution of the Internet driven by the availability of *high-speed, low-latency connections everywhere*. Of course there are many other innovation factors that influence the evolution and enactment of the FI, but we believe that the availability of high-speed, low-latency connections everywhere is the most influential and critical one. Thus, the vision and roadmap presented in this deliverable start from the implicit assumption that, soon, the worldwide Internet infrastructure will be modernized into a high-bandwidth and low-latency infrastructure.

As discussed above, the roadmapping activity embraces both European and global FI activities and contextualizes them in the FIWARE scope. Thus, while the roadmap starts from a broader vision and covers aspects beyond FIWARE itself, the major focus, especially in term of follow up actions, is given to FIWARE relevant developments. In line with the goal of supporting the FIWARE programme, the following version of the roadmap (May 2016) will increasingly focus on FIWARE-related business and technology targets.

1.1 What is a roadmap? What is the FI-LINKS roadmap?

As discussed in deliverable D1.1, 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.

This deliverable, following the roadmapping methodology defined in deliverable D1.1 progresses from the challenges identified so far to elaborate a roadmap for Future Internet technologies in synch with the FIWARE initiative. In the following, we highlight the most important elements of our roadmap:

- **The contributing team:** The roadmapping team is composed by a set of in-house experts - part of the FI-LINKS consortium - and a set of external subject matter experts, who collaborate with FI-LINKS to steer the development of the roadmap. The external experts may change during the roadmapping process, in line with the specific goals and expertise needed at a given phase.
- **The schedule:** The activities are 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. This deliverable reports the result of the first cycle.
- **The scope:** The roadmap focuses on technologies that have been core in the development of the FI-PPP initiative, so as to foster the next round of innovation. Thus, while certain technologies (or their parts) may be relevant (or key) in the overall FI panorama, they are not within the radar of FI-LINKS. 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 audience:** The main stakeholders that this documents aims to target are the **FIWARE developers' community**, that need to envision the evolution of the technology; the **EC DG Innovation officers**, who need to plan for further strategies around - and beyond - FIWARE; and the **FIWARE adopters community**, that needs to understand what may be the future steps of the technology they are using today.
- **The temporal scope:** The initial work on the map differentiates between short-term challenges (timeframe from 2015 to 2020) and long-term challenges (timeframe from 2020 to 2030+).
- **The geographical scope:** The roadmapping exercise conducted in FI-LINKS does not have specific geographical boundaries and is to be considered generally valid for technologically 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.

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

It is important to underline that the roadmap introduced in this deliverable - as the conceptual maps of challenges in D1.1 - is not, and do not aim to be, exhaustive, although it highlights the most important technology evolutions that have been identified for the ecosystem associated with FIWARE.

1.2 Why yet another roadmap?

As evidenced earlier and discussed in deliverable D1.1, several different initiatives have been built worldwide around the FI. A spontaneous question that might arise, considering the availability of various roadmaps, visions, etc., 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 FIWARE 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 are still investing- in the FIWARE concept can be pushed forward effectively*.

The objectives pursued by the FI-LINKS roadmap include:

- 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 transforming challenges identified in deliverable D1.1 into a technology and business roadmap for the FI.

2 THE ROADMAP METHODOLOGY

The roadmap methodology followed in FI-LINKS adopts a lightweight iterative methodology inspired by the well-established work by Phaal et al [3]. The Phaal et al methodology – discussed in more detail in deliverable D1.1 - has been selected for two main reasons: i) differently from other methodologies, it provides support for roadmaps related to the implementation of R&D programmes (which is in the end the ultimate goal of FI-LINKS) rather than being product oriented; and ii) the methodology is sufficiently flexible to accommodate the specific needs of FI-LINKS, such as the combination of business and technology visions. Figure 1 presents the customized T-Plan adopted in FI-LINKS. In this section we summarize the relevant elements for this deliverable. The reader can refer to deliverable D1.1 for further details.

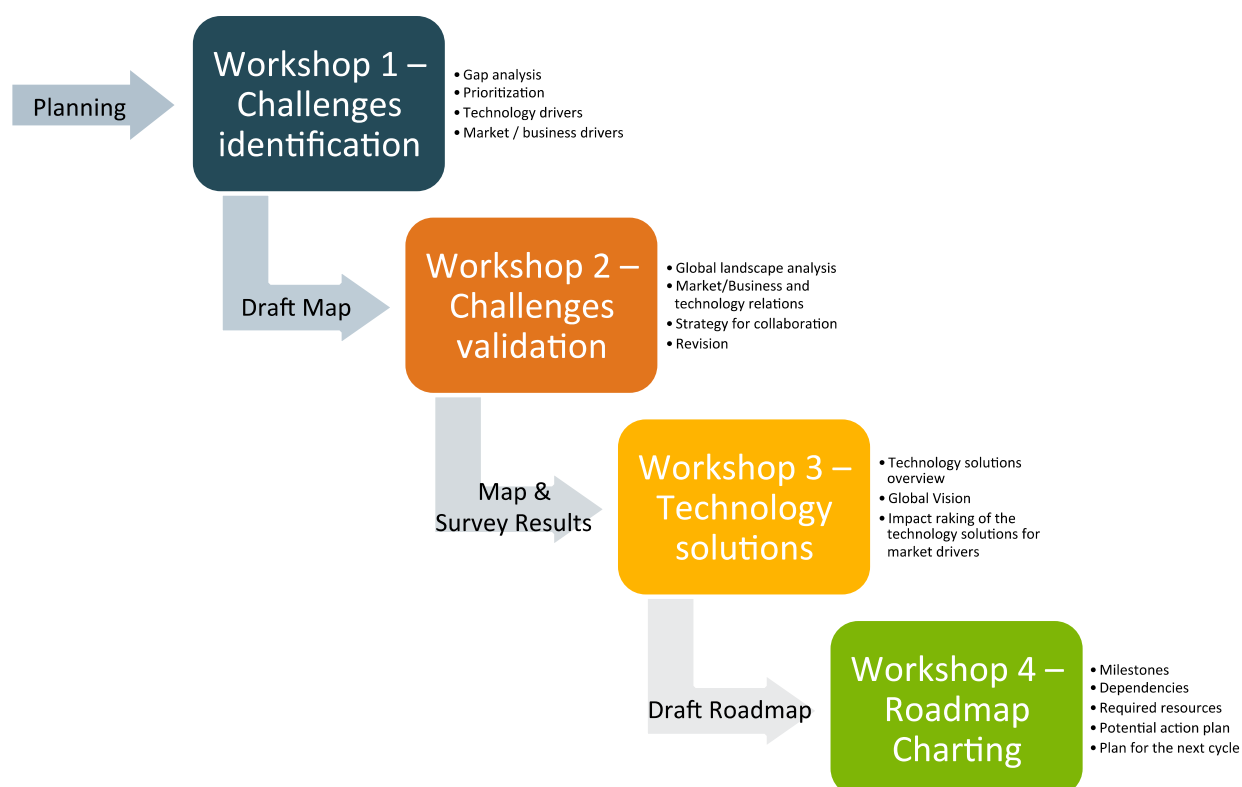


Figure 1: FI-LINKS Customized T-Plan approach

The first workshop was run by internal experts and led to the identification of a number of challenges - or *drivers* - that have a high chance to drive the innovation, either from a technological or market/business perspective; the proposed challenges were then filtered by importance and mapped into the different technological areas (e.g. Cloud Computing, Big Data, etc.) and the relationships/dependencies across challenges were analyzed and detailed. 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 (see Figure 3).

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 Gonzalez	Networks
Eunah Kim	Internet of Things and Networks
Timo Lahnalampi	Market and business analysis
Elio Salvadori	Networks

Table 1: List of Internal Experts

The second workshop focused on the validation of the work done with the help of high-level experts (see the list in Table 2). The outcome was formulated as a report including a discussion of the global context (summarized in deliverable D1.1) and a revised visual map accompanied by a description of the challenges.

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 was ready to be shared with a wider audience and was presented at different events to collect informal feedback from other relevant players and initiatives. An example of such an activity was the FIRE Experimental Platforms Concertation meeting held in Net Futures 2015⁸, where another two roadmaps were taken into consideration; both FIRE and 5G visions. In addition, the first roadmap was presented in a workshop with the rest of the FI-PPP CSAs and the FI-IMPACT project accepted to check and provide comments⁹. The comments were mainly regarding the alignment with the FI-PPP in terms of the

⁸ FIRE Concertation Meeting: <http://www.ict-fire.eu/events/past-events/fire-concertation-meeting.html>

⁹ <http://fi-impact.net>

business perspective and offered some reports to help in that part.

The third workshop, held in April 2015, focused on analysing the feedback received and on discussing their application to the roadmap. From the above inputs, the discussion during the workshop aimed 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 the exercise into a summary vision for the roadmap. The outcome of the workshop is the draft roadmap presented in this deliverable.

The fourth workshop – that for availability reasons of the experts could not be organized before June 2015 – focused on the validation and the discussion of the draft roadmap with subject matter external experts (see Table 3). This deliverable incorporates the results of the discussion held in the 4th workshop; to incorporate such feedback, the deliverable was postponed until the end of July 2015.

Expert Name	Expertise Field	Affiliation
George Wright	Internet Media	BBC
Alexander Gluhak	Internet of Things	Intel
Lutz Schubert	Cloud Computing	University of Ulm
Stuart Campbell	Big Data	TIE Kinetix
Richard Stevens	Market and business analysis	IDC
Diego Lopez ¹⁰	Network	Telefonica

Table 3: List of subject matter experts invited for 3rd Roadmapping Workshop.

During the second year of the FI-LINKS project, this process will be repeated to further elaborate the roadmap vision; the work will focus on drilling down into selected technologies and business areas of major interest for the FIWARE initiative and into incorporating relevant insights from the results of the FIWARE Accelerator Programme, in term of relevant technologies and business aspects to be covered by FIWARE. This activity will be conducted leveraging on the analysis of Accelerators' results conducted by FI-IMPACT, the project of the Workprogramme responsible for measuring the impacts of the FIWARE initiative.

2.1 From challenges to the roadmap design

The main outcome of deliverable D1.1 “FI-LINKS technology and business models map [9]” was a set of interlinked challenges that we identified as important to be tackled to advance Future Internet platforms. A challenge is a “problem” but does not provide a “solution”. According to its common definition [3], a roadmap provides *a mechanism to help forecast technology developments; and a framework to help plan and coordinate technology developments*. Thus a roadmap is the path we propose to follow to “solve” challenges.

In this deliverable, a key instrument that the reader will find is a “technology development plan” – i.e. a roadmap – that presents the technological steps required to solve a challenge in a given timeline, as well as their existing relations between the different technological steps. In the following, we shortly describe how the conceptual roadmaps are defined and how to interpret them (essentially providing more details about the process described above for the third workshop).

¹⁰ Diego Lopez could not attend the workshop, but he has actively contributed as valuable expert to the revision and enhancement of this document

The 3rd workshop was run as follows:

1. For each chapter¹¹ or technology area, the group of internal experts presented the status of the analysis.
2. Each chapter presentation included:
 - a. The summary of the identified challenges as results of the 1st and 2nd workshops
 - b. Internal experts' vision on the future of each technology area
3. The outcomes from discussions outlined:
 - a. Which technologies will solve a challenge
 - b. The timeline of the technologies
 - c. The relationships between the technologies
4. The results were captured in several timelines, following a common format displayed in Figure 2. Each particular roadmap highlights the following information:
 - a. Each chapter is identified by a specific colour (e.g. Cloud is red and Network is green)
 - b. Technology steps are represented by a rounded rectangle. The light colour represents a basic technology that contributes to the realization of a more complex technology (in dark colour) that constitutes the resolution of a challenge
 - c. The roadmap spans from a short-term line (timeframe from 2015 to 2020) to a long-term line (timeframe from 2020 to 2030+)
 - d. Timeline of technologies, i.e. whether a technology is estimated to reach market maturity (i.e. TRL 6¹² or greater) in the short-, medium- or long-term periods. This does not imply that no research or development has yet occurred on that given technology
 - e. Dependences among technologies, i.e. the most relevant prerequisites for a technology to emerge (arrows evidence that A is a pre-requisite to B). In case of lighter relations with other chapters, these are evidenced in the graph with the corresponding technology marked with its colour

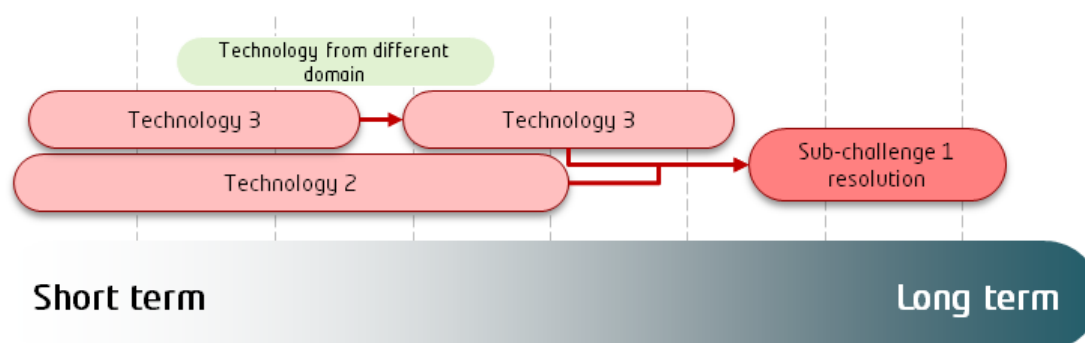


Figure 2: Roadmap format

5. All experts of the different technology areas discussed cross-relations between the different roadmaps.
6. Discussions were summarized in a high-level summary roadmap and in the refinement of the individual roadmaps.

¹¹ Technology Chapter is the term used in the context of FIWARE. FIWARE Chapters are discussed at this link: <http://www.FIWARE.org/our-vision/>

¹² http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

2.2 Results of the fourth workshop and evolution of the roadmap

The result of the fourth workshop was a series of recommendations and actions towards the improvement of the roadmap in each of the chapters. The experts were asked to provide some suggestions on the content as separate papers and the need to improve some of the general content of the roadmap.

In the part of the general discussion we asked the experts to provide comments for the roadmap in general.

General advice was to:

- Contextualize the terms used and provide a better understanding of the meaning for the authors.
- Replace specific years by short-, medium-, long-term, since it is very difficult to classify by year.
- Reconsider if some of the technologies are more short-term than long-term, unless they are explained in a better way.
- Fully describe the importance.
- Take into account how this is interesting for SMEs, not only to big companies. This will provide more capabilities and functionalities. Ask the accelerators in the programme for suggestions and views.
- Provide a way to integrate recommendations and a methodology to realise it.
- Clarify the focus. In some cases, the background (where you come from) is not so clear. The positioning within the overall ecosystem should be clear to external readers. The roadmap is very broad and should be better constrained.
- Explain why the items were included in the picture and why the emphasis is on Phase III (which is community driven).
- Make the diagrams easier to read and understand. Explain what semantics you are following with the arrows
- Clarify what knowledge you bring forward.

The rest of the workshop was dedicated to discussing the roadmap chapter by chapter. A long discussions took place and the invited experts made several recommendations to each chapter. (For the sake of keeping this document as short as possible, we have not listed them in the body of this document, but the information can be found in the minutes and in the papers the experts developed).



Advisory Board
Meeting Minutes.pdf

The experts were asked to provide a document covering their views, and the recommendations have been taken into account in each of the chapters.

3 SUMMARY ROADMAP FOR THE EVOLUTION OF FUTURE INTERNET INNOVATION

Short introduction that presents the highlights of work done in moving from high level challenges to high level roadmap.

3.1 An Overview of Challenges for Future Internet Innovation

There are numerous challenges in the Future Internet, which we grouped in 5 different categories: Cloud Computing, Big Data, Internet of Things, Media Internet and Networks.

The identified challenges consider only the elements and aspects which are contributing to the Future Internet following a holistic approach, considering challenges which may have implications on each other (e.g. at the “Networks” domain level we considered the virtualization via Software Defined Networks, which have implications for “Cloud Computing” and/or “IoT”, but not the research that is done on the physical network layer since, although it may be correlated to larger capacity and higher speed, it is something which can be considered as a general challenge of the network – and covered in other roadmaps such as 5G)

The following picture shows the different challenges which we considered as most relevant and how we grouped them together and their relationships.

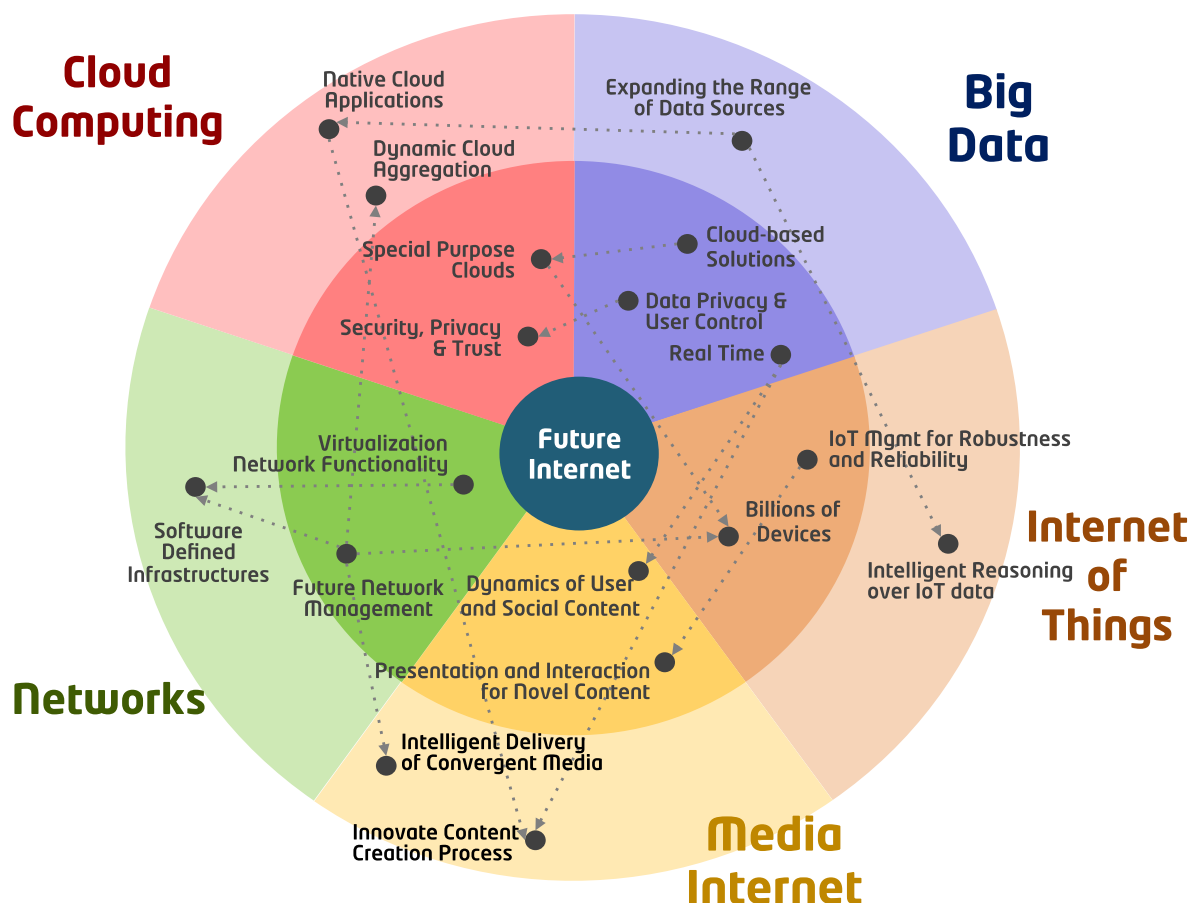


Figure 3: Map of the main challenges for the Future Internet Innovation programme and their relationship

As can be seen in Figure 3, the challenges closer to the centre of the picture are those which are short-term and those on the outside are challenges which pertain to the long-term as defined in this roadmap.

Starting with the Media Internet, challenges considered of short-term are the dynamics of user and social content, which includes the online influence and the understanding of social media management, analytics and its marketing, and the presentation and interaction of novel content, which includes challenges for immersive and mixed environments, multisensory experiences and novel ways of data visualization. In the Media Internet, long-term challenges are the intelligent delivery of convergent media and the innovative content creation processes; this includes flexible data delivery, personalized content delivery and scalability of content on one hand, and online co-creation and distributed multimodal content search on the other.

In the Internet of Things, the short-term challenges identified are, on one hand, the need to cope with billions of IoT devices, which encompasses the virtualization of sensing, the energy consumption management including the progress on the “hardware-related” energy harvesting, the interoperability of IoT data, the friendliness for the environment and scalable discovery and registration; and, on the other hand, the IoT management for robustness and reliability which is addressing the IoT in becoming more mature and established, enabling contextually also the support for critical services, and including IoT virtualization, orchestration of resources and how to counter security threats. In the long-term, the main challenge identified is the intelligent reasoning of IoT data to address how to best leverage on IoT harvested data, notably to produce the usable and useful knowledge for compelling IoT-based services and applications; this is including the need for avoiding data deluge, semantic modelling, distributed reasoning and data-to-knowledge conversion and low-latency.

Moving to Big Data, in the short-term the challenges identified are data privacy and user control, real-time Big Data and Cloud-based solutions. The first challenge is related to the enhancement of privacy and the need for better anonymization, and a set of policies to offer better and more understandable privacy: trans-border regulation and governmental means for regulation enforcement. The second challenge is the need to provide real-time Big Data which should be useful to many applications, and the sub-challenges to overcome the current limitations, especially for the creation of meaning from the Big Data analysis in real-time. The third challenge, which is also looking at the Cloud data part of the roadmap, is the need for an easier, cheaper, scalable and better data transfer from different located infrastructures. For the long-term, the main challenge is the expansion of the range of data sources, needed to diversify the types of data analysis and improve the results, and to deal with the increasingly complex analysis which is requiring more and more specialized computing.

In the Cloud Computing area, two challenges are identified as short-term and two as long-term. In the short-term, special purpose Clouds are the first challenge. They are related to customized Clouds as the highly distributed Clouds, micro Clouds, low energy Clouds and edge Clouds, which are specialized Clouds with different requirements as kinds of niche applications Clouds. The second is the security, privacy and trust, something which is close to the Big Data needs of privacy, where data tracing, data location or inter-Cloud connectivity is needed for a better Cloud operation. In the long-term, native Clouds and dynamic Cloud aggregation are the challenges identified. The first one comprises the programming frameworks and languages dedicated to Cloud environments and the infrastructure-aware applications, with an understanding of the underlying infrastructure.

The last piece of the picture is the networks. In the short-term, the main challenge is the virtualization of network functionalities and future network management. The first challenge is related to the provision of automation and service flexibility, the service elasticity, and the network “softwarization” and the second challenge is the simplification of service provisioning, the enhancement and enforcement of SLA management, the fine grain control oriented especially to Clouds and cognitive networking. For the long-term, the software defined infrastructures which can provide customized context-aware networking, agile management, fully dynamic trust and quasi-full automation are included in this challenge.

Wider, deeper and more granular information can be found in chapter 5 of this document.

3.2 Dependencies on other innovation factors

3.2.1. Infrastructure innovation

The abovementioned Future Internet challenges and innovations should be supported by the provision of new infrastructures which can accommodate the new requirements of the Future Internet services and applications.

A good perspective is given in [26] where a roadmap for future Internet infrastructures and a guide of priorities for investment is provided. For the new investments in infrastructures, different criteria were established, for technical, economic and social implications. The roadmap is supported by a good profiling of the European (and some other third country) infrastructures available for public experimentation in www.xipi.eu. The following breakdown of the main purpose for experimentation on these infrastructures can be derived: backbone networks represent 25% of the total, Cloud 14,8%, sensor networks 9,4%, wired access 19,6%, satellite 0,5%, mobile 12,3% and wireless fixed (Wi-Fi) 18,4%. This is a good indication on the interest for future infrastructures covering Future Internet applications and services.

A good example for the Future Internet services requiring infrastructure innovation in resource provisioning is the need for faster networks infrastructure. Without high-bandwidth and low-latency infrastructure, most of the innovation we define in our roadmap will not be possible. Beyond that, the “Gigabit Internet frontier”, as well represented in Figure 4, will not only allow us to do to what we do today faster, it is going to be a disruptive innovation factor opening up to scenarios yet unforeseen: *a terra incognita* which is waiting for us beyond that frontier.

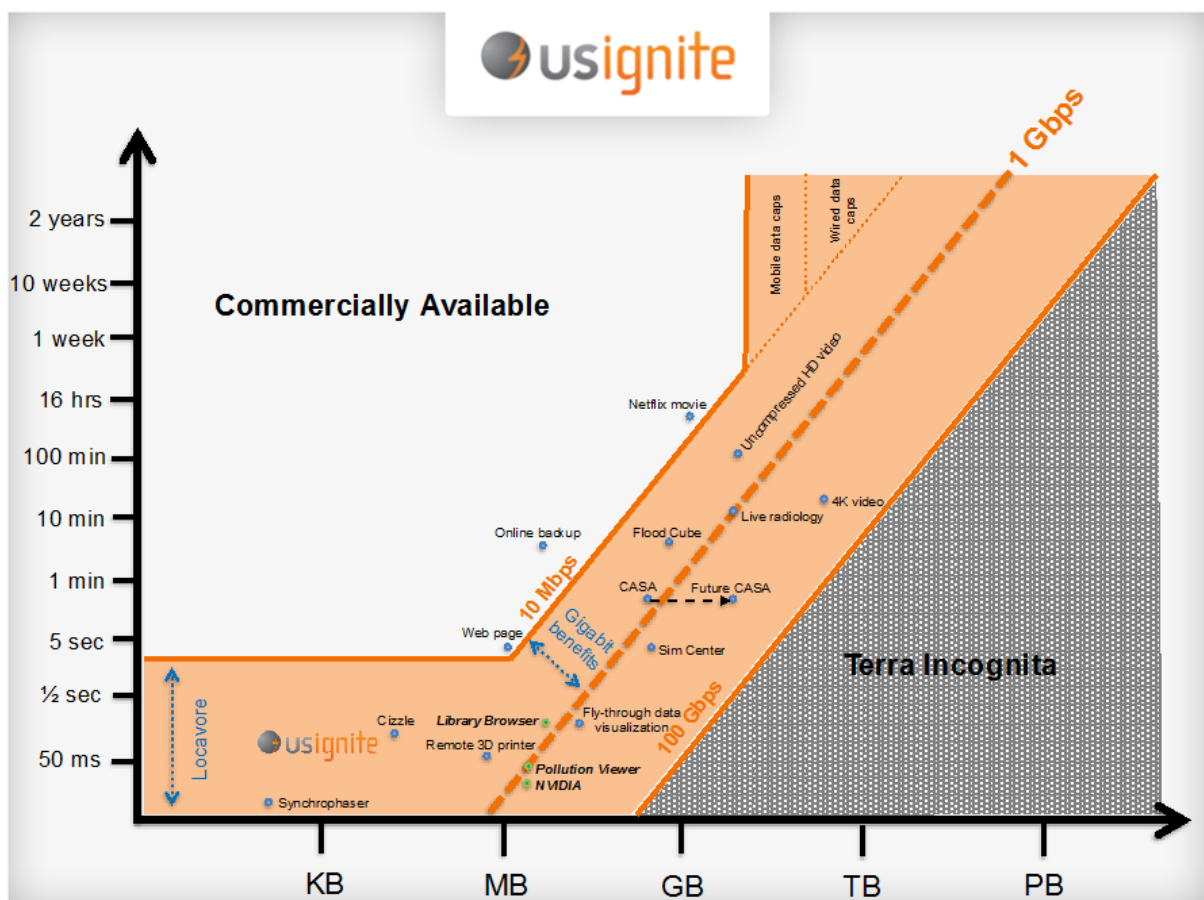


Figure 4: The gigabit Internet frontier, courtesy of Glenn Ricart and US Ignite¹³

Another example of infrastructure innovation is the proposal from the 5G Infrastructure Public Private Partnership (5G-PPP)¹⁴ which plans to breach the gigabit frontier. The 5G-PPP is an initiative by the European Commission and industry manufacturers, telecommunications operators, service providers, SMEs and researchers, devoted to deliver solutions, architectures, technologies and standards with the aim of reinforcing the European telco industry to successfully compete on global markets and open new innovation opportunities.

¹³ Gigabit apps by Glenn Ricart <http://www.slideshare.net/KCDigitalDrive/glenn-ricart-gigabit-apps-panel> (last access July 2015)

¹⁴ The 5G Infrastructure Public Private Partnership: <http://5g-ppp.eu/>



Figure 5: 5G-PPP's Key Challenges

As can be seen in Figure 5, there are different advances in the ICT infrastructures which can be summarized as parameters which are indicative for new network characteristics to be achieved at an operational level in 2020 [29]:

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
- Saving up to 90% of energy per service provided. The main focus will be in mobile
- Communication networks, where the dominating energy consumption comes from the radio access network.
- Reducing the average service creation time cycle from 90 hours to 90 minutes.
- Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.
- Enabling advanced user controlled privacy

This new high-performance network will be operated via a scalable management framework enabling fast deployment of novel applications, including sensor-based applications, with a reduction of the network management OPEX by at least 20% compared to today.

In addition, new lightweight but robust security and authentication metrics suitable for a new era of pervasive multi domain virtualized networks and services will have to be provided.

3.2.2. Regulation policies innovation

As can be understood, the Future Internet innovation cannot happen without a reasonable regulatory framework easing the development of such innovation. Different main elements have been identified in the regulatory environment.

First of all, in the area of Big Data and Cloud, one regulatory element which may prevent the technological or business development is the regulation of privacy and security in those areas. Especially cross-border privacy regulation is one of main regulatory needs since Clouds are global and span over several countries in which there might be subtle changes in regulation which prevent applications to be deployed in different areas due to differences in the user data protection regulations. Another relevant issue to be considered are the governmental means for regulation enforcement as national and supranational authorities might require tools and means that enable them to validate compliance to regulatory requirements.

Privacy regulation with respect to anonymization is another requirement which can help the Big Data applications to achieve better and innovative applications meanwhile protecting the user privacy.

For the networks, the regulations considering the right protection of the competition, as not giving too much power to the incumbent or dominant operators, but not limiting the innovation capabilities and investments of

those players, can support the innovation in networks which requires a great amount of economic resources.

Another element in the regulation is the great difference in the pricing of the access when roaming between different countries, which is - and will be - hindering the development of applications for people visiting another country (e.g. Future Internet tourism services).

Last but not least in networks, the net neutrality regulation and the push for an open Internet is another regulatory element which should be considered for a fair competition in the Future Internet services.

In the area of media, the access to content irrespective of the location, especially when users are abroad, is another regulatory challenge that can influence the provision of media services.

The IoT regulations face similar issues as the ones presented, and the need to offer privacy-by-design in the IoT systems is something which should be considered when developing such kinds of systems.

3.3 An Overview of Roadmap for Future Internet Innovation

Different Future Internet innovations, listed as short- or long-term, are provided. We divided the explanation into chapters, challenges and technologies.

Technologies are needed to solve chapter challenges, and they are described and depicted in a timeframe which shows the roadmap vs. the expected timeframe.

The technologies and challenges per chapter should be aligned to the FIWARE Generic Enablers (GEs) connected to the chapter, to understand and support the future FIWARE directions.

3.3.1. Cross chapter technologies

Of the different technologies for the Future Internet, some of them cannot be classified as a chapter-only technology and therefore have been classified as cross chapter.

A summary of technologies which can be considered as cross-chapter can be found below:

	IoT	Big Data	Network	Cloud	Content	Media
Edge clouds						
Massive data transfer						
Real-time Audio/Video Bigdata						
Customized context-aware Networks						
Agile management framework						
Cognitive Content Delivery						
Terminal virtualization						
Cognitive networking						
Enhanced privacy						
Multisensory interfaces						
Batch Data Analysis						
BigData visualization						
Evolved Map and Reduce						
Trust models for cloud providers						
Data Tracing and Data Localization						
Distributed trust						
Sentiment analysis						
Multimedia Content Analysis						
Scalable Media Clouds						
Network APIs						
Video curation						
Autonomic Management of IoT						
IoT function virtualization						
Virtual Objects						
Convergent Content delivery platforms						
Machine learning for decentralized reasoning						
Stream-based programming paradigms						
Fast Intercloud connectivity						
Data migration						
User Control						

Figure 6: Cross-chapter Technologies

Technologies are described in section 5, where dedicated challenges–technologies timeline descriptions are provided, along with the impact on FIWARE technology.

4 BUSINESS ROADMAP FOR THE FUTURE INTERNET INNOVATION

This section describes the evolution of the European Future Internet initiatives from a business perspective. It aims to describe a scenario in which Future Internet brings value to the European economy and citizens and provides a set of guidelines for achieving this vision.

This section, complements section 4 in the deliverable D1.1 [9], and builds upon some of the information contained therein.

4.1 Introduction

Sustainable innovation happens at the convergence of three conditions:

- **Technological differentiation** - is achieved through R&D in the technological fields
- **Business viability** - a sustainable business model covering the end-to-end product or service lifecycle
- **Customer desirability** - the value that is delivered to the customer or user

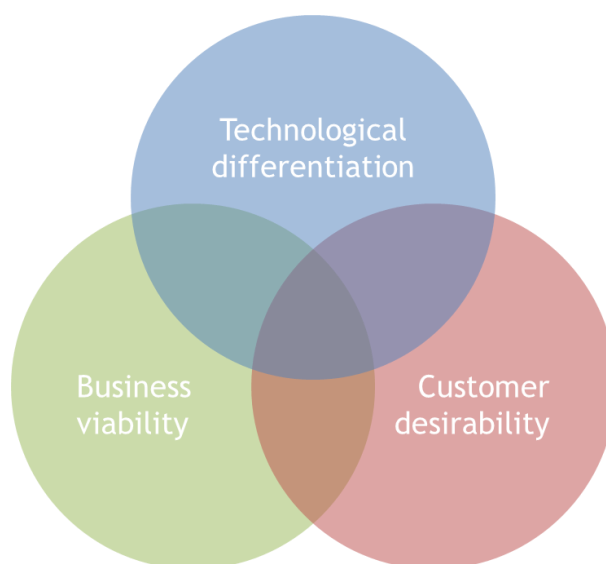


Figure 7: Conditions for Sustainable Innovation

The **technological differentiation** is discussed thoroughly in the next section of this document. The following two subsections cover the other two conditions:

The Subsection “**European Future Internet Ecosystem Vision & Roadmap**” explores the business viability, and the possibilities to achieve sustainable Future Internet innovation initiatives in relation to the distinguishing features of the European economy context. It also describes the vision that is subject to be achieved and the list of factors (levers) that can hinder or promote this vision.

The Subsection “**Impact of Future Internet in the Different Fields of Application**” explores the value delivered to customers in the different economic sectors, taking into consideration information from past FI initiatives, ongoing projects and predictions of the Future Internet evolution.

4.2 European Future Internet Ecosystem Vision & Roadmap

4.2.1. Future Internet Impact

The Future Internet will impact the European socio-economic tissue at multiple levels. From a business standpoint we can differentiate:

- The impact on the **European Future Internet Industry**, comprising all the actors providing the technologies, applications and services that constitute the Future Internet infrastructures and enablers, and promoting its usage in Europe.
- Impact **driven by Future Internet on other economic sectors** – either industries where disruptive innovation changes the players and market conditions, or sectors that see an enhancement of productivity, something of particular relevance to Europe.

These two are thoroughly intertwined in a push-pull model. An example can be found in the new LPWA Internet of Things networks, like Neul or Sigfox, arising recently: some Internet of Things pilot experiences involve the large scale deployment of sensors over vast geographical areas (e.g. sensorization of large forest areas in order to detect early outbreaks of fire); this posed the issue of the maintenance of the deployed sensor base, in particular, having to physically interact with each of the sensors to change the batteries after the original power supply is depleted; with battery life becoming a critical factor to the success of the deployment, new networking standards and protocols aiming at minimising battery consumption have arisen (business pull); the existence of these new devices, networks, protocols, etc. has now given place to new potential applications that go beyond the initial scope, for example now LPWA networks are the foundation of disruptions in other fields, such as underground connectivity required in sewer management or assessing deep underground building basements (technology push).

Telecommunication service providers, leveraging on their billing capabilities, consumer base, strong retail arm and distribution and delivery networks, can play an enhanced role as the customers' touch point with new Future Internet based services, by increasingly aggregating value from third parties:

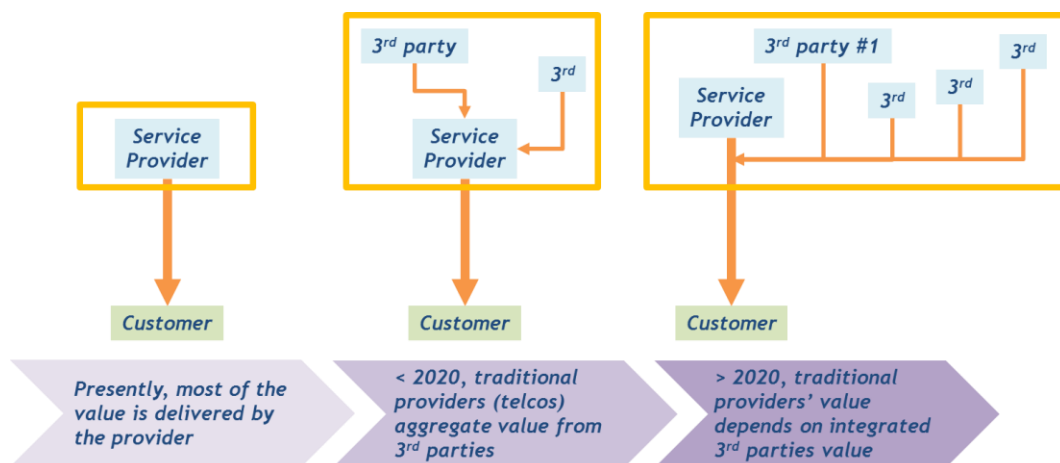


Figure 8: Possible telco B2C offering evolution

On a different level, the **socio-cultural impact** will be driven by the B2C offer of new services and the changed economic tissue- In general terms, socio-cultural aspects are more difficult to address from a business perspective in the short and mid-term, but likely to generate bigger impacts in the longer term.. However, some of the current trends, such as the democratization of the access to information and globalization of cultural influence, allow us to anticipate that end-users and citizens, empowered by the new services and technologies will play a key role in Future Internet innovation.

4.2.2. An European Vision

The five technological drivers that are subject of this study are deeply intertwined and cross-dependent. However rather than a monolithic, or tightly vertically integrated architecture, the European Future Internet industry vision is based on the interoperation of many players that conform an European Future Internet ecosystem.

This interpretation matches Europe's landscape for a number of reasons:

1. Start-ups and SMEs have a big weight in Europe economy. Many efforts are now being exerted into facilitating the creation and growth of start-ups, with particular focus in the technology area.
2. Europe lacks big champions in the Internet industry.
3. In a strong sector, an individual's possibilities to enter into the global market are higher.
4. Public administration support from Europe and the member states to a whole sector is preferred over support to a single proprietary initiative.
5. Coordinated Research & Innovation initiatives, such as the FI-PPP which follows a modular, component-based structure, and other related initiatives, are a useful tool for aligning the investment of many players.

In this scheme, the innovation and boost to the EU economy in the form of productivity will not only be the result of each individual element; it will also depend on how well all of the elements integrate with one another to form the coordinated product that ultimately delivers value to the end user.

4.2.3. Overview of Value Chain and Commoditization

The Future Internet PPP has already produced a large number of results that can be used to deliver new value to businesses and citizens, but importantly, a big effort has been devoted to make all the pieces fit together seamlessly.

While the Future Internet PPP will not cover all the advancements in each of the five technological drivers that are the subject of this roadmap, it will focus on providing a common platform that developers, service providers, start-ups or large companies can leverage on and further enhance, effectively commoditizing several technologies, ensuring compatibility in an open and growing environment.

The main stakeholders of this scheme are depicted in the following diagram:

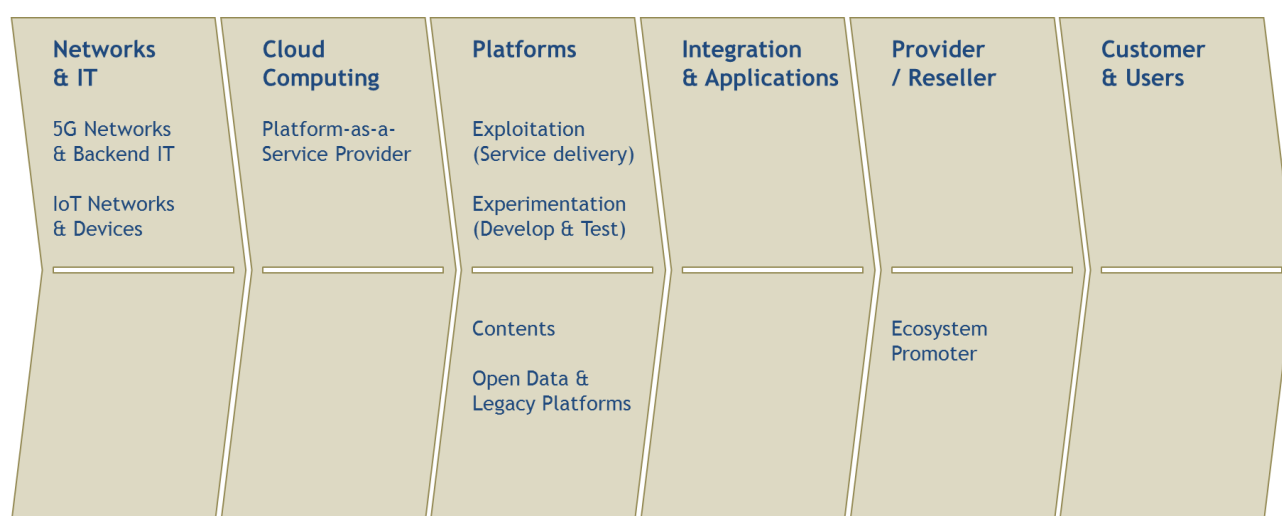


Figure 9: Main stakeholders in the ecosystem-based FI value chain

- **Networks & IT** – are the basic elements at this level of discussion:
 - **5G Networks & Backend IT** – are essential for the networking and IT infrastructure that is required for the fruitful delivery of Future Internet services, encompassing traditional telco infrastructure and services, as well as new services as being evolved by initiatives such as the 5G-PPP.
 - **IoT Networks & Devices** – represent the IoT inputs to the system, comprising all the IoT chain, from the pre-requisites of the technology, choice of protocols, design, integration and adaption to the current needs of the business, to the selling of the devices.

- **Cloud Computing** – represents the public and private Cloud systems that fulfil the system hardware and networking capabilities requirements for the platform.
- **Platforms** – the centrepiece of the system, comprises a set of different platforms:
 - **Exploitation platform (service delivery)** – the centralized- or decentralized- element on which information from the IoT devices, and also from other sources of data, such as legacy systems or application-specific will be stored, analysed, queried, etc. In current FI-PPP efforts, the FIWARE Platform would play this role.
 - **Experimentation platform (Development & test)** – the platform where developers, data publishers, device providers can setup their systems to ensure that they can be seamlessly integrated in the overall system. This element is essential in an ecosystem-based as vertical integrators that can handle end-to-end tests more easily. In current FI-PPP efforts, FIWARE Lab¹⁵ would play this role.
 - **Open Data & Legacy platform** – the single or multiple sources of data available for any particular application. Data can be stored separately from the platform, particularly if storage must meet high levels of confidentiality, privacy and security.
 - **Contents** – as a particular case of the sources of data available to application in external systems, multimedia content usually requires specific treatment.
- **Integration and Applications** – i.e. the integration of the system including the development of the applications, the interfaces, and the access, analysis and visualization of the data and contents from the external platforms.
- **Provider / Reseller** – represents the deployment of the technology and the promoter of this implantation. As a special case, the **Ecosystem Promoter** represents the stakeholder interested in promoting the platform-centric vision. As an example, a municipality promoting the FIWARE platform as a Smart City platform choice, steers local development ecosystem into FIWARE-compliant apps to deliver value to the citizens.
- **Customer and End Users** – are the end of the value chain in this discussion.

As stated above, the focus of FI-PPP is on commoditizing certain sets of technology so as to speed up and ease the development of new Internet based business in Europe and lower the entry barrier to new technology providers.

This commoditization is happening:

1. At the application development level, creating open APIs for fast application development, with FIWARE GEs
2. At the platform level, with the set of tools that enable the easy deployment and management of FIWARE nodes with FIWARE Ops
3. At the network level, with the integration of different IoT providers through the IoT agents' paradigm and the I2ND (Interface to Network and Devices) Enablers.

¹⁵ <https://www.fiware.org/about-us/>

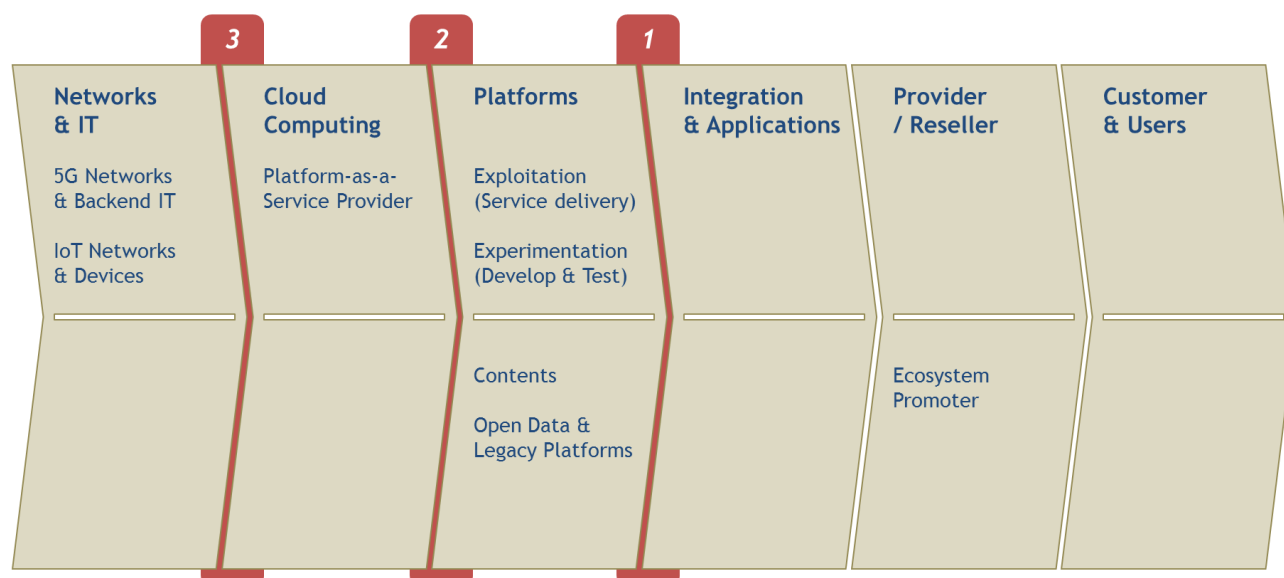


Figure 10: Areas where stakeholders' interaction is being commoditized

Within this scheme, stakeholders can interoperate in a more harmonic way. The following section discusses what elements, within each of the technological drivers can foster or impede this vision.

4.2.4. Levers (Catalysts & Impediments) for the Formation and Performance of the Ecosystem

This section describes the list of elements that affect the interoperation of elements. They are generally similar in every economic ecosystem.

Standardization

While standardization activities are associated with a heavy load of technical activity, it is indeed a determining business factor. The promotion of a given technology or set of technologies into a standard “can help to maximize compatibility, interoperability, safety, repeatability, or quality. It can also facilitate commoditization of formerly custom processes.”¹⁶

Currently, different standards are being promoted by a number of public and private initiatives. Each one is at a different maturity state, and has implications on the whole ecosystem. On a rapidly evolving playground like the Internet, the most likely succeeding standards will be the most broadly accepted - the “de facto” standards.

Promoting or detracting a given standard can be the result of administrative decisions made by regulators, and therefore is linked to the next section.

Regulation

Legislative and policy issues in the Internet have been a concern for multiple years now, but yet still remain widely unsolved. Following the OECD taxonomy of regulations, we can differentiate between:

- Economic regulations - try to keep a high level of competitive pressure
- Social regulations - mainly addressing negative external effects towards the protection of the environment, the health and safety of citizens, etc.
- Institutional regulations - only the innovation impacts of intellectual property rights (IPRs) confirm the expected and intended general positive impacts.

Finally, the development of an “innovation culture” within regulatory bodies certainly promotes the positive innovation impact of regulations.

¹⁶ <https://en.wikipedia.org/wiki/Standardization>

Critical Mass

A strong ecosystem with thousands, or even millions of users, is built by mutual trust that interactive players are providing value to one another. According to Rogers¹⁷, the critical mass in the diffusion of innovations is “the point after which further diffusion becomes self-sustaining”

The most important factor regarding the critical mass theory is the form of the production function of collective action which can be accelerating or decelerating¹⁸. In a collaborative environment it outlines at which point the user involvement - in form of information sharing, production of knowledge and the like - is critical. In an environment with an accelerating production function, it is relatively hard to reach the critical mass. But, when this point is reached, it is likely to become self-sustaining. Prasarnphanich and Wagner¹⁹ showed that Wikipedia is a platform with an accelerating production function. It initially started with a small group producing content and more and more users joined as the content improved in both quantity and quality over time. However, in the case of a decelerating production function it is easier to get people involved. Yet, as more users are involved and more content is produced, there is a reduction in the perceived individual value of one's involvement and contribution. In such a case there will be no start-up problem, but a maintenance problem.

The use of creativity in the innovation process (“gamification”) is a promising solution for keeping the critical mass of users involved²⁰.

Awareness

It is essential to have general knowledge of the impact on the technical drivers in an ecosystem as well as mutual outreach activities among the technical drivers. Two elements are also useful to achieve this objective: a clearly defined technology, business and R&D roadmap, and a set of common strategies softly-agreed among the players.

Investment

The availability of investment is essential for the initial steps of a business. However during the early steps of an ecosystem, small parties might encounter an additional layer of reticence as investors struggle to understand the commitment from other parties. In the case of Future Internet start-ups and entrepreneurs are intended to play a key role, and therefore lack of investment is an important impediment.

Sustainable Business Models

Investors and parties need to understand not only the level of commitments from other parties, but also the subtle value exchanges between all the parties, in order for them to come up with a solid business model, even if it depends on a great degree on the evolution of an ecosystem that is difficult to assess.

IPRs & Technology Transfer

The licensing schemes are also of paramount importance, as it determines who can benefit from the technology in which conditions on exchange for which value. In order to favour the flourishing of the ecosystem, there are a number of considerations, such as: availability of source code or support, RAND (Reasonable and non-discriminatory) or FRAND (Fair, Reasonable and non-discriminatory) licensing, etc.

¹⁷ E. M. Rogers, *Diffusion of innovations*, 5th ed. New York: Free Press, 2003

¹⁸ P. Oliver, G. Marwell, and R. Teixeira, “A theory of the critical mass. I. Interdependence, group heterogeneity, and the production of collective action”, *American Journal of Sociology*, vol. 91, no. 3, pp. 522–556, 1985

¹⁹ “Creating critical mass in collaboration systems: Insights from Wikipedia” in *Digital Ecosystems and Technologies (DEST 2008)*, 2nd IEEE International Conference on, 2008, pp. 126–130

²⁰ M. Witt, C. Scheiner, and S. Robra-Bissantz, “Gamification of online idea competitions: Insights from an explorative case”, *INFORMATIK 2011 - Informatik schafft Communities*, vol. 192, 2011

Once an IPR holder has made a F/RAND commitment, all designers have the right to implement the standard in their products and use the inventions from any declared essential IPRs, and there is no need to wait until all the particular F/RAND terms and conditions have been negotiated with the IPR holder or until a definitive license agreement is executed setting out those terms²¹.

Research & Innovation

Monolithic systems usually follow a private, business-driven roadmap that provides seamlessly integrated evolution in the different areas. In an ecosystem-based sector there is a need for external factors that help harmonized research & innovation initiatives so that the individual investment adds value to the overall group instead of repeating efforts or pushing on opposite directions.

4.2.5. Internet Of Things

Detailed Value Chain

A more detailed value chain would include a few additional specific actors:

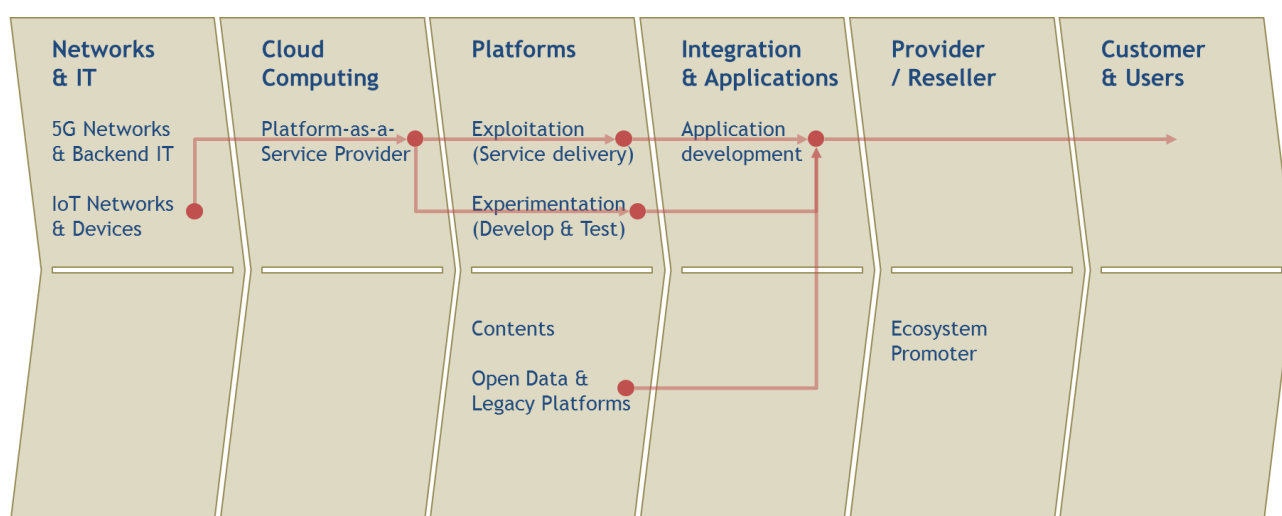


Figure 11: IoT detailed value chain

From a value perspective, value will be appropriated at each layer of the IoT model: device, connectivity, applications, platforms and services. Devices and connectivity are viewed as commodities with consequently low value appropriation whereas in applications, platforms and services is where the value lies because that's where the 'brains' of the operation resides as opposed to the connected limbs and veins that represent devices and connectivity.

²¹ <http://itlaw.wikia.com/wiki/F/RAND>

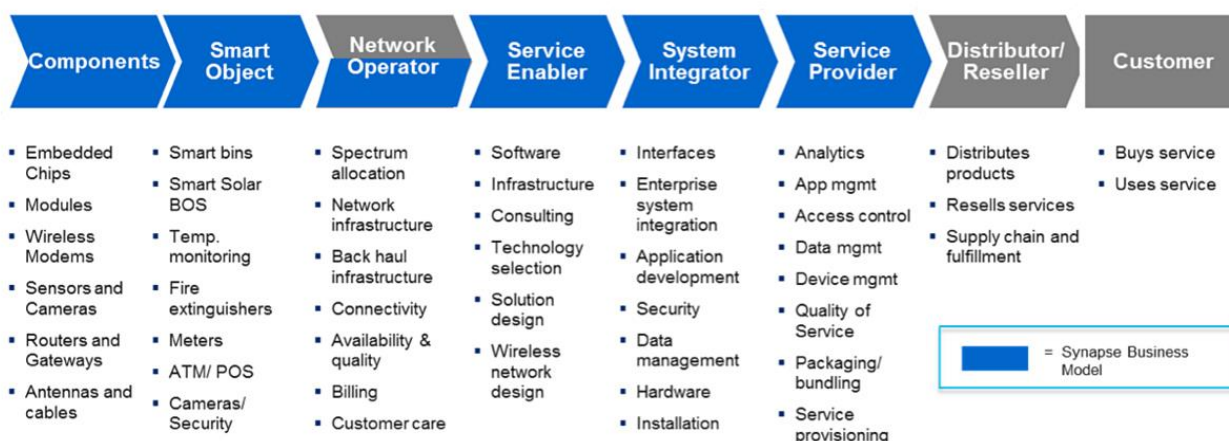


Figure 12: IoT value chain by Synapse Wireless Inc.

Standardization

There are several standardization initiatives that operate at different layers. On the lower “device-level” there are initiatives dealing with the device status and management, networking and connectivity, raw data, etc. At a higher abstraction level there are initiatives pursuing a “thing-level” standard: semantic dependent, dealing with the representation of the reality being sensed by the device, the data models, etc.

Two of the most relevant IoT standardization initiatives for this vision of FI-PPP are:

- OneM2M – is an industrial initiative with strong support from many of the industry’s more active players
- OMA NGSI – has received contributions from FIWARE and is broadly used therein

In any case, it has to be kept in mind that, although standards are important for many of the technologies that impact the way we live, implementing them too soon can be a distraction to true innovation and growth in the emerging IoT space. Allowing time to freely cultivate new concepts and push the envelope with new technologies will be a major factor in determining the eventual success of IoT. Standardizing too soon will mean stunted advancement for an industry that shows enormous promise for changing the way we live, connect and operate.

Regulation

The regulatory aspects of IoT that can influence the ecosystem performance can be grouped according to the following:

- Measures to ensure the proper operation of deployed IoT sensors and actuators, such as wireless spectrum regulation for new LPWA networks, etc.
- Measures to guarantee data integrity, privacy and user control, and security; generating trust and promoting usage and adoption

IoT is also perceived as a tool for the citizen engagement in politics and decision-making, they can, armed with a smartphone or wearable device interact with the city administrators, creating a symbiotic relationship that makes it possible for the Smart City to respond to their needs like a living organism. This implies, from one side, a challenge for city administrators tasked with finding new models of operation, but also a way to affect regulatory aspects. For example, in the list of issues that the law needs to address are loss of privacy and data protection.

Critical Mass

Although the IoT is growing in importance, it has yet to reach critical mass. For the IoT to work, objects must be redesigned and manufactured so they are Internet-enabled. Experts indicate that, for this to happen,

technologies must improve and become cost-effective enough to gain wide acceptance. The challenge for the embedded industry is to unlock the value of this growing interconnected web of devices, often referred to as the Internet of Things (IoT).

According to Metcalfe's Law, the value of a network is equal to the square of the number of devices connected to it.

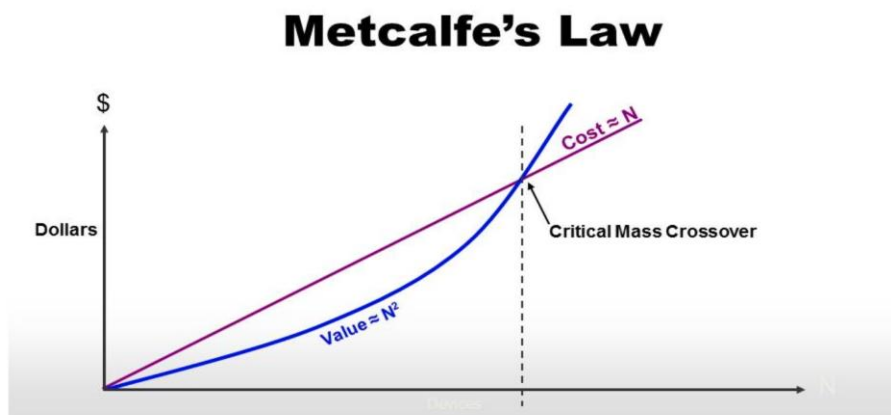


Figure 13: "The Value of a Network is Equal to the Square of the Number of Devices Connected to It"

One of the biggest deployments of IoT technologies already launched is indeed related to European Future Internet initiatives: Smart Santander, an early Smart City initiative in which nearly 20,000 IoT devices have been deployed as a city experimental lab.

In another noteworthy European initiative, starting in 2014, the French company Sigfox will deploy over 4,000 base stations connecting 30 cities in the United States, and effectively making it the largest IoT deployment.

Awareness

European Future Internet initiatives about Internet of Things are particularly well known across the EU and beyond the EU for the R&D actors. Awareness is occurring at three different layers: 1) Decision makers in cities and industries, 2) developers and SMEs, 3) citizens and end-users.

Associations and trade shows such as the IoT Forum and its periodical event IoT week, the IoT Expo, IoT world, and other private initiatives are representative examples of these awareness-creating actions.

Investment

Today, Europe is laying the ground work for the Third Industrial Revolution. The digitalized communication Internet is converging with a digitalized renewable Energy Internet, and a digitalized automated Transportation and Logistics Internet, to create a "super-Internet of Things (IoT)", that between 2015 and 2020 will create a high-tech 21st century integrated single market.

The plan approved end last year by Junker, aims to create a new European Fund for Strategic Investments (EFSI), with €5 billion coming from the European Investment Bank (EIB) and an €8 billion guarantee from existing EU funds designed to secure a contribution of €16 billion in total from the institutions.

But this is not enough. As said in the last EIB conference, Europe needs to mobilize much more than €315 billion to embark in the transformation of its economy, create millions of jobs, create new business opportunities and create a genuine post-carbon society

The availability of private capital for IoT deployments is now well established. From the public perspective, the biggest investment comes from municipalities requesting Smarter Cities. From the private perspective, a few Smart Industry deployments still outnumber the many long-tail opportunities.

Sustainable Business Models

Across the IoT value chain, European players are particularly strong in the integration link. This allows them to move upstream towards the definition of network protocols, devices and even impact on components.

Currently, device makers are trying to maintain hold of their platforms in order to gain greater exclusivity over added value services, especially in small or sector-specific deployments.

For the Internet of Things to become a reality, industry participants need to collaborate to ensure that solutions can securely and easily interoperate with one another. Efforts towards building standards-based solutions are emerging, but need to be further refined to ensure that solutions are future-proof.

Large and generic deployments seek open platforms and standards and leverage on size.

From a networking point of view, specific access and traffic tariffs have to be taken into consideration.

IPRs & Technology Transfer

There is a well-established patent base in IoT. The biggest owners of the IPRs are hardware manufacturers, and component providers, two areas where Europe is less active in the overall picture.

Research & Innovation

The IERC (IoT European Research Cluster), aims to establish a cooperation platform and develop a research vision for IoT activities in Europe and become a major entry and contact point for IoT research in the world.

It is expected that IoT will enjoy a prominent focus in the new Horizon2020 work programme 2016-17.

4.2.6. Big Data

Detailed Value Chain

A more detailed value chain would include a few additional specific actors:

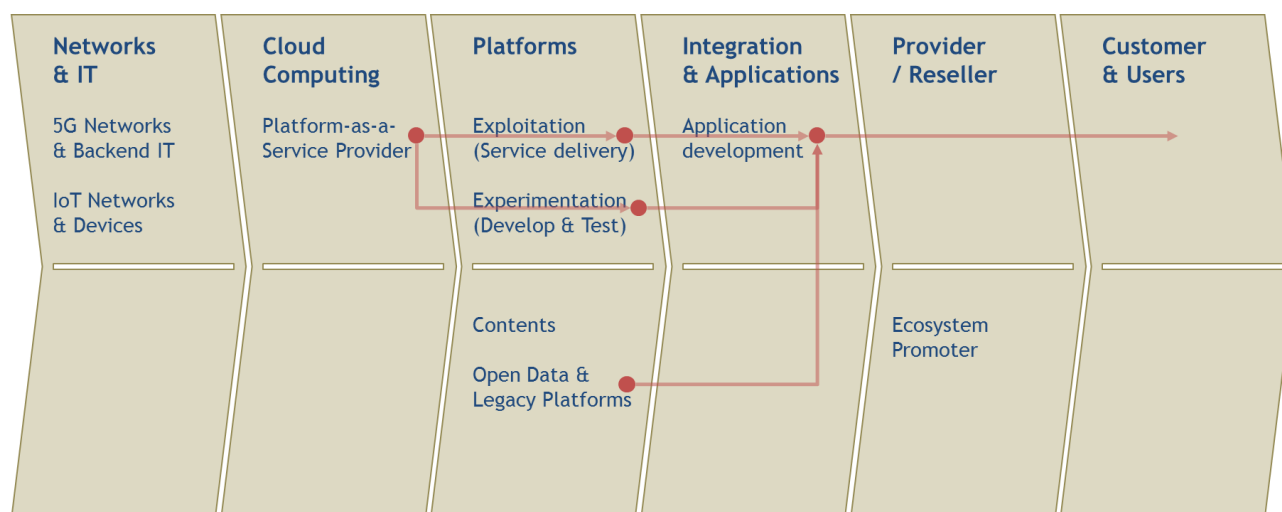


Figure 14: Big Data detailed value chain

A more detailed examination of the value chain is represented in Figure 15 that aims to:

- manage and coordinate the data from its generation up to the consumers that use the data, in order to make decisions,
- streamline the data management activities to enable positive outcomes for all relevant stakeholders,
- establish a portfolio-management approach to invest in people, processes, and technology that maximizes the value of the combined data and enables informed decisions to be taken that enhance the organization's performance.

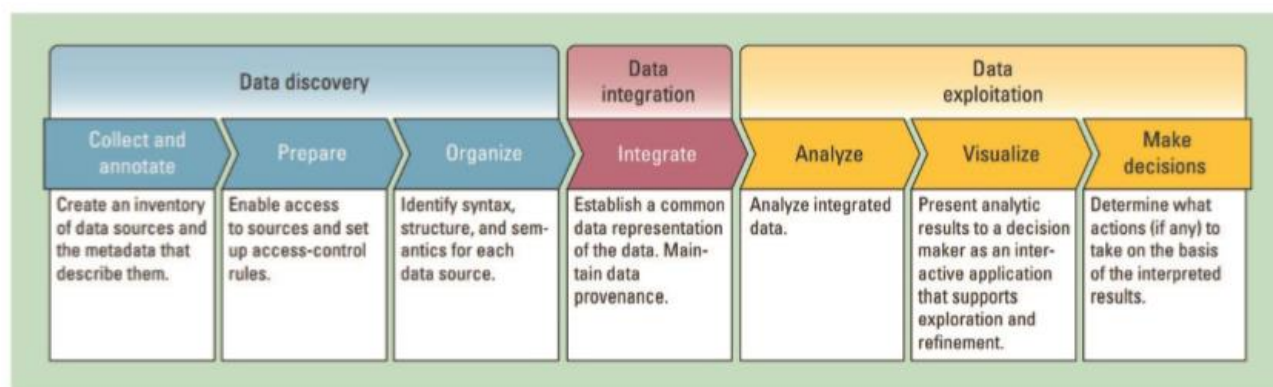


Figure 15: Big Data value chain (Miller and Mork, 2013)

Standardization

There are two types of standardization that are relevant to Big Data initiatives: standards about the structure and contents of the data that is to be extracted and loaded (including multimedia standards, such as WebRTC) and standards about the syntax and semantics of the data that is stored and analysis (including OWL and RDF).

Regulation

Data regulation is becoming a sensitive issue in the European Union and beyond. Strict regulation aims at ensuring the right to privacy and generating trust through security, which is resulting in one of the most complete regulations worldwide.

Critical Mass

The latest statistics say that 90 percent of the world's data has been generated in just the past two years. From customer transactions, Web-browsing data trails, social network posts and, increasingly, machine-embedded sensors, it can be absolutely overwhelming. And this is occurring on a global level across all types of industries.

Companies are still scrambling to manage ongoing data growth even as they pursue projects designed to generate more value from the data they already have.

According to a new IDG Enterprise survey of 1,139 IT decision makers, interest in Big Data continues its steady rise. In any case according to Gartner, Big Data has now officially passed the “peak of inflated expectations”, and is now on a one-way trip to the “trough of disillusionment”. Gartner says it's done so rather rapidly, because we already have consistency in the way we approach this technology, and because most new advances are additive rather than revolutionary

Awareness

Actions raising awareness should be handled carefully. On one hand, there is a positive impact in the ecosystem when the possibilities that Big Data brings to businesses and administrations start to be explored, but on the other hand, there is a negative perception of the loss of privacy and individuality that can hinder deployments of Big Data applications.

Investment

Private investment is linked to the availability of data in a given field of application. Turnkey solutions are now appearing (Big Data as a Service) and boosted by the implantation of Internet of Things solutions and the deployments of myriads of devices generating new information.

Public investment is focused on longer term objectives such as R&D initiatives, etc.

Sustainable Business Models

Applications with focus on analytics or visualization need commitment from the field of application in the form of a sufficient data flow. It is therefore easier for an ecosystem-based actor to rely in public administration data sources and platforms and aim at providing value to cities and citizens.

IPRs & Technology Transfer

Many companies now fight the Big Data IPRs arena. In particular the three active areas are batch processing algorithms, interactive analytics and visualization. However, a big share of these patents is sector-specific (healthcare, urban planning, etc.).

Research & Innovation

The recently founded Big Data Value Association²² aims at steering a Big Data Public Private Partnership and therefore securing a significant budget for Research and Innovation activities in EU.

4.2.7. Cloud Computing

Detailed Value Chain

A more detailed value chain would include a few additional specific actors:

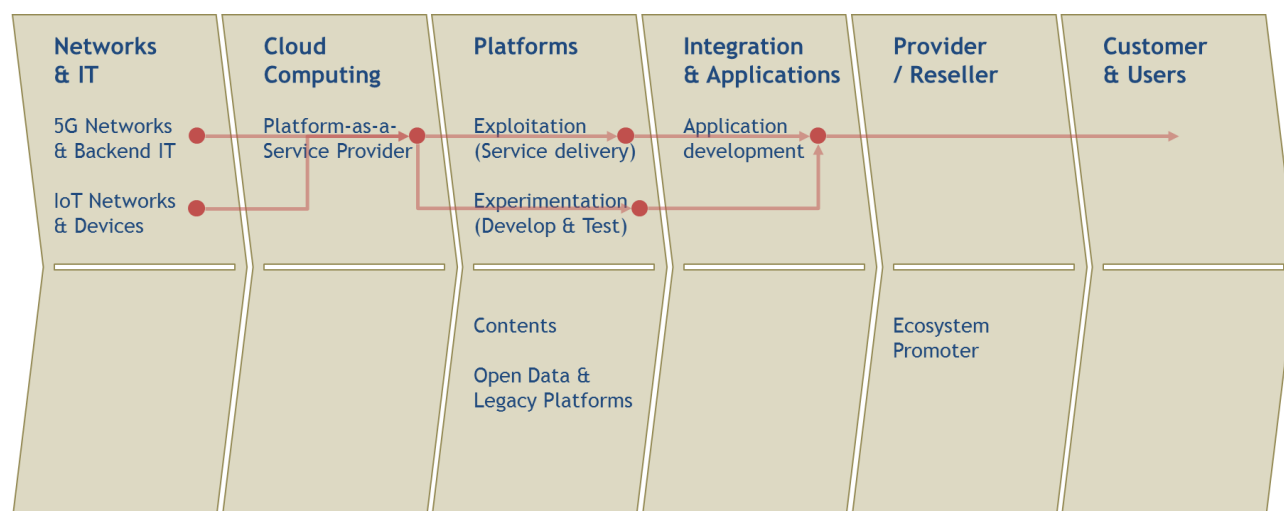


Figure 16: Cloud Computing detailed value chain

²² <http://www.bdva.eu/>

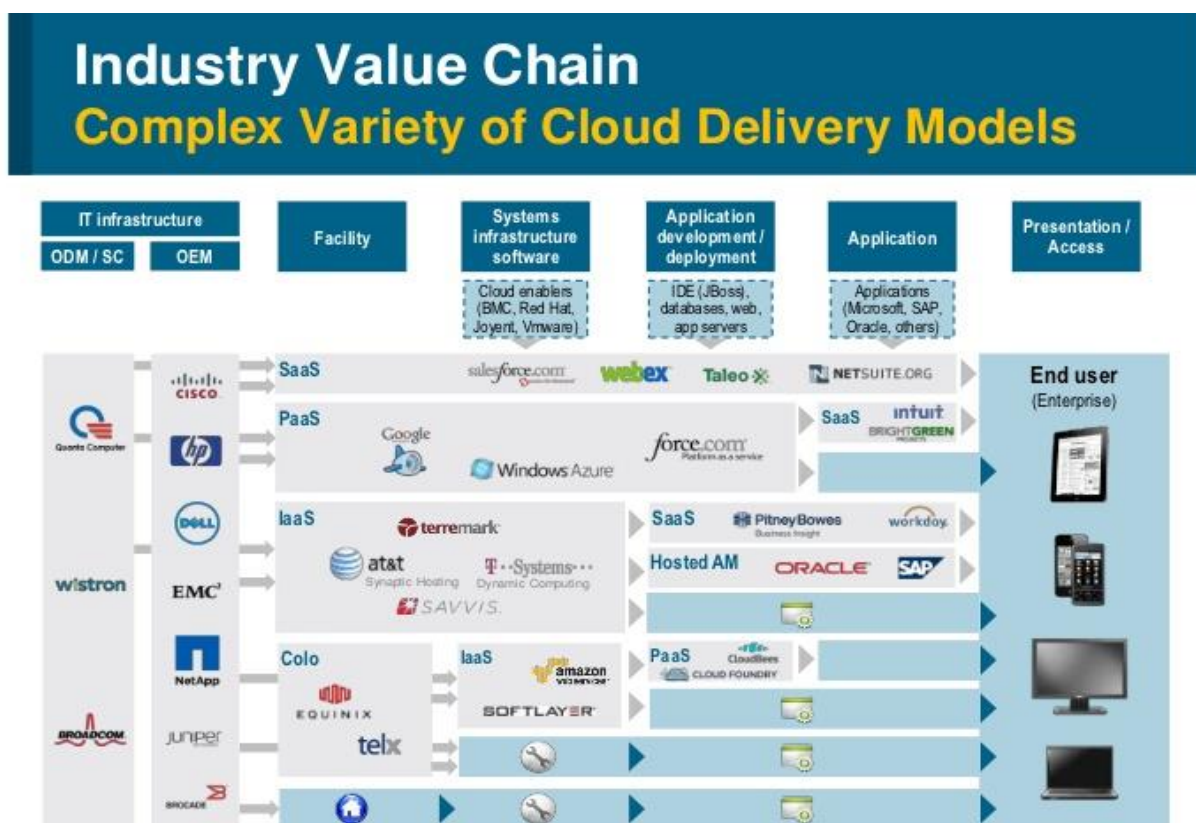


Figure 17: Cloud Computing value chain (CISCO IBSG 2011)

Standardization

There is a large number of underlying technologies under the generic umbrella of the term “Cloud Computing” and, associated to many of those technologies, is a number of competing standards and standardization initiatives.

DMTF	CIMI, Cloud Audit, OVF	Cloud Infrastructure Management Interface Open Virtualization Format
IETF	OAuth	Web authorization protocol
ISO/IEC JTC 1	CCRA	Cloud Computing Reference Architecture
OASIS	TOSCA, IDCloud	Topology & Orchestration Specification for Cloud Applications Identity in the Cloud
The Open Group		Reference Architecture
SNIA	CDMI	Cloud Data Management Interface
W3C	Linked Data	Data format standard

Figure 18: Standards for the Cloud (IBM – ECD Conference)

Two of the most relevant standardization initiatives for the FI-PPP are:

- ETSI Cloud Standards Coordination Initiative, promoted by the European Commission
- DMTF Open Virtualization Format, to which FIWARE initiative has contributed notably

Regulation

Cloud Computing enables the efficient, expedient and seamless transfer of data from one place to another. However, as a consequence, this means that data which could be considered personal or sensitive could be transferred without conforming to data protection laws. Even though it is extremely easy to transfer such data, this does not automatically equate to data protection laws not being applicable. Therefore, regulation is necessary to ensure data is transferred in accordance with the data protection laws in place and that Cloud Computing is not abused to flagrantly transfer personal data to countries with inadequate data protection laws.

The picture below gives a snapshot of the current EU legal framework

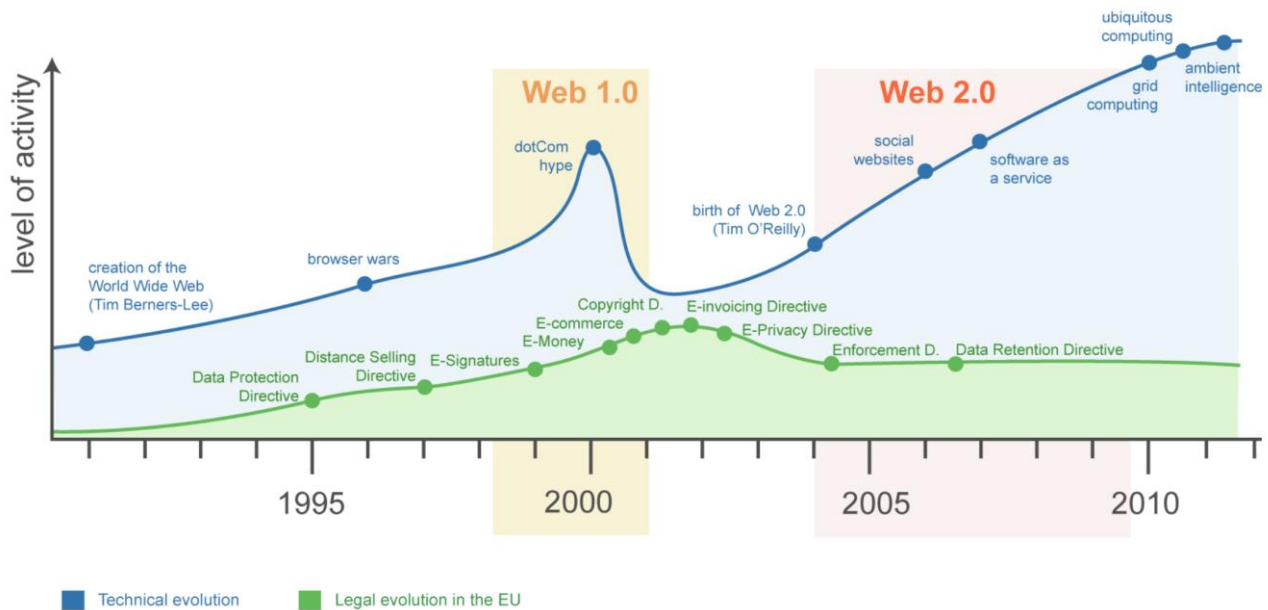


Figure 19: Cloud Computing legal issue (DLA Piper Brussels)

The development of public, private, government and hybrid Cloud Computing services has complicated data storage and processing over the last twenty years. The GDPR (General Data Protection Regulation) will help by clarifying the responsibilities of organizations relating to the data they handle and store, thus making it easier for both European and non-European companies to comply and avoid penalties.

The EU's European Council aims for adoption in 2015/16 (see the timeline in Figure 19) and the Regulation is planned to take effect after a transition period of two years

Cloud Computing regulatory issues orbit around two main focuses: the first is related to the data regulation laid out in the Big Data chapter. The second is how to guarantee that the suppliers meet all the regulatory requirements that apply to the customer ("back to back" agreement).

Critical Mass

19% of EU enterprises used Cloud Computing in 2014, mostly for hosting their e-mail systems and storing files in electronic form.

46% of those firms used advanced Cloud services relating to financial and accounting software applications, customer relationship management or to the use of computing power to run business applications.

In 2014, almost twice as many firms used public Cloud servers (12%) as private Cloud servers (7%), i.e. infrastructure for their exclusive use.

Almost four out of ten enterprises (39%) using the Cloud reported the risk of a security breach as the main limiting factor in the use of Cloud Computing services.

A similar proportion (42%) of those not using the Cloud reported insufficient knowledge of Cloud Computing as the main factor that prevented them from using it.

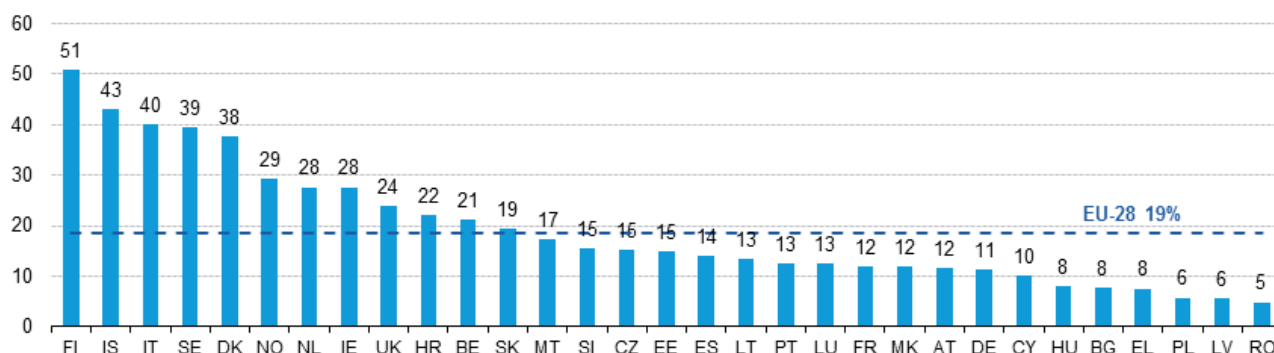


Figure 20: Use of Cloud Computing services, 2014 (% of enterprises) (Eurostat)

It's predicted that, by 2020, more than a quarter of all applications will be available via the Cloud.

A Goldman Sachs study published this month projects that spending on Cloud Computing infrastructure and platforms will grow at a 30% CAGR from 2013 through 2018 compared with 5% growth for the overall enterprise IT²³.

The following graphic and table provides an overview of Forrester's Global Public Cloud Computing market size analysis and forecast for the years 2011 to 2020.

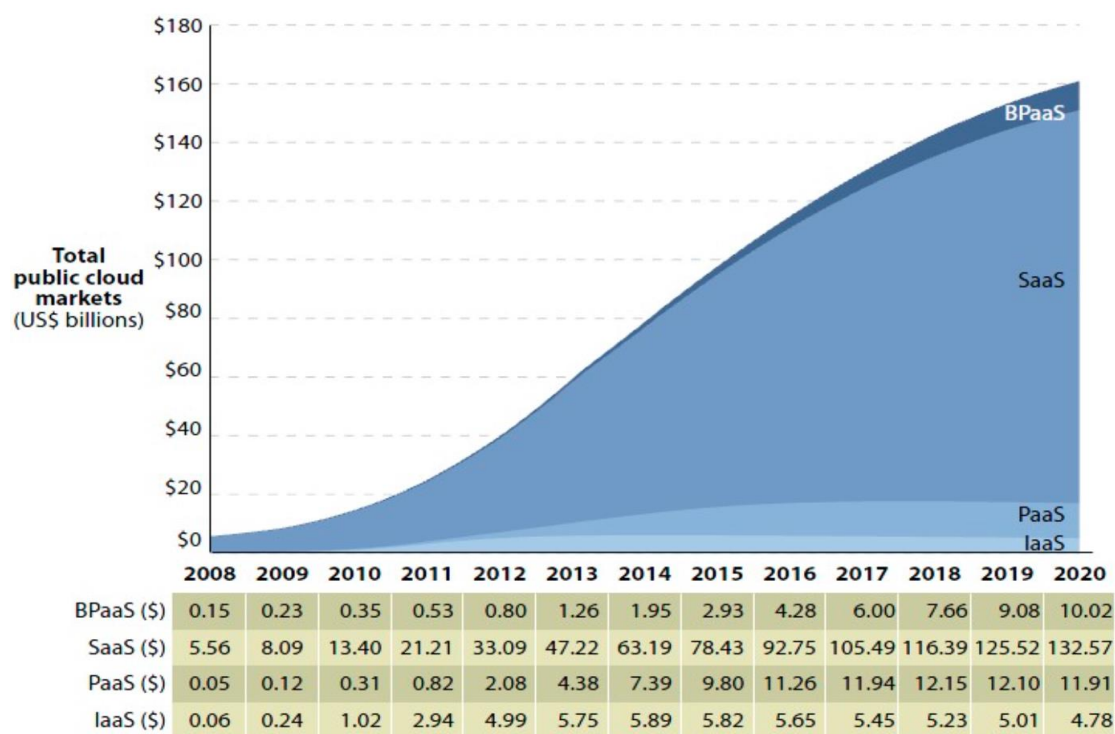


Figure 21: Forecast Global Public Cloud 2011-2020 (Institut Sage)

Awareness

²³ <http://www.forbes.com/enterprise/>

Across the industry there are multiple ongoing tradeshows and initiatives promoting the adoption of Cloud technologies. The main target is the prescripts and users of traditional IT infrastructure and technology.

A dedicated trade show will be held in November 2015 and in June 2016 in US: Cloud Expo

Cloud Expo is the single show where delegates and technology vendors can meet to experience and discuss the entire world of the Cloud:

- Cloud Computing
- Big Data
- SDDC
- IoT
- DevOps
- WebRTC

An equivalent trade show will be held in London, Cloud Expo Europe, in April 2016 where themes such: virtualization, infrastructure, storage, Cloud management, security & compliance, SDD & SDN, Data Analytics and Open Cloud are the key discussion points of the conference.

Investment

Public investment in Cloud Computing normally comes bundled with traditional IT systems vendors, and is likely to be provided from traditional IT services providers.

Private investment is also on a rise: according to the latest Cowen & Company IT spending survey, 53% of enterprises plan to purchase Infrastructure-as-a-Service (IaaS) services from an IT services provider, and is the highest spending priority for enterprises in 2015 for one fifth of the companies.

Spending on Cloud Computing infrastructure and platforms is expected to grow at a 30% CAGR from 2013 through 2018 compared with 5% growth for the overall enterprise IT.

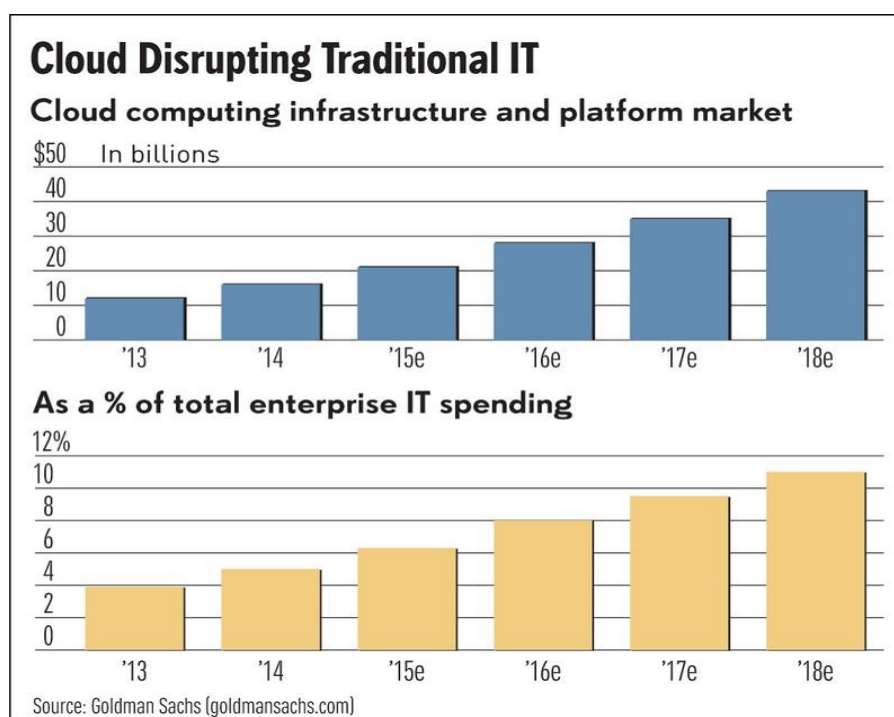


Figure 22: Cloud Investment 2013-2018 (Goldman Sachs)

Sustainable Business Models

Business models for Cloud Computing providers are increasingly bundling communication packages and normally include communication QoS considerations.

A sustainable Cloud Computing business model should have the capability of translating new technologies into a service value proposition.

Scalability, reliability, security and cost effectiveness are the parameters on which the available Cloud storage services are being evaluated.

IPRs & Technology Transfer

One of the most important aspects regarding IPRs in Cloud Computing is the jurisdiction of IPRs, which is normally quite local. On the other hand in Cloud Computing deployments, customers, virtualized software and Cloud providers, etc. can operate from different countries where the validity of IPRs differs and might result in infringements.

Research & Innovation

Cloud Computing has been part of the R&D&I agenda for a number of years. The evolution of the technology is leading to new paradigms such as networking in the context of software-defined data and the merging with software defined networks. Domain-specific Clouds are the subject of research in many fields.

4.2.8. Networks

Detailed Value Chain

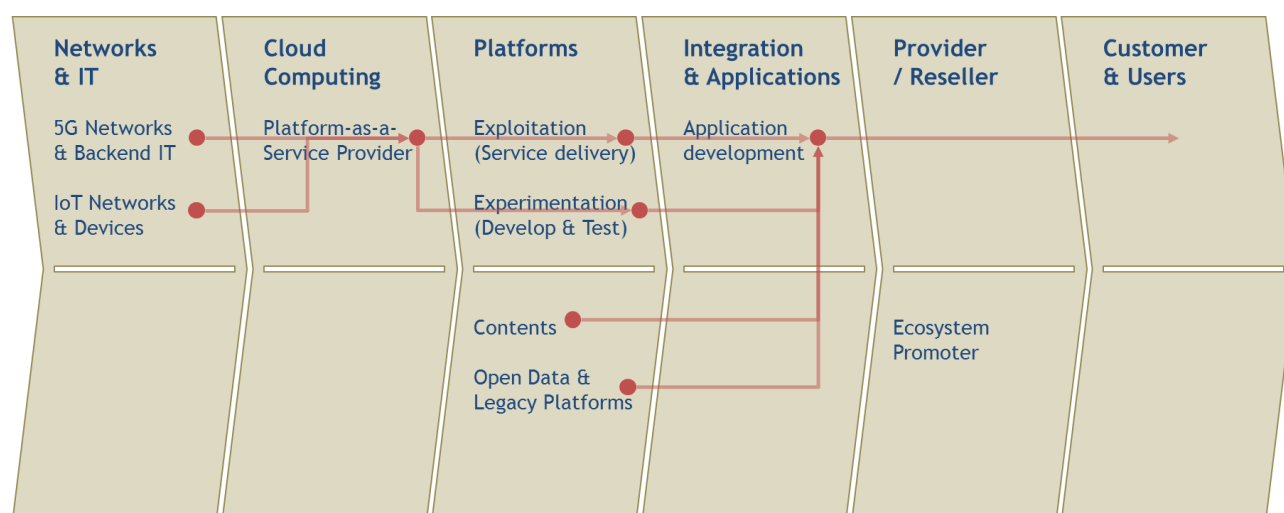


Figure 23: Network detailed value chain

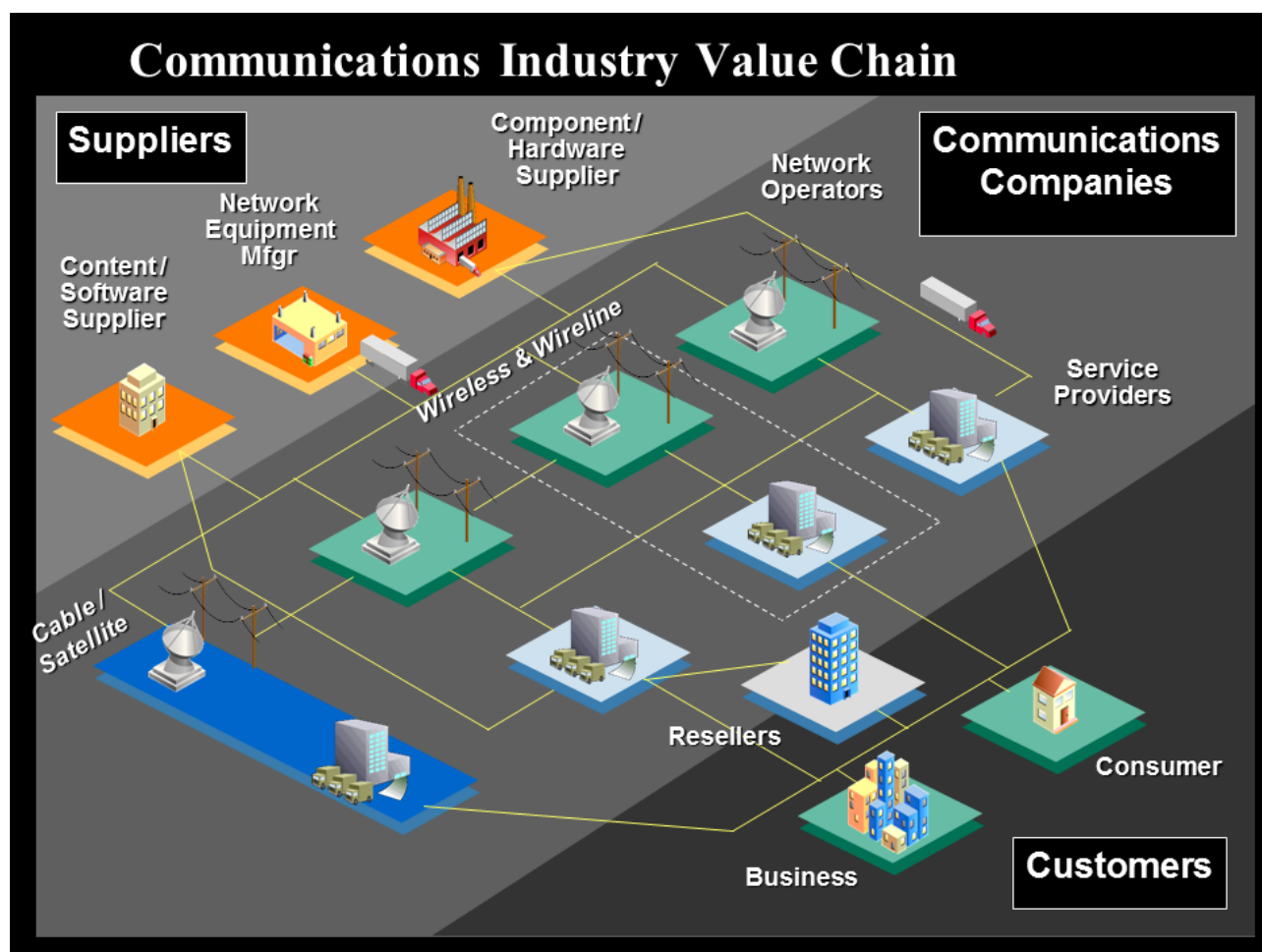


Figure 24: Communication Industries value chain²⁴

In the first instance, networks must evolve in terms of pure capacity and connectivity speed. However, in the 2020 scenario this will not be sufficient. The functional capability of the network must be matched with highly sophisticated network control functionality that is capable of overseeing the networking, ensuring all delivery promises are kept, while optimizing the use of resources and energy for both cost and environmental reasons.

At the same time, the whole value chain (including content owners, network operators, equipment vendors, and device manufacturers) should work together to create attractive services and elevate user experiences. Operators benefit from the added perceived value of bundled content and can augment their brands through association with carefully selected players, with ‘cool’ factors or ‘household name’ recognition. Content owners, on the other hand, benefit from the operators’ reach (subscriber base and network coverage) as well as their established capabilities for marketing, charging, and revenue sharing.

Standardization

There are countless standards, organizations and initiatives related to network technologies that will impact Future Internet innovation. However, given the scope of this document, two important sets are mentioned:

- Network standards related to the interaction and integration to Cloud Computing, such as Software Defined Networks and Network Function Virtualization, for example: the OpenFlow protocol and the IRTF’s Software Defined Networking Research Group.
- Network standards related to the increased capacities required by the newly created businesses. For

²⁴ practicalanalytics.wordpress.com

example, a large share of the work being carried out in the 5G-PPP.

Regulation

The European telecom sector is faced with significant challenges in terms of rapidly emerging new technologies and new forms of competition and business models driven by these technology changes. However, the current regulatory framework in Europe lacks incentives to invest and shows clear signs of obsolescence.

Along the future regulatory trajectory in Europe, there are a series of challenging issues, which require steps to be taken to modernize the regulatory situation. When defining the trajectory of regulatory modernization, Europe should avoid going for incremental improvement and rather aim at an ambitious scenario and step into a “*Virtuous Circle*” model, based on innovation, investment and smart regulation (“*Regulation 2.0*”)²⁵.

Critical Mass

The transformational impact of digitization (the mass adoption of connected digital technologies and applications by consumers, enterprises, and governments) continues to drive telecommunications operators’ most critical strategic and operational decisions.

Global operators’ revenues are stagnating, even as operating and capital expenditures are increasing. Meanwhile, the “over-the-top” (OTT) players - video, audio, and other services such as Netflix and Spotify that piggyback for free on telecom systems - are gaining in number and popularity, making the traditional operators’ task much more difficult.

Telecom operators that have adopted aggressive digitization strategies are generally faring better than their more conservative rivals, although the transition has not been smooth. In some cases, early digital initiatives have been haphazard, and many telecom companies have learned that they must take a more focused approach in determining which digital products and services to offer if they are to capture real opportunities in adjacent businesses and broader digital ecosystems.

Awareness

Although traditional networks are very well known, there are two areas that require promotion: the possibilities of Network IT in coordination with Cloud Computing, and the capabilities and deployments of new ultra narrowband LPWA networks.

Investment

A spectre of lack of investment is haunting the telecom sector in Europe. The European Union (EU) had a lead in mobile technology in the 1990s, but has since fallen behind in investments in networks. Despite the EU’s leading role in the standardization and development of LTE, in 2012 the EU’s share of global LTE (4G) investments was 6%, compared to 47% in USA, 27% in South Korea and 13% in Japan. Investments in connectivity boost economic growth, particularly under the conditions that exist in Europe today.

Whilst, globally, operators’ revenues are stagnant, the European telecom sector is suffering from a downward spiral in revenues and earnings, combined with heavy competition on prices, with a detrimental effect on investments in network deployments. On the other hand, the leading markets, such as the US, South Korea and Japan, are witnessing an upward spiral in revenues and earnings, combined with healthy rates of investments and competitive dynamics focused on differentiation with quality, performance and coverage of networks rather than prices.

²⁵ http://www.serentschy.com/wp-content/uploads/2014/02/The_Virtuous_Circle_Buch-download.pdf



Figure 25: Investment levels led by financial returns (ETNO)

This digital gap in infrastructures is not caused by a lack of willingness by the European industry to invest revenues: **USA and Europe have similar investment/income ratios, but different incentives and rewards.**

Sustainable Business Models

The business models of a Network provider depend heavily on the initial investment required to setup the associated network infrastructure. Traditional telcos have existing networks and capabilities that facilitate the launch of any new innovation, whereas new entrants face an access barrier.

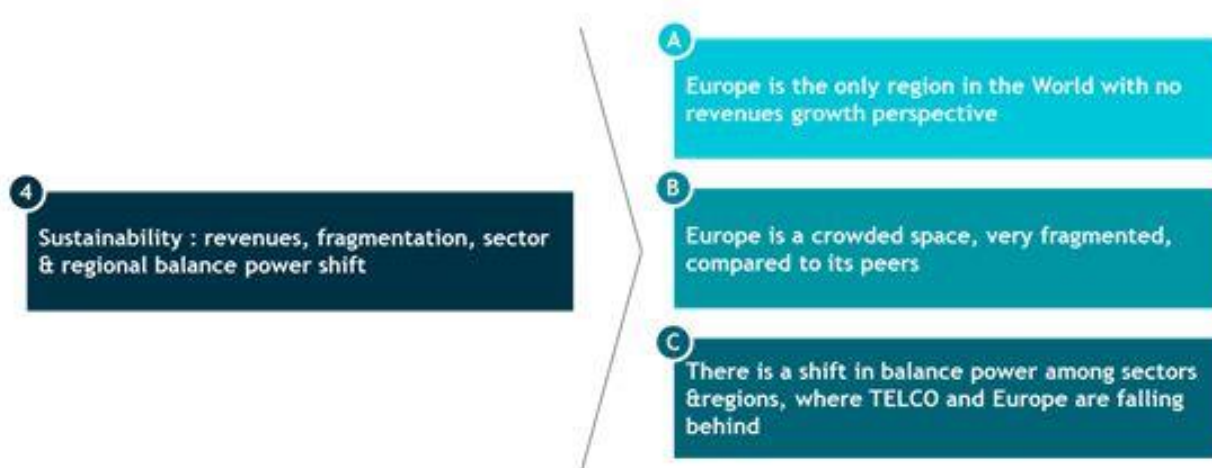


Figure 26: Investment levels led by financial returns (ETNO)

The negative outlook on European telecom revenues, **despite a strong traffic increase**, reveals a structural problem in Europe.

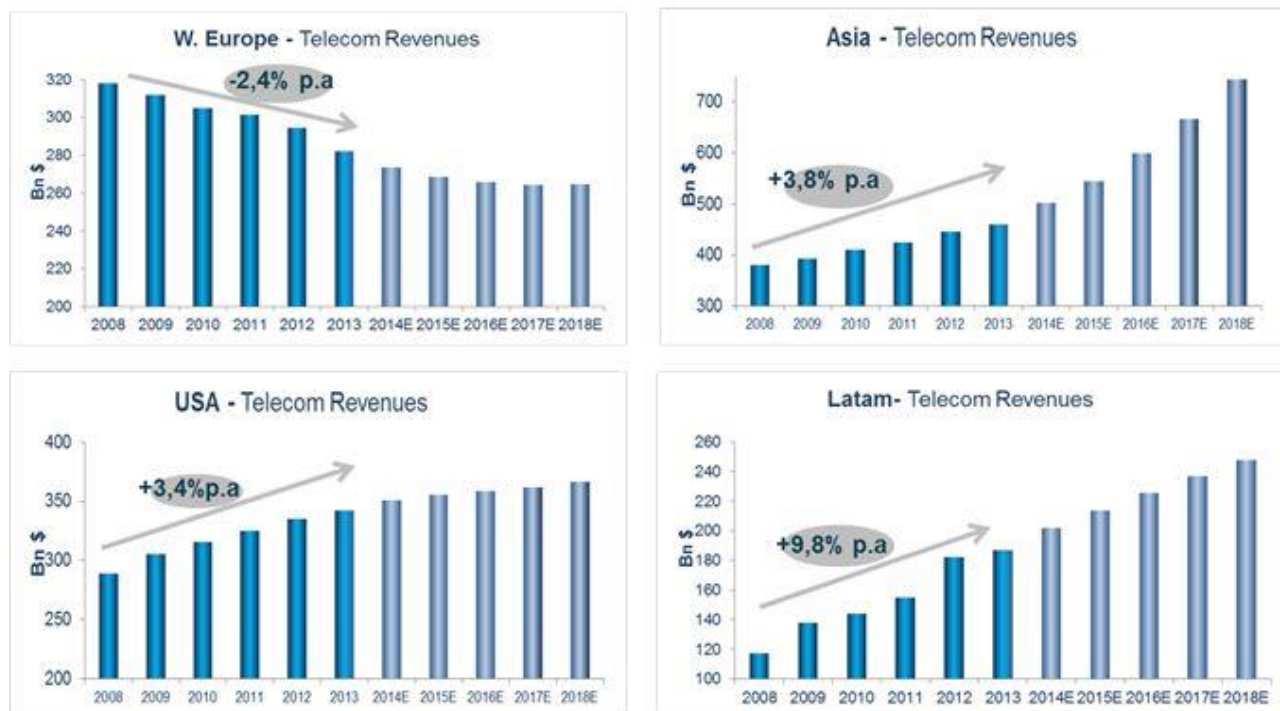


Figure 27: Worldwide overview of Telecom Revenues (IDC Worldwide Blackbook 2014)

Europe has five times more fixed Network Operators than the US and more than 10 times the number of Mobile Network Operators. There have been **big consolidation movements in the US and less in Europe**.

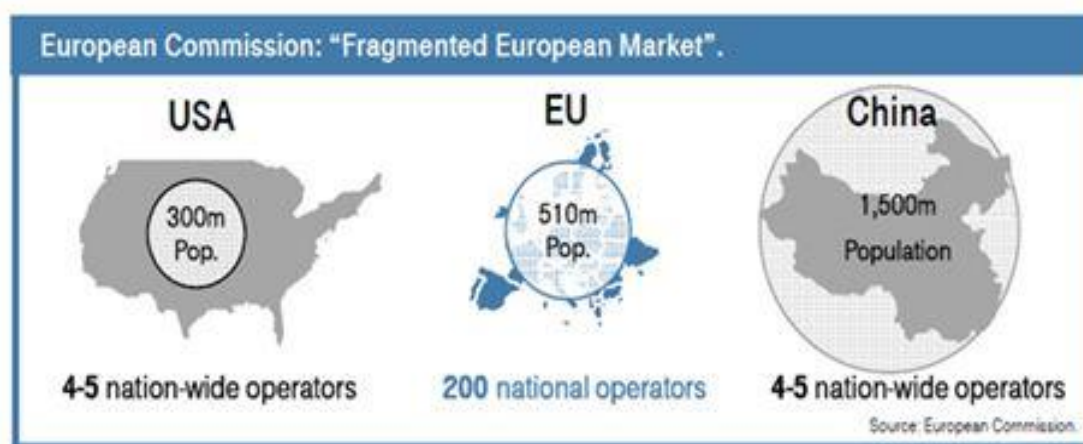


Figure 28: Fragmented European Market

Europe is losing leadership in the Digital Industry. The return on invested capital is falling behind in the telco industry. Europe has no presence in the Internet Service Business. The telco sector contribution to ICT growth is falling in Europe.

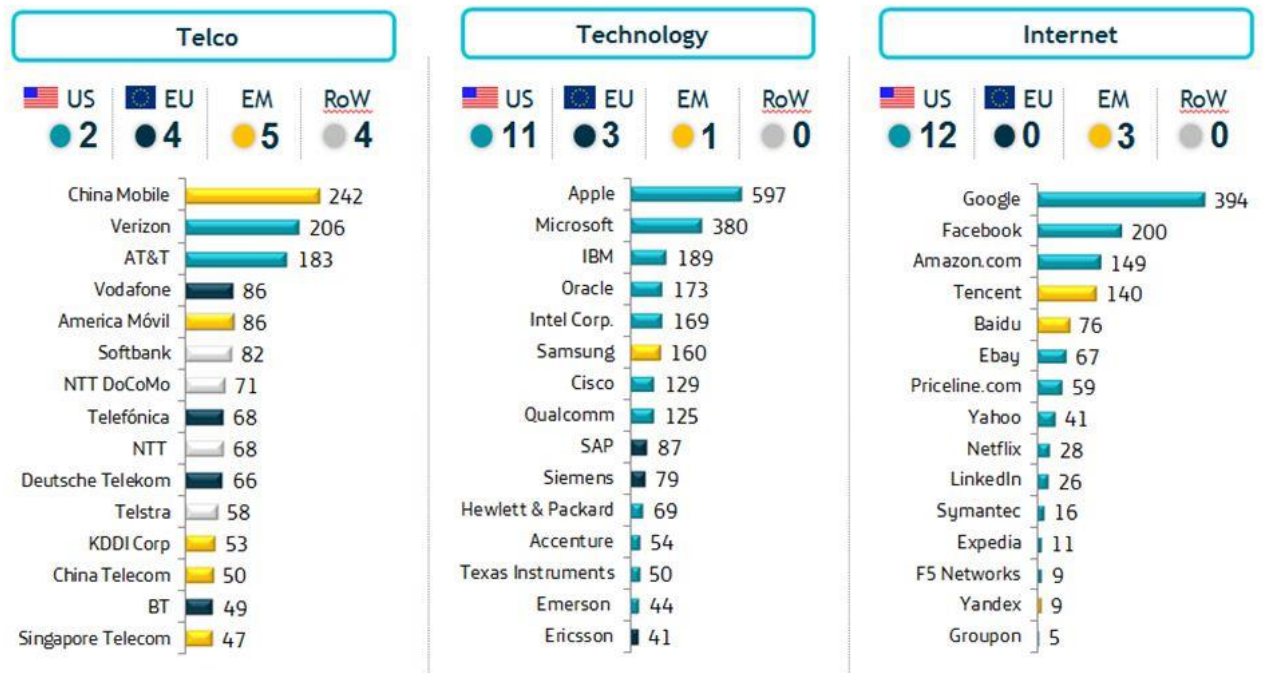


Figure 29: Data Market Cap (Bloomberg, October 2014)

IPRs & Technology Transfer

The list of existing networks IPRs is vast, and telcos, having been a key player and innovator over the last years, are owners of a large share of them. The need of alignment between national telco operation and national jurisdiction of IPRs, alleviates the possibility of infringements and subsequent impediment.

Research & Innovation

Networks have been part of the Research & Development agenda of the European Commission and the Member States, having been the target of dedicated Calls for Proposals. The 5G-PPP will include many aspects of Network R&D&I mentioned in this document.

4.2.9. Media Internet

Detailed Value Chain

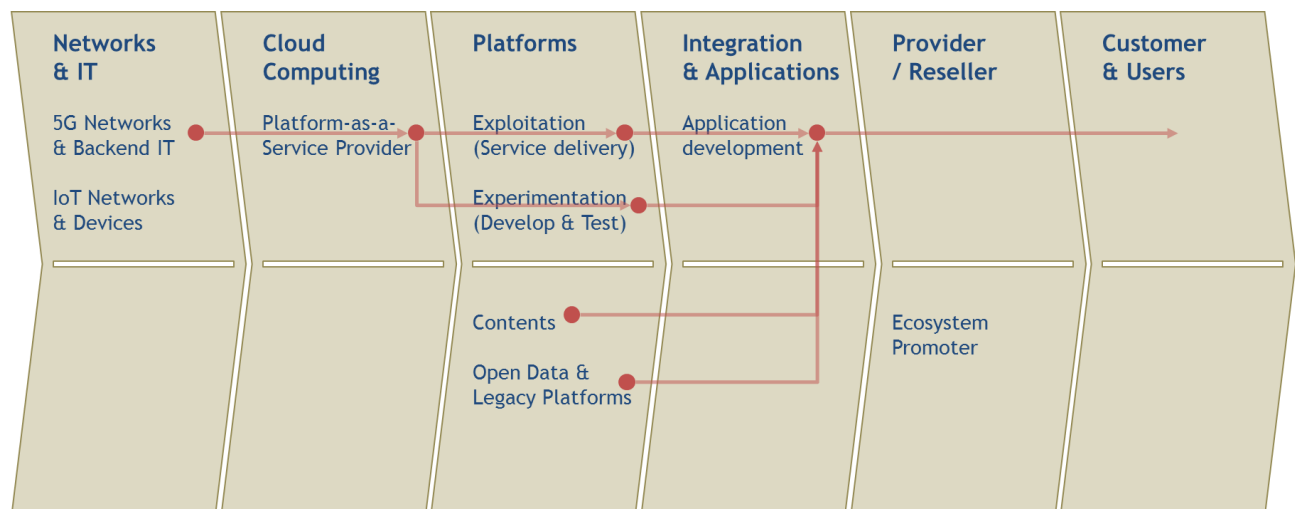


Figure 30: Media Internet detailed value chain

The Internet value chain

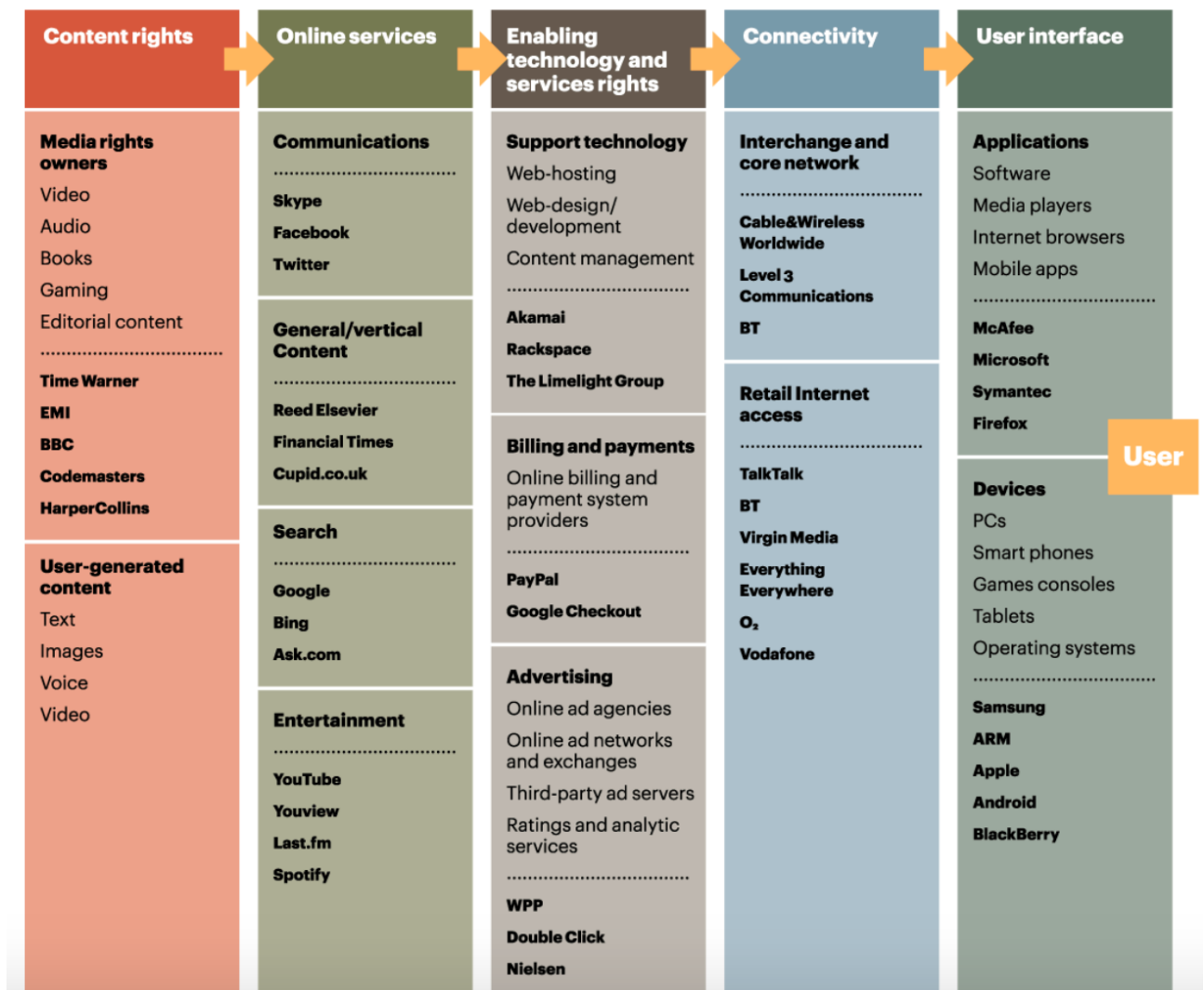


Figure 31: Media Internet Value Chain (A.T. Kearney)

Standardization

The Media Internet encompasses a large number of technologies. The main standardization initiatives relate to: content format, encoding and transmission over CDNs, SLAs, advertizing integration, and application development and marketplaces. For example, online social networks rely on FOAF²⁶ to describe people and relationships; computer systems use WSDL²⁷ to describe distributed software-based services; GoodRelations²⁸ is used to mainly describe products; and business-to-business systems use ebXML4 to describe transactions, orders, and invoices. Adding to these existing standards, Linked USDL describes services in a comprehensive way by providing a business or commercial description around services. Therefore, Linked USDL is seen as one of the foundational technologies for setting up emerging infrastructures for the Future Internet, web service ecosystems, and the Internet of Services.

²⁶ <http://www.foaf-project.org/>

²⁷ <http://www.w3.org/TR/wsdl>

²⁸ <http://purl.org/goodrelations/v1>

The most referred-to application standards quoted in FIWARE are USDL (Unified Service Description Language) and RESTful APIs for application development.

Regulation

The convergence between media, Internet and telecoms is a game changer that has brought many new services, devices and distribution models. One of the key outcomes of the convergence is that the traditional value chain has evolved into a *value web*, with multiple, parallel routes that services can follow between creation and consumption. Services that are very similar to end users can be subject to different regulations, depending on the route through the value web and the organizations involved.

The figure below shows some of the key classes of regulation that are important in the value web for video, together with the approximate area in the value web where to apply.

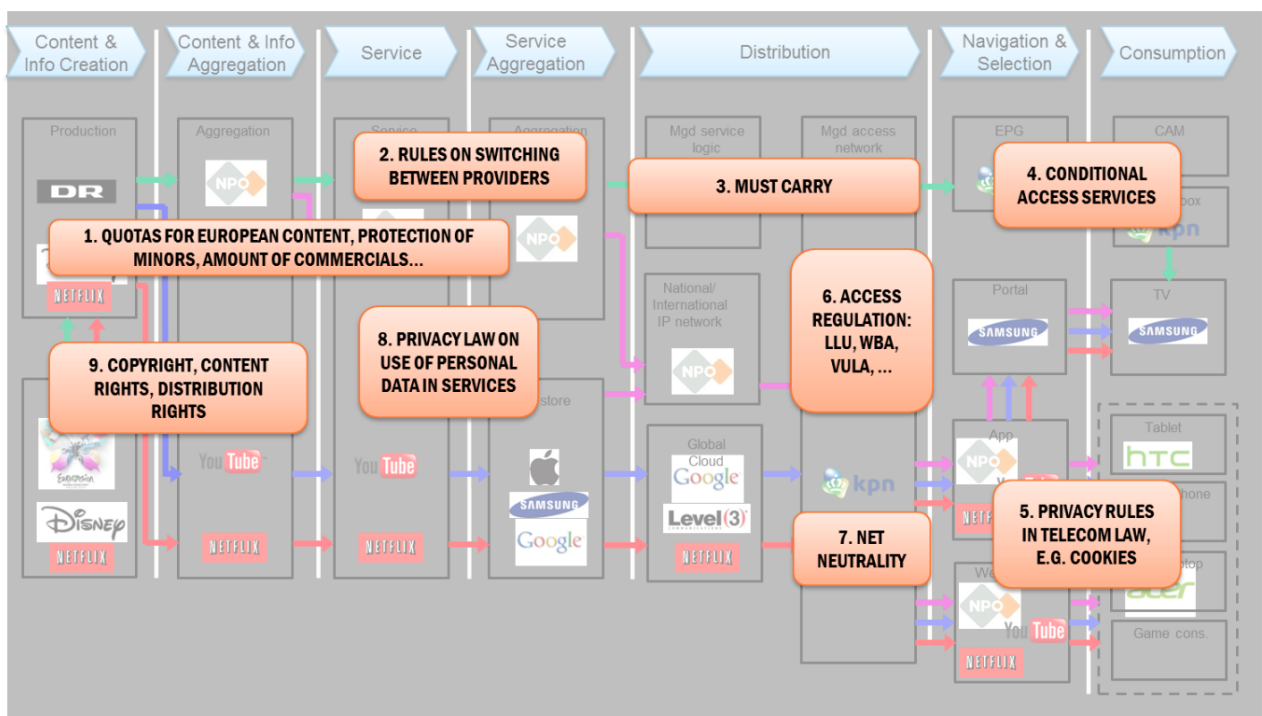


Figure 32: Regulations that Affect Video Services in the Converged Value WEB (TNO Innovation for Life)

Awareness

The Media Internet, applying FI technologies, is implemented in diverse business areas. Among them, social media, IPTV, games and e-learning represent important business areas addressed by the FI-PPP. As the Media Internet directly influences the daily lives of citizens, innovative services and applications are rapidly distributed to the early adopters and stimulate the market's appetite for new technologies and services.

Investment

Investment in new Internet Media innovation often has to deal with the cost of provisioning content, which in some cases can prove to be a deterring access barrier.

Content marketing is a key, and powerful, channel across different marketplaces, but marketers must make it part of the entire programme across campaigns and channels.

A separate report found marketers' main content marketing goals as being to: acquire new customers (42%) and increasing brand awareness (more than 37%).

Sustainable Business Models

The shape of media is changing as users shift from desktop to mobile. Today, content providers need to focus on different formats, shorter stories and new monetisation models. With the viral consumption of online media we will see a future of new emerging business models among the online media players.

The analysts predict that the most successful media players will be those that are most able to target, repackage and programme creative content.

The new media consumption paradigms are often criticized for being non-sustainable, for example, on-demand music or video streaming services like Spotify. However, new content generators and aggregator are now getting involved in the complete distribution process, controlling the experience from end to end, and are promoting the Media Internet as the new predominant media distribution and consumption platform.

Several start-ups are now focusing on efficiency in terms of storytelling, content marketing, branding, native content, marketing, pricing and distribution, and some interesting new business models are:

- Crowdsourced payment (Groupon model) for in-depth articles (rapport.fi, etsuri)
- Personalized mobile news aggregators (Zycks app, Newsanglr, Dashbook, Etalia, brickflow, lekiosk)
- Branded social open spaces (shore.li)
- Crowdsourced and location based news (nunki, storyhunter, newstag)
- Targeting for reach and scale (newsatme.com, 8bit, feedspy, wordlift, buzzfeed)

IPRs & Technology Transfer

As shown in Figure 32, IPRs for content (copyright) are a fundamental element in Media Internet innovation. This differs from the other technological drivers in which IPRs for technology (patents) are the most relevant. Patents are also very relevant in Media Internet underlying technology, such as CDNs or Codecs.

Research & Innovation

While there is the intention to promote a Rich Media PPP in Europe, research is mainly addressed at profiling users and content and improving recommender algorithms to foster media consumption, and facilitating ubiquitous access to content.

Such R&D initiatives are designed to prove the viability of new technologies and validate innovative solutions through large-scale demonstrations, piloting and testing of use cases in order to ensure sustainable distribution that facilitates the convergence and integration of broadcasting, Internet-based services on broadband, audio-visual and social media. Multimodal and multidisciplinary approaches to research technologies should be developed that respond to the new demands on the side of *content* (3D, user-generated, real-time media, social media, ...) and on the side of the *users* (context-centric, semantic, relevant community feed-back, ...). This includes new forms of experiencing environments (immersive, multisensory and interactive, in any device, always connected).

4.3 Impact of Future Internet in the Different Fields of Application

The Future Internet itself is a key driver for the future European economy. However, the biggest impact will come from its convergence with other economic sectors, through the digitalization of the industries, the possibility of rapid start-up creation and unprecedented growth prospective. The FI-PPP has been created to provide 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. To enable such multi-sectorial services taking advantage of the advanced Future Internet technologies, the FI-PPP provides an open standard platform named FIWARE, which provides a rich library of GEs of important Future Internet features such as IoT, Big Data, Clouds, virtual networks, etc. A list of the FI-PPP Use Case projects and Accelerator projects are illustrated in Table 4. Their detailed service and business coverage are given in Annex B.

Business Sector	FI-PPP Projects
Smart City	Outsmart, Safecity, FI-C3, CEEDTech, European Pioneers, IMPACT, INCENSE, Frontier Cities, SOUL-FI, SpeedUP!
Smart Energy	FINSNEY, FINESCE, SOUL-FI, INCENSE, Finodex, CEEDTech, SpeedUP!
Smart Transport	Instant mobility, Frontier Cities, Soul-FI, Finodex, Finish
Smart logistics	Finest, FIspace, Finish
Smart manufacture	FITMAN, FABulous, CEEDTech, Finish
Smart Agriculture	SmartAgriFood, FIspace, FRACTALS, Finish, SpeedUP!
Healthcare	FISTAR, FICHe, FI-C3, Finodex, FI-ADOPT
Multimedia	FI-CONTENT, FI-CONTENT2, European Pioneers, FI-C3, IMPACT, CreatiFI, FABulous
Environment	ENVIROFI
eLearning	FI-CONTENT, SOUL-FI, IMPACT, FI-ADOPT, European Pioneers

Table 4: Business sectors covered by FI-PPP Use cases and Accelerators projects

As shown in Table 4, the FI-PPP provides opportunities to build large communities, through the creation of multi-sectorial services based on FI technologies. A large set of services and applications are being tested within the FI-PPP Programme, and more innovative services and applications will emerge via the Phase III Accelerators. The final study report of FI3P²⁹ estimates that the annual overall positive impact of the FI-PPP on European real GDP will reach a maximum of €28 bn in 2020. This corresponds to 0.24% of EU27 real GDP. Of course, such a positive economic impact will only be achieved if the FI-PPP successfully meets the full set of its objectives.

To achieve further positive impact of the FI-PPP Programme, it is important to bring innovation in FI-PPP beyond its current business scope. After reviewing some references of emerging technologies (e.g., Gartner's yearly hype cycle for emerging technologies 2014³⁰ and timeline of emerging science and technology³¹), four science & technologies have been selected as FI business drivers that could provide mutual growth of FI technologies and FI-PPP business sectors. The Gartner's hype cycle indicates the following technologies as being *innovation triggers*: brain-computer interface, neuro-business, biochips, virtual personal assistants, speech-to-speech translation, autonomous vehicles, bio-acoustics sensing, speech to speech translation, etc. Imperial College's Timeline of Emerging Science and Technology illustrates the trends and ideas of present and future services in the areas of: Digital, Green, Bio, Neuro and Nano. A more detailed analysis of Gartner's hype cycle and Imperial College's timeline is introduced in Section 4 of deliverable D1.1.

By integrating such study results, we conclude that:

- BIO (Bio medical, Bio pharmaceutical) and FI are triggering each other for business innovations and will widen the scope of eHealthcare and influence the improvement in the overall quality of lives (e.g., biochips lifelog, DNA Internet). New trends of healthcare systems are already being created with the

²⁹ <http://www.fi3p.eu/assets/pdf/final/FI3P%20Final%20Study20Report%20v1%200.pdf>

³⁰ <http://www.gartner.com/newsroom/id/2819918>

³¹ <http://www.imperialtechforesight.com/future-visions/87/vision/timeline-of-emerging-science-and-technology.html>

convergence of ICT and BIO in biomedical engineering areas that include the application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g. diagnostic, or therapeutic). The organization Research and Markets estimated (2013) that the global BIO market, valued at \$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 2020³².

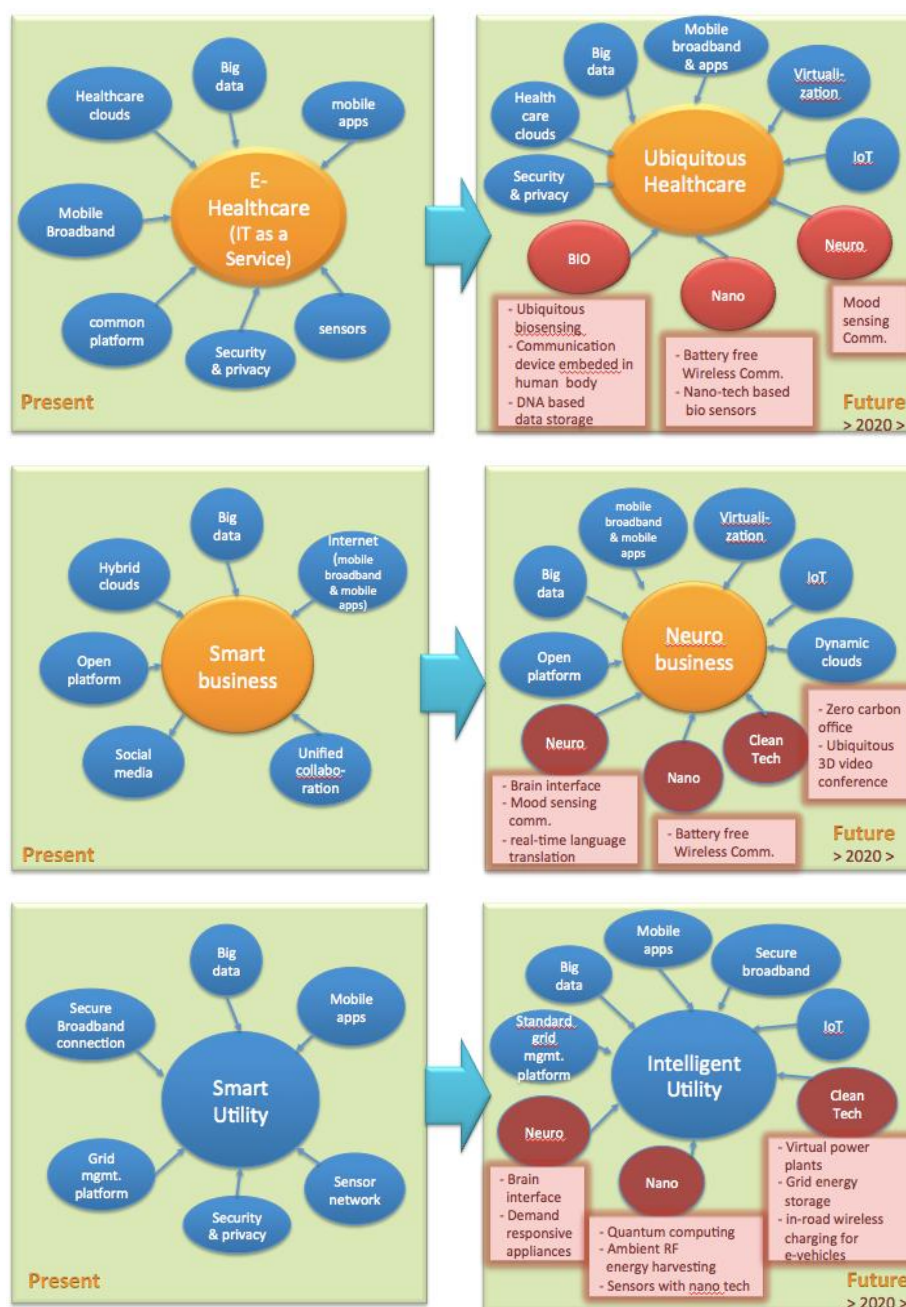
- CleanTech (i.e., green technology) and FI are influencing each other and make co-competition between traditional sectors (e.g., manufacturing, automobile industry) and the Internet industry that leads to business evolution and innovation for each other (e.g., smart grid, autonomous vehicles, virtual personal assistant). There are strong driving forces in the CleanTech industries, such as demographic change, urbanization, globalization, scarcity of resources and the challenges of climate change. Greater energy and materials efficiency gives the economy in general strategic benefits in light of international competition. A wide area of industries and services is included in this category, e.g., Smart grid, smart utility, electric vehicles, e-administration, remote work collaboration, video conferencing, etc. Worldwide, the CleanTech 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 government³³.
- Neuroscience, that deals with the structure or function of the nervous system and brain, has great impact on the innovation of ICT and the Future Internet. integration of Neuroscience and FI will bring new opportunities to create innovative business ideas in many sectors (e.g., neuro-business, brain-computer interfaces). Understanding the brain's computing algorithms 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 a machine that is capable of emulating human cognition (neuro-morphic computing). In 2013, Gartner chose 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.
- Nanotechnologies are the essential technologies to make tangible the revolution and evolution of FI (e.g., new materials for sensors, extremely thin film, long-life batteries, tiny but powerful microprocessors). It opens the door to a hyper-tech era in which electronics and ICT will 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 nano-scale materials, more sensitive, specific, and adaptable sensors can be built that are expected to impact multiple sectors of the economy, including the healthcare, pharmaceutical, agricultural, food, environmental, consumer products, and defence sectors that contribute ubiquitous connected things. Nanotechnology can now realistically look forward to a much longed-for quantum-computing breakthrough.

With these observations and findings, we applied our selected innovation drivers (BIO, CleanTech, Neuro, and Nano) into some selected current FI-PPP business sectors. The FI3P report²⁹ explains that the demand for Internet technologies and services is expected to grow faster in sectors previously lagging behind such as utilities, healthcare/education, business services, etc. In the current FI-PPP, Smart utility, eHealthcare and Smart Business have been mapped with those sectors that were identified as having a high demand on ICT adaption at present. Thus, using the selected innovation drivers, we show the possible evolution of such business sectors as illustrated in Table 5 that introduces present and future innovation in healthcare, business, and energy sectors. We believe that fulfilling the demand of applying ICT technologies to such business sectors will benefit the mutual growth of FI technologies and of the services and technologies of such sectors, and, as shown in the Table 5, the convergence of the innovation drivers with FI technologies brings wider opportunities for new business types and services that will drive the next phase of business evolution.

³² <http://www.researchandmarkets.com/research/mrzjdp/biopharmaceuticals>

³³ <http://cleantechnica.com/2012/09/17/global-cleantech-market-expected-to-expand-to-e4-trillion-by-2020s-germany-to-capitalize/>

Table 5: Business Innovation of present and future at Healthcare, Business and Utility sectors



Healthcare is one of the most dynamically changing sectors by adopting FI technologies. Such dramatic evolution will be highlighted when FI technologies are integrated with BIO, Neuro and Nano technologies.

The Business sector is being changed dynamically by IT technologies, and has a large potential to evolve. When FI is innovating with Neuro, Nano, and CleanTech, such movement of new innovation will directly influence new types of business innovation.

Smart grid and smart utility are already moving fast toward digitalized business innovation by applying IT technologies. Advanced FI technologies together with Neuro, Nano, and CleanTech will bring further opportunities for the business innovation in this sector.

The practical products/services in the current FI-PPP projects already cover a wide variety of different application/service areas from Smart Energy (e.g. home/building energy management) to e-learning (e.g. Mobility based service models in education; see Annex I). In the following we provide short descriptions about the practical applications/services within each Science / technology field today and in the future: BIO, CleanTech, Neuro, and Nano.

BIO

The healthcare system needs to be further developed as the population around the globe gets older. One example is that people need to be more physically active, in order to maintain their fitness level in later life, and yet, in practice, we are sitting down almost all the day. Lifelogging is the process of tracking personal data generated by our own activities. Lifelogging tracks personal activity data like exercising, sleeping, and eating, but also follows elderly people and e.g. their movements at home especially if they live alone. Many smartphone apps support lifelogs, especially fitness tracking apps are already widely used. The future related service is

Ubiquitous Biosensing that means personalized health monitoring via the increasing availability of small high fidelity sensors that can be used to extend e-health services.

Another, longer-term, area is the embedding of communication devices in the human body. Currently, there are already sensors hidden into clothing, attached to the body as intelligent patches, or even, in the extreme case, implanted. Sensors can measure body parameters and send them wirelessly to a base station, and then to the hospital. The next step is that they are worn on the body as tattooed circuits as seen in the figure below (the 1st RFID tattoos were tested in 2014).



Figure 33: Healthcare and Sensor technology evolution (Juniper)

CleanTech

The climate change has influenced people to think “green” and more about the different energy and saving mechanisms, together with overall material efficiency. Smart home heating can already today be controlled remotely, but in the future it will happen fully automatically when, for example, the controlling devices can reduce the temperature level if there is nobody at home; on the other hand the home temperature can be increased if the electricity price is lower on the market. In a similar way as the wireless smartphone charging is a daily routine today, in the longer-term future, electric (driverless) cars will be able to be charged on the move with the help of specific in-road wireless charging systems.



Figure 34: The electric driverless car (Juniper)

NEURO

The gaming industry is keen to get faster mechanisms to control PC/console games. At the same time, the end

user application developers would like to create connection mechanism between brains and the devices. In the longer-term future, the end user devices/applications, and the electronic games will be able to be controlled only by means of the modulation of the players' cerebral activity. Today, Virtual Reality (VR) and wireless game control solutions are still dominant, examples in the Figure 35.



Figure 35: Virtual Reality

NANO

Current smartphones today have the computing power of supercomputers from 20 years ago. This indicates how supercomputer power is in everyone's pocket. Similarly, the NANO technology development will make it possible to have more processing power, more memory and more communication mechanism in smaller devices i.e. sensors. Additionally new materials will create new products/services and business opportunities.

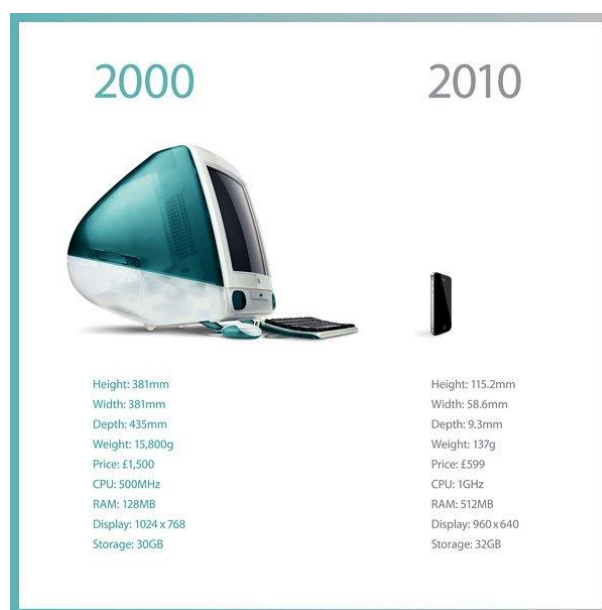


Figure 36: From a Computer to a Smartphone

Ubiquitous Biosensing is a good example of how nanotechnology is used for biology and ICT convergence. In the Figure 33 above, we showed a future example of tattooed circuits attached to the skin. A biosensor is an evolution of it that can be embedded in the organ to monitor e.g. the heart.

In summary, as identified in section 4.4.5 of deliverable D1.1 FI-LINKS technology and business models map, the tables in Figure 38 show how (i) the current FI-PPP sectors, (ii) the FI technology drivers (Media Internet,

Internet of Things, Cloud Computing, Big Data and Networks), are connected to (iii) the selected services and applications that converge with Bio, CleanTech, Neuro and Nano science & technology fields.

The idea is to map different potential future services/applications/products to the related technology drivers, (the upper table in the Figure 38³⁴) further analysed in this document, and find the needed supporting technology area to be able to, for example, use a new future application/product or to start a future service. The services/applications/products were selected by using both the Gartner's Hype Cycle for Emerging Technologies and Imperial College's Timeline of Emerging Science and Technology, which are described in more detail in deliverable D1.1. The circle sizes on the lower table of Figure 38 illustrate how much the selected services/applications/products match to the each technology and their "sub categories".

It can be seen that the Bio field has the widest interrelation to all selected technology drivers, although with the Media Internet only to a little bit lesser degree. The Nano field comes next, especially with the Networks and the IoT. The Neuro and the CleanTech fields are interrelated, but to a lesser degree, with all the technology areas. This can also imply that more attention should be paid to the Media Internet in the Nano field, and to the Networks in the Neuro field as there is no common service and/or product identified. A high level summary between the technology drivers and the scientific fields is shown in the Figure 37 (the larger is the science field circle, the greater is the interrelation to each technology area).

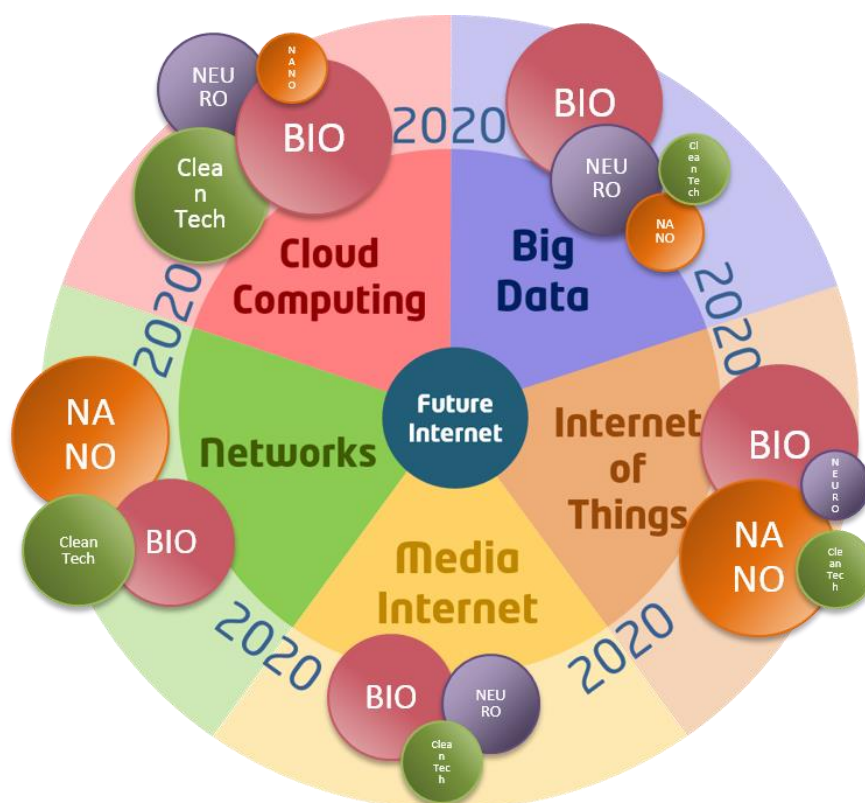


Figure 37: Technology drivers and science interrelation

³⁴ Bigger picture in the Annex B

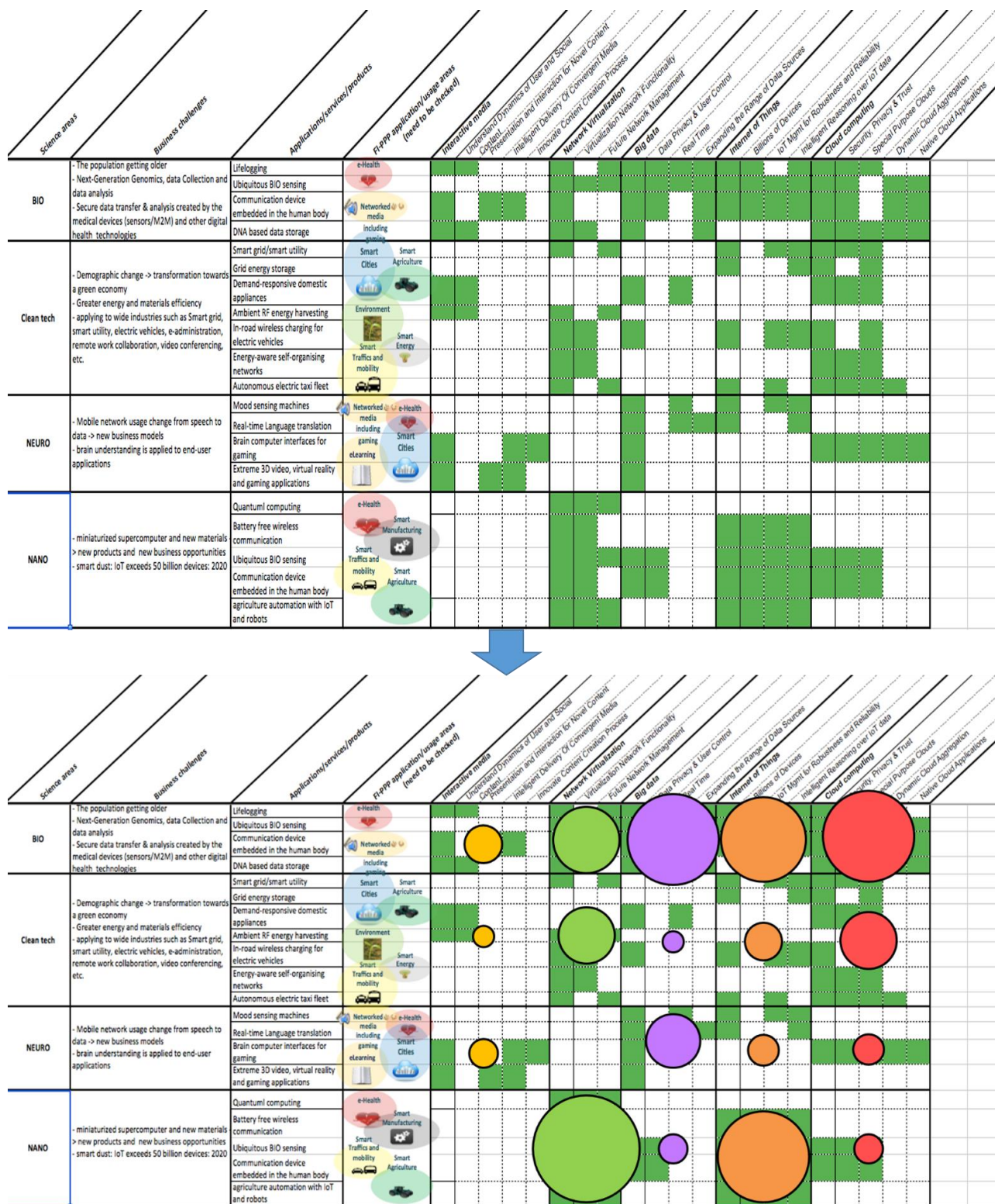


Figure 38: Current FI-PPP sectors, FI technology drivers and Science area interrelation

5 ROADMAPS FOR THE FUTURE INTERNET INNOVATION

This section discusses in detail the roadmap defined for each chapter as introduced in Section 3. Each section is structured as follow:

- An introduction to the chapter is provided highlighting the related challenges and providing hints on a few related technologies.
- A section is dedicated to the discussion of the technologies needed to solve the challenges related to the chapter. This section ends with a high-level roadmap.
- A timeline section provides a fine-grained roadmap for the different challenges.
- Finally, a section is dedicated to the discussion within respect to the FIWARE Generic Enablers relevant to the chapter.

5.1 Media Internet

5.1.1. Introduction

The progressive merging of traditional broadcast services and the Internet, convergence among the different content delivery networks and with ICT technologies have enabled a process of transformation of the audio-visual content market; all these elements are opening - at the same time - new opportunities for creative industries and creative people, thanks to the availability of new tools and paradigms for communication, user interaction, content creation and distribution. Creative industries and media industries in particular, are experiencing a disruptive market change where incumbent players are competing with a growing number of new entrants to preserve their market share and to reposition themselves within a changing scenario. The evolution of Media Internet technologies will play an important role in enabling and accelerating innovation in this market.

The following analysis and identification of challenges originate, as discussed also in deliverable D1.1, from the current FIWARE roadmap, in conjunction with a number of existing roadmaps produced by European initiatives ([10], [24]) and studies from non EU governmental organizations ([12]).

There are some relevant factors that drive the evolution of the Media Internet market and that require to address new challenges when thinking to service evolutions in this domain:

- Focusing on the evolution of traditional audio-visual services in a context where media content is continuously growing in terms of volumes and intrinsic quality, there is the need to continue to guarantee high levels of quality in the whole process for production, delivery and consumption of content (in terms of delays, latency, data integrity);
- At the same time, users have at their disposal new tools and new devices offering novel paradigms for interaction with content and offering enhanced immersivity and interactivity with it;
- The emergence/evolution of novel forms of inter-personal and social communication impacting the way content is socially produced, and how content (whether in a casual, professional, or market-oriented context) is written and narrated, and is pervasively present.

While some of these factors are influenced by - and cross-cut - different technological areas (Networks, Cloud, and Big Data) we can in any case summarize, from a Media Internet perspective, the main macro-challenges to be addressed (see also deliverable D1.1 [9] for more details).

We have challenges on the *Content* side:

- How to overcome infrastructural limits in content access and sharing, in order to improve the Quality of Experience (QoE) and enable new scenarios for content delivery, creation and co-creation;
- How to enable the creation of novel forms of content offering a more immersive and intuitive user experience (to access, present and interact with it);

- Which tools and platforms will help in lowering barriers for content creation and production (making easier the access, search, retrieval, sharing of relevant content) and fostering individual creativity and the co-creation process.

And on the *Social Media* side:

- How to achieve an improved understanding of opportunities that arise from social media and that can help organizations to engage the communities more effectively and gain useful insights about them in order to improve their services or business models.

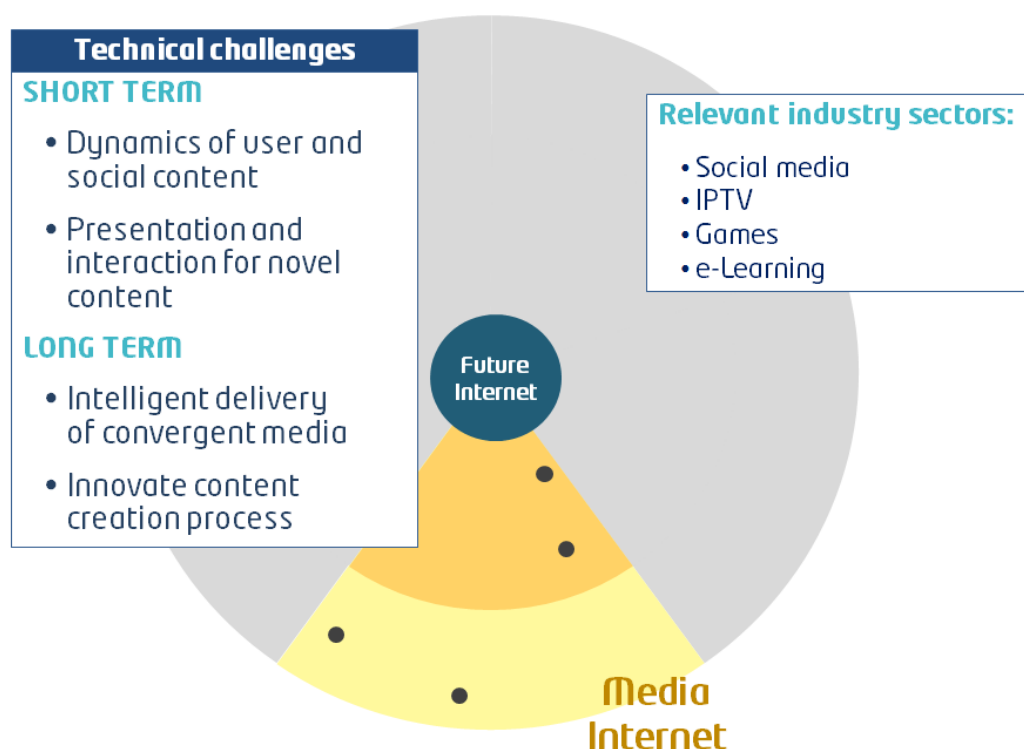


Figure 39: Media Internet- Technical and Business Overview

In the following paragraphs we will better characterize the technologies that are expected to have a major impact in addressing the above-described challenges. What is important to highlight here is that technological evolution will not be the unique element (and probably not the most relevant) that will directly or indirectly influence market evolution. Other key relevant factors are influencing - and will continue to condition - the effective speed of innovation in the target markets. The presence of regulatory frameworks at different regional and national levels, both for telecommunication (ruling network access, network neutrality conditions, etc.) and audiovisual media services (IPR, content sharing and licensing rules) are a major element strongly influencing the way towards an integrated and single digital market, at the European and International level. The development of new technological standards will also influence how markets will evolve opening access to new players, especially to SMEs.

5.1.2. From challenges to technology solutions

The following figure summarizes the main challenges and sub-challenges that have been already assessed and described in our previous roadmapping deliverable (D1.1) and depicts the main relevant relationships existing among them.

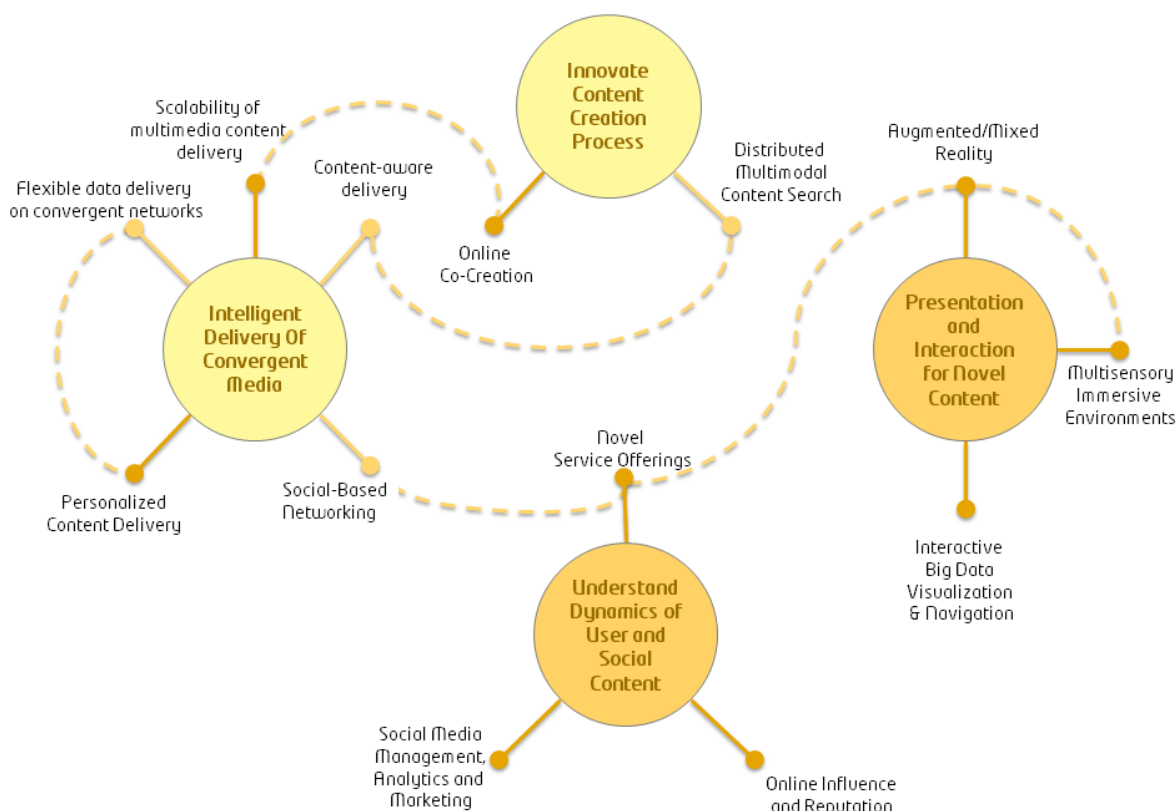


Figure 40: Media Internet- Challenges conceptual map

In this section we briefly describe the expected evolutions of the Media Internet technologies that will influence and address the above-mentioned challenges.

Short-Term

- Integrated Multisensory Interfaces:** multisensory technologies (haptic, tactile, audio-visual, gesture recognition technologies, etc.) combined with immersive technologies (augmented and virtual reality technologies and displays) allow the creation of immersive environments where users can access and seamlessly interact with mixed virtual and real worlds. Applications based on these technologies are gaining real market adoption not only in the entertainment market, but also in manufacturing, medical, engineering, and education for many different application purposes (such as training, simulation, rehabilitation, etc.). The growing availability of low cost head-mounted displays integrating sensing and interactive solutions will enable wider market adoption.
- Augmented, Virtual Reality and Gaming Platforms in the Cloud:** the shift of services supporting the creation of augmented, virtual reality and gaming applications in the Cloud will open new opportunities to reuse these technologies on a wider scale. Augmented reality Cloud platforms currently mainly focus on mobile apps, but they will gain wider application also in other domains (e.g. web and augmented TV applications). In particular, Cloud-enabled gaming applications will reduce the need for specialized and costly gaming consoles and the need for cross-porting gaming applications among different closed vertical gaming platforms.
- Big Data Visualizations as a service:** while the amount of available information at our disposal is growing massively, at the same time this trend makes it significantly more difficult to analyse and process 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. Interactivity and user experience can also greatly benefit from the availability of immersive technologies for information

navigation, search and display.

- **Social Network Intelligence:** organizations wanting to effectively manage the impact of their brand on social networks and to understand how to best handle community engagement on these channels require tools offering insights, metrics and analytics making it easy for them to understand the results of their interactions with and among people, about the most discussed topics and trends, allowing them to drive their marketing decisions. While metrics can vary greatly according to the specific organizations' needs, the underlying social media management systems will evolve to act as the underlying infrastructure to centrally manage the collection, processing and analysis of social interactions about relationships among companies and their current and potential customers.
- **Sentiment Analysis:** another important aspect of social media analysis for organizations pertains to the understanding of what people think about a brand, a company, a product or a service. We expect that the combination of the aforementioned social networking intelligence technologies with semantic and media content analysis technologies will allow the provisioning of specialized solutions supporting opinion mining from social networks.
- **Social Content Aggregation and Processing:** the capabilities offered by real time processing and aggregation of social media content will enable the creation of specialized social media platforms exploiting new dynamics and practices of user social content sharing: some meaningful examples are already emerging such as social casting, citizen journalism platforms, social gaming, collaborative storytelling. Big Data solutions for handling media content in real-time will be key enablers for additional new services leveraging on real time social content sharing.

Long-Term

- **Convergent Content Delivery Platforms:** the strong competition existing on the market among different players (broadcasters, telcos, TV manufacturers and OTT players) has led to the creation of a wide set of concurrent and competing multi-channel delivery platforms. Independently from the specific technologies that will be adopted in the future, audio-visual content market will be strongly influenced by the availability of interoperable, open and convergent media platforms. HbbTV is an example of what is currently happening in Europe in the domain broadcast/broadband convergence for connected TV. The expectation is to go towards convergent content delivery platforms allowing the delivery of integrated fixed and mobile audio-visual services where the same content can be seamlessly adapted to the different channels and end user's devices both for consumption and interaction. These platforms will constitute the infrastructure for the delivery of innovative audio-visual services especially for SMEs' benefit.
- **Scalable Media Clouds:** the continuous growth of quantity and quality of audio-visual content imposes growing technical requirements to infrastructure in terms of management, processing and delivery capabilities. The most critical requirement to be addressed is scalability of the infrastructure, at both networking and computing level. Consider for example, to the requirements needed to transcode content to adapt it in real-time to the different available delivery channels, for the multiplicity of specific user's needs, contexts and devices for its consumption: the availability of a scalable media computing infrastructure in the Cloud is a key enabler to allow the delivery of high volume and high quality content to users. On the other hand, the need for the fast transfer of high data volumes and the need for interacting in real-time with delivered content can be addressed by having at disposal a more capable network infrastructure (in terms of bandwidth and latency) and by the availability of Cloud resources in the edge of the network putting content and services for interacting with it closer to the user. The combination of all these scalable Cloud capabilities (both at core and at the edge of the network) will represent specialized Cloud platforms for wide scale media content management and delivery.
- **Multimedia Content Analysis and Description:** According to Cisco forecasts³⁵, "every second, nearly a million minutes of video content will cross the network by 2019". The amount of audio-visual content

³⁵ Cisco Visual Networking Index: Forecast and Methodology, 2014–2019

available thanks to Media Internet sharing and distributed in many different vertical, heterogeneous repositories is useless if it cannot be easily searched and retrieved. Contributions from research on media content analysis technologies will greatly improve our current capability to analyse and describe in detail and categorize media content, discovering cross-links among different digital objects: object recognition, object tracking, audio fingerprinting, semantic extraction and enrichment, natural language processing technologies are key technologies that, combined with Big Data analysis, will allow to improve our capability to extract spatial-temporal and semantic metadata from audio-visual content. In parallel new standards capturing enhanced audio-visual content descriptions are expected to appear in order to spread the usage and adoption of new metadata.

- **Distributed Multimodal Content Search:** The capability to search across distributed audio-visual repositories is another barrier that has to be overcome, in order to allow consumers to find relevant content they need, exactly when they need it. This limitation can be addressed thanks to the availability of federated search engines allowing users and applications to abstract from the different content representations and content access rules in the different media repositories where content is stored/described. Moreover, content search engines should be aware of a user's context and of their preferences in order to maximize the matching of searches with expected results; recommender systems can help to address this challenge benefitting of availability of enhanced knowledge about content structure and semantics.
- **Interactive Video Content Curation platforms:** online collaborative platforms can greatly impact and innovate the process of content ideation, creation and curation supporting distributed teams and people in exploiting collaborative creativity. Currently the wider adoption of collaborative audio-visual services in the Cloud is mainly prevented by limits imposed by the network infrastructure to transfer and concurrently manipulate in real-time high quality audio-visual material. The availability of ubiquitous high-bandwidth network access and of a low-latency infrastructure, together with availability of Clouds in the edge providing more distributed computational and storage resources closer to the user will allow overcoming current existing limitations and opening the way to the creation of more effective on-line audio-visual content curation platforms.
- **Personalized and content-aware delivery:** as for enhanced content search, also a personalized and context-aware content delivery will impact on QoE but also on the allocation and usage of infrastructural resources needed for content delivery. As highlighted in the Network chapter, the availability of customized context-aware networks is a prerequisite to tailor content delivery to the user context.

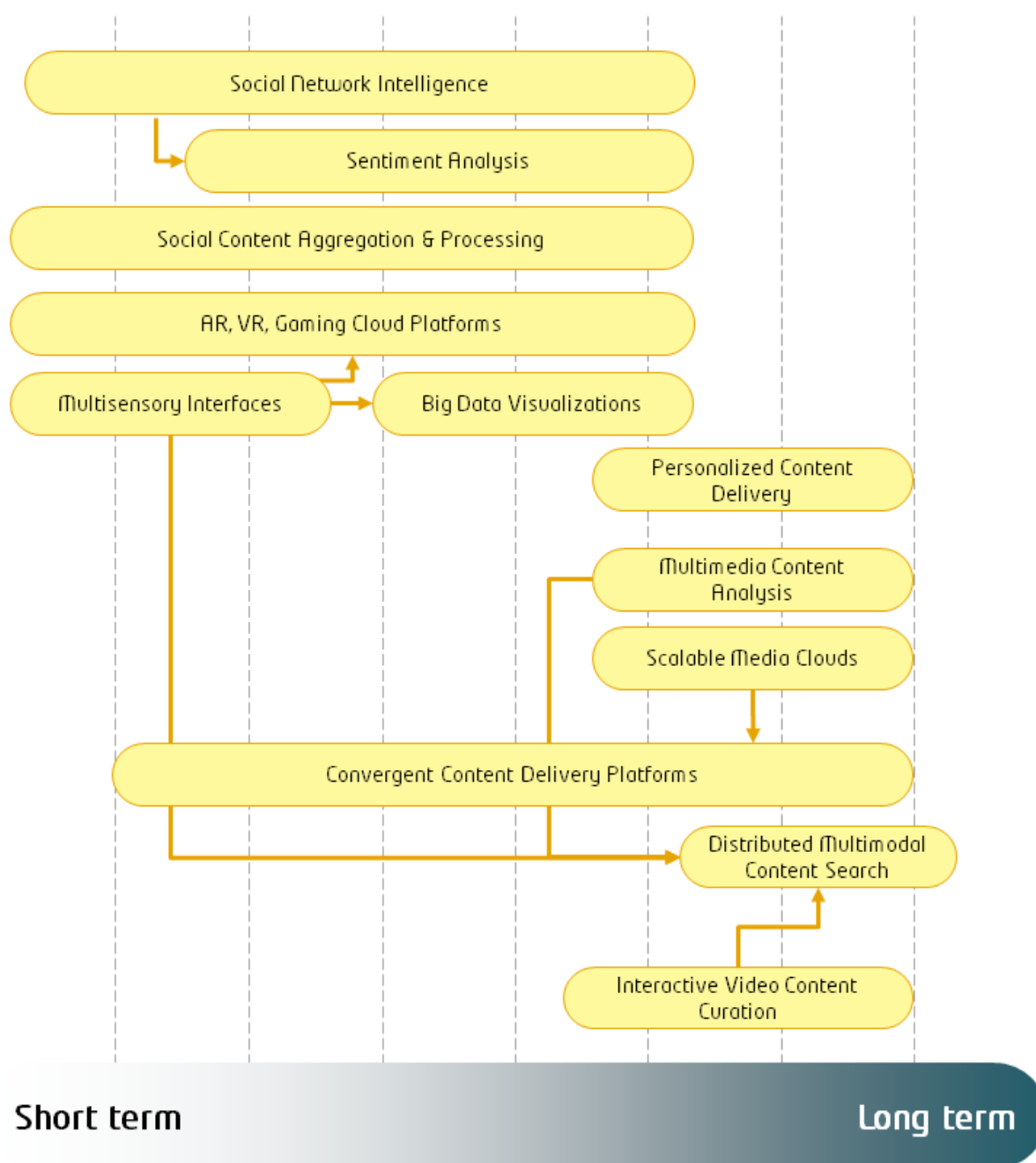


Figure 41: Media Internet Technology Solutions Map

5.1.3. Timeline

According to the overall framework defined, the roadmap shall evaluate two main periods: the **short-term**, with the year 2020 as fixed deadline; and the **long-term**, which includes all the initiatives beyond 2020.

In the following we introduce a detailed roadmap, including:

- Addressed challenge;
- Detailed timeline;
- Dependencies among technologies;
- Reference technology from other chapters.

Presentation and Interaction for Novel Content

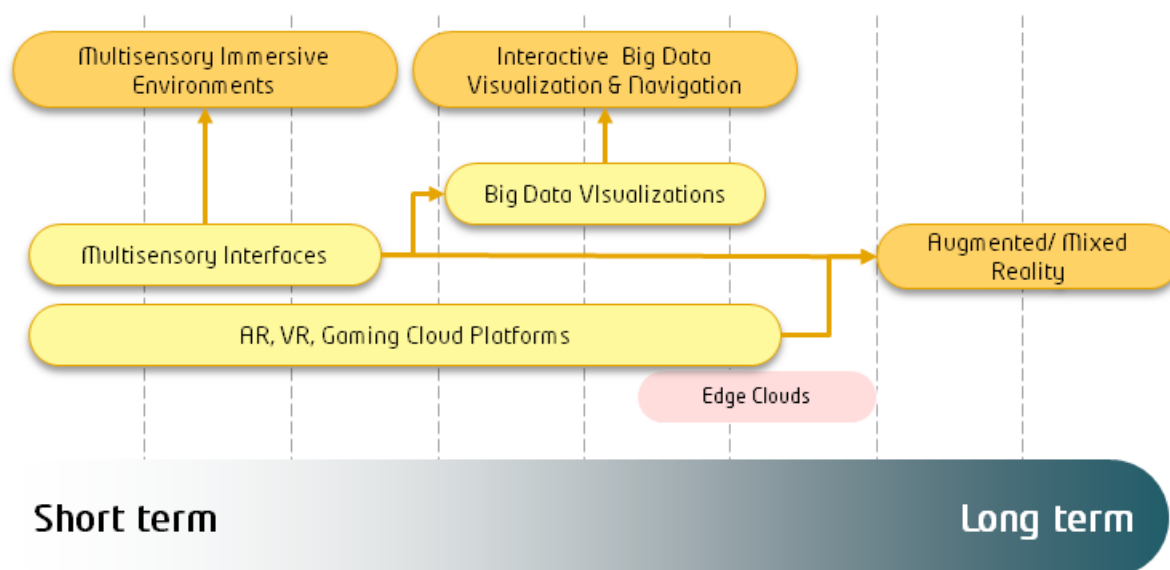


Figure 42: Media Internet Challenge- Presentation and Interaction for Novel Content

Social Content Dynamics

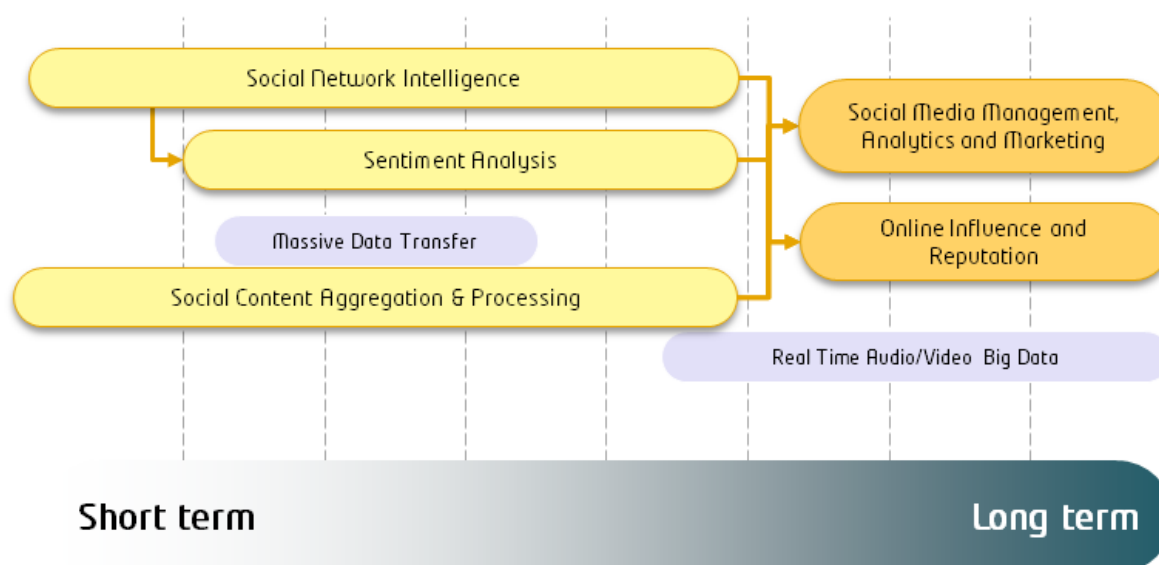


Figure 43: Media Internet Challenge- Social Content Dynamics

Intelligent Delivery of Convergent Media

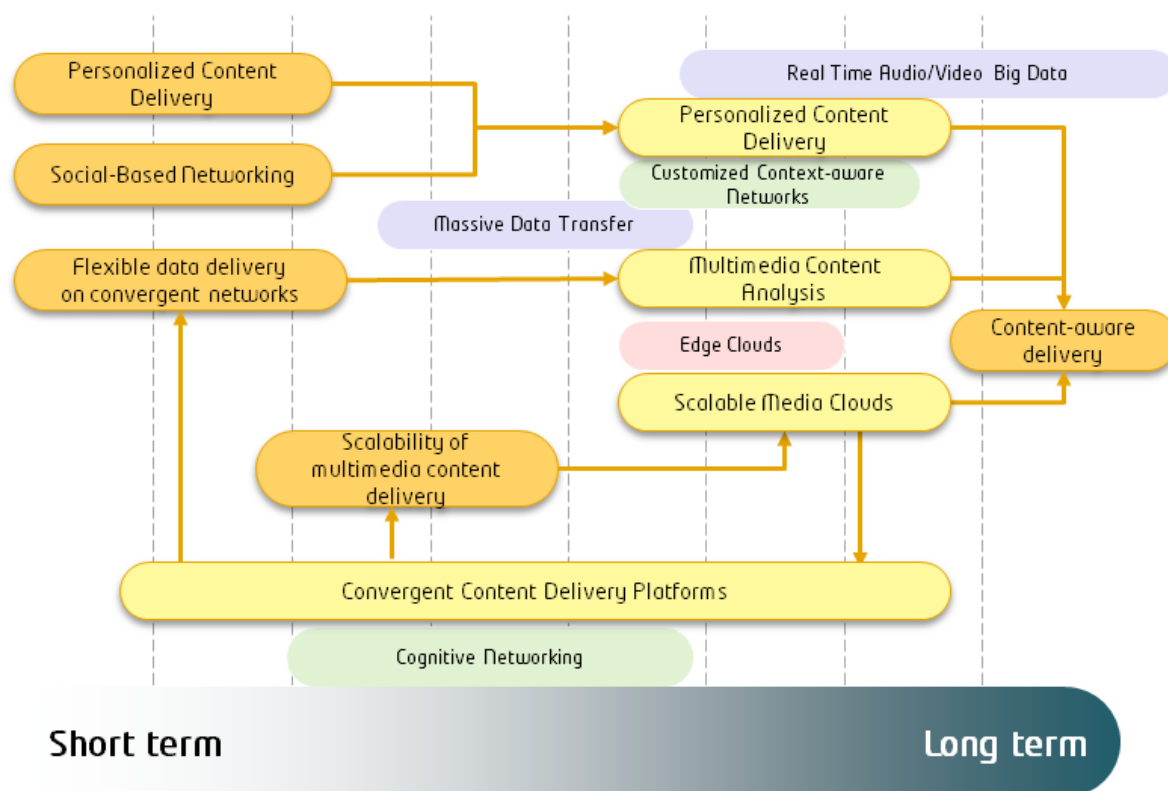


Figure 44: Media Internet Challenge- Intelligent Delivery of Convergent Media

Innovation of Content Creation Process

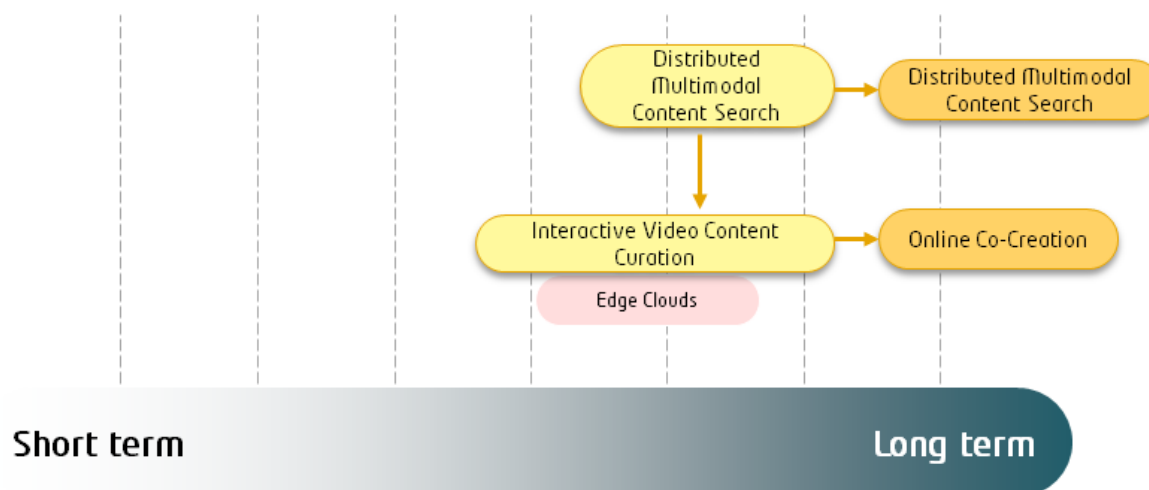


Figure 45: Media Internet Challenge- Innovation of Content Creation Process

5.1.4. FIWARE Technology Mapping

Within FIWARE there are different enablers relevant for the Media Internet chapter. One part of them belongs to the set of Generic Enablers while a set of specific enablers for the Media Internet domain have been developed³⁶, in order to support domain-specific features focusing in particular on three application areas: social connected TV, Smart City services and pervasive games. Here follows a brief description of the relevant enablers for this chapter, while a deeper description of the enablers can be found in the FIWARE catalogue.

Generic Enablers

Advanced Web-based User Interface		
A set of enablers that make it easy to incorporate 3D & Augmented Reality capabilities in web-based user interfaces, plus efficient backend middleware.		
Functionality	Name of GE	Description
3D graphics for the web (HTML5)	3D-UI-XML3D	Integrate interactive declarative 3D graphics within your web pages
Realtime collaborative 3D applications	WebTundra	Web client for accessing 3D virtual worlds from a web browser. The web client (through SDK) can connect to the server side server (realXtend) for creating multiuser interaction.
	Synchronization	Allow an easy way to synchronize scenes in the case of multi-user applications.
Design of 3D environments	Interface Designer	Easy-to-use full manipulator / editor of 3D objects within a scene
Virtual Characters on the Web	Virtual Characters	Reference implementation to create display and animate virtual characters on the web, to be presented in a web browser. The characters can be composed of multiple mesh parts, to e.g. allow easily swappable parts like upper or lower bodies, and attached objects such as clothing.
Infrastructure for interaction with real world objects	Real Virtual Interaction	Offer services to interact with real objects (sensors) in the world and UI components and associated (remote) services It is composed by a Real Virtual Interaction server and a Reference Real-Virtual Interaction client.
GIS 3D presentations	GIS Data Provider – Geoserver/3D	It hosts geographical data and serves it in 3D form (where applicable to both mobile and web client)
	POI Data Provider	Provides spatial search services and data on Points of Interest via RESTful web service API

³⁶ See FI-CONTENT FP7 project and specific enabler catalogue described at <http://mediafi.org>

Data/Context Management		
The enablers easing access, gathering, processing, publication and analysis of data at large scale, transforming it into valuable knowledge available to applications.		
Functionality	Name of GE	Description
Media Streaming and Processing	Stream-oriented Kurento	Powerful media server, supporting webRTC for real-time web streaming communication, integration of object recognition software (e.g. openCV), media transcoding, for the creation of rich multimedia applications.

Specific Enablers

The FI-CONTENT project has developed a set of Specific Enablers complementing the Generic Enablers available in FIWARE, in order to offer a set of capabilities addressing specifically the following three application domains:

- The **Social Connected TV platform** is designed to foster the development and uptake of TV applications based on Future Internet technologies: an entirely new ecosystem is evolving around connected TVs, enabling new applications and concepts around TV content.
- The **Smart City Platform** is an unique platform allowing the apps of tomorrow to be created rapidly, providing both state-of-the-art technologies (Enablers) focused around the use, and seamless integration of Open Data solutions;
- The **Pervasive games platform** demonstrates a strong mix of real life and Internet experience in a playful way and shows advances in 3D or virtual world environments in a way that becomes immersive and “real”. The platform focuses on multiplayer mobile gaming that leverages the Future Internet technology in order to enable large groups of users to participate in innovative mobile gameplay experiences.

Appendix D summarizes a description of all available specific enablers and their mapping to the target application domains.

5.2 Internet of Things – IoT

5.2.1. Introduction

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 “trough of disillusionment” is somewhat reduced and the market remains sustained also on the long-term. Given the current situation in the IoT domain, where many solutions already exist but in a very diversified and fragmented market, to achieve wide uptake one must certainly focus on adoption and on user-friendliness, but from a technology viewpoint, effort should go towards ensuring that the right Enablers to support this vision are also developed.

In this chapter we highlight how the IoT future evolution and success is underpinned by the progress in separate technology areas that deal with making the communication substrate more software oriented and therefore more flexibly controllable to address the diverse needs of M2M traffic.

In the previous FI-LINKS deliverable we split the future IoT challenges under three main categories, one related to dealing with billions of connected things, one related to having to manage these devices and a last one associated with making the most of data these things will produce in other words, how to create useful knowledge (cf. D1.1 [9] and Figure 46):

- Billions of devices (short-term): what is clear from a top-level analysis of what is currently being written and envisaged about IoT is that connecting billions of devices and building associated IoT applications will not be achievable with current wireless technologies and communication protocols. Many challenges are associated with scaling-up the Internet of Things
- IoT management for robustness and reliability (short-term): in the immediate, one of the problems related to the IoT is the perception that current services are still best-effort and hardly exploitable in emergency scenarios or for critical services. The potential capillarity of IoT however, makes it ideal for dealing with many situations where reliable and dependable applications have to be used. Ensuring this can be achieved is already a clear objective for the short-term evolution of IoT.
- Intelligent reasoning over IoT data (long-term): harvesting data from billions of connected devices brings the problem of what to do with such data and how to deal with it without necessarily having humans in the loop. This is the long-term challenge for IoT: acquire features from cognitive computing domain to ensure intelligent reasoning can be made to transform data into information and eventually exploitable knowledge.

A more detailed explanation about the illustrated technologies is to be found in the next paragraph.

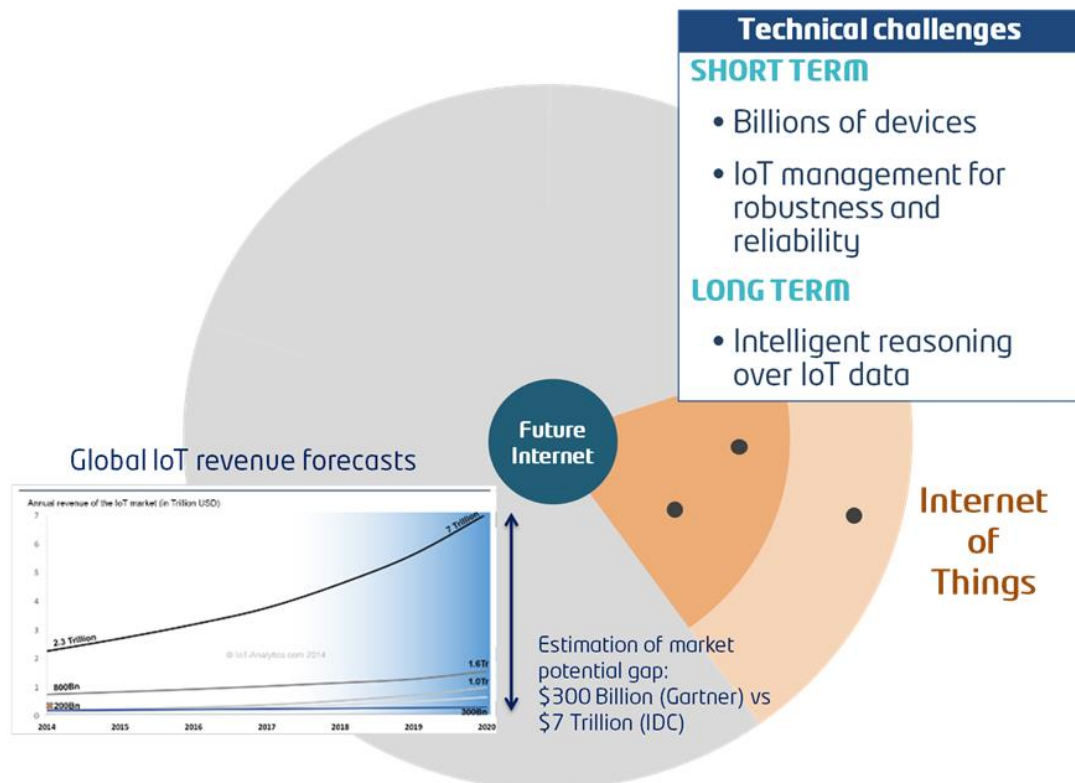


Figure 46: Internet of Things- Technical and Business Overview

5.2.2. From challenges to technology solutions

In this section, we explore the required technological building blocks for the resolution of challenges introduced in deliverable D1.1 (see Figure 47 for an overview of those challenges). Moving beyond the challenges and their interaction we have identified a number of corner-stone technologies that will empower the resolution of these IoT challenges, which are to be categorised into the need for increased flexibility in the “communication infrastructure substrate” as well as progress in more “IoT specific” domains.

This translates into ensuring adequate evolution in the following technology domains: flexible networks for prioritized and M2M-specific communications, edge Cloud Computing and distributed Big Data analytics.

Besides these very “infrastructure oriented” technologies, also progress in more “IoT specific” domains will be needed. This relates to progress on the “hardware-related” energy harvesting side to ensure more reliable and durable IoT services, whereas on the “software side” semantic technologies as well as ensuring security and privacy protection solutions need to be reliable and usable to foster wide acceptance. Having to deal with billions of objects will demand the automation of basic tasks such as the lifetime management of the objects, their discovery and use for a given purpose, etc. Hence, advances in the machine learning, predictive modelling and more generally cognitive computing domains will also be needed to provide suitable solutions to address not only the first but also the other two macro-challenges.

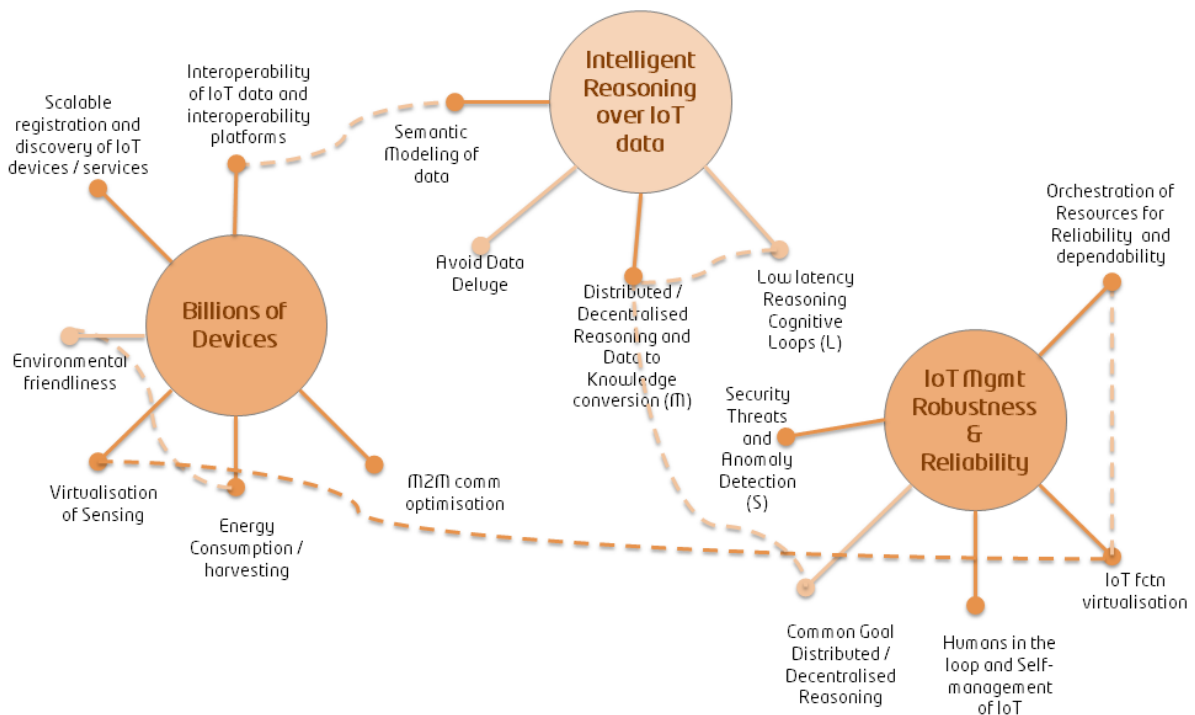


Figure 47: Internet of Things- Challenges conceptual map

Short-term

- **Virtual Objects:** this relates to the need for separation between software and hardware for edge IoT devices, for energy management as well as for remote device management, as we scale up towards billions of connected devices and objects.
- **Semantic Technologies:** the challenges of scaling up while keeping humans out of the loop is difficult to address without the support of semantic technologies. In a sense this is related to the virtualization of objects as it promotes the semantic enrichment of metadata used to describe objects. Such enrichment, coupled with standardized ontologies for different application contexts will support automated IoT systems management solutions, with objects that are selected according to context and to the need of the application at hand.
- **Predictive modelling:** as the processing power and storage capacity, in the Cloud as well as in devices increases, there will be more and more harvested data that can be used to relate sensing and applications / actuations. Predictive modelling enables the understanding and replication of those relationships to support applications that can be used to solve problems or rather intervene before problems occur. Increased data availability will produce more datasets that can be used to validate models and increase their accuracy leading to more efficient and accurate automated IoT systems.
- **Machine learning and distributed reasoning:** predictive models are underpinned by machine learning solutions. The ability to distribute those over different processing units connected through the

network will enable the distributed reasoning needed to limit the network overload caused by data produced by billions of devices.

- **Energy harvesting:** infrastructure-free “place and forget” IoT sensing devices will be a large part of the Future Internet. For this vision to become reality, besides the virtualization of objects, on the hardware front, progress will have to be made on the energy harvesting capabilities of these devices.
- **IoT virtual gateways:** Virtual Gateways are associated with bridging Cloud Computing features and IoT needs. They will be the result of distributed reasoning technologies providing the means to minimize network overload and have bespoke virtualized processing capabilities matching different sets of requirements.
- **IoT function virtualization:** this relates to gathering the understanding of which IoT functionality makes sense to virtualize and instantiate on the fly. Specific examples are data aggregation, support for interoperability-driven data translation, and data-to-knowledge conversion.

Long-term

- **Cognitive computing:** the development of cognitive technologies “as a service” (ref. IBM Watson) will mean that cognitive computing will become more and more “mainstream”. This, coupled with the increased availability of datasets for validation of models, will give IoT system engineers and application developers new tools to produce advanced, IoT-based solutions.
- **Data-to-knowledge conversion:** cognitive computing and the availability of powerful solutions “as a service” will increase the accuracy and therefore the widespread use of data-to-knowledge conversion techniques.
- **Orchestration of resources for reliability and dependability:** resources modelling from different domains (sensing, communication, storage and processing) on the end-to-end “sensing to application delivery path” will give new tools to design performance applications that exploit best the features of the underlying resources. This is where orchestrating technologies will play a crucial role in enabling reliable and dependable IoT-based solutions.
- **Autonomic management of IoT Platforms:** progress in the domain of machine learning and reasoning technologies will give way to IoT platforms that become easier to configure as a substantial part of their features set will be based on autonomic solutions.
- **Tactile Internet:** this is hailed as the ultimate evolution for the Internet of Things as we see it today, given it will be supported by very quick cognitive loop cycles (sensing, processing, actuation produced with timeframes below the order of milliseconds). It will require progress in the wireless technologies and communication protocols domain, in order to minimize round-trip delays as well as quick data-processing that allow reacting to monitoring and sensing data.

As a result, Figure 48 depicts the overall map of solutions, placing the different technology areas together with their respective links.

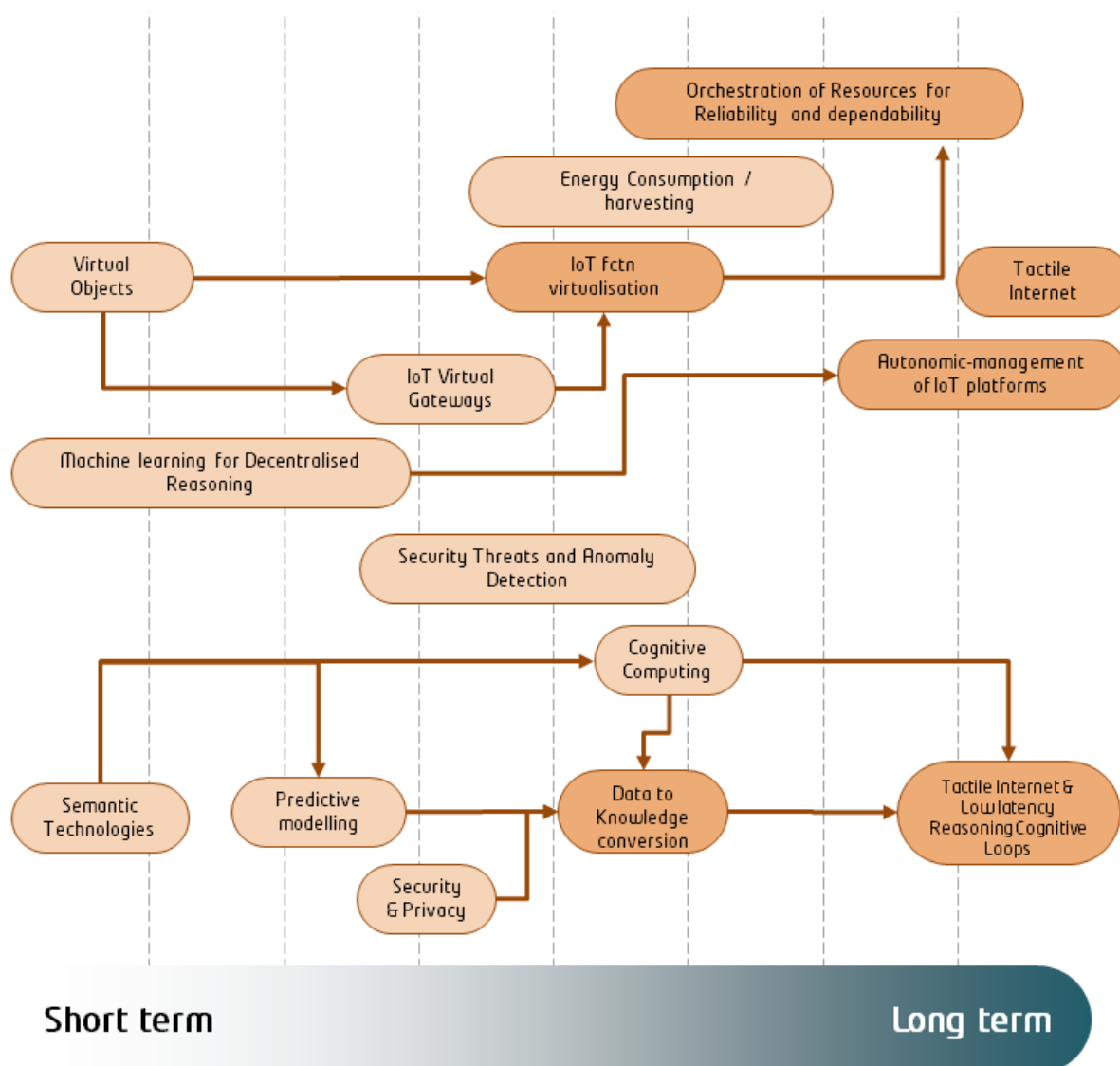


Figure 48: IoT Technology Solutions Map

5.2.3. Timeline

In this section we evaluate more in detail how each of the three earlier identified challenges is to be achieved and how the envisaged technologies needed for this purpose are positioned on the overall roadmap spanning from today until well after 2020.

Billions of connected devices

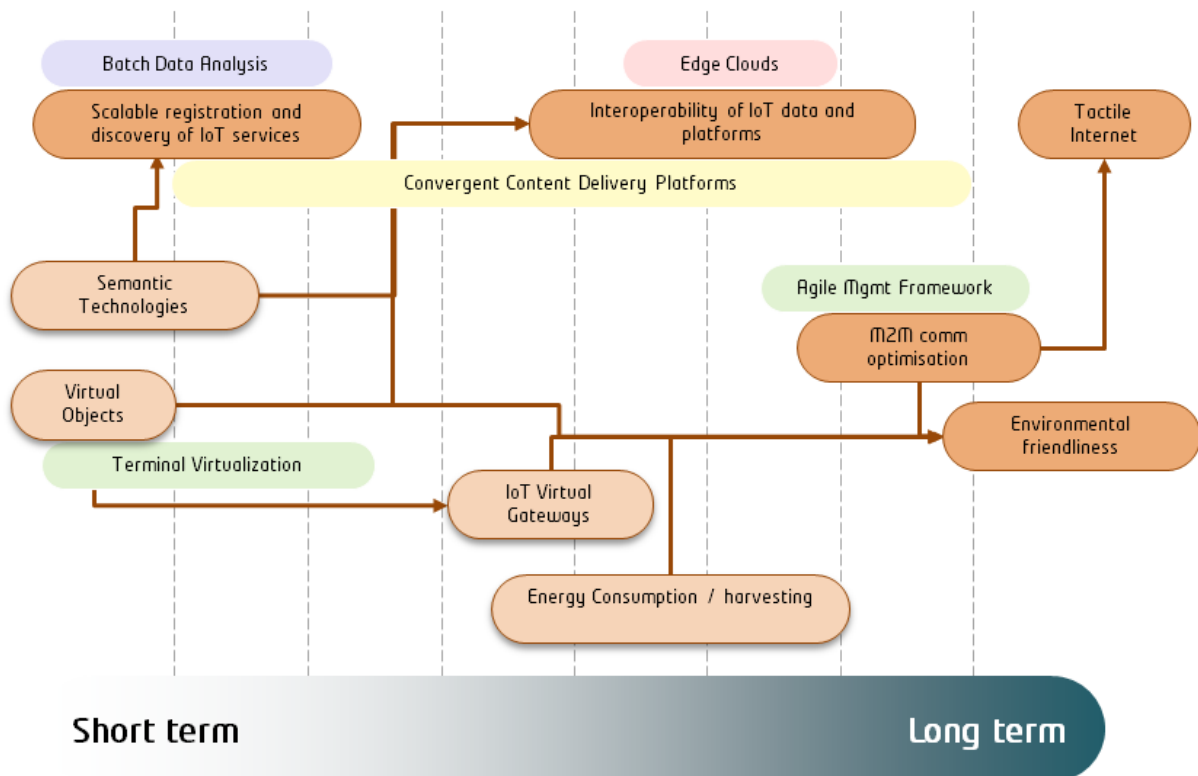


Figure 49 : IoT Challenge- Billions of connected devices

Addressing the challenge of billions of connected devices will certainly require some scale-proof technologies for enabling their automated registration, search and discovery, maintenance and management.

This has much to do with progress on the semantic technologies introduced earlier (and subsequent semantic annotation of objects). Through the use of semantics one can design how to automatically relate all devices that for example share a similar location, or that can produce a certain type of data, or that are owned by the same person etc. Moreover progress on the semantic technologies front is also needed to address IoT application silos interoperability problems. In particular this will enable the system's understanding of "what" needs done to achieve interoperability between data in separate domains. As far as the "how" is concerned, once it is clear what conversion needs to be applied to the sensed data to make it also available for example, across application domains, here come the role of edge Clouds where appropriate algorithms can be instantiated and run to address interoperability issues.

Looking at more "hardware" related issues, progress in the energy harvesting field has many implications on the achievement of the billions devices challenge. It certainly contributes to environmental friendliness as it relies upon renewable energy for the installation of sensing devices at zero energy impact i.e. without connection to power sources. Similarly, the relatively slow advances in battery technologies compared to evolution of computing capabilities, mean that wireless IoT devices will always be more resource constrained than their wired counterparts. Virtualization (of sensing) techniques therefore empower wireless devices by adding "always-on" functionality on the "wired side" of the network and breaking functionality from hardware ownership which also contributes to achieving better environmental friendliness as it makes for more efficient (re-)use of hardware resources. This is aligned to leveraging on functionality at the edge of the network, therefore enabling a more sustainable evolution of virtual objects/ IoT Virtual Gateway functionality.

With regards to achieving more efficient M2M communications, it is envisaged that progress on the low-latency wireless networks technologies and agile networks management will be needed, to ensure, on the one hand, low-overhead for short-lived communications to edge devices (through more agile network management

schemes) while, on the other hand, achieving shorter cognitive loops for sensing-processing-actuating close to the edge, a “must-have” requirement for tactile Internet future scenarios.

Management of IoT devices for robustness and reliability

The importance of this challenge stems from IoT becoming more mature and established, enabling contextually also support for critical services, or more robust and dependable ones in general.

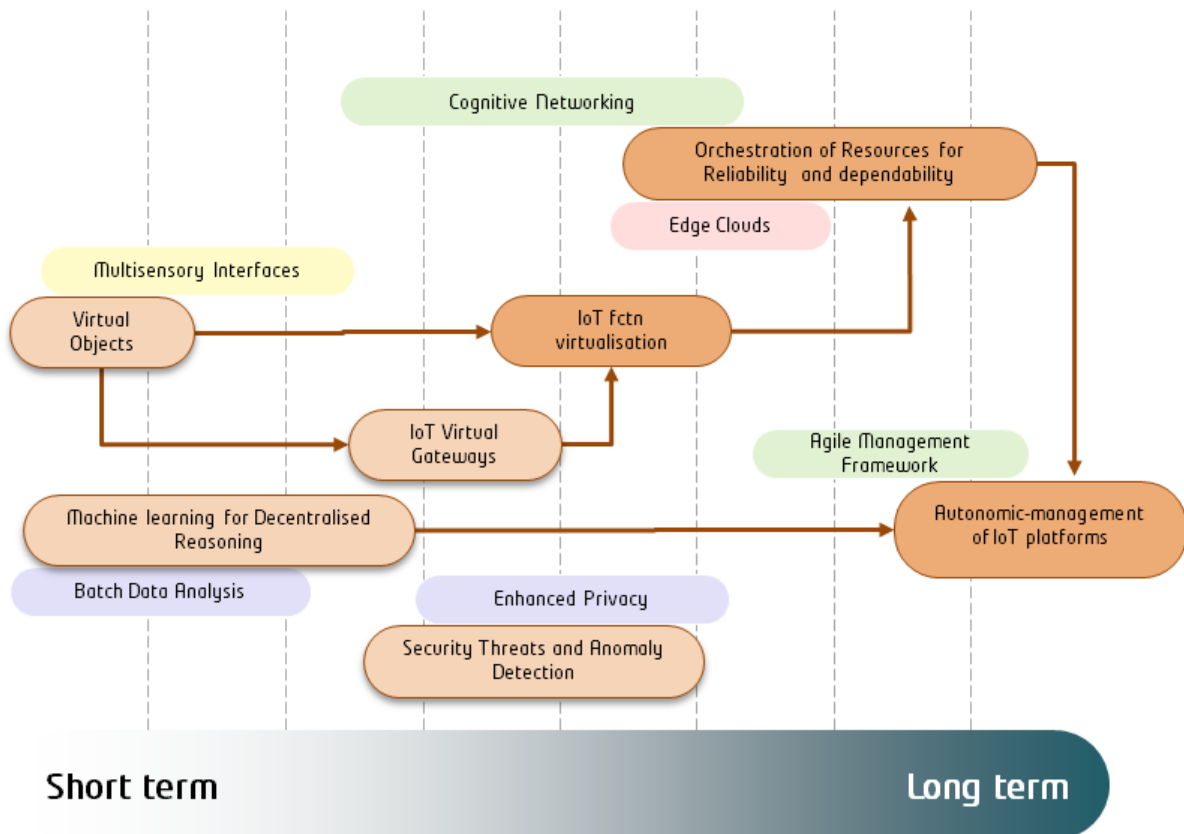


Figure 50 : IoT Challenge- Management of IoT for robustness and reliability

From a technology viewpoint, there is a need for more flexible “infrastructure oriented” technologies to mature, where edge Clouds and software networks are there to support and complement the constrained nature of devices and have therefore implications on the sub-challenges of virtualizing IoT functionality and orchestrating the use of these “infrastructure technologies” for a more robust IoT. Virtual Objects and Virtual Gateways are also specific IoT technologies, building bricks of virtual IoT functions which can be more robust and resilient to connected objects hardware failures / limited coverage.

With an increase of the number of devices beyond what humans can successfully manage comes the need to rely on cognitive technologies for autonomic management of IoT platforms and for security threats and anomaly detection. In the specific, this is supported by progress in the Big Data analytics and leverages on machine learning and decentralized reasoning technologies.

Intelligent reasoning over IoT data

While previous challenges were related to IoT hardware and more infrastructure oriented, this one is about how to best leverage on IoT harvested data, notably to produce the usable and useful knowledge for compelling IoT-based services and applications in many different domains.

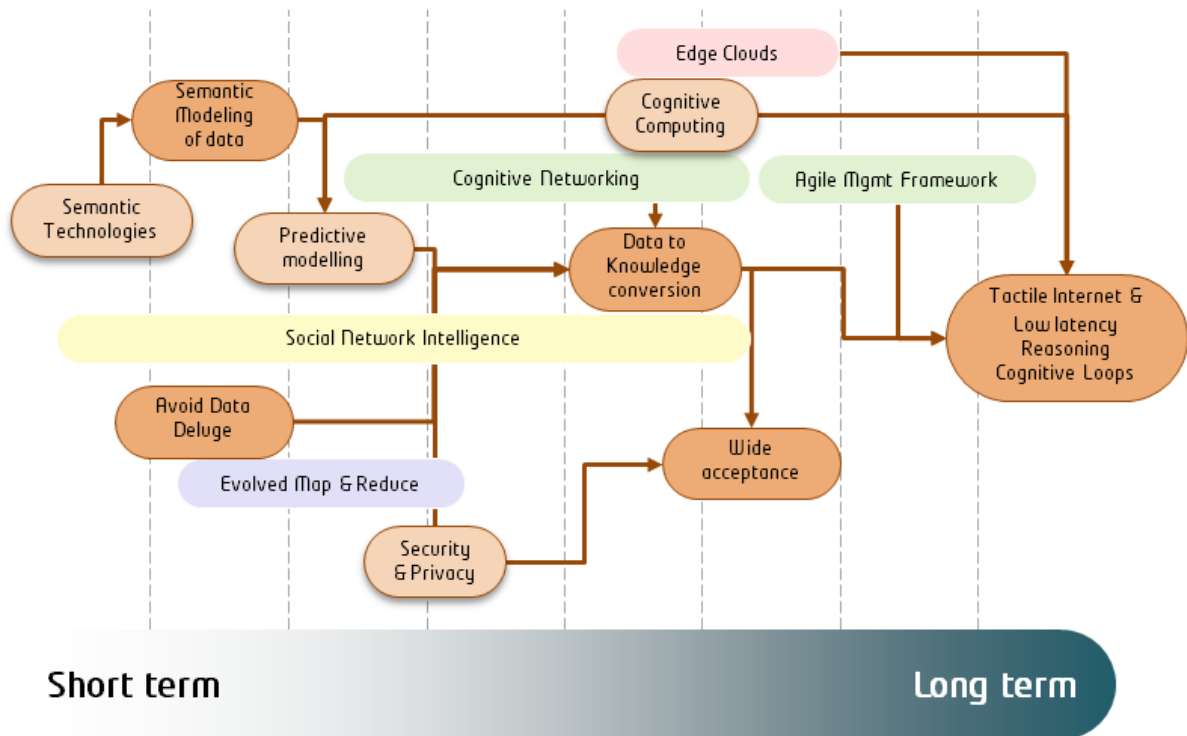


Figure 51: IoT Challenge- Intelligent reasoning over IoT data

Semantic annotation of data is a “must” to be able to automatically draw “relevance boundaries” amongst available data, hence progress on semantic technologies underpins the development of data models that foster and support well-targeted data-to-knowledge conversions which is key ensuring wide adoptions (i.e. cognitive systems that take the right decisions through predictive models).

Besides semantic technologies, techniques of cognitive computing are also required. Here we refer to the more and more reliable services that large computing machines such as IBM Watson for example will enable. The algorithms for data-to-knowledge manipulation and for predictive modelling contribute to better quality decisions and wide acceptance. This is also where Big Data steps-in, as well as “security and privacy by design” which are also key to ensure wide acceptance.

On the “data-to-knowledge conversion” path we also illustrate the importance of real-time Big Data analytics applied to reduce in size, through pre-processing done close to the edge, the produced IoT data and therefore avoid data deluge, lowering IoT impact on communication networks.

Edge Clouds and low-latency networks, together with well-targeted data-to-knowledge conversion, are the key technologies for achieving very fast reasoning loops, which underpin future Tactile Internet scenarios.

5.2.4. FIWARE Technology Mapping

In this section we provide a brief overview of how the envisaged roadmap for FIWARE IoT services³⁷ aligns with what we described in the previous sections of this IoT chapter.

FIWARE considers two main service typologies, one considered as *backend functionality* (IoT Backend in the FIWARE IoT Services Enablement architecture picture below) and one as *gateway functionality* (IoT Edge in the picture below).

³⁷ FIWARE Roadmap on Internet of Things.

[http://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/Roadmap_of_Internet_of_Things_\(IoT\)_Services](http://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/Roadmap_of_Internet_of_Things_(IoT)_Services)

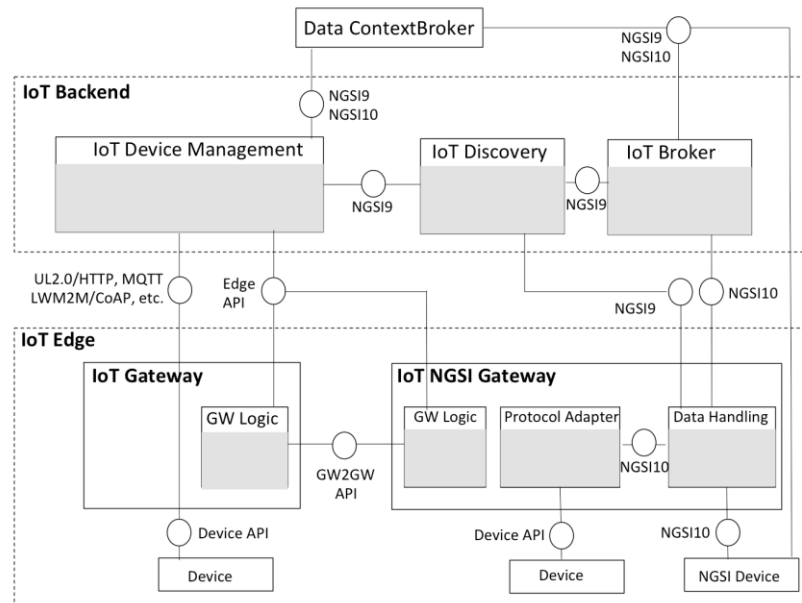


Figure 52: FIWARE IoT Services Enablement architecture

- IoT Backend.** Given the mission and goals of FIWARE project these can be seen as valuable, yet very specific, stepping stones towards the road-mapping activity envisaged earlier for IoT by FI-LINKS analysis. As far as IoT Backend functionality is concerned, the three envisaged building blocks have all relevance to the two main challenges identified for IoT in FI-LINKS: that is challenges to do with Billions of Devices and with adding robustness and reliability to IoT. In particular, the component for *IoT Device Management* clearly contributes towards having means for more automatically managing IoT devices removing the need for physical vicinity of a human operator with the device first, and providing the necessary tools for any autonomic management processes to enforce decisions at a later stage (in the context of “Autonomic Management of IoT Platforms”). *IoT discovery* is well aligned and poised to play a role within the “Scalable Registration and discovery of IoT services” sub-challenge; though in its current release it is missing semantic-related aspects. Both *IoT Broker* and *Data Context Broker* are instead mostly related to the “Intelligent Reasoning over IoT data” macro-challenge given they deal with issues such as data interoperability and data interpretation and aggregation, which again, provides some concrete stepping stones to rely. Looser relevance is also present in the sub-challenge linked to the “orchestration of resources for reliability and dependability”.
- IoT Edge.** The *IoT Edge* part is mostly to deal with functions envisaged to address interoperability, heterogeneity of devices as well as *data handling* and *protocol adaptation*. This is poised to also play an important role as technology for virtualizing objects and more in general, IoT services.

At architectural level mapping it is expected that the *IoT Gateway*, with a non-better defined *GW logic* will be the place that within FIWARE architectural framework will foster the advances mentioned before, relating to pushing the functionality as much as possible to the edge of the network to minimize impact of billions of connected devices on the backhaul network connectivity. Clearly the figure illustrates also current choices related to the expected implementation that FIWARE releases will be compliant with, but this should be kept out of overall judgement given the multitude of IoT protocols that could be indeed used to perform similar type of functionality.

5.2.5. Recommendations for FIWARE evolution

In conclusion, the brief analysis of the IoT related chapter of FIWARE, despite its short-term oriented focus and mission, has highlighted a reasonable alignment with the road-mapping activities performed in FI-LINKS.

5.2.6. Recommendations for future work programmes

In order to enable the realisation of the vision where billions of devices are connected by 2020, future work-programmes should address the design and improvement of the technologies that underpin such a vision, especially on the front of integration of cognitive computing into the high-granularity monitoring features of Internet of Things. Substantial progress on the front of large-scale solutions is expected to be realised with the 2016-17 work-programme execution. Beyond that timeframe, future work-programmes will need to foster research and development where the hardware / software boundaries are further blurred, realising a highly flexible infrastructure substrate that can be tailored to the needs of the applications running on top of it.

5.3 Big Data

5.3.1. Introduction

There seem to be a consensus in the specialized media as well as in the reports from the most prestigious analyst's agencies 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 [31] 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 Insurance and Utilities industries have higher expectations to invest in the next 1-2 years.

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.

We expect that in the next years, the following main challenges will need to be tackled in the Big Data area (cf. D1.1 and Figure 53):

- **Data Privacy and User Control (short-term):** Although Big Data analysis seems to have a huge potential for enterprises it is a source of distrust for many individuals and organizations. If it's true that measures are being taken by regulators in this context, e.g. EU directive on cookies, there seems to be a demand for a greater control by the user on the information they consciously or unconsciously generate.
- **Real Time (short-term):** 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 analysed as it arrives rather than storing it and then retrieving it to analyse it.
- **Cloud-based Solutions (short-term):** 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.
- **Expanding the Range of Data Sources (long-term):** 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.

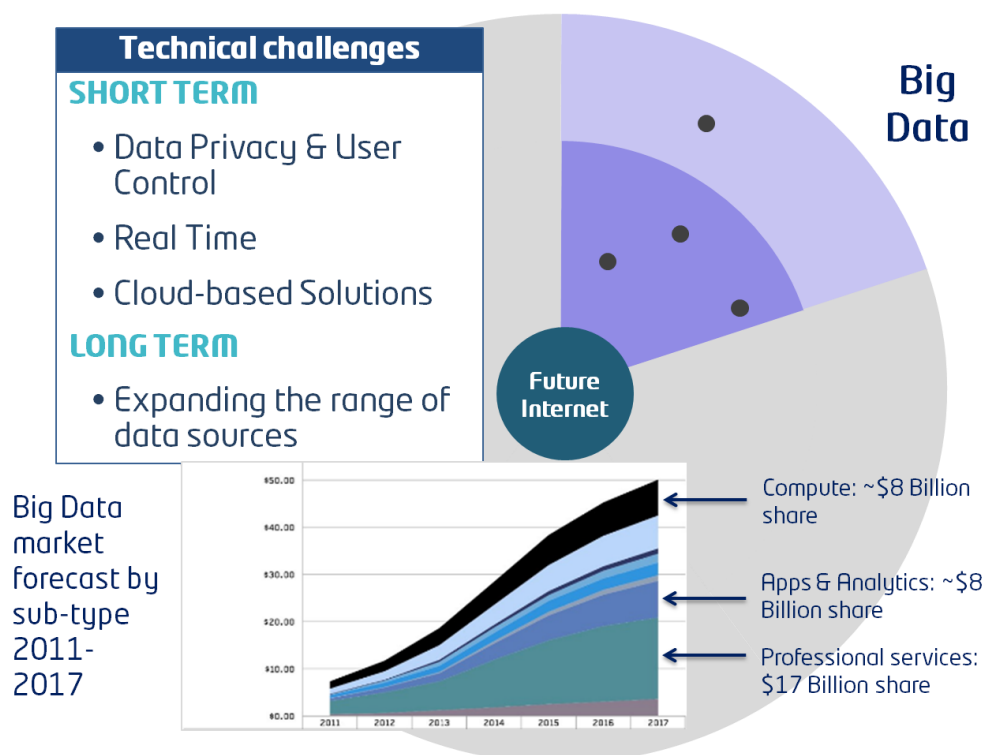


Figure 53: Big Data- Technical and Business Overview

5.3.2. From challenges to technology solutions

This section analyses some technological trends around Big Data, which starting from the currently existing technologies, which are the results from many R&D efforts in the last years, are expected to capture a good part of the work around Big Data over the next few years.

Also an analysis is done in terms of the technological pieces that should be developed over the next years in order to meet the previously mentioned challenges.

The following high-level map describes the main impacts to overcome as well as the several lower-level challenges. Figure below summarizes the assessment included in D1.1.

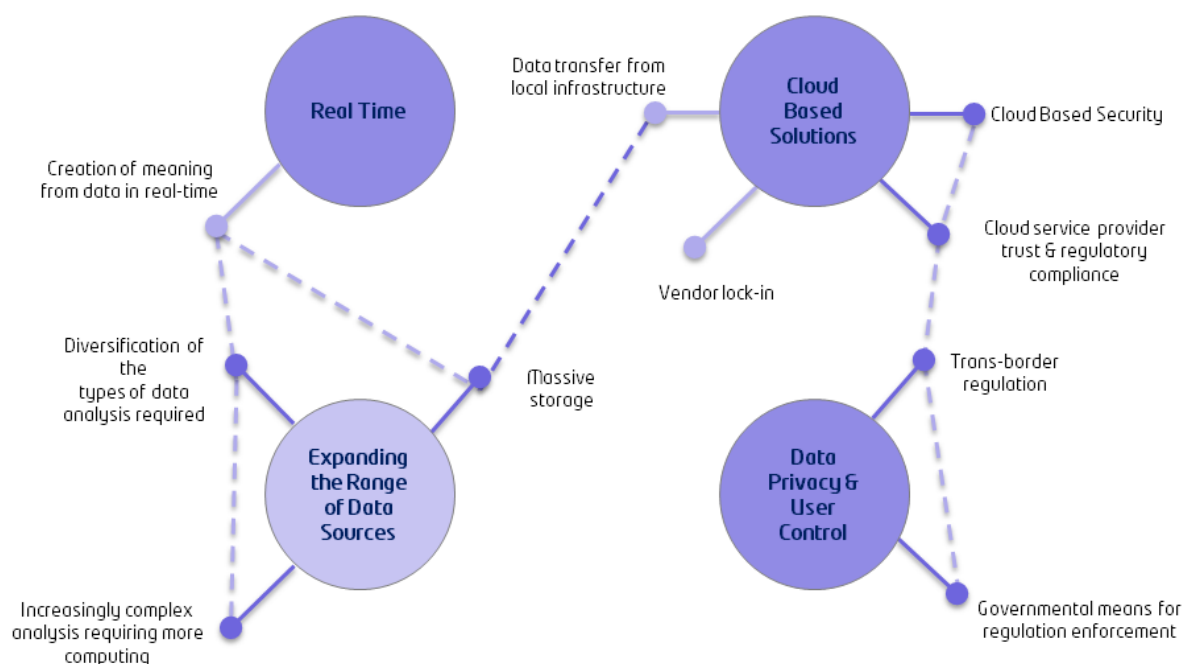


Figure 54: Big Data- Challenges conceptual map

The objective of this section is to expound the expected technological solutions that will set the path throughout the defined timeline (both before 2020 and beyond), highlighting the foreseen links with other branches of the roadmap.

Short-term

- **Enhanced Privacy.** 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. To that regard the technological tools that allow effective anonymization and efficient against reverse engineering (de-anonymization) are a key success factor to gain user's confidence in Big Data technologies.

It should be noted that the effect of the anonymization (also known as de-identification) is affected by the technical progress of Big Data's analysis techniques. In fact the more computing power is available and the more effective the Big Data algorithms are the more affected are the data to correlation attacks.

For instance, fingerprinting algorithms can be used to identify single users by means of their browsing data (user agent, plug-ins installed, time zone, etc.) as the combination of a series of apparently common information can be used to create a fingerprint which is unique among millions of users (see for instance <https://panoptickick.eff.org>).

The interaction with mobile phone networks can be also used to identify single users from apparently anonymous data. For example, computational social scientist Yves-Alexandre de Montjoye¹ at MIT demonstrated that 11 randomly chosen interactions with cell phone networks were needed to identify a person by the routes he or she regularly travelled, while identifying someone by other fingerprinting techniques may require at least 12 reference points.

This previous examples clearly indicate that anonymization is still at an early stage and there is room for improvement.

- **Evolved Map & Reduce.** 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.

One of the core components technologies of Big Data are the parallel processing technologies. Map Reduce, proposed by Google^{38,39} 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 Spark⁴⁰, which claims to “run programs up to 100x faster than Hadoop Map&Reduce in memory, or 10x faster on disk”, or Storm⁴¹, which “makes it easy to reliably process unbounded streams of data, doing for real-time processing what Hadoop did for batch processing”.

- **Massive Data Transfer.** Stepping up from a local infrastructure to a scalable and reliable public Cloud-based solution implies transferring a massive amount of information before the new system is ready to operate.

Traditional transport methods are not suitable to move petabytes of data at the speed required by certain applications, and imply unacceptable delays in moving data into, out of, and within the Cloud.

Especially critical is the migration of information from one Cloud provider to another as it may require moving data accumulated over a period of years. The development of new techniques to perform an effective migration of data would prevent the vendor lock-in for Cloud-based Big Data solutions.

An example of this challenge is the case of one of the world’s largest genomics research institute, producing the equivalent of 2,000 human genomes a day, which facing the challenge to transmit its results to clients or collaborators over the Internet or other communications lines, what could take weeks took the decision to send computer disks containing the data by courier⁴².

- **Natural Language Understanding & Automatic Translation.** Human brain uses semantics and natural language understanding (NLU) to very efficiently use unstructured data. Computers are very good in processing structured data as mathematical devices they are, but in order to understand unstructured data, computer need innovative brain-inspired technologies to acquire the ability to understand semantics.

Big Data opens the door to a more effective translation of text what in turn reverts in an even more efficient use of the data, expanding the range of data available to obtain semantic insights. Human translators work by firstly gaining semantic understanding of a text in its original language and then drafting the equivalent to that meaning in the target language. A different approach for machine automatic translation, which is facilitated by Big Data technologies, works very differently. Namely it works by comparing huge databases of already translated texts and looks for the nearest excerpt to the one to be translated, and then taking as starting point its equivalent form in the target language, requiring then just minor adaptations to be performed.

³⁸ Anonymized cell phone data could be better at identifying users than fingerprints
<http://spectrum.ieee.org/riskfactor/telecom/security/this-week-in-cybercrime-anonymized-cellphone-tracking-data-is-pure-fiction/>

³⁹ <http://research.google.com/archive/mapreduce.html>

⁴⁰ <http://spark.apache.org/>

⁴¹ <http://storm.apache.org/>

⁴² http://www.nytimes.com/2011/12/01/business/dna-sequencing-caught-in-deluge-of-data.html?pagewanted=all&_r=0

Long-term

- **User in Control of its information.** In addition to performing an effective anonymization users will welcome a greater control over the use of the information they consciously or unconsciously generate. Aside from early measures such as the EU directive on web cookies, users seemingly demand for a greater control. To this regard, control tools offered by the companies that control / analyse user data, will be certainly welcome by final users and will increase the level of trust towards those companies. The benefit extracted from Big Data techniques is quite unbalanced, with the companies having a great commercial benefit from the obtained insights and the individuals usually gaining nothing (beyond being offered a product they want to buy). But in the long run the interactions should be made more balanced to be sustainable, allowing the users to control the use of their data and to get some benefit when they allow its use.
- **Public Cloud-based Big Data.** 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. There are, though, relevant challenges associated to this kind of deployments. As described above 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. Another crucial point to solve in order to make Cloud-based Big Data solutions trustable is protecting the stored data in order to ensure its integrity and the conformity to privacy rules. Moreover 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.
- **Real-Time Audio/Video Big Data.** Real-time 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.
- **Rich Media Big Data:** The development of the Audio and Video Big Data technologies together with the evolution of the Natural Language Understanding and Processing would open the door to a wider range of new applications for Big Data. These new source data used for the analysis should not be seen in isolation as Big Data is characterized by the ability to extract meaningful insights from the analysis of heterogeneous sources of data.

Figure 55 depicts the overall map of solutions, placing the different technology areas together with their respective links.

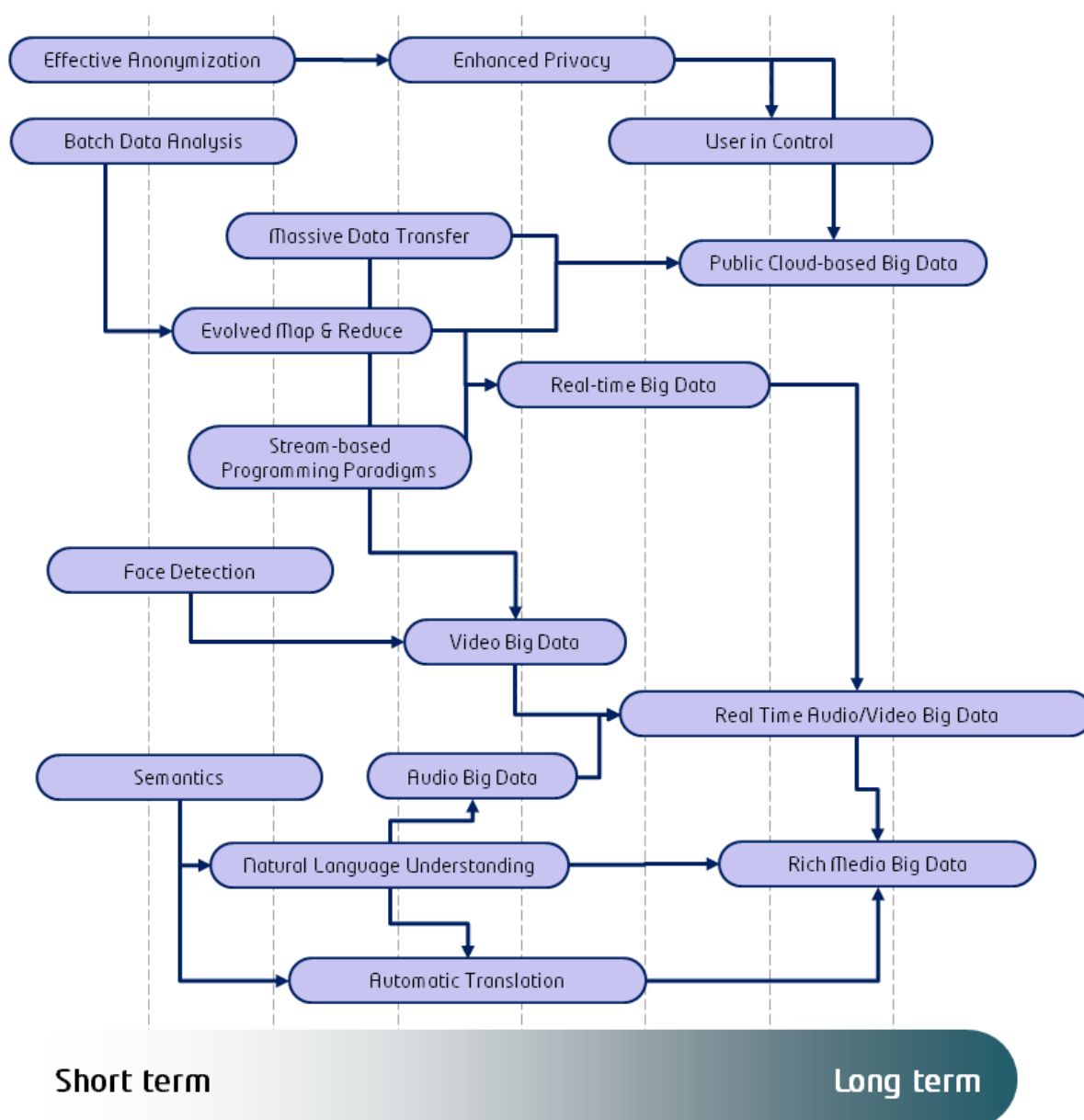


Figure 55: Big Data Technology Solutions Map

5.3.3. Timeline

According to the overall framework defined, the roadmap shall evaluate two main periods: the **short-term**, with the year 2020 as fixed deadline; and the **long-term**, which includes all the initiatives beyond 2020.

In the following, for each challenge, we introduce a detailed roadmap, including:

- Detailed timeline;
- Dependences among technologies;
- Reference technology from other chapters;

Data Privacy & User Control

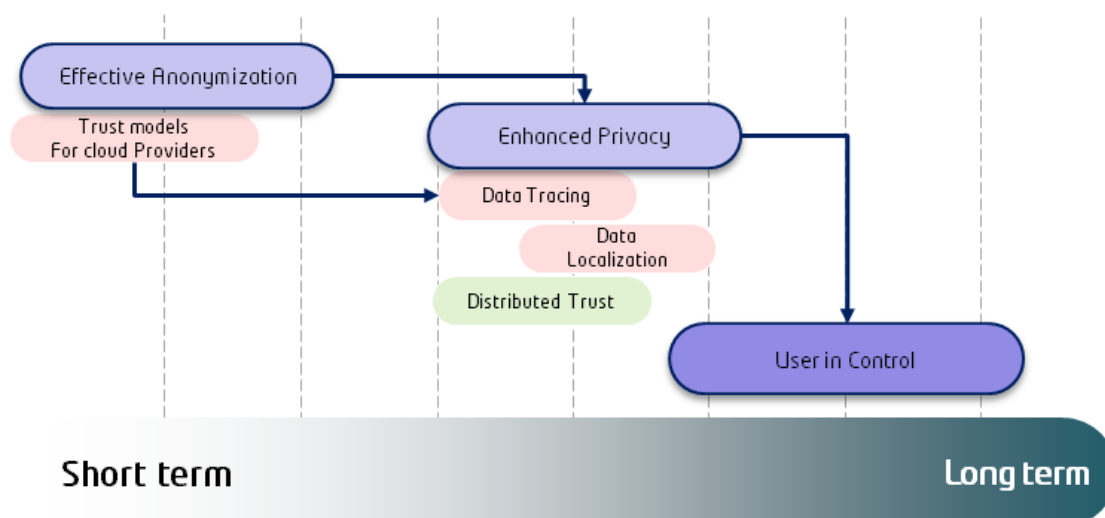


Figure 56: Big Data Challenge- Data Privacy & User Control

Cloud-based Solutions

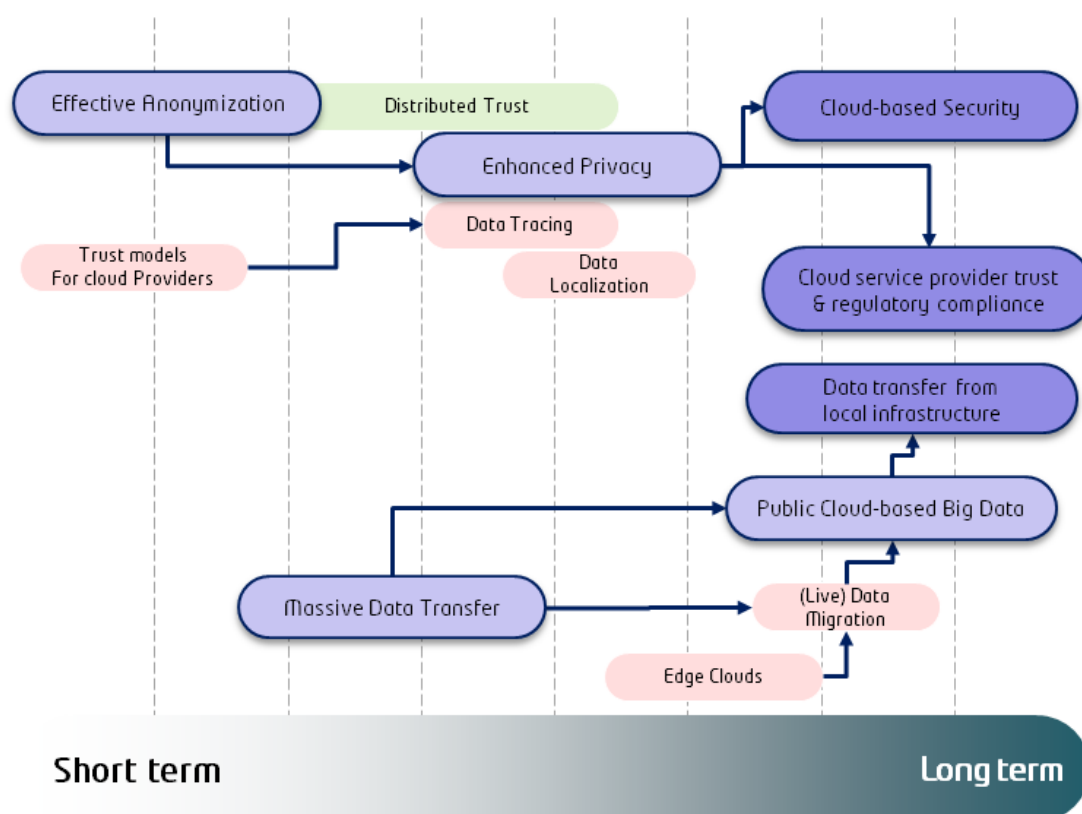


Figure 57: Big Data Challenge- Cloud-based Solutions

Real Time

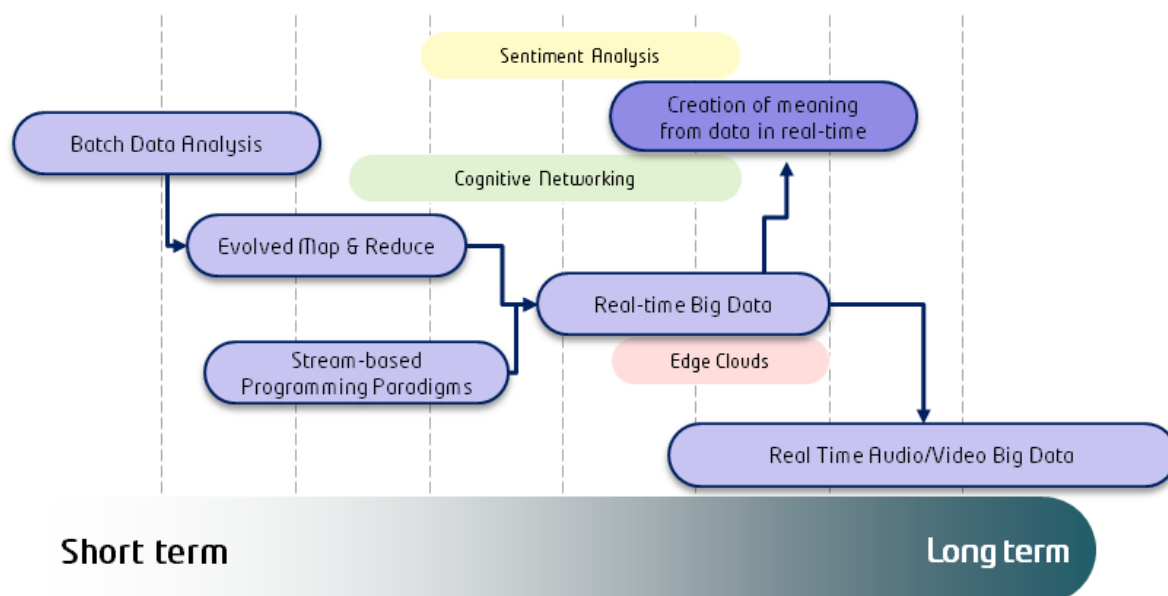


Figure 58: Big Data Challenge- Real Time

Expanding the Range of Data Sources

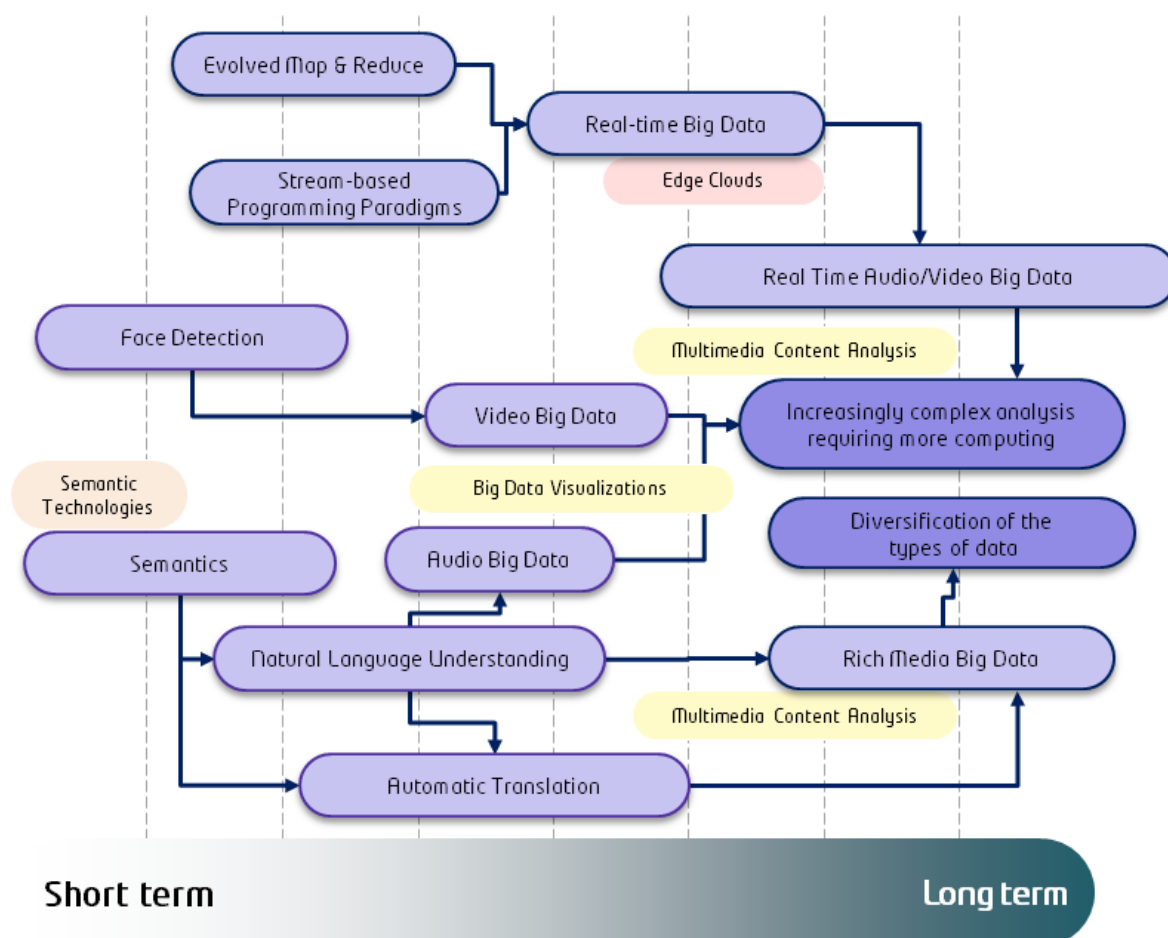


Figure 59: Big Data Challenge- Expanding the Range of Data Sources

5.3.4. FIWARE Technology Mapping

There is a FIWARE Generic Enabler providing Big Data functionality:

- **Big Data Analysis - Cosmos.** Cosmos is an implementation of the Big Data GE, allowing the deployment of private computing clusters based on Hadoop ecosystem. Current version of Cosmos allows users to:
 - I/O operations regarding Infinity, a persistent storage cluster based on HDFS.
 - Creation, usage and deletion of private computing clusters based on Map&Reduce and SQL-like querying systems such as Hive or Pig.
 - Manage the platform, in many aspects such as services, users, clusters, etc, from the Cosmos API or the Cosmos CLI
 - Receive context data from Orion (Context Broker GE implementation) and store it in HDFS.

It is expected that Hadoop platform, the de facto standard for Big Data, conducts itself a certain evolution along the lines described on this roadmap. Other evolutions may be conducted within the FIWARE ecosystem as wrappers of the Hadoop platform.

Other FIWARE Generic Enabler providing Data/Context Management functionality:

- **Configuration Manager - Orion Context Broker:** allows publishing context information by the context producers and makes it available to context consumers. It can work following two different models: request-response (pull) or subscription-notification (push).
- **Complex Event Processing (CEP) - Proactive Technology Online (Proton):** The CEP GE analyses event data in real-time, generates immediate insight and enables instant response to changing conditions. While standard reactive applications are based on reactions to single events, the CEP GE reacts to situations rather than to single events. A situation is a condition that is based on a series of events that have occurred within a dynamic time window called processing context. Situations include composite events (e.g., sequence), counting operators on events (e.g. aggregation) and absence operators. The Proactive Technology Online is an implementation of the FIWARE CEP (Complex Event Processing) GE.
- **Stream Oriented – Kurento:** The Stream Oriented GE is a development framework that provides an abstraction layer for multimedia capabilities, allowing non-expert developers to include interactive media components to their applications. At the heart of this enabler there is the Open API. A REST-like API, based on JSON RPC 2.0, exposing a toolbox of Media Elements that can be chained to create complex media processing pipelines. The Stream Oriented GE provides developers with a set of robust end-to-end interoperable multimedia communication capabilities to deal with the complexity of transport, encoding/decoding, processing and rendering tasks in an easy and efficient way.
- **Open Data - CKAN:** component released by Open Knowledge that allows easily publishing, accessing and using open data in multiple formats. The plan is offering CKAN as a FIWARE Generic Enabler, enhancing CKAN's Usability and improving harvesting and federation of data sources in CKAN in order to support better interoperability with the rest of FIWARE Generic Enablers

5.3.5. Recommendations for FIWARE evolution

FIWARE platform is being increasingly seen as an alternative platform for Big Data research, development and service delivery. It provides new entrants with a seamless vertical integration with many IoT deployments and sources of data (e.g. CKAN). FIWARE provides a set of assets, especially the Generic Enablers, which enables easier development, test and deployment.

However, from the Big Data standpoint, this roadmap raises some suggestions that would help focus FIWARE evolution. First, FIWARE efforts in the security field, are not as publicly known as other FIWARE aspects

(ecosystem, access to funding, available GEs, etc.) and concerns around potential privacy issues are not addressed in public communication messages.

In addition, application developers looking to incorporate real time features can test the applications in FIWARE Lab, but the actual experience might differ greatly from that of the exploitation platform, as commercial instances of FIWARE platform might be much more powerful and the agreement with the provider might differ greatly. If real time is something to be incorporated into FIWARE evolution, then FIWARE Lab should also be prepared to deliver a test platform that allows real-time testing under reasonable conditions.

Also the semantic analysis, especially in terms of extracting structured data and insights from real-time data (audio & video), is perceived as a relevant area of technological evolution and a great challenge that could be addressed.

Not a purely technological aspect but rather related with usability is the evolution of innovative interfaces to explore, visualize and query data. One of the challenges for organizations embracing Big Data analytics is extracting meaningful insight. However the current scarcity of Big Data expert profiles and the entry barrier to this kind of technologies causes some organizations not to be able to take the most out of their platforms. This problem would be alleviated by developing more visual and intuitive ways to exploit Big Data, allowing a wider customer base to benefit from it.

5.3.6. Recommendations for future work programmes

The Future Internet PPP has been one of the earliest initiatives that set the way forward for other of partnerships seeking to leverage on the PPP model to attain a similar level of achievements. One of those recent initiatives is the Big Data Value PPP. It is relevant noting that the BDV-PPP and its founding private part the Big Data Value Association set the focus on the “Value”. With Value being considered one of the five essential “V”s of Big Data (the other four being Volume, Velocity, Variety and Veracity) it is clear that the industry is focusing on the application of Big Data to add value to the industry, BDVA is not so much focused on the underlying technical challenges which can be addressed in FI-PPP and FIWARE.

In that sense, Big Data Value leverages on the existing technical developments, and FIWARE represents one of the most comprehensive and accessible platform for Big Data experimentation, innovation and service delivery. One of FI-Links recommendations for future work programmes in relation to Big Data is to explore and promote where possible the use (re-use) of FIWARE platform and all of its enablers as a preferred platform for Big Data when possible. This way future work programmes would benefit from the ecosystem created around FIWARE that provides a good “Volume” and specially “Variety” of data on which to relay for a further technological evolution.

5.4 Cloud Computing

5.4.1. Introduction

Cloud Computing technologies are facing a fast pace evolution through the different layers of its architecture, i.e. IaaS, PaaS, SaaS. The infrastructure layer – as discussed in Section 5.5 – is moving fast in the direction of Software-defined infrastructure, where more and more the overall computing (and underling) infrastructure is softwarized. The softwarization of infrastructure and its potential, are affecting the layer above, opening up to new scenarios within the Cloud platform and software provisioning. At the same time the maturity and widespread of Cloud Computing technologies open up to new interesting potential business scenario for Cloud providers stimulating their interaction.

Still, Cloud Computing architectures will evolve in new directions to support the demanding requirements of advanced 5G infrastructures, which implies highly decoupled and de-centralized Cloud models. In this context the availability of high-bandwidth and low-latency infrastructures will be a key enabler to support such evolution.

It is expected that the larger adoption of Cloud and the availability of Cloud platforms (IaaS or PaaS) customized for specific sectors (e.g. Media Internet, Internet of Things, 5G Infrastructures), will drive the

constant growth of Cloud Computing market.

We expect that in the next years, the following main challenges will need to be tackled in the Cloud Computing area (cf. D1.1 [9] and Figure 60):

- **Customized Clouds (short-term):** a number of relevant markets (e.g. IoT, media) are more and more requesting for Cloud services offering dedicated capacities and functionalities for their segment needs; first offers are starting to appear, still the degree of “customization” to a given market segment is very low and expected to mature in the future; FIWARE, through development of vertical platforms, is moving some initial steps in this direction.
- **Security, Privacy & Trust (short-term):** security and privacy is a general concern for online resources, and it is particularly relevant in markets dealing with sensible data; Cloud technologies, pushing more and more services in the network, is making it a primary concern for the adoption of Cloud services; within FIWARE, several technologies are devoted to Context/Data Management, these services are ultimately meant to work in a Cloud-based platform, increasing the importance of managing this data in a transparent way within the Cloud platform provided.
- **Dynamic Cloud Aggregation (long-term):** developers are more and more demanding for abilities to select and combine resources from the Cloud service providers according to the specific needs of the different components of their applications; within the FIWARE initiative the approach so far is more focused on a specific platform and a simple and pragmatic approach to federation is in place for that platform; looking at the market needs, this is not enough to reflect developers’ needs
- **Native Cloud Applications (long-term):** currently most of the IT services, move functions on Cloud architectures without benefiting from Cloud potential. This is intrinsically related to the fact that, instead of being properly re-designed, services and applications are ported to the Cloud. To facilitate this step, proper frameworks and methods are required. As of today, most of the FIWARE GEs/SEs are not natively designed for the Cloud.

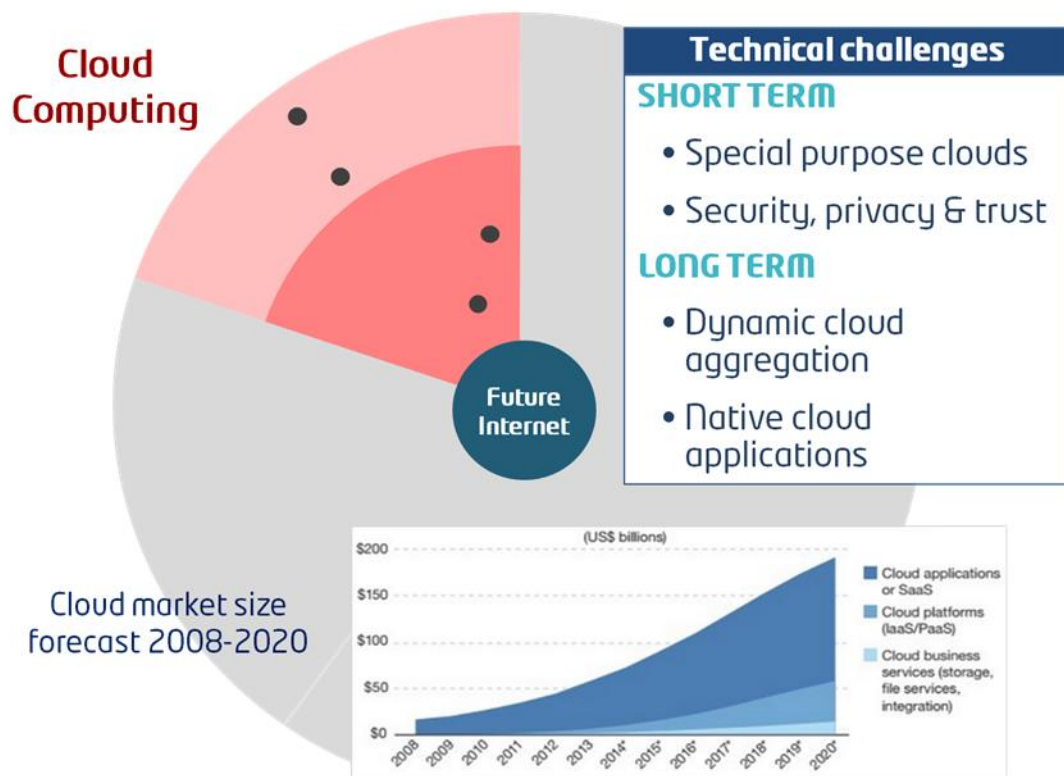


Figure 60: Cloud Computing- Technical and Business Overview

As discussed in deliverable D1.1, the challenges proposed originates from the analysis of FIWARE and a number of existing roadmaps, including: Standardization Roadmaps (e.g. the NIST roadmap [18]), Industrial public roadmaps (e.g. the Oracle Roadmap for Cloud Computing [25]), European Research and Innovation Roadmaps [15] and Innovation roadmaps produced by other industrialized countries (e.g. the roadmap by Singapore Innovation agency [12]).

From the discussion above, it is clear that Cloud Computing's challenges are tightly related to the challenges in the other chapters and in the business domain. Hence, the Cloud Computing chapter is – in combination with the Network chapter – a fundamental brick for the construction of the Future Internet.

It is important to highlight –as already mentioned in D1.1– that the identified challenges are not the only ones relevant and possible, rather they represent a selection of challenges, relevant to the FIWARE and FI-PPP context.

5.4.2. From challenges to technology solutions

In this section, we explore the required technological building blocks for the resolution of challenges introduced in deliverable D1.1. The challenges are broken down into a number of sub-challenges that allows highlighting relations among challenges (*Figure 61*). Moving beyond the challenges and their interaction we have identified a number of corner-stone technologies that will empower their resolution. In the following paragraphs we discuss them and use them as starting point for our high-level roadmap.

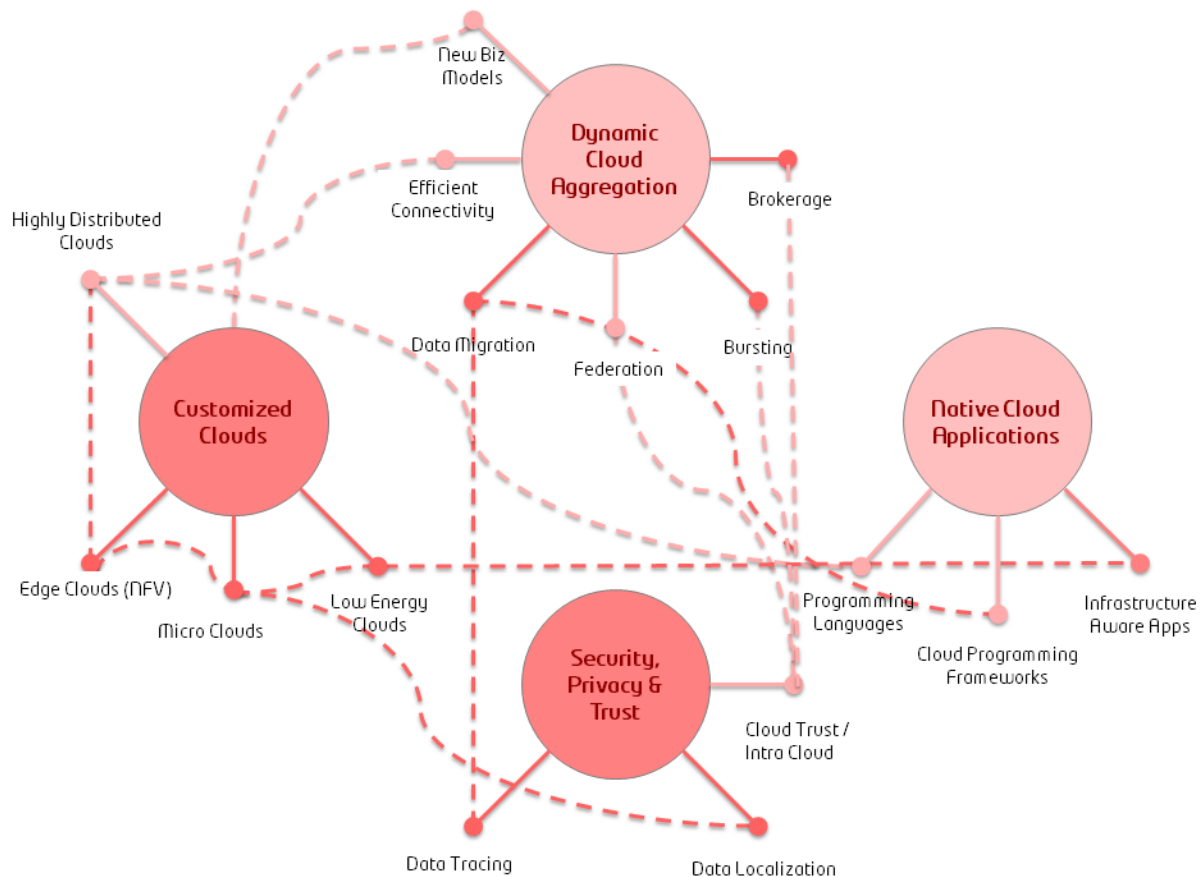


Figure 61: Cloud Computing- Challenges conceptual map

Short-term

- **Infrastructure Aware apps.** Regardless of 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 the status of network and the availability of bandwidth at a given point in time. A key enabler for this to occur is the rise of *Standardized infrastructure sensing technologies*. This will allow as well for *energy aware applications*.

- **Micro Clouds.** On one side, different organizations are unable to move data onto the Cloud due to insufficient bandwidth, latency, location-specific processing needs, Big Data, security, or compliance reasons. On the other side, 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. Following this need Cloud Solutions will more and more embrace lightweight virtualization such as *containers and unikernels*.
- **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-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 is already occurring, beyond adopting novel *Energy Management Solutions*, Cloud solutions will decouple from the traditional virtualization concept to embrace alternative technologies (e.g. containers, bare-metal, library operating systems/unikernels, etc.).
- **Efficient inter-Cloud connectivity.** In the global context in which 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 of the fact that the applications are hosted by the same provider or different providers – that applications are more and more globally distributed. This demands 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. This demands for novel *SDN for distributed Cloud solutions facilitating the inter-Cloud connection*.
- **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 (QoS) 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 fulfil 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. Key factors for the achievement of such technology are: *Novel business models for Cloud providers* that make profitable the creation of business Cloud federation (beyond the computational research ones) and standards *for resource information sharing* and for Cloud identity sharing.
- **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 the ability to orchestrate and make seamless resources that are hosted in different contexts. The road to automate this process, especially across infrastructure based on different monitoring and management mechanisms is still an open challenge. Key factors for the achievement of such technology are *standards for resource information sharing* and *Trust models for Cloud providers*.
- **Data Tracing.** More and more data is hosted in the Cloud. For trust and privacy reasons 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 the 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. Enabling data tracing, requires *Cloud data control probes* that provides at any time information on the status, access and localization of data.

- **Data Localization.** In most 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 (c.f. Dropbox or Google Drive). In several scenarios, this is not acceptable, e.g. due to legislation, and users fall back onto localized solutions that may not give them the advantages of public Cloud adoption.

Long-term

- **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 allows for simplifying the development of applications that benefit from the 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). To increase the control from applications we foresee the rise of *auto scale app programming frameworks* and *High available app programming frameworks*.
- **Cloud 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. A prerequisite for such development is the creation of *Cloud apps software engineering methods*.
- **Highly distributed Clouds.** Current Clouds are by 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 *loosely management coupled management of Cloud resources* and novel solutions in the field of *SDN for distributed Clouds*.
- **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 the 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. Telcos themselves are facing this challenge, for example for the virtualization of network functions in the edge of their network. This demands *Specialized hardware virtualization* beyond today's technology capacity.
- **Live Data Migration.** The difficulty to migrate users' virtual appliances between, for example, different providers, or Cloud technologies is characterized as a *vendor lock-in* problem. This challenge requires, beyond *Fast inter-Cloud connectivity*, standards for the migration of data (and services) that maximize the interoperability between the different providers' offers.

Figure 62 depicts the overall map of solutions, placing the different network technology areas together with their respective links.

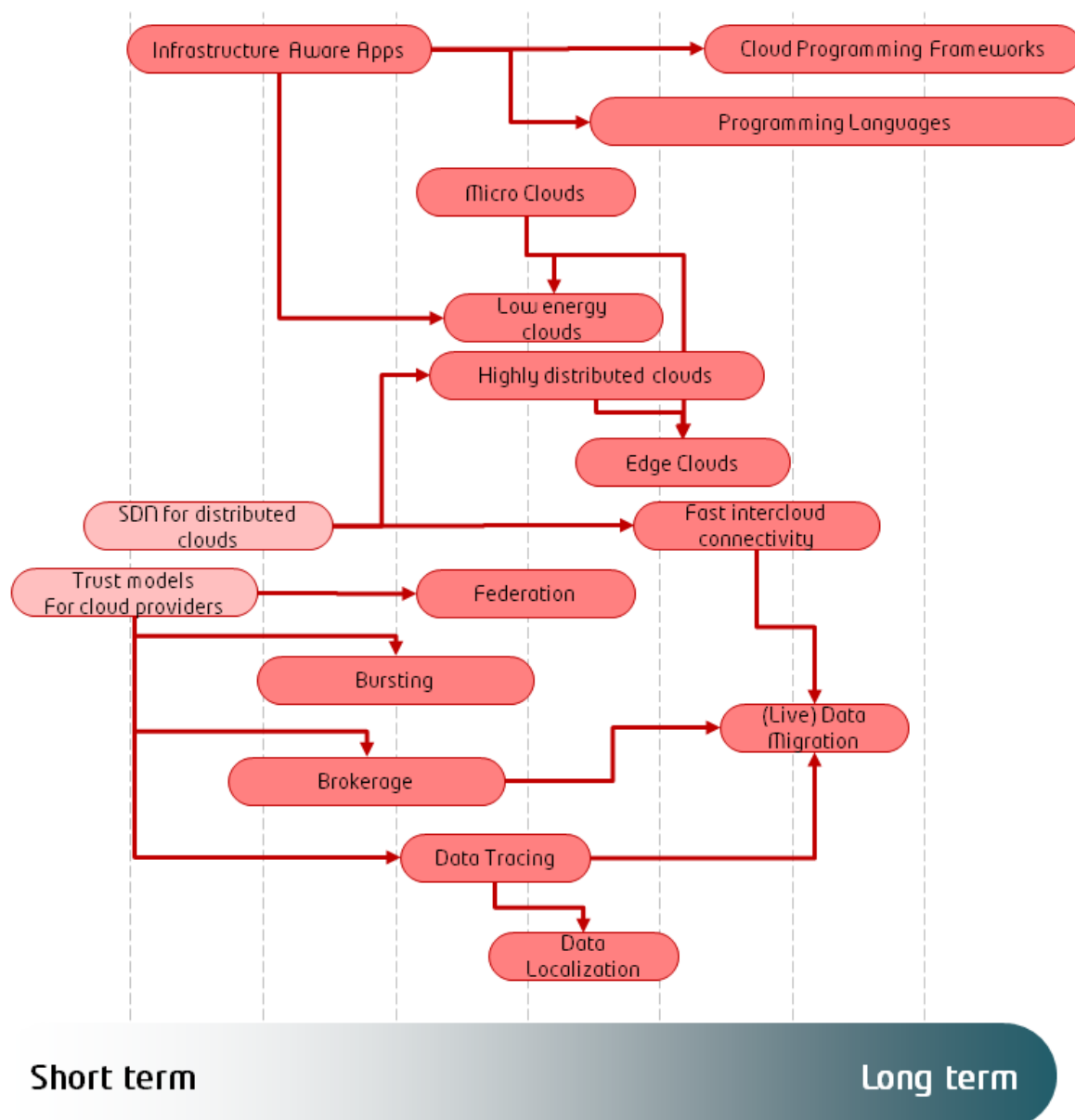


Figure 62: Cloud Computing Technology Solutions Map

5.4.3. Timeline

According to the overall framework defined, the roadmap evaluates two main periods: the **short-term**, with the year 2020 as fixed deadline; and the **long-term**, which includes all the initiatives beyond 2020.

In the following, for each challenge, we introduce a detailed roadmap, including:

- Detailed timeline;
- Dependencies among technologies;
- Reference technologies from other chapters;

Customized Clouds

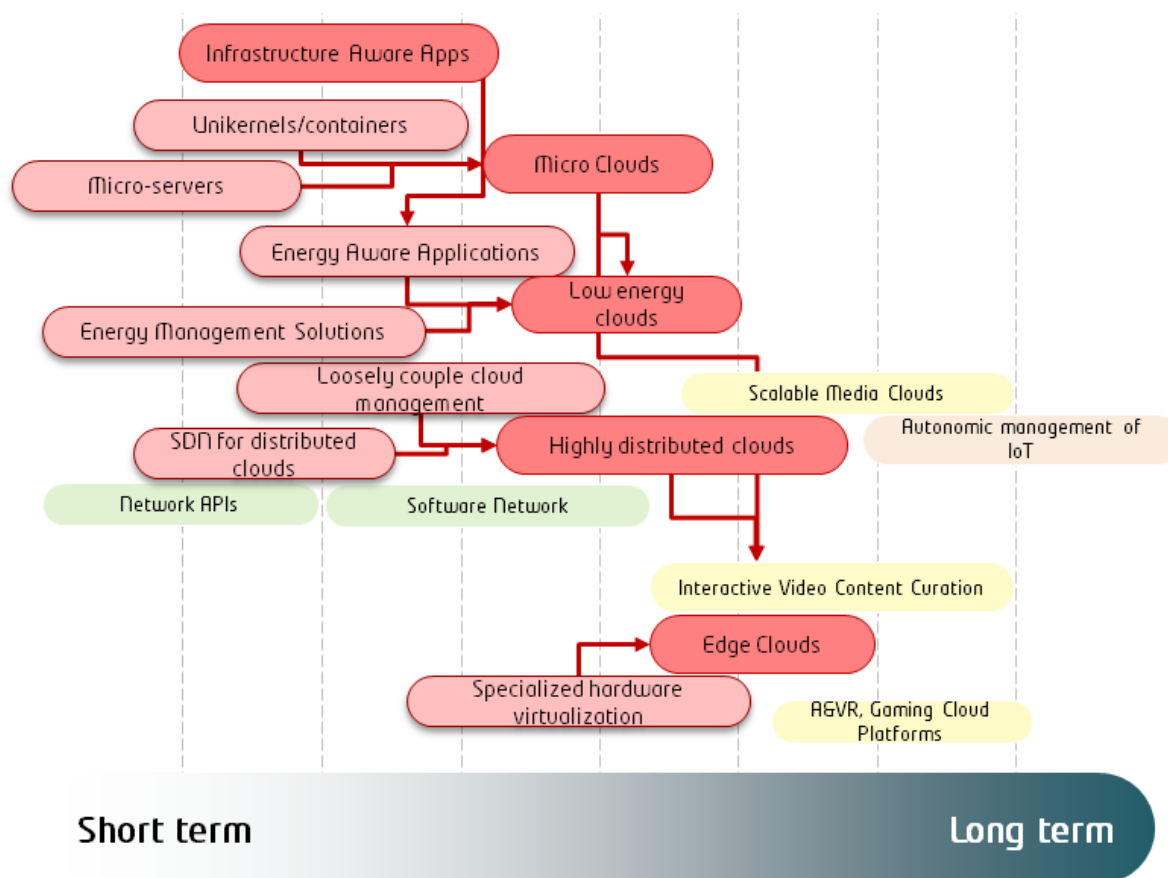


Figure 63: Cloud Computing Challenge- Customized Clouds

Privacy, Security & Trust

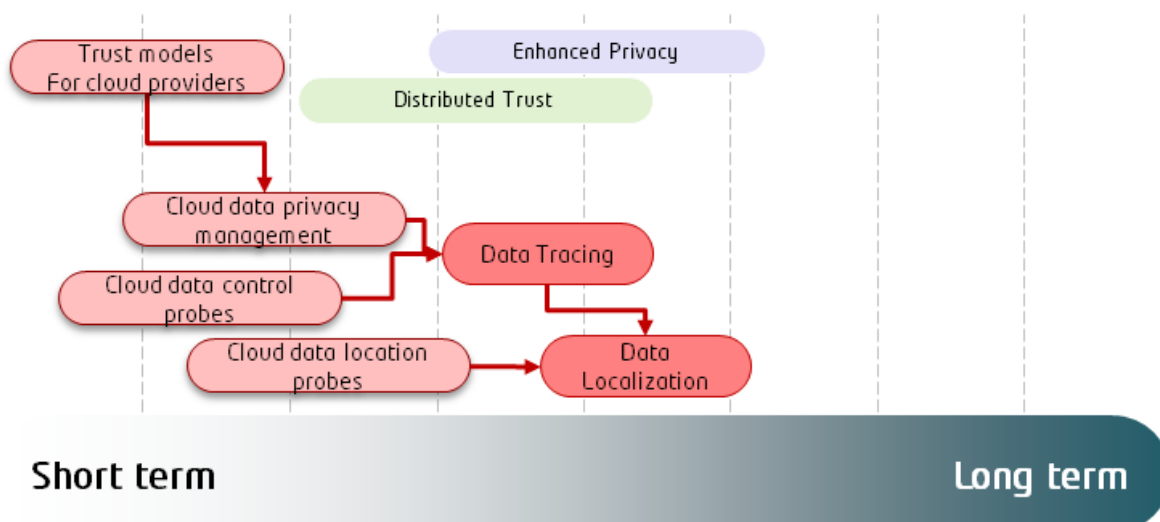


Figure 64: Cloud Computing Challenge- Privacy, Security & Trust

Dynamic Cloud Aggregation

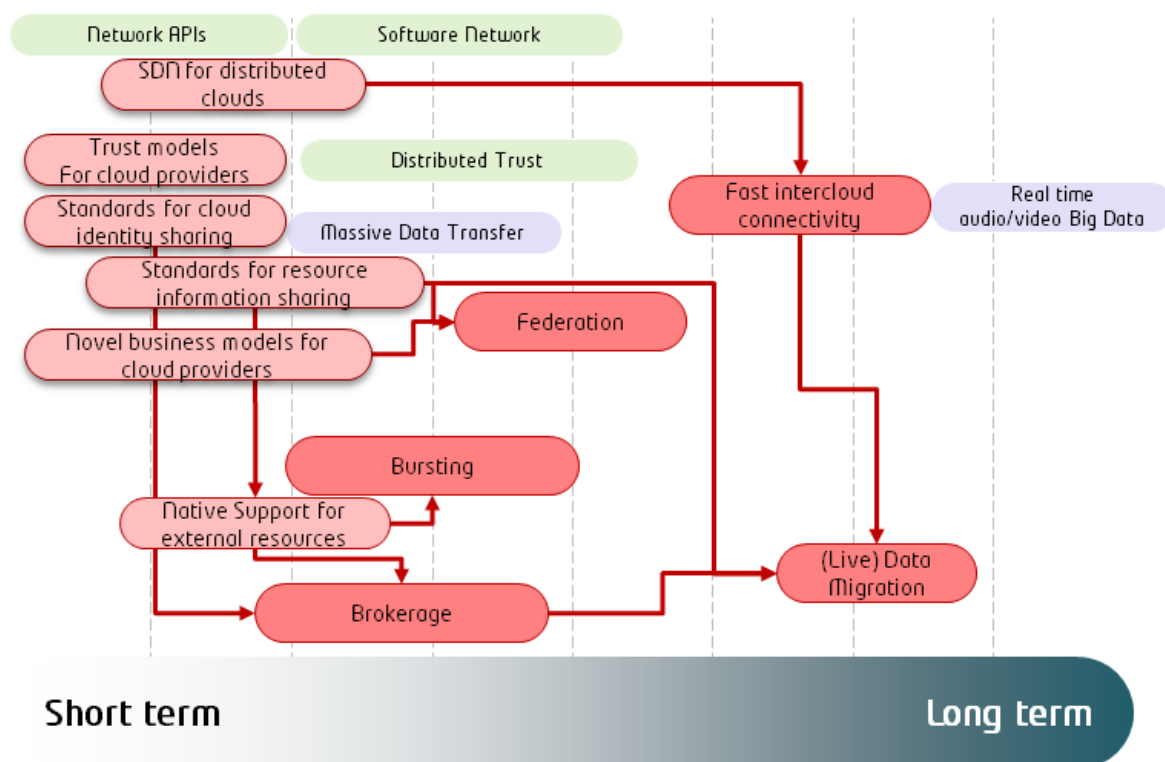


Figure 65: Cloud Computing Challenge- Dynamic Cloud Aggregation

Native Cloud Applications

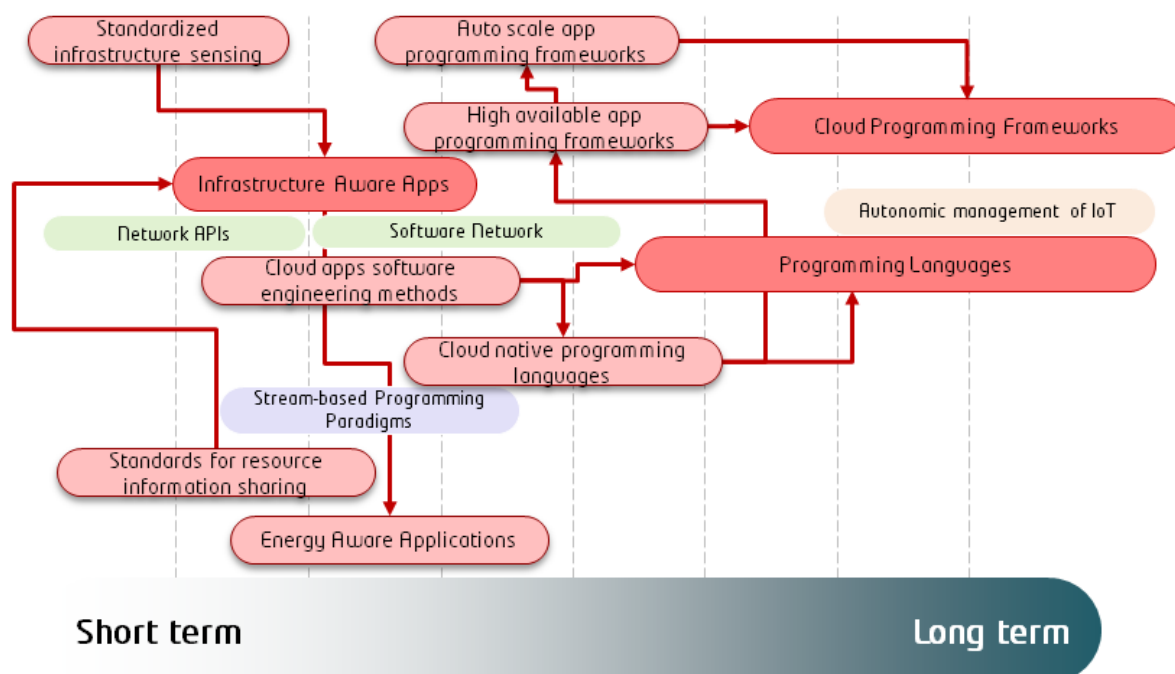


Figure 66: Cloud Computing Challenge- Native Cloud Applications

5.4.4. FIWARE Technology Mapping

Within FIWARE, the Cloud chapter has a primary role. It provides the basis for the provisioning of FIWARE services belonging to the different chapters and its technologies have been validated in the FIWARE Lab⁴³ – a live instance of the FIWARE platform. Beyond that, Cloud technologies have been developed in different FIWARE related projects (e.g. FI-Space, FI-Content).

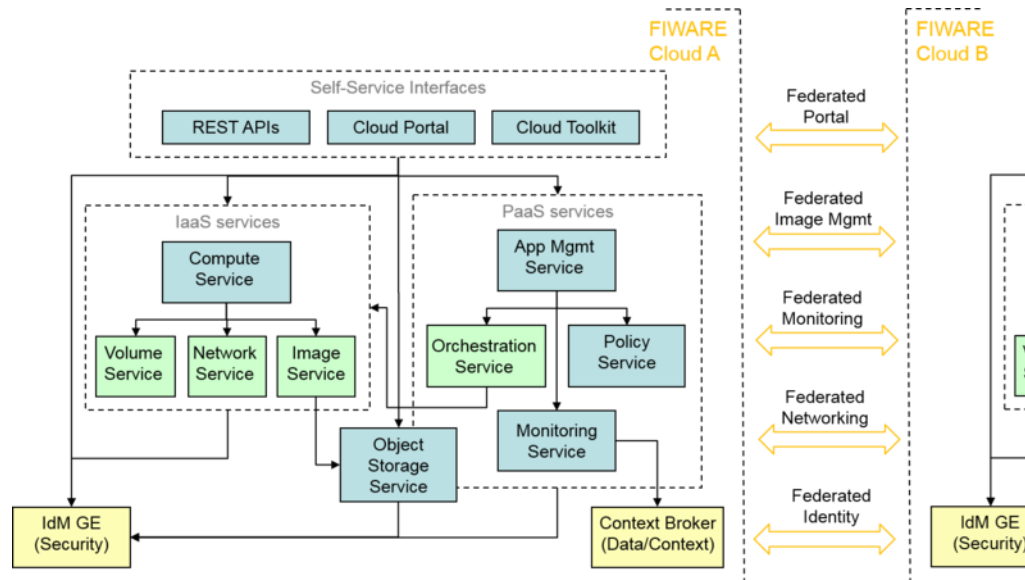


Figure 67. FIWARE Cloud Chapter Architecture – R4.

In relation to the FIWARE Cloud chapter roadmap⁴⁴, the most relevant technologies in respect to the presented roadmap are:

- **IaaS services.** This set of Generic Enablers deals with the management of infrastructure resources. In particular, within FIWARE, developments relate to: compute services (that includes early stage support for containers and advancements to virtual machine scheduling policies). Object storage is also part of the IaaS services.
- **PaaS services.** This set of Generic Enablers supports the deployment and management of application stacks on top of Cloud infrastructure resources.

Within FI-Space, FI-Content and FI-Health, a number of vertical PaaS have been developed, following the trend well identified in the roadmap of need for customized Clouds.

5.4.5. Recommendations for FIWARE evolution

Taking into consideration the time-to-market of FIWARE, the already ongoing actions in FIWARE and Open Source communities, and the roadmap presented above, FI-LINKS identified the following recommendations to the FIWARE community:

- Extend the support for Cloud application management beyond the current focus on the selected IaaS platform within FIWARE (i.e. OpenStack), enabling more open deployment scenarios to the developers (e.g. brokerage / bursting).
- Integrate better containers in the current IaaS services. Currently, the easiest deployment model to not

⁴³ <http://lab.fiware.org>

⁴⁴ https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/Cloud_Hosting_Architecture_R4

lose the power of developer tools for containers, is deploying container run times over virtual machine, limiting – in term of resource efficiency – the impact of container adoption. Lower level integration is needed and more alignment between the container and Cloud management communities (spanning from the network management level to the consistence multi-tenancy of “container” hypervisors).

- Invest more effort in the creation of vertical PaaS that target specific markets starting from providing simple pre-combined architectures based on GEs and so simplifying the life of market-specific developers.
- Introduce a simple framework for the development of “Cloud native” applications, based on current open source solution state-of-the-art.

5.4.6. Recommendations for future work programmes

Beyond the short-term directions discussed above for the FIWARE community, as identified in the roadmap there are a number of interesting technology evolutions that are certainly relevant for the future of FIWARE Cloud technology. These are more forward looking and hence should be covered in the context of initiatives with a longer-term impact and adoption timeline.

In the scope of the roadmap, FI-LINKS identified the following challenges as priority in the Advanced Computing and Cloud Computing objectives:

- Cloud native programming frameworks
- Cloud native programming languages
- Micro-Clouds
- Highly-distributed Clouds

5.5 Network

5.5.1. Introduction

The outlook for network-based architectures and services is heading towards the global adoption and deployment of the **Advanced 5G Infrastructure**; the ubiquitous and pervasive ultra-broadband network in charge of enabling the Future Internet. Future European society and economy will strongly rely on these 5G infrastructures, which will not represent a mere evolution of current legacy, but shall be aligned and embrace new paradigms to support emerging markets’ needs.

5G will be designed to be a sustainable and scalable technology, integrating networking, computing and storage resources into one programmable and unified infrastructure. This unification will allow for an optimized and more dynamic usage of all distributed resources, and the convergence of fixed, mobile and broadcast services. This is a good indicator that explains why use cases have been leading the change into the new network paradigm and are expected to remain the largest consumer of new network technologies through 2020⁴⁵.

From the evaluation of former relevant roadmaps (in particular [4] and [27]), and taking the assessment performed in deliverable D1.1 [9] as a basis, it can be outlined that three major challenges will need to be tackled (Figure 68):

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

⁴⁵ SDxCentral: SDN and NFV Market Size Report. 2015 Edition

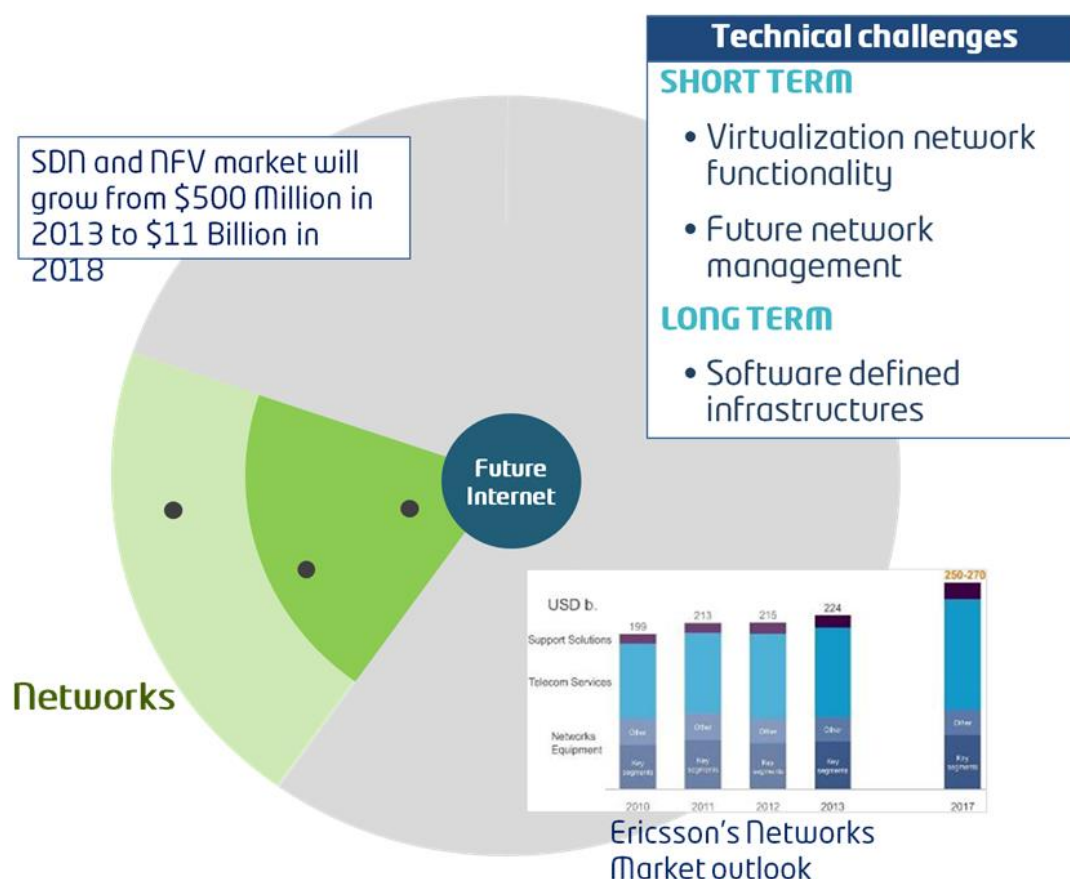


Figure 68: Network- Technical and Business Overview

Taking into consideration that the 5G landscape spans multiple layers, it is important to delimit strategically only those aspects relevant to the Future Internet. In the description of the roadmap (D1.1) it was already mentioned that the challenges to be considered focus on the system level perspective, ignoring a detailed analysis of the low level service and performance indicators. This means the reader shall be aware that there will be relevant research initiatives which will not be covered intentionally by this technical roadmap, such as the radio network architecture, the convergence beyond the last mile and the improvement of capacities in terms of latency and bandwidth.

5.5.2. From challenges to technology solutions

The high-level roadmap identifies the main impacts to overcome, but as it was assessed in deliverable D1.1, each of these is composed of several lower-level challenges. Figure 69 below summarizes the bonds based on that assessment:

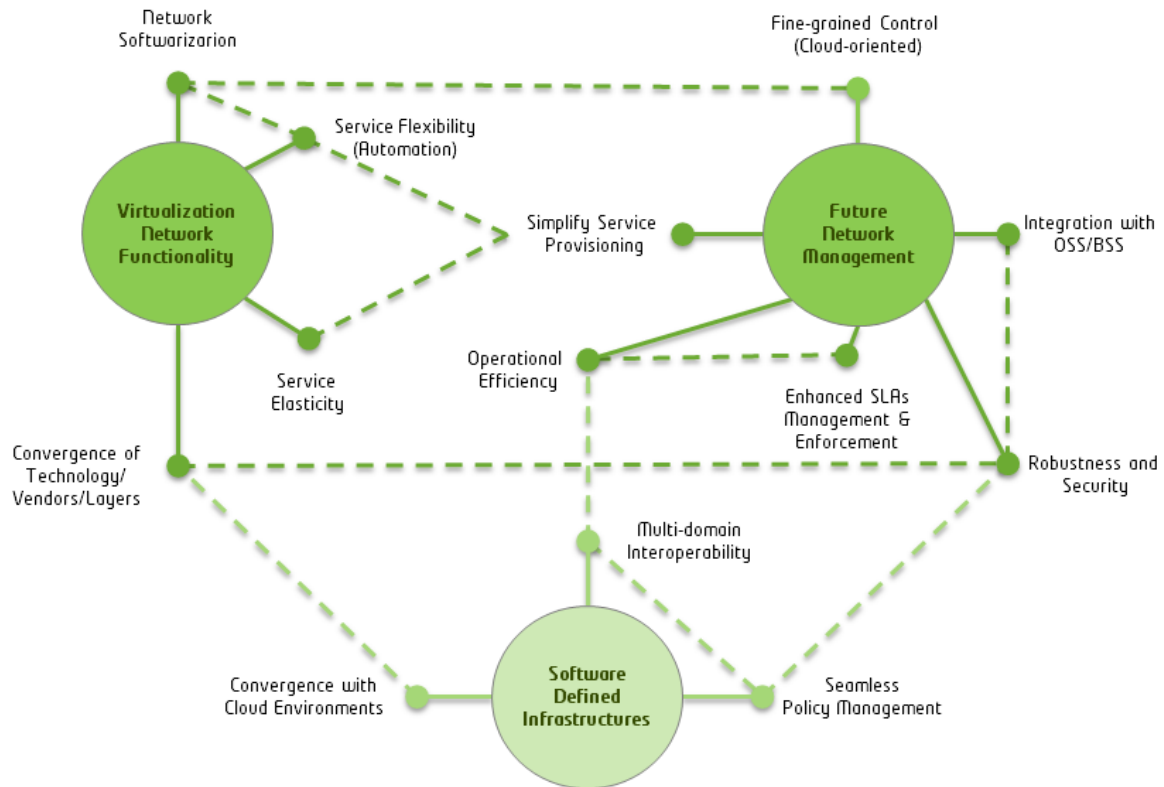


Figure 69: Network- Challenges conceptual map

The objective of this section is to expound the expected technological solutions that will set the path throughout the defined timeline (both before 2020 and beyond), highlighting the foreseen links with other branches of the roadmap.

Short-term

- **Network APIs:** Management and Data Planes require easier and uniform interaction means, through more powerful and rich APIs. It is important to enable external actors to use appropriate configuration interfaces. Some growing initiatives are emerging in this sense, such as intent-based networking, enabling the management of network services and resources based on describing the “Intent” for network behaviours and network policies.
- **Standard Interfaces:** The current heterogeneity in technology, connectivity and multi-tenancy implies that new protocols and layers should be adapted from existing standards in order to ensure a transparent and seamless end-to-end connectivity between services. Standardization for multi-domain and SLA management.
- **Terminal Virtualization:** Network virtualization must not be limited to the infrastructure providing connectivity, but should be extended to the end-user device. It is expected an explosion in the number of user-centred devices in the forthcoming years, with increasingly connected human-owned devices.
- **Network Analytics:** Smart monitoring and trend analysis based on Data Analytics.
- **Distributed Trust:** Security is - and will be - a cross-cutting topic of paramount importance. Secure mechanisms must allow access to only authorized parties, a characteristic that becomes especially relevant in a distributed and flexible framework. Isolation between virtualized networks has to be guaranteed as well as providing trust for the users on the virtual service enablement. It is required to have trust relationships to map the changing trust environment using that network, avoiding trust establishment rigidly defined and largely centralized.

In a second wave, from the evolution and combination of initiatives:

- **Software Networks:** 5G will be driven by software. For a full exploitation of flexibility and programmability in the network services, a major goal should be the improvement in control capability on the part of infrastructure and service providers, context-awareness in carrying out the actions required by a service, users' QoE, and time-to-market service offerings and their deployment. It will promote evolutionary approaches to network deployment, on demand function migration and will potentiate the usage of virtualization techniques to network deployment, and facilitate federation of networks and services.
- **Cognitive Networking:** To meet the new technical requirements on scalability, 5G networks have a need to adopt novel architectures, posing challenges on the management and control of the resulting distributed system. Decisions regarding planning and performance shall be taken with respect to the end-to-end goals of a data flow. Hence, the expected complexity demands some "intelligence" in the network, taking a look at the whole "network picture". Self-awareness and capabilities for learning from the consequences of past actions are inherent characteristics that a Smart Network Service Orchestration shall include. A logically centralized process can analyse the network context and act consequently, or even depending on expected/predicted future events. The orchestration should be dynamic enough to be able to:
 - Keep track of all available and used resources
 - Determine the best available resource containers
 - Implement different scheduling strategies to best adapt to the different context
 - Deallocate unused functions and release resources at the end of the execution/lifecycle
- **Virtual Policy Enforcement Points:** The evolution of networks implies the virtualization of resources that can be instantiated and released on demand to timely meet customers' demands or to optimize operator's internal processes. Therefore, in order to attend the needs for adaptability of 5G networks, virtual policy enforcement points will be required to assure control accordingly to the circumstances.

Long-term

- **Virtual Policy Automation:** Advanced 5G networks will demand higher levels of automation, not depending on the users to adapt to the changeable context. Virtual instances of policy points will require fitting the requirements in real-time.
- **Fully Dynamic Trust:** As the environment becomes more dynamic, trust relationships among all the parties will require adapt accordingly. The network may support high flexibility, but security cannot be harmed.
- **Customized Context-aware Networks:** Service virtualization techniques and faster deployment of new network services on demand will allow dynamically creating and moving personal networks, enabling 'follow-me' architectures with minimal impact on its access experience. Such personalized networks can adapt their characteristics to the user profile, location and general context. They will also allow providing a homogeneous and customized network access environment to users, regardless of their location and adapting to the end-user device capabilities. In addition, tailored QoE should be a usual ability for the system management.
- **Agile Management Framework:** Advanced techniques will entail managing the deployment and following the dynamic nature of the network by means of agile principles, where higher degrees of intelligence, adaptability and self-management are expected. Mechanisms to realize and dynamically adapt the connectivity in an efficient manner, without affecting the end-to-end communication. A powerful (self-) management framework is necessary in order to achieve optimality in 5G systems and meet strict usage and development requirements. 'On-the-fly' sharing of network infrastructure is a feature especially required in order to obtain a fast-adaptable robust network, through dynamic orchestration of network functions and elements belonging to different operators.

As a result, Figure 70 depicts the overall map of solutions, placing the different network technology areas together with their respective links.

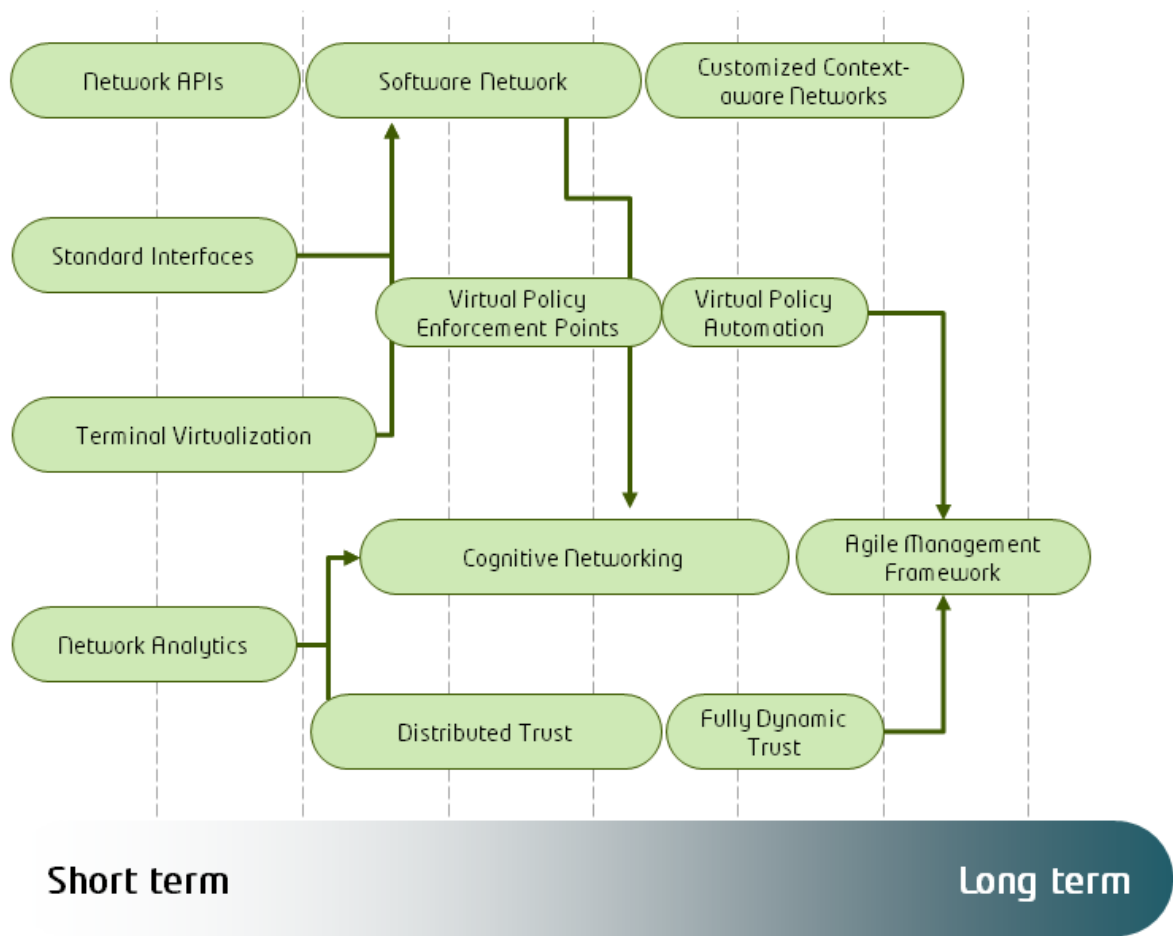


Figure 70: Network Technology Solutions Map

5.5.3. Timeline

According to the overall framework defined, the roadmap shall evaluate two main periods: the **short-term**, with the year 2020 as deadline; and the **long-term**, which includes all the initiatives beyond 2020.

The table below summarizes some specific milestones envisioned by the 5G-PPP that will help as a baseline:



Time Slot	Milestones
2015-2017	Exploratory phase and specification. Detailed system research and development for all access means, backbone and core networks (including SDN, NFV, Cloud systems, undedicated programmable hardware...) by taking into account economic conditions for future deployment.
2016-2018	Detailed research and optimization. Investigation, prototypes, technology demos and pilots of network management and operation, Cloud-based distributed computing and Big Data for network operation. Extension of pilots and trials to non ICT stakeholders to evaluate the technical solutions and the impact in the real economy. Detailed standardization process based on validated system concepts by means of simulations and close to real-world trials.
2018-2020	Experimentation and trials. Demonstrations, trials and scalability testing of different complexity depending on standard readiness and component availability.
2020	Close to commercial systems deployment under real world conditions with selected customers to prepare economic exploitation on global basis.
2020+	Start of commercial deployments of 5G systems.

In order to complete the full-fledged picture for each challenge it will be necessary to align:

- Specific sub-challenges
- Network technology solutions
- Technology solutions relevant from other domains
- Reference timeline

Virtualization Network Functionality

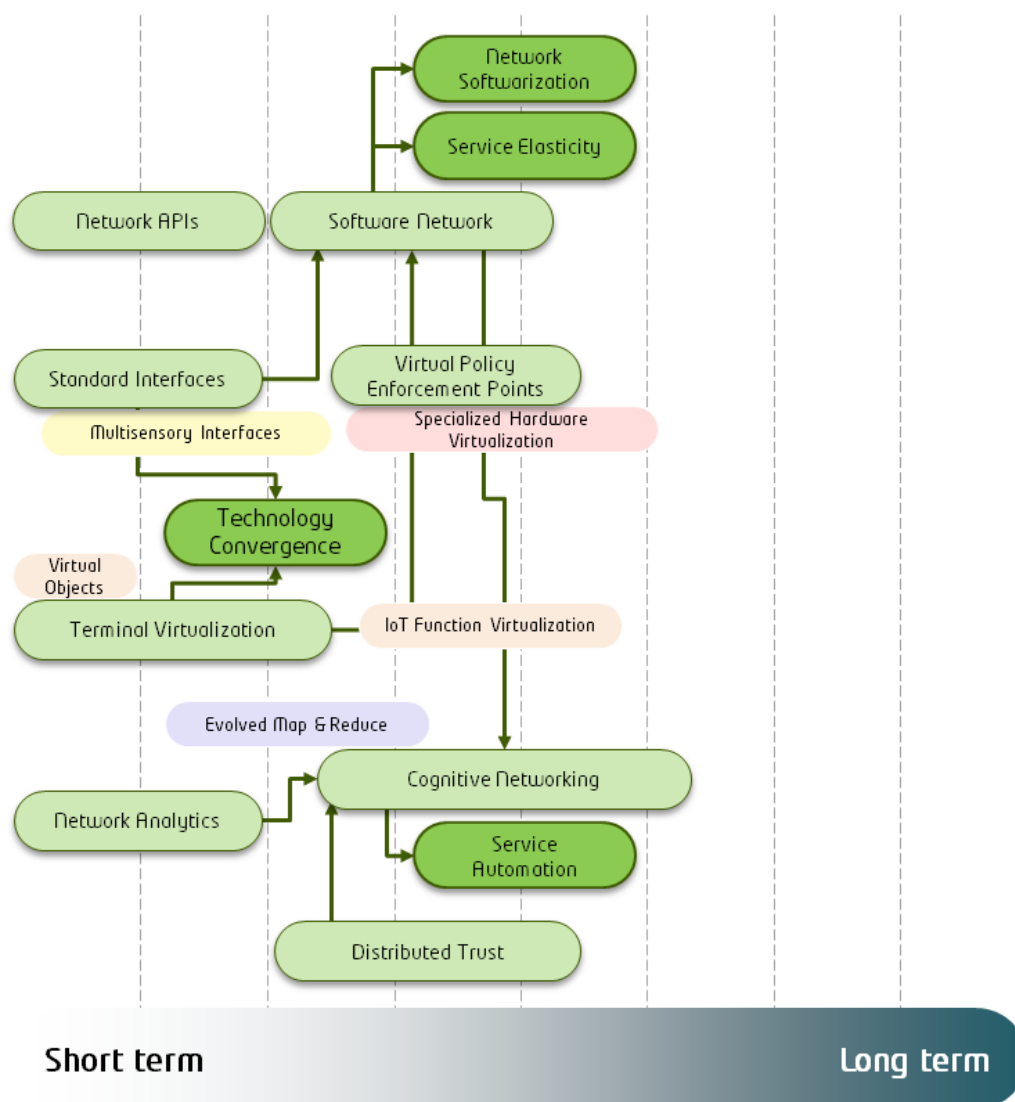


Figure 71: Network Challenge- Virtualization Network Functionality

Future Network Management

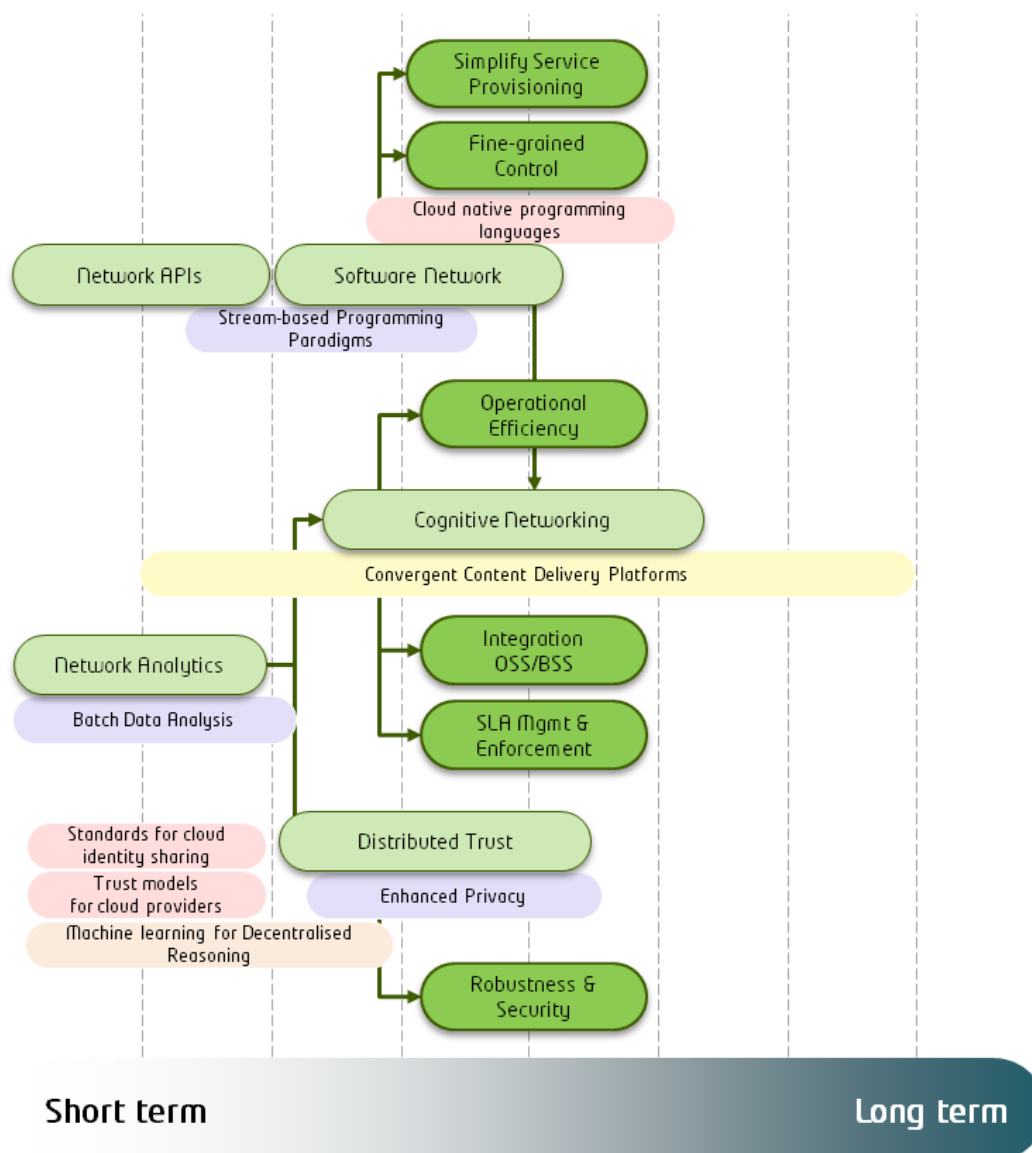


Figure 72: Network Challenge- Future Network management

Software Defined Infrastructures

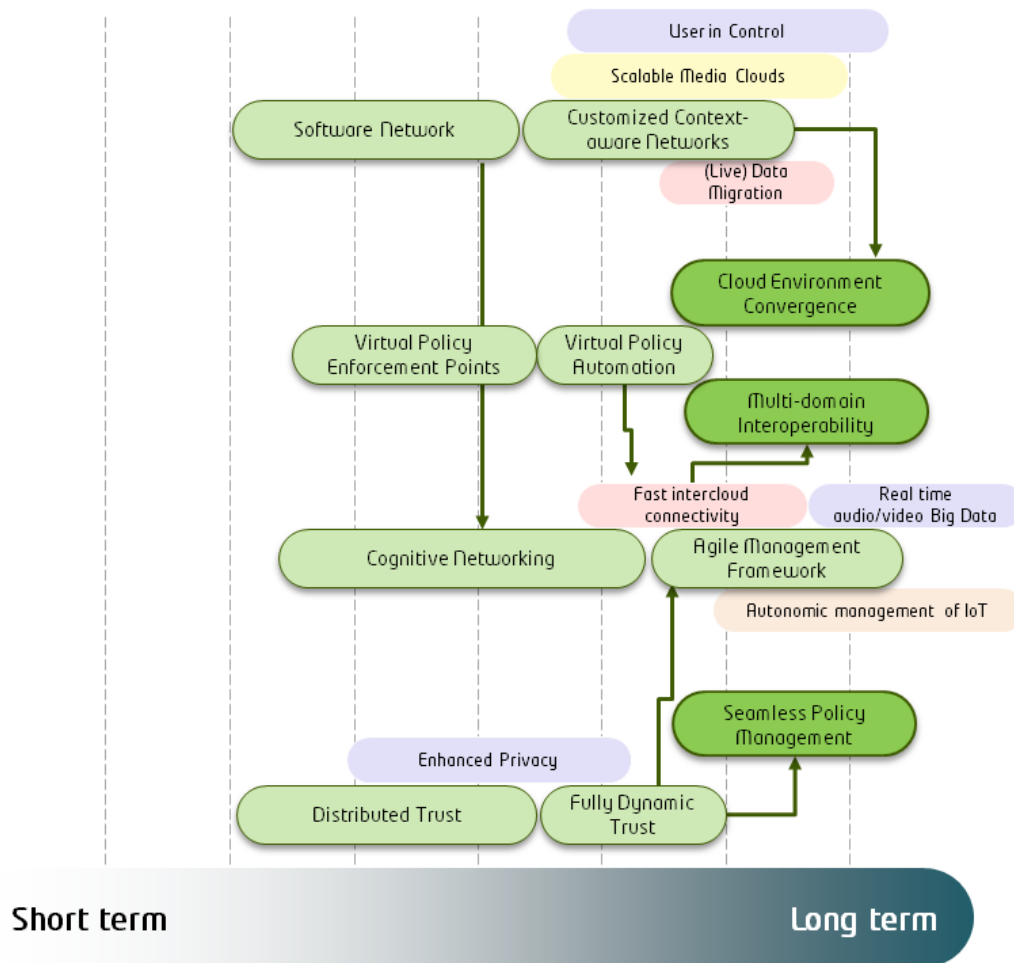


Figure 73: Network Challenge- Software Defined Infrastructures

5.5.4. FIWARE Technology Mapping

Taking into consideration the technical roadmap handled within the FIWARE community, network-based solutions are tackled in the technical chapter ‘Advanced Middleware and Interfaces to Network and Devices’. In the specification for that chapter⁴⁶, 4 main Generic Enablers shall cope with the expected features in forthcoming releases (starting from release 4):

- **Network Information and Control - OFNIC⁴⁷.** This GE belongs to the current efforts in the abstraction and virtualization of network resources and functionalities, providing distributed Software Defined Network (SDN) controller for enterprises’ OpenFlow-enabled network.
- **Network Flow for Clouds - Netfloc.** A framework that will provide a set of tools to manage flows, analyze and monitor traffic in a Cloud native network. The added intelligence and utility will ease the maintenance and deployment of networks.
- **Robotics.** This GE brings to FIWARE the ability to manage and interact with robots and to connect

⁴⁶ FIWARE Roadmap of Advanced middleware, Interface to Networks and Robotics.

http://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/Roadmap_of_Advanced_middleware_Interface_to_Networks_and_Robotics

⁴⁷ FIWARE Network Information and Control - OFNIC Generic Enabler instance.

<http://catalogue.fiware.org/enablers/network-information-and-control-ofnic>

Robots with smart devices, providing a platform acting as an interoperability layer between FIWARE and the robotics world. Its adoption will enable the developers to quickly build applications that use robots in the FIWARE context.

- **Advanced Middleware - Kiara.** Implementation of a modern communication middleware for efficient and secure applications, providing easy-to-use and extensible APIs.

5.5.5. Recommendations for FIWARE evolution

The weight of network functionalities and its management is not currently within the top priorities of the FIWARE community. Nonetheless, this does not necessarily imply the lack of potential and required boundaries. The following assessment highlights the major recommendations to the FIWARE ecosystem with regard to the evolution of network in the forthcoming years:

- **FIWARE Providers**
 - FIWARE instances operated by platform providers have a strong focus on the management of their respective Cloud platforms. However, the interconnection of multiple nodes and the orchestration of resources is an issue to improve. The current federation of nodes in FIWARE Lab requires strengthening its operation and integrating novel features to be released in the context of 5G. This will allow the creation of more robust and efficient distributed large-scale platforms.
 - Connecting and managing FIWARE instances opens up multiple possibilities. Apart from the initial achievements from FIWARE Ops⁴⁸, FIWARE can act as the technology enabler of future use cases. Current 5G market segments are a valuable reference to follow in this sense [30].
 - Today, network architectures are not designed to handle huge amount of sensors. The emergence of IoT within the Smart Cities context will require tailored paradigms with specific requirements.
- **FIWARE Developers**
 - As evaluated throughout this section, the softwarization of network functionalities is one of the major trends by 2020. In this process, the know-how already achieved in Cloud Computing will represent a strong asset, where FIWARE developers may bring their knowledge to foster such adoption.

5.5.6. Recommendations for future work programmes

As previously introduced, the European initiative 5G-PPP undertakes to perform huge advances throughout the next years in the research and innovation of future networks. In this context, the FIWARE community shall keep an important role supporting the integration and interconnection of 5G infrastructures with the corresponding application layers, providing the proper interfaces to reach such goals.

⁴⁸ FIWARE Ops. <http://www.fiware.org/fiware-operations/>

6 CONCLUSIONS

In this roadmap different directions were provided for the challenges which we believe will be most relevant ones for FIWARE in the future, spanning from short- to long-term.

We presented the business and technical views of the roadmap, facing the most relevant areas and challenges, and, of course, including the relationship with FIWARE. For both business and technology orientations, the most relevant areas or chapters identified were Networks, IoT, Media, Cloud and Big Data.

In the business part, the description of the European Future Internet Ecosystem Vision & Roadmap explored the business viability, and the possibilities to achieve sustainable Future Internet innovation initiatives in relation to the distinguishing features of the European economy context. The analysis was organized around the most relevant factors we identified: standardization, regulation critical mass, awareness, investment, sustainable business models, IPRs and technology transfer and R&I. They are considered the catalysts and impediments of the Future Internet ecosystem. They were specified for every defined chapter and we found that this classification was really helpful to understand each particular ecosystem.

The other relevant part of the business roadmap was the Impact of Future Internet in the Different Fields of Application, where we explored the value delivered to customers in the different economic sectors, taking into consideration information from past FI initiatives, ongoing projects and predictions of the future FI evolution. It showed a clear potential of the Future Internet for current business sectors such as agriculture, health, energy, etc. and for the future sectors that we classified as science & technology drivers: CleanTech, Bio, Neuro and Nano. The result of this exercise was linked to provide overall interrelation maps between current FI-PPP sectors, FI technology drivers and scientific areas.

On the technical side, we provided directions for the challenges and technologies present where Future Internet and FIWARE can create a higher impact. They are:

- **Media Internet:** where the progressive merger of traditional broadcast services and the Internet, convergence among the different content delivery networks and with ICT technologies have enabled a process of transformation of audio-visual content market. Here the challenges consisted of:
 - **Short-term:** The dynamics of user and social content, which includes the online influence and the understanding of social media management, analytics and its marketing, and presentation and interaction for novel content which includes challenges for immersive and mixed environments, multisensory experiences and novel ways of data visualization.
 - **Long-term:** The intelligent delivery of convergent media and the innovative content creation processes; they include flexible data delivery, personalized content delivery and scalability of content on one side, and online co-creation and distributed multimodal content search on the other.
- **Internet of Things:** IoT future evolution and success is underpinned by the progress in separate technology areas that deal with making the communication substrate more software oriented and therefore more flexibly controllable to address the diverse needs of M2M traffic. The challenges are:
 - The short-term challenges identified are, on one hand, the need to cope with billions of IoT devices, which encompasses the virtualization of sensing, the energy consumption management including the need to progress on the “hardware-related” energy harvesting, the interoperability of IoT data, the friendliness for the environment and scalable discovery and registration; and, on the other hand, the IoT management for robustness and reliability which is addressing the IoT in becoming more mature and established enabling contextually also support for critical services, and including IoT virtualization, orchestration of resources and how to counter security threats.
 - In the long-term, the main challenge identified is the intelligent reasoning over IoT data to address how to best leverage on IoT harvested data, notably to produce usable and useful knowledge for compelling IoT-based services and applications; this includes the need for avoiding data deluge, semantic modelling, distributed reasoning and data-to-knowledge

conversion and low-latency.

- **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. The challenges are:
 - In the short-term the challenges identified are data privacy and user control, real-time Big Data and Cloud-based solutions. The first challenge is related to the enhancement of privacy and the need for better anonymization, and the set of policies to offer better and more understandable privacy: trans-border regulation and governmental means for regulation enforcement. The second challenge is needed to provide a real-time Big Data which should be useful to many applications, and the sub-challenges to overcome the current limitations, especially for the creation of meaning from the Big Data analysis in real-time. The third challenge, which is also looking at the Cloud data part of the map, is needed for easier, cheaper, scalable solutions and the provision of better data transfer from different located infrastructures.
 - For the long-term, the main challenge is the expansion of the range of data sources, needed to diversify the types of data analysis and improve the results and deal with the increasingly complex analysis which is requiring more and more specialized computing.
- **Cloud Computing:** Cloud Computing technologies are facing a fast pace evolution through the different layers of its architecture, i.e. IaaS, PaaS, SaaS. The infrastructure layer is moving fast in the direction of Software Defined Infrastructure, where more and more of the overall computing (and underling) infrastructure is softwarized. The challenges are:
 - In the short-term, special purpose Clouds are the first challenge. They are related to customized Clouds as the highly distributed Clouds, micro Clouds, low energy Clouds and edge Clouds, which are specialized Clouds with different requirements as kinds of niche application Clouds. The second is the security, privacy and trust, something which is close to the Big Data needs for privacy, where data tracing, data location or inter-Cloud connectivity are needed for a better Cloud operation.
 - In the long-term, native Clouds and dynamic Cloud aggregation are the challenges identified. The first one comprises the programming frameworks and languages dedicated to Cloud environments and the infrastructure-aware applications, with understanding of the underlying infrastructure.
- **Networks:** Taking into consideration the 5G landscape spans multiple layers, it is important to delimit strategically only those aspects relevant to the Future Internet. The challenges to be considered focus on the system level perspective, ignoring a detailed analysis of the low level service and performance indicators. This means the reader shall be aware that there will be relevant research initiatives which will not be covered intentionally by this technical roadmap, such as the radio network architecture, the convergence beyond last mile and the improvement of capacities in terms of latency and bandwidth.
 - In the short-term, the main challenge is the virtualization of network functionalities and future network management. The first challenge is related to the provision of automation and service flexibility, the service elasticity, and the network “softwarization” and the second to the simplification of service provisioning, the enhancement and enforcement of SLA management, the fine grain control oriented especially to Clouds and cognitive networking.
 - For the long-term, the challenges include software defined infrastructures which can provide customized context-aware networking, agile management, fully dynamic trust and quasi-full automation.

Last but not least we detailed the relationship to the FIWARE Enablers and we believe that this roadmap will be useful for the FIWARE community and to anybody interested in the Future Internet as a holistic view.

Since we understand that not everything can be covered in the current version of the roadmap, the next version of the roadmap will be published in May 2016.

REFERENCES

- [1] Alcatel-Lucent, "Network Functions Virtualization - Challenges and Solutions", White Paper, 2013
- [2] Alexander, P. (2006). Creating a Technology Road Map. <http://www.entrepreneur.com/article/83000>
- [3] B.A.A. Nunes et al., "A Survey of Software-Defined Networking: Past, Present, and Future of Programmable Networks", Communications Surveys & Tutorials, IEEE, Volume 16, Issue 3, August 2014
- [4] D. Trossen et al., "5G: Challenges, Research Priorities, and Recommendations". European Technology Platform for Communications Networks and Services (NetWorld2020), Joint White Paper, September 2014. <http://networld2020.eu/wp-content/uploads/2015/01/Joint-Whitepaper-V12-clean-after-consultation.pdf>
- [5] E. Simperl et al., "Future Internet Roadmap", 2009
- [6] Engineering Secure Future Internet Services: A Research Manifesto and Agenda from the NESSoS Community, by NESSoS project.
- [7] Ericsson, "The Real-time Cloud. Combining Cloud, NFV and Service Provider SDN", White Paper, February 2014
- [8] ETSI NFV. <http://www.etsi.org/technologies-clusters/technologies/nfv>
- [9] F. M. Facca et al., "FI-LINKS technology and business models map", D1.1, 2015. http://fi-links.eu/wp-content/uploads/FI-LINKS%20D1.1_final.pdf
- [10] Future Media Internet Research Challenges and the Road Ahead, Future Media Internet-Task Force – Whitepaper from NextMedia, Apr 2010.
- [11] H. Schaffers et al., "Landscape and Roadmap of Future Internet and Smart Cities", 2009, FIREBALL
- [12] Info-communications Development Authority of Singapore (IDA), "Infocomm Technology Roadmap (ITR) 2012"; <http://www.ida.gov.sg/Infocomm-Landscape/Technology/Technology-Roadmap>
- [13] Infonetics Research, "SDN and NFV Strategies: Global Service Provider Survey", March 2014
- [14] L. Kart, Gartner, Big Data Industry Insights, Sept 2014.
- [15] L. Schubert et al. "A Roadmap for Advanced Cloud Technologies under H2020", 2012
- [16] Laube, T. and Abele, T. (2005). Technologie-Roadmap: Strategisches und taktisches Technologiemanagement. Ein Leitfaden. Fraunhofer-Institut Produktionstechnik und Automatisierung (IPA), Stuttgart, Germany.
- [17] M. Hirabaru et al., "New Generation Network Architecture AKARI Conceptual Design", 2009, NICT
- [18] M. Hogan et al. "NIST Cloud Computing Standards Roadmap", 2011.
- [19] N. Wainwright et al., "Future Internet Assembly Research Roadmap", 2011
- [20] O. Vermesan et al., "Internet of Things Strategic Research Roadmap", 2012
- [21] Ovum, 2014 Trends to Watch Big Data, 24 Oct 2013.
- [22] Phaal, R., Farrukh, C. and Probert, D. (2001). Technology Roadmapping: linking technology resources to business objectives. Centre for Technology Management, University of Cambridge.
- [23] Phaal, R., Farrukh, C. and Probert, D. (2001). T-Plan - the fast-start to technology roadmapping: planning your route to success, Institute for Manufacturing, University Of Cambridge.
- [24] Position Paper on Future Research Directions - Opportunities for an Innovative Europe, NEM Sept 2011.
- [25] S. Mattoon: "Creating a Roadmap to Cloud Computing", April 2013
- [26] S. Modafferi et al., "Future Internet roadmap and proposals for sustainability v3", 2013, INFINITY

- project. Available in www.fi-infinity.eu
- [27] S.C. Bang et al., “5G Vision, Requirements, and Enabling Technologies”, 5G Forum, March 2015
 - [28] T. Nagellen, D. Ferrer, C. Pena, “Future Internet Technologies Roadmap for Transport and Mobility”, 2012
 - [29] The 5G Infrastructure Public Private Partnership. <http://5g-ppp.eu/>
 - [30] 5G-PPP, “5G Vision. The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services”, <https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>
 - [31] Gartner Hype Cycle 2014. Available in <http://www.gartner.com/technology/research/hype-cycles/>

APPENDIX A: WHAT IS FIWARE?

FIWARE is a public-private initiative aiming at creating an open ecosystem based on Internet technologies to stimulate the innovation in the European industry. The European Commission - through the Framework Programme 7 - supports the initiative.

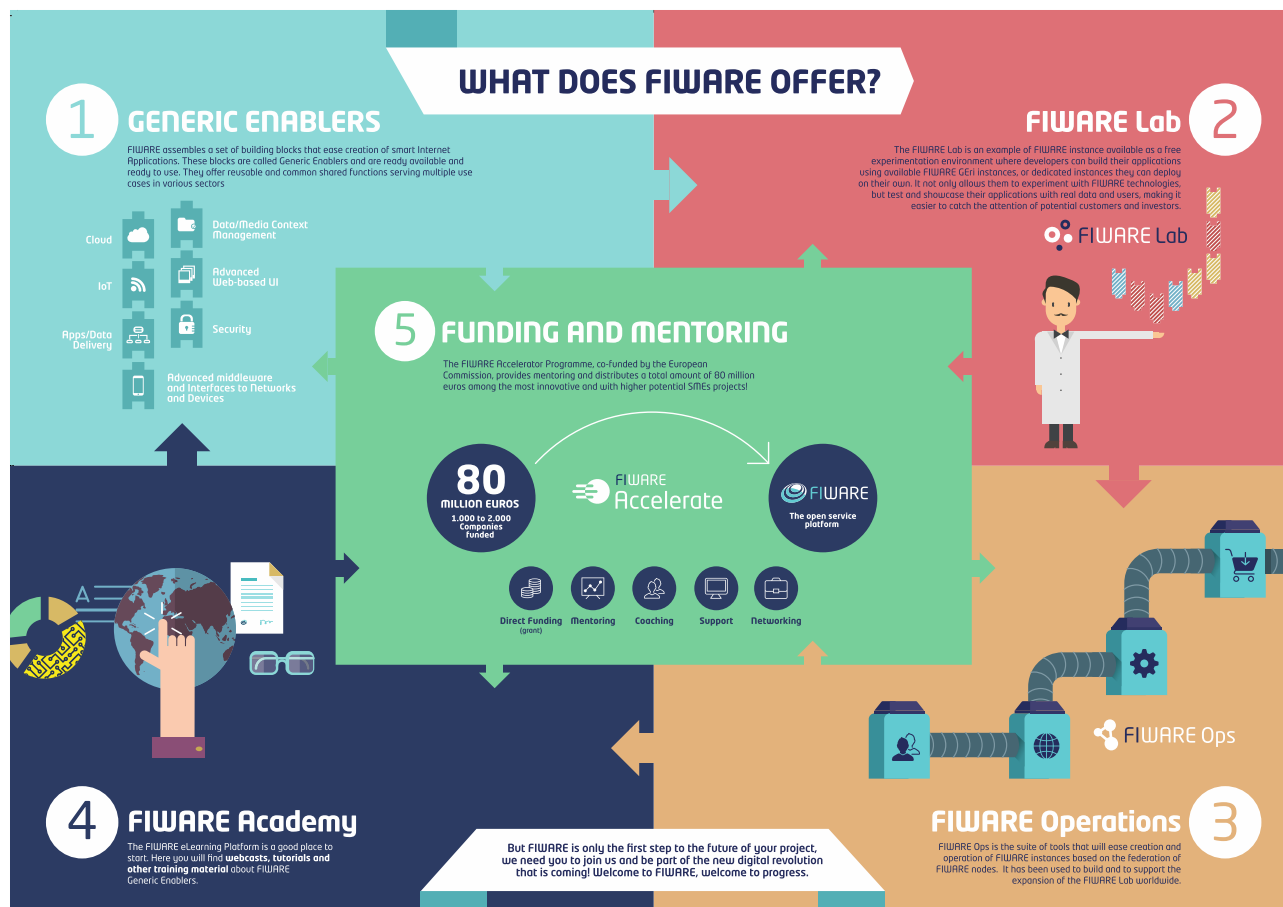


Figure 74: Infographic presenting the FIWARE Offer

FIWARE is a complete ecosystem for innovation that includes (cf. Figure 74):

- **FIWARE platform:** a set of APIs that ease the development of applications for Smart Cities and Smart Business. The platform is Open Source and is based on state-of-the-art solutions such as OpenStack and Apache Hadoop.
- **FIWARE Lab:** a sandbox environment where entrepreneurs and developers interested to experiment FIWARE technology can play with it for free. The Lab hosts as well a number of Open Data and sensors published by European cities and other organizations.
- **FIWARE Ops:** a set of tools that ease the deployment, setup and operation of FIWARE instances. FIWARE Ops is the tool used to build, operate and expand FIWARE Lab.
- **FIWARE Academy:** an e-learning platform offering insights on the usage of FIWARE platform.
- **FIWARE Acceleration Programme:** a programme that supports the development of new products based on FIWARE technology through funds without equity and consultancy services.

The above ingredients have been complemented recently by FIWARE Mundus, an initiative to promote FIWARE beyond the European context, linking it to different parts of the world such as Latin America, Africa and Asia.

The FIWARE platform includes 7 main areas (called chapters):

- The Cloud hosting that provides functionalities to provision and orchestrate services in an OpenStack-based Cloud.
- The data/context management that facilitate the management of data at large scale, from collection to publication and analysis based on Apache Hadoop and NGSI standards.
- The application and service delivery framework that allow co-creation, publication and consumption of Web-based services and applications.
- The interface to the networks and devices that facilitates interaction between application and network capabilities.
- The security that provides solutions to deliver trustworthy services based on OAuth2 and XACML technologies.
- The Internet of Things that enables the management of smart devices linking them to data and context management solutions.
- The advanced web interfaces that allows the development of 3D and augmented reality services.

On top of this basic technologies, a number of vertical platform have been developed in the context of Smart Media (<http://mediafi.org>), Transport and Logistics (<http://www.fispace.eu>), E-Health (<https://www.fi-star.eu>), Smart Energy (<http://www.finesce.eu>) and Smart Factories (<http://www.fitman-fi.eu>). The covered industrial sectors expanded with the start of the accelerator programme and the financing of SMEs and Startups in Europe (cf. *Figure 75*).



Figure 75: The industry sectors covered by the Accelerator Programme

For more information on FIWARE, we invite the interested readers to visit the FIWARE web site (<http://www.fiware.org>) and wiki (<http://wiki.fiware.org>).

APPENDIX B: FI-PPP USE CASE AND ACCELERATOR PROJECTS

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 presents, FI-PPP covers diverse areas of industries with support of FIWARE technologies that implement innovative Future Internet technologies.

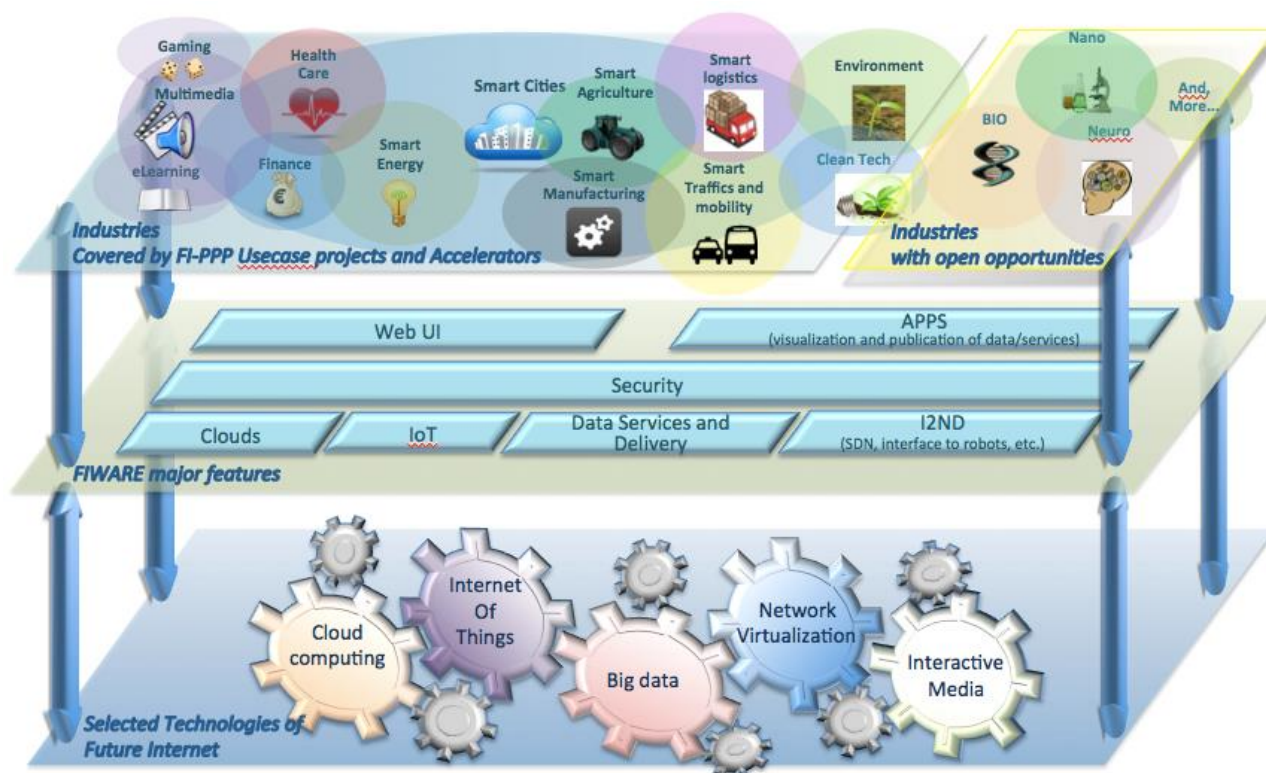








Figure 76: Multi-sectorial business opportunities in FI-PPP

As shown above, 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 initial phase and 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	Services/ Applications
 <p>Smart Cities</p> <p>Note: other sectors are connected to the Smart Cities scenarios. Here the focus is on services related to city infrastructure and citizens' living condition.</p>	Outsmart Safecity FI-C3 CEEDTech EuropeanPioneers IMPACT INCENSE FrontierCities SOUL-FI SpeedUP!	<ul style="list-style-type: none"> Smart City infrastructure <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> smart home indoor position
 <p>Smart Energy</p>	FINSENY FINESCE SOUL-FI INCENSE Finodex CEEDTech SpeedUP!	<ul style="list-style-type: none"> Smart utilities <ul style="list-style-type: none"> virtual power plants electric vehicle grid home energy management building energy management energy grid management
 <p>Smart Transport</p>	Instant mobility FrontierCities Soul-FI Finodex Finish	<ul style="list-style-type: none"> Smart mobility <ul style="list-style-type: none"> Increased Citizen Smart Mobility Awareness Sustainable mobility
 <p>Smart logistics</p>	Finest FIspace Finish	<ul style="list-style-type: none"> Business-to-Business (B2B) software platform Smart-agri-logistics with virtualization, connectivity, and logistics intelligence 3D printing technologies for logistics
 <p>Smart Manufacture</p>	FITMAN FABulous CEEDTech FInish	<ul style="list-style-type: none"> Smart factory <ul style="list-style-type: none"> safe & healthy workplace Cloud manufacturing mobile workforce Digital factory <ul style="list-style-type: none"> product lifecycle management training service As-designed vs. As-built Interoperability Virtual factory <ul style="list-style-type: none"> Collaboration valorization Networked Business Innovation Collaborative Production 3D printing technologies for designing and manufacturing
 <p>Smart Agriculture</p>	SmartAgriFood FIspace FRACTALS Finish SpeedUP!	<ul style="list-style-type: none"> Smart farming with sensors and traceability Smart-food awareness (transparency of data and knowledge representation)

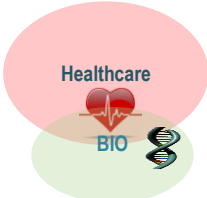

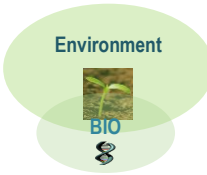

	FISTAR FICHe FI-C3 Finodex FI-ADOPT	<ul style="list-style-type: none"> • Interactive online healthcare • Medicament supply chain • Virtualization of operating theatre environments and real-time data integration • Healthy behaviour and wellbeing shaping
	FI-CONTENT FI-CONTENT2 EuropeanPioneers FI-C3 IMPACT CreatiFI FABulous	<ul style="list-style-type: none"> • Media and Contents <ul style="list-style-type: none"> - 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
	ENVIROFI	<ul style="list-style-type: none"> • Observation of environment <ul style="list-style-type: none"> - marine asset - biodiversity - personalized info. on air pollutants
	FI-CONTENT SOUL-FI IMPACT FI-ADOPT EuropeanPioneers	<ul style="list-style-type: none"> • Corporate and citizen's learning/training • Mobility based service models in education

Table 6: FI-PPP Use Cases and Accelerator projects and their service areas

APPENDIX C: QUESTIONNAIRE FOR 3RD WORKSHOP EXPERTS

1. Is the roadmap aligned with the FIWARE and FI-PPP?
Provide a mark from 1 to 10 to assess the alignment with FIWARE and the FI-PPP and shortly discuss if – according to your knowledge of FIWARE and the FI-PPP programme – the roadmap developed in FI-LINKs is aligned with the FIWARE and FI-PPP technology and business goals.
2. Is the FI-LINKS roadmap relevant in general for the Future Internet and for your for your expertise field?
Provide a mark from 1 to 10 to assess the relevance of the roadmap and shortly discuss your grading of the roadmap alignment within respect your expertise field.
3. Do you agree on the focus of the FI-LINKS roadmap in relation to the challenges and technology solutions for your expertise field?
Provide a mark from 1 to 10 to evaluate the focus of the roadmap in relation to your expertise field and shortly discuss your grading of the roadmap focus.
4. Do you agree on the timeline of the FI-LINKS roadmap in relation to the challenges and technology solutions for your expertise field?
Provide a mark from 1 to 10 to evaluate the timeline of the roadmap in relation to your expertise field and shortly discuss your grading of the roadmap timeline.
5. Do you think the FI-LINKS roadmap coverage is broader enough, considering the focus of FIWARE and FI-PPP?
Provide a mark from 1 to 10 to assess the coverage level of FI-LINKS roadmap and shortly discuss your grading of the roadmap coverage.
6. For the second year of roadmapping activities, do you think FI-LINKS should introduce any additional technology chapter considering the focus of FIWARE and FI-PPP?
In case you think so, please describe shortly the chapter you would include and the rational for including an additional technology chapter.

APPENDIX D: SPECIFIC ENABLERS FOR MEDIA INTERNET

The following table summarizes a description of all available specific enablers and their mapping to the target application domains.

Social	Smart City	Pervasive	Name of Specific Enabler	Description
X		X	3D Map Tiles	The 3D-Map Tiles SE supplies in an OpenStreetMap-like manner map tiles of the ground. These tiles are a 3D representation of the scene ground in contrast to usual image tiles of OSM. Moreover, the 3D-Map Tiles SE supports different backend data providers to offer different kinds of tiles, such as projected OSM-tiles and laser-scanned elevation data with textures. Therefore, the 3D-Map Tiles SE incorporates the GIS-DP GE from FIWARE.
	X		App Generator	The App Generator SE is a set of services able to instantly deploy a complete application ecosystem on-the-fly: - custom mobile applications with custom content (app name, icons, data...) - custom webapps, backends... This tool changes the paradigm of your deployment issues, or “how to do n-times what I did once”.
X			Audio Mining	Audio Mining analyses a given audio/video file in German spoken language (e.g. content from a TV news show) and returns textual information for indexing (e.g. for search engines). Speech and speaker segmentation as well as speech recognition are performed in order to turn speech into text. The SE delivers segments, the speakers identified, characteristic keywords and various metadata in XML. Finally, the SE builds an index for Multimedia Search.
		X	Augmented Reality – Fast Feature Tracking	All specific enablers of the Augmented Reality (AR) group provide various tracking methods to enable AR applications. The Fast Feature Tracking SE learns targets by colour and then matches the centre of a colour area (for example a coloured football or road sign) in the camera image to retrieve the relative camera pose information. This extends an application with the capabilities to apply the matching transformation to 3D-scene content and render them onto respective targets.
		X	Augmented Reality – Marker Tracking	All SEs of the Augmented Reality group provide various tracking methods to enable augmented reality (AR) applications. The Marker Tracking SE utilizes AR markers to retrieve camera pose information through Xflow. This extends XML3D with the capabilities to apply the matching transformation to 3D scene content and render them onto respective markers in a web-based environment. The Marker Tracking SE follows the declarative approach of XML3D and is real-time capable.

X	X		Content Enrichment	Content Enrichment provides functions to create, distribute and play interactive video content across platforms and devices by making objects in the video clickable for their viewers. It also provides interfaces to incorporate Web 2.0 capabilities and community functionalities. Thus, the enabler acts as a common building block in future video and multimedia infrastructures. It allows seamless, platform-independent and convenient enrichment of any type of video content using any type of device for a plurality of application cases.
X			Content Optimization	Content Optimization processes incoming textual content (e.g. from the Audio Mining SE) and extracts characteristic keywords. Afterwards, semantic enrichment based on natural language processing (NLP) will be performed to connect the transcripts and keywords with additional, contextual information. Therefore, the SE integrates and harmonizes additional content from disperse sources. The software is intended for SMEs that want to build second screen applications (e.g. for TV documentaries).
	X	X	Content Sharing	The main functionality that the Content Sharing SE provides are: (i) Transparent content synchronization with regards to underlying network connectivity (infrastructure, ad hoc) and (ii) Synchronization of feeds containing linked content (comments on images, images related to one another...). The Content Sharing SE is a combination of services plugged together into an Android Library to provide above functionalities.
	X		Context Aware Recommendation	This Specific Enabler consists of two modules: 1. ContextSENSE (located on mobile devices and WiFi APs. Its role is to collect contextual and sensory data from mobile devices and wearables. 2. Custom data analysis (DA) and machine learning (ML) framework which is implemented on the VizLore contextual DA platform. The DA/ML framework analyses contextual data provided by the ContextSENSE module in order to provide user activity recognition. The recognized user activity is further used for enabling activity aware POI recommendation.
	X		Fusion Engine	The Fusion Engine (FE) is able to fusion Points of Interest (POIs) from different data sources. The main objective is to build Open City Databases (OCDs) with different POIs obtained from different data sources (OSM, DBPedia, etc). Matching POIs will not be replicated. Categories of POIs can be set up in order to fusion and retrieve only interesting POIs. The FE Specific Enabler is implemented as a backend service, there is no normal interaction with a normal user, but an administrator.
		X	Game Synchronization	The Game Synchronization SE provides functionality to synchronize the game world using the RTS Lockstep mechanism. Provides an efficient way to synchronize many objects by sending their actions instead of streaming their positions.

		X	Geospatial – POI Interface	The PoI Interface SE implements an interface to the POI Data Provider GE or POI Storage SE APIs for Unity3d. It provides access to all the POI Data Provider GE methods and wraps the POI data structures into C# objects.
		X	Geospatial – POI Matchmaking	The POI Matchmaking SE is an extension of the Spatial Matchmaking SE, originally in the 09/13 release. This enabler allows any number of players to group together based on their spatial proximity to a point of interest.
X			HbbTV Application Toolkit	Developing HbbTV applications can be quite demanding due to the lack of proper tools for content creators and developers. The HbbTV Application Toolkit SE provides a powerful tool set for both Broadcasters, program editors as well as TV app developers to create HbbTV compliant TV apps in a fast and easy way.
		X	Leaderboard	The main functionality that the Leaderboard SE provides, is the storage of high scores and the retrieval of a sorted list of high scores. In addition, it can connect to the Social Network Enabler and automatically post a message when a new player broke the highscore.
		X	Networked Virtual Character	The animation of virtual characters is a usual task in game development. Regardless of the way how to animate the virtual character, it is desirable to synchronize the sequence of motions across multiple clients. Therefore, the Networked Virtual Character (NVC) SE is provided as a plugin to the Synchronization GE and thereby extends its synchronization capabilities to virtual characters while supporting a variety of cross-platform clients.
	X		Open City Database	The Open City Database (OCDB) SE is an open source database management system for any Smart City related data (e.g. points of interest, open city data and related media from various sources). Besides its database functionality the OCDB provides a comprehensive API to create, modify and request data sets for their integration with Smart City guide apps or any other application or service that may take advantage of open city data.
	X	X	POI Storage	<p>The ODS SE has been specifically designed for non-technical business users to share, publish and reuse structured data. To both create interactive data visualizations and feed external applications with data through a rich set of REST APIs.</p> <p>The POI Storage SE provides a flexible, lightweight web service to store POI-related data. Furthermore, it is a GE-compliant implementation of the POI-DP GE from FIWARE and amends the use of this GE with additional features, such as storing and retrieving of custom data components and easy import of sample data (e.g. geonames.org, other POI-DP instances, etc.).</p>

	X		POIPProxy	The POIPProxy SE is a service to retrieve Points of Interest from almost any public remote service that exposes geolocated data through a REST API or static files. Some examples of the kind of services that POIPProxy can interact with: Open data portals (static files, OData APIs, REST APIs...), social networks (Flickr, Panoramio, Instagram, 500px, Twitter, Facebook, Foursquare...), event services (LastFM, Nvivo, SongKick, Meetup, Eventbrite, ...), and other services, including real time services (Wikilocation, Geonames, OpenWeatherMap, CityBikes,
		X	Reality Mixer – Camera Artifact Rendering	All visually-oriented SEs of the Reality Mixer group measure camera properties and adapt the virtual objects to fit to the camera image background visually. This client-side code modifies the virtual rendered content to match the camera image more closely in an AR context to provide more realistic appearance.
		X	Reality Mixer – Reflection Mapping	All visually-oriented SEs of the Reality Mixer group measure camera properties and adapt the virtual objects to fit to the camera image background visually. The Reflection Mapping SE utilizes a light probe to extract a sphere map from the camera image, which contains the environmental lighting conditions. This sphere map will be used to apply an appropriate lighting model to rendered virtual objects. Thus, the additional virtual objects are incorporated into the resulting image in a very seamless fashion leading to a more realistic experience of mixed reality applications.
	X		Recommendation as a Service	The Recommendations as a Service (RaaS) SE provides the ability to create a professional recommendation engine with just a few mouse clicks and no programming skills. This SE can maintain your item and user data and will host your recommendation engine as a service in the Cloud or on your own server infrastructure. Thereby, decision makers can choose whether to use ratings, likes, check-ins or implicit feedback, such as clicks or consumption time. In addition, they can adjust the way the personalization works by selecting from a wide range of well-explained algorithms.
X			Second Screen Framework	The Second Screen Framework (SSF) provides web applications that are running on a TV with all the crucial functionalities to establish a persistent bi-directional communication path to a web application running in the browser of any second-screen device. This includes the possibility to launch applications from one a TV to a second screen.
	X	X	Social Network	The Social Network SE Core (or SNE) is a REST Service with a Web interface that gives end users the opportunity to communicate with each other. Unlike monolithic infrastructures (like Facebook) the SNE provides not only full autonomy of the user data but also gives the opportunity to run it as a federated service.

X			TV Application Layer	TAL was developed internally within the BBC as a way of vastly simplifying TV application development whilst increasing the reach of BBC TV applications such as iPlayer. Today all of the BBC's HTML-based TV applications (such as BBC News and BBC Sport) are built using TAL.
		X	Visual Agent Design	This SE provides the bricks to visually design the behaviour of agents in Unity 3D. These agents will typically be physical robots. This SE also allows inspecting their behaviour in real time through augmented reality.

Table 7: Specific Enablers for Media Internet