Grant Agreement No.: 632912
Coordination and support action
Call Identifier: FP7-2013-ICT-FI 1.9

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

D1.3: FI-LINKS Roadmap v2.0 and specific focus releases

Revision: v.1.0

Work package	WP1
Due date	31/05/2013
Submission date	07/07/2013
Deliverable lead	CREATE-NET, UPM
Version	1.0
Authors	Federico Alvarez (UPM), Fabio Antonelli (Create-Net), Monique Calisti (Martel Consulting), Claudia Cosoli (Engineering), Stefano De Panfilis (Engineering), Federico M. Facca (Martel), Estanislao Fernandez (Telefonica), Raffaele Giaffreda (Create-Net), Jose González (Universidad Politécnica de Madrid), TimoLahnalampi (Interinnov), Martin Potts (Martel Consulting), Elio Salvadori (Create-Net)
Reviewers	Federico M. Facca (Martel), Timo Lahnalampi (Interinnov)

Abstract	This deliverable documents the final version of the FI-LINKS Roadmap and its declination for the different target audiences selected in the project.
Keywords	FIWARE, Future Internet, Cloud, Network, Big Data, Internet of Things, Media Internet

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	31.05. 2016	First complete of deliverable draft	R. Giaffreda (CREATE-NET) based on previous contributions and feedback from experts workshop
V0.2	30.06.2016	Input from internal revision	Federico M. Facca (Martel), Timo Lahnalampi (Interinnov)
V1.0	07.07.2016	Final version	Federico Alvarez (UPM), Jose Gonzalez (UPM), Federico Facca (MARTEL)

Disclaimer

The information, documentation and figures available in this deliverable, is written by the FI-Links project consortium under EC grant agreement FP7-ICT-632912 and does not necessarily reflect the views of the European Commission. The European Commission is not liable for any use that may be made of the information contained herein.

Project co-funded by the European Commission in the 7th Framework Programme (2007-2013)		
Nature of the deliverable:	R	
Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to bodies determined by the FI-LINKS project	
CO	Confidential to FI-LINKS project and Commission Services	

EXECUTIVE SUMMARY

The Future Internet Public Private Partnership (FI-PPP) is an initiative launched in 2011 that aims at promoting the establishment of a European-based Internet ecosystem for the growth of new and innovative businesses. The FI-PPP changed the landscape of European Research projects introducing the notion of "Programme", i.e. a group of project collaborating toward the same goal, and the first set of projects adopting widely open innovation and start-up acceleration mechanisms. The major outcome of the FI-PPP programme that will end in 2016 is the FIWARE ecosystem: an Open source and Internet-based platform, accompanied by an Open experimentation environment, and supported by a set of initiatives promoting the international adoption of the platform and the adoption by start-ups through an equity-free acceleration programme.

After five years, FIWARE is moving the first steps out of the public funding, thanks to the establishment of the FIWARE Foundation, grouping the major commercial providers of FIWARE offerings (e.g. Atos, Engineering, Orange, and Telefonica). While this is a major step in the future of FIWARE and EU Internet-based ecosystems, the road ahead is still long and includes several challenges, either technical or business related, for increasing the success of FIWARE and keeping it at the edge of Internet Open Innovation.

This deliverable summarizes the road mapping activities run within FI-LINKS to scout important future directions for FIWARE, in relation to technical and business challenges. The contents of the deliverable are the results of an interactive process that involved different actors part of the FIWARE ecosystem: technology experts, business experts, FIWARE technical leaders, FIWARE adopters and so on.

As result of the road mapping process, the following pre-requisites and priorities have been identified for the future of FIWARE as Internet platform ecosystem:

- **Availability of broadband coverage in Europe**. No internet-based business will be ever possible in areas where internet connectivity is still behind EU-average and 2020 targets.
- **Realisation of the legal conditions for a European-based internet ecosystem**. The EU digital market is still very fragmented in term of regulations, and this hindering the ability to scale of EU internet platforms.
- **Reach and retention of the critical mass.** More than 1000 start-ups and SMEs **adopted** FIWARE, also thanks to the availability of equity-free funding. In the next few months, the momentum will be critical. Either the community will survive and increase his size thanks to the improvements the platform and the ecosystem will have, or the whole ecosystem will fall down.
- **Convergence with other EU-wide initiatives**. A number of new programmes, following the success of the FI-PPPP programme, are starting in the last 12 months, including a programme on Big Data value and one 5G. Outcomes of FIWARE should be largely reused in those programmes, both in term of technology, ecosystems, and best practises.
- **Inclusion of cutting edge technologies in the platform**. FIWARE needs to maintain its novelty as way to distinguish from other platforms and compete with them. To do so, it needs to always scout for the most promising technologies and include them as part of the platform: e.g. Blockchains could be a great solution to provide novel means for trustful management of distributed data in the Cloud.

Within the deliverable and its appendixes, the reader can find the above high-level corner stones as part of the FIWARE future roadmap, and other more detailed to specific FIWARE technologies and the components of its business ecosystem.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

API	Application Program Interface
B2B	Business-to-Business
B2C	Business-to-Consumer
FI	Future Internet
GE	Generic Enabler
IaaS	Infrastructure-as-a-Service
IoT	Internet of Things
M2M	Machine-to-Machine
PaaS	Platform-as-a-Service
PPP	Public Private Partnership
QoE	Quality of Experience
SaaS	Software-as-a-Service
SME	Small and Medium-sized Enterprise

1 INTRODUCTION

Looking into the future of technology and its potential uptake is a fundamental step to innovate the industry and everyone's life. The road to the vision about the evolution of one or several technologies is, however, a challenging path that requires significant efforts going beyond a single person and a single vision, as it requires an understanding of the world as it currently is and as it could become.

FIWARE initiative from the FI-PPP Programme, supported by the European Commission and the most relevant industries in Europe, is expected to provide an ecosystem to stimulate Internet-based innovation in the different business sectors. Similar initiatives are currently active in other countries such as: US IGNITE[1] in US; New-Generation Network[2] (NWGN) in Japan, etc.

Because of these various initiatives, the *"Future Internet"* expression may mean different things to different researchers and innovators around the world and providing a unifying definition is as challenging as forecasting the future. Within the context of this document, we assume 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 deliverable we provide a roadmap on the forecasted evolution of the Future Internet considering FIWARE as the platform to support that future. The content presented is based on i) the challenges identified in previous project outputs (deliverables and white papers) and ii) their updates following the outcome of the feedbacks received on the white papers [2] from the FIWARE community. The set of open challenges, solutions and temporal evolution was classified into 5 areas, mapped to FIWARE technology Chapters: Media Internet, Big Data, Internet of Things, Cloud Computing and Communication Networks.

This document is the final version of the FI-LINKS roadmap, starting from the business and technological challenges identified in the previous project outcomes, provides:

- An overview of the roadmap for the evolution of the FIWARE technology. The overview takes into consideration current technologies and highlights dependencies and relations across key technology developments in the mentioned technology areas. The overview also highlights dependencies on other fundamental innovation factors, such as availability of high speed connectivity.
- A short introduction of the FIWARE business vision and roadmap for the creation of a European Future Internet Ecosystem. This introduction is complemented with a discussion of the FIWARE value chain and fundamental levers for the realization of the FIWARE vision. Taking on from that discussion, this document presents current market trends in the adoption of FIWARE technologies and potential future adoption markets.
- A summary that includes a number of suggestions for the priorities to be covered within the evolution of FIWARE and, beyond that, in Future Internet-related H2020 initiatives.

A set of more specific roadmaps covering each of the technology areas identified above are summarised in the document and with an extended version in the annexes of this document (and in the FIWARE Mundus website [1]). All those technology specific roadmaps extend the general concepts introduced in this deliverable and provide:

- A discussion on the value chain and levers for the specific technology area;
- An overview of current developments in the specific technology area in the context of FIWARE;

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

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

- A roadmap for the evolution of FIWARE technologies in the given area, including priorities to be covered in the short term within FIWARE;
- A short summary including suggestions for priorities related to the specific technology area to be covered in Future Internet-related H2020 initiatives.

In addition, it is including the feedback we got in different workshops with experts, some of them with technical experts in each of the areas presented, and business experts. Opinion from the FIWARE architects which wanted to contribute is also included in the technical section.

1.1 Background: why yet another roadmap?

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

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

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

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

Secondly, the FIWARE initiative is now finishing its third phase, which is a turning point in the path from development to consolidation and uptake of research results into market deployment (see results from FI-IMPACT assessment in http://www.fi-impact.eu). In this perspective, the FI-LINKS roadmap aims at providing precious insights into how *further evolution of results achieved so far and sustainable growth for the EU industries having invested - and still investing - in the FIWARE approach can be pushed forward effectively*.

1.2 The ingredients of the roadmap

The FI-LINKS roadmap activity follows a lightweight iterative methodology inspired by the well-established work by Phaal et al [3]. The Phaal et al methodology 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 rather than being product oriented; and ii) the methodology is flexible enough to accommodate the specific needs of FIWARE, 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.

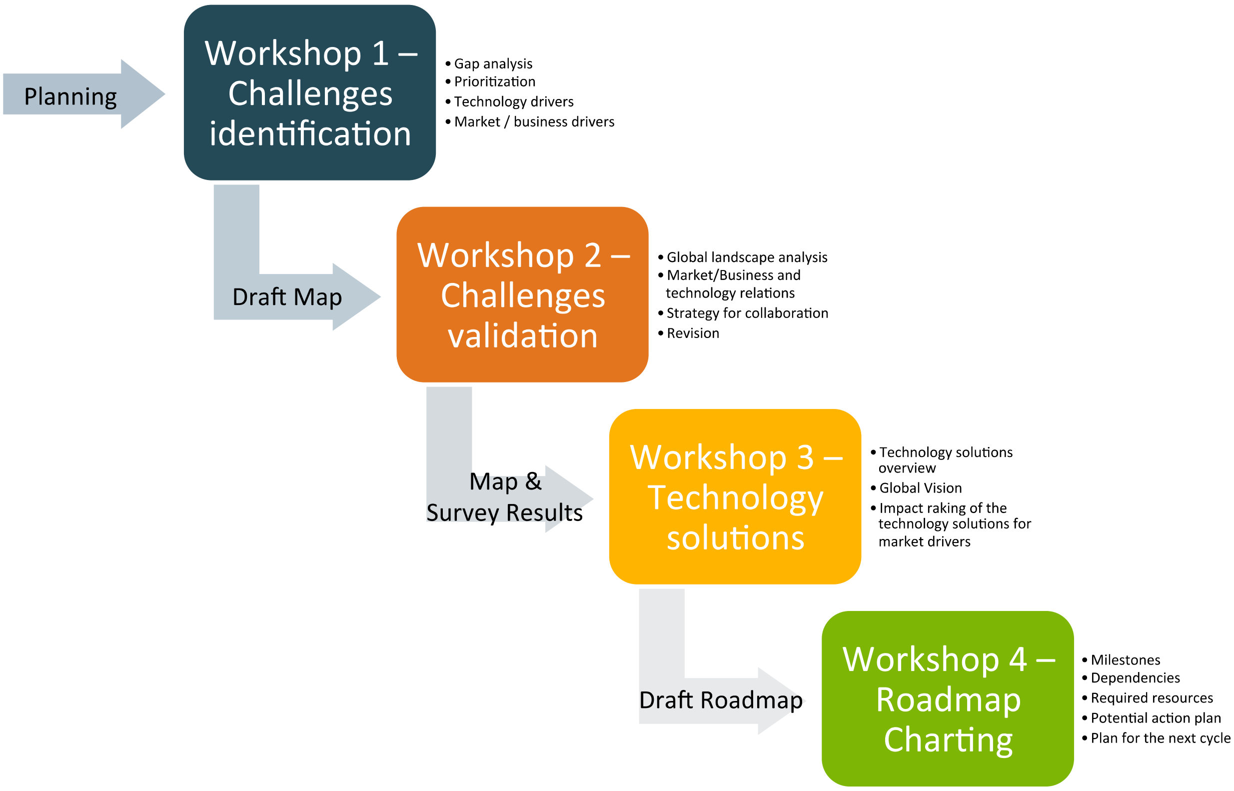

Figure 1: FI-LINKS Customized T-Plan approach

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 analysed 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 5).

Internal Expert Name	Expertise Field
Federico Alvarez	Networks and Internet Media
Fabio Antonelli	Internet Media
Federico M. Facca, Silvio Cretti	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 2015[3], 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 comments[4]. The comments were mainly regarding the alignment with the FI-PPP in terms of the 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 focused on the validation and the discussion of the draft roadmap with subject

[3] FIRE Concertation Meeting: http://www.ict-fire.eu/events/past-events/fire-concertation-meeting.html

[4] http://fi-impact.net

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[5]	Network	Telefonica

Table 3: List of subject matter experts invited for 4th Roadmapping Workshop.

During the second year of the FI-LINKS project, the different roadmaps have been open for public feedbacks, and validated by the FIWARE Chapter Architects and, finally, an additional workshop with only business experts was held on 19th April 2016.

Expert Name	Expertise Field	Affiliation
Richard Stevens	Market and business analysis	IDC
Angelo Giuliana	Market and business analysis	EIT Digital
Susanne Kuherer	Market and business analysis	EIT Digital

Table 4: List of subject matter experts invited for 5th Roadmapping Workshop.

1.3 Results of the fifth workshop and evolution of the roadmap

The result of the fifth workshop was a series of recommendations and actions towards the improvement of the business related aspects of the roadmap.

The following bullets highlights the most relevant suggestions categorised by topic:

- **Standardization:** the document is essentially an "as-is" analysis, while it should be a “forward looking” analysis. For example, the hype chart has to be updated with 2015 data and further on. Therefore, the idea is to better specify vertical market sectors and to identify the existing standards for these. What comes out from the discussion, is that FIWARE has done

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

much to little w.r.t. standards. Also, the work done by FIWARE so far has not been properly disseminated, and there is no such thing as roadmap for standards yet. What needs to be done is to make standards to become an active part of the Workprogramme for all the organisations involved in FIWARE.

- **Regulation:** Regulation is technology-dependent and in some cases - like Big Data-Privacy & Security of information, health and safety - it comes down to people. Therefore, the approach to regulation roadmap has to be bottom-up, instead of top-down. In addition, regulation is dependent on each specific country, and this impacts, for example, on the distribution and localisation of data (in the case of data hosting and cloud computing). For example, it can be the case that data has to be maintained in the specific country generating the data, while computation capacity could instead be moved outside, however, data shall need to remain within the specific country. For example, the Blockchain technology allows data to be spread all over the countries but no one seems to care for the impact of the regulatory aspect of having such data "all over". It seems that, in many cases, technology is moving too fast with respect to real regulation efforts. In other words, the document provides an obsolete view on these issues, and regulation tends to lack behind the actual deployment of FIWARE technologies, in the end. In addition, regulation efforts at EU level should not provide overregulation, as it now seems to be, but should provide a coherent regulatory framework.
- **Critical Mass:** The document does not clarify the pressing need for FIWARE to have a business vision for the technology proposed. The first question a CIO asks before adopting any new technology will always be: "who is using it". If the answer is no-one, FIWARE will end up expiring. From this consideration, it derives that FIWARE needs to be not only a innovation enabler, but especially a business ecosystem enabler. Critical mass is therefore crucial in order to guarantee that FIWARE is moving and impacting also at business level, and not only at a technological level.
- **Awareness:** It is not clear in the document how FIWARE is planning to raise awareness, reach a critical mass and build a relevant ecosystem, including a proper dissemination and communication plan.
- **Investment:** Investors invest in ideas and not in technologies, and investors are interested in the verticals: FIWARE should be no exception to this market rule, and this process should be clarified in the document. In the document is also missing the analysis of where the current investment is going, as well as the prediction of where the investment trends will go to (in particular, what needs to be specified is to choose vertical areas where financing is appropriate).
- **Sustainability:** The effort has been made as 985 SMEs / startups have already adopted FIWARE (sustainability). In order to continue on this roadmap, the FIWARE Foundation has been established (Note: FIWARE Foundation needs to be described in the document). FIWARE Foundation will address key issues such as alliances, targeted market, sales model, and so on. It can be noted and reported in the document that the sustainability of FIWARE platform is, in fact, ensured by the sustainability of the business adopters themselves. Therefore, FIWARE sustainability shall rely on the soundness of each adopters' business model**.**
- **IPRs & Tech Transfer:** In the foundation, the issue is being addressed. However, the document should focus more on IPR from the Generic Enablers and Service Enablers point of view. The document should describe more in detail the services provides by the Foundation, in terms of IPRs.
- **Research & Innovation:** How fast is FIWARE able to adapt or to include things that are coming out from other developers and organisations? In the document we should be able to answer to this question. There should be investment for FIWARE to adopt new and emerging trends and technologies for the Future Internet. R&I should leverage on single organisations' investments, for example when responding to public authority's tenders. In other words,

public sector shall issue investments requiring organisations' innovative solutions, which will be provided by research & innovation at corporate level, always in an open innovation view with respect to FIWARE technology.

- **Short and Long term markets impacted by FI:** It has been reported in the discussion that, just because there has been availability FIWARE budget, one organisation achieved funding for 9 proposals in phase 3. In some cases, people set up different companies with same email, and maybe same business idea. In addition to clarify this issue, the document should clarify the fact that, currently, the process is still in the market validation phase, instead of in a market adoption phase. This aspect is also linked to awareness and critical mass adoption, in fact, without accounting for these two key performance indicators, FIWARE cannot claim to be having real market success. Therefore, the document should introduce KPI with respect to the FIWARE adoption by the market. For example, revenues, jobs created, or perhaps simply the survival rate of the sub-grantees as compared to the survival rate in other programmes and in "the wild". For example, there is a higher mortality rate of start-ups than in the wild, perhaps because many proposers are simply there for the budget, and not because they are start-ups that would have invested anyway. Also, there is surely a number of public funding / project spammers as well.

The FI-LINKS team tried to address as much as possible the comments received by business experts. Nevertheless, it is worth noticing that several of the comments pertains more the status quo of FIWARE initiative rather than roadmap by FI-LINKS as such.

2 FIWARE

FIWARE was launched in 2011 as a public-private initiative aiming at creating an open ecosystem based on Internet technologies to stimulate innovation in the European industry. The European Commission - through the Framework Programme 7 – was the major supporter of the initiative. Since then, the different efforts around has led to form what is today: an open, sustainable and global community (cf. **¡Error! No se encuentra el origen de la referencia.**), where multiple stakeholders from the academia, industry, entrepreneurs and public authorities interact with each other.

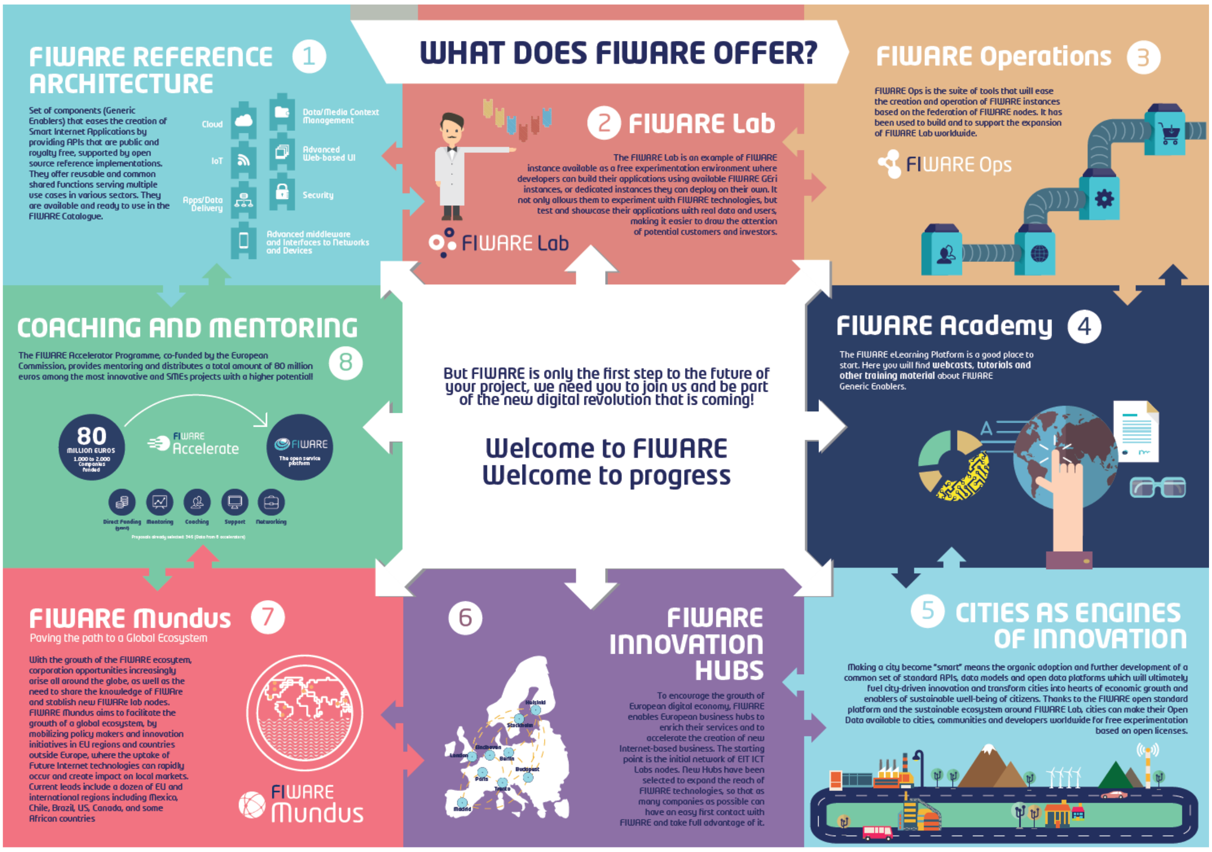

Figure 2: Infographic presenting the FIWARE Offer

The main pillars of such ecosystem are:

- **FIWARE platform** provides a rather **simple yet powerful set of APIs** (Application Programming Interfaces) that ease the development of Smart Applications in multiple vertical sectors. The specifications of these APIs are **public and royalty-free**. Besides, an **open source reference implementation of each of the FIWARE components is publicly available** so that multiple FIWARE providers can emerge faster in the market with a low-cost proposition.

- **FIWARE Lab** is a sandbox environment where entrepreneurs and developers interested to experiment FIWARE technology can play with it for free[6]. The Lab also hosts sensors and the associated Open Data published by European cities and other organizations.
- **FIWARE Acceleration Programme** aims at promoting the **take up of FIWARE technologies** among solution integrators and application developers, **with special focus on SMEs and start-ups**. Linked to this program, the EU launched an ambitious campaign in September 2014 mobilizing 80M€ to support SMEs and entrepreneurs who will develop innovative applications based on FIWARE. Similar programmes may be defined in other regions. Success stories can be found at www.fiware.org/success_stories
- **FIWARE Mundus,** initiative designed to bring coverage to this effort **engaging local ICT players and domain stakeholders, and eventually liaising with local governments** in different parts of the world, including North America, Latin America, Africa and Asia.
- **FIWARE Ops** is 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 the FIWARE Lab.
- **FIWARE Academy** is the e-learning platform offering insights on the usage of the FIWARE platform.

The **FIWARE Foundation** is the legal independent body that from 2016 will provide shared resources to help achieve the FIWARE Mission:

"to build an open sustainable ecosystem around public,
royalty-free and implementation-driven software platform standards
that will ease the development of Smart Applications in multiple sectors"

The Foundation will empower, promote, augment, protect and validate the FIWARE technologies and support the Community around, including users, developers and the entire ecosystem.

2.1 FIWARE Technology

The cornerstone of the FIWARE technology is the Generic Enablers (GEs), a rich library of public, royalty-free and open source components that allow developers to put into effect functionalities such as the connection to the Internet of Things or Big Data analysis, making programming much easier. These components offer a number of general-purpose functions, offered through well-defined APIs, easing development of smart applications in multiple sectors.

The Generic Enablers are organized in 7 main technology domains (called *Chapters*) and an extensive description of each one is available through the FIWARE Catalogue[7]:

[6] Commercial offers of the FIWARE Lab, offering FIWARE GEs and different level of SLA, will go live during 2016.

[7] http://catalogue.fiware.org/

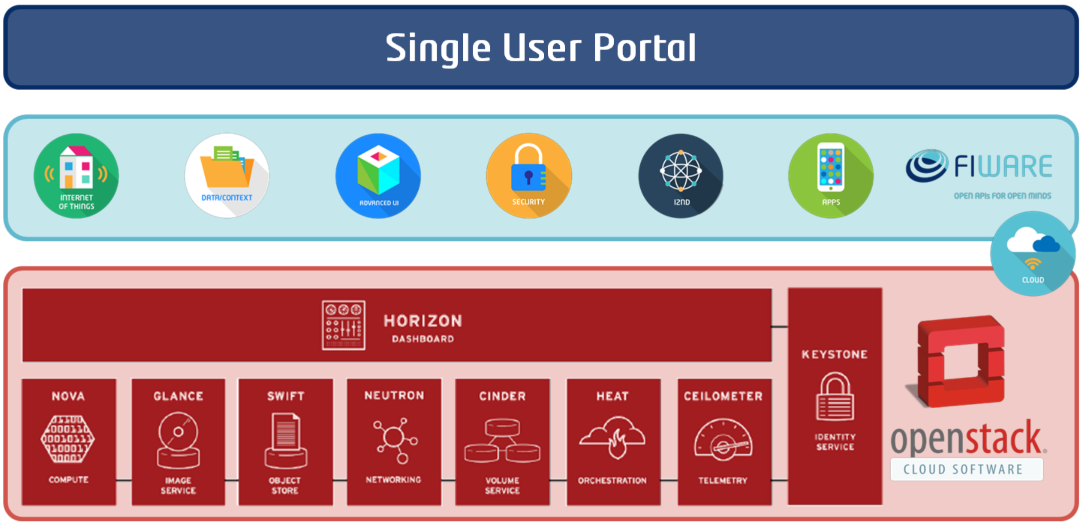

Figure 3: An overview of FIWARE platform as a cloud based ecosystem.

- The *Cloud hosting* that provides functionalities to provision and orchestrate services in an OpenStack-based Cloud.
- The *data/context management* that facilitates the management of data at large scale, from collection to publication and analysis based on Apache Hadoop[8] and NGSI[9] standard.
- The *application and service delivery framework* that allows the co-creation, publication and consumption of Web-based services and applications.
- The *interface to the networks and devices* that facilitates interaction between applications and network capabilities.
- The *security* that provides solutions to deliver trustworthy services based on OAuth2[10] and XACML[11] 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 allow the development of 3D and Augmented Reality services.

On top of these 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). Contrary to the FIWARE official platform, not all the software for the verticals (including Enablers) is Open Source.

[8] http://hadoop.apache.org

[9] http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/ngsi-v1-0

[10] http://oauth.net/2/

[11] http://docs.oasis-open.org/xacml/3.0/xacml-3.0-core-spec-os-en.html

2.2 FIWARE Lab

As above-mentioned, FIWARE Lab[12] is a non-commercial sandbox environment where innovation and experimentation based on FIWARE technologies take place. Entrepreneurs and individuals can test FIWARE technologies, as well as their applications, on FIWARE Lab cloud-based resources, as well as exploiting Open Data published by cities and other organizations. FIWARE Lab is deployed over a geographically distributed network of federated FIWARE Lab nodes. Each FIWARE Lab node maps to one (or a network of) data centres, on top of which an OpenStack instance has been deployed which has been federated and configured as a FIWARE Lab node (Cloud region) operated by a concrete organization. Nonetheless, the nodes are not only providing cloud resources. They also represent a local entry-point to support and promote access to FIWARE technology.

As of today, FIWARE Lab consists of 16 nodes providing 3300+ cores, 12TB+ RAM, 750TB+ HD and with around 6800 users. These nodes are mainly located in European infrastructures, plus one running in Brazil and another one in Mexico. Such international engagement is progressing through the efforts of FIWARE Mundus, and some other worldwide communities have expressed willingness to proceed with the installation (e.g. the Portland State University in Portland, USA[13]).

For more information on FIWARE, we invite the interested readers to visit the FIWARE web site[14] and wiki[15].

Figure 4: FIWARE Lab Map

[12] http://lab.fiware.org

[13] New Portland State "smart city" lab first of its kind in the US. https://www.fiware.org/news/new-portland-state-smart-city-lab-first-of-its-kind-in-the-us/

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

[15] http://wiki.fiware.org

3 FUTURE INTERNET TECHNOLOGY ROADMAP

Following the organization of FIWARE technologies, the roadmap is organized around five core technological areas for the Future Internet research and innovation activities: Cloud Computing, Big Data, Internet of Things, Media Internet and Communication Networks. In the previous white paper "Map of technology and business challenges for the Future Internet" [24], different challenges were identified, interlinked and related to FIWARE Enablers.

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 "Communication 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 the 5G roadmap).

In this document we follow on from the discussion of challenges to identify concrete technological solutions (i.e. a technological roadmap) that, in relation to FIWARE, can support the resolution of the mentioned challenges.

Before looking into the roadmaps, for the convenience of the reader, we summarize the challenges considered as most relevant and their relationships (cf. Figure 5).

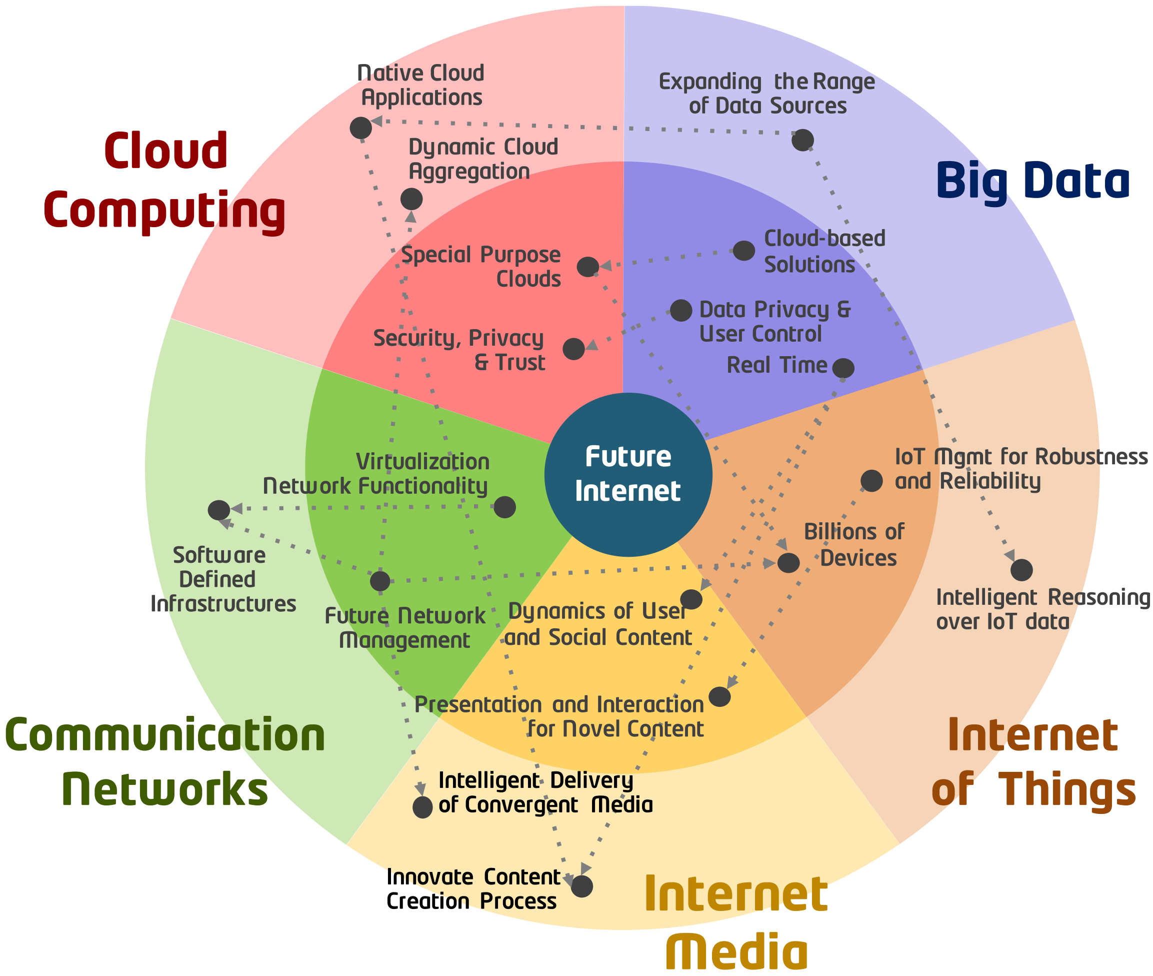

Figure 5: Map of the main challenges for the Future Internet Innovation programme and their relations

In Figure 5, the challenges closer to the centre of the picture are the ones expected to be solved in a short-term time frame (up to 2020) and those on the outside are challenges expected to be solved in a long-term time frame (beyond 2020).

Starting with the **Media Internet**, challenges considered as 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, 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, such as 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 domain of **Communication 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.

3.1 From challenges to technology solutions and their alignment with FIWARE

This section expounds the technological solutions expected to set the path throughout the defined timeline (both before 2020 and beyond), highlighting the links of each identified domain with other branches of the roadmap.

¡Error! No se encuentra el origen de la referencia. provides a visual representation of the timeline for each technology area, pinpointing those solutions foreseen to address the challenges from the map (**¡Error! No se encuentra el origen de la referencia.**) and highlighting the relations among the domains and with regard to the existing FIWARE technologies. For more information and details on each technology area, we invite the interested readers to refer to the specific roadmaps downloadable from [2].

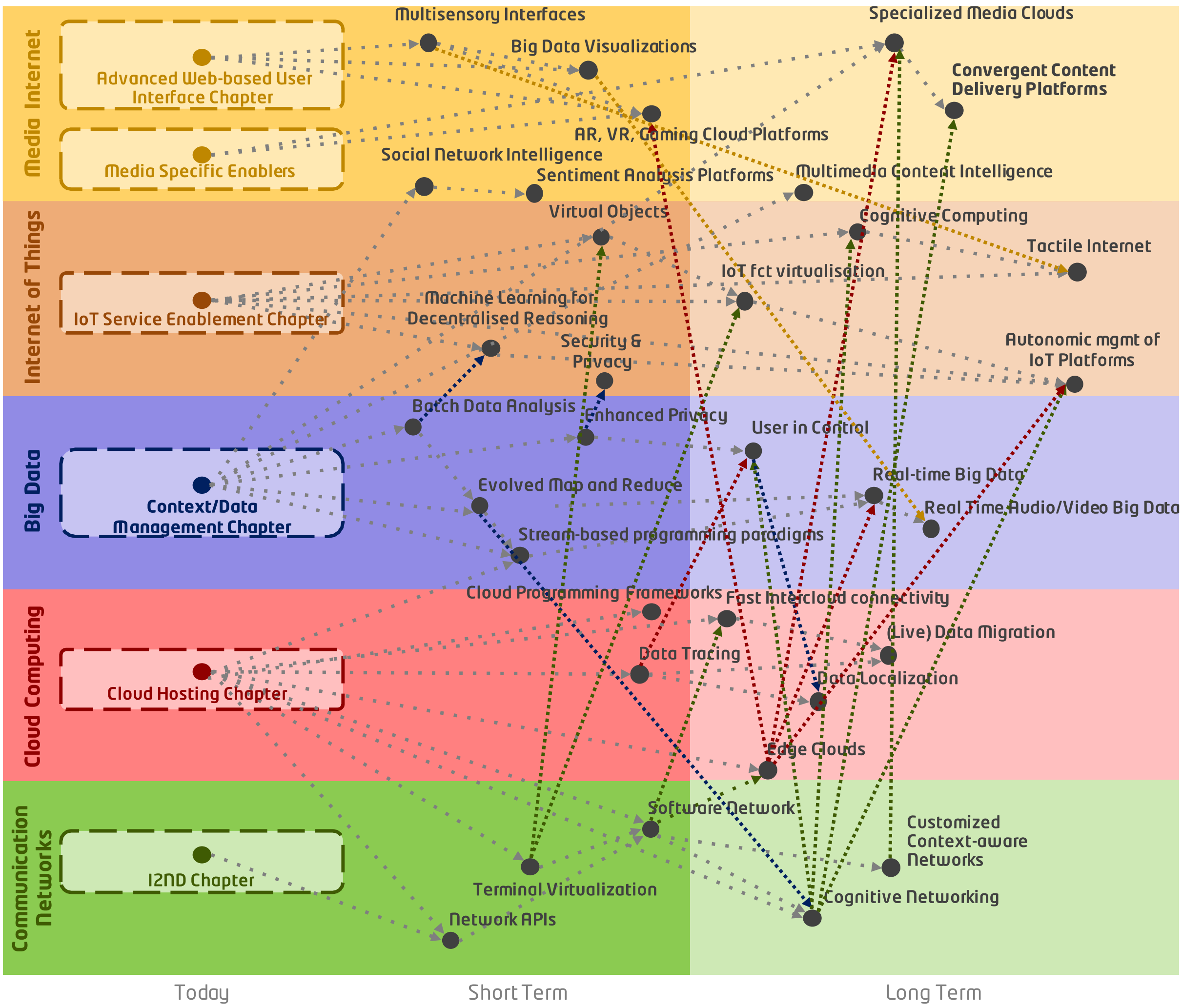

Figure 6: Summary FIWARE Mundus Roadmap, highlighting key technology solutions and their interrelations across technology areas

Figure above highlights some fundamental cornerstones of the FIWARE Mundus roadmap. In our context, cornerstones are those solutions that will be required by other technologies. The figure represents intentionally the technology areas as a stack where the tiers closer to the infrastructure layer are at the bottom and the ones closer to the application layer are on top. Naturally, cornerstones are more frequent at the bottom of the stack.

From the analysis of the diagram, some solutions are identified as crucial (the ones with outgoing bold arrows):

- Terminal Virtualization (Communication Networks) that will empower virtualization in the IoT context;
- Cognitive Networks (Communication Networks) that will enable cognitive solutions in the Big Data, IoT and Media context;
- Edge Clouds (Cloud Computing) that will enable Cloud architectures satisfying the needs of Big Data, IoT, Media and Communication Networks.

In the following sub-sections each technology area (from the top of the stack to the bottom) will be briefly introduced. The reader shall refer to the specific roadmaps in the annexes for a detailed description of all the elements of the roadmap, including the ones not represented here.

3.1.1 Media Internet

Media Internet lies at the application boundary and combines two distinct but related dimensions: on one side, the "digital content" and all related capabilities for content creation and management, on the other side "content distribution and access", i.e. all means for delivering, accessing manipulating, sharing and experiencing it through the Internet. Future Internet technologies have the potential to strongly impact all processes involved in digital content/information creation and distribution. These technologies can impact and change the structure of costs needed to handle all these processes and, as such, they have the capability to enable new potential business models for the media sector.

Moving beyond the challenges and their interaction, FIWARE Mundus identified a number of cornerstone technologies that will empower their resolution. A summary is offered in the following sub-challenges and technological solutions.

Short-Term

- **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.
- **Sentiment Analysis Platforms**: 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.
- **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.
- **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.
- **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.

Long-Term

- **Multimedia Content Intelligence**: The amount of audio-visual content available thanks to Media Internet sharing and distributed in many different vertical, heterogeneous repositories is useless if it cannot be easily searched and retrieved.
- **Specialized Media Clouds**: The continuous growth in the quantity and quality of audio-visual content imposes growing technical requirements on infrastructure in terms of management, processing and delivery capabilities.
- **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

Concerning the evolution of FIWARE in relation to the presented roadmap, in a short term perspective two main additional directions should be addressed within the FIWARE ecosystem: on one side, a stronger integration of existing immersive technologies (devices, platforms) for augmented reality, virtual reality and gaming will enhance user experience and offer more intuitive ways to interact with content; on the other side, a smarter social media and social network intelligence will allow to design, build and structure new and more profitable relationships among companies and their target audiences.

In a longer term perspective, technologies that allow to gain a deeper knowledge, a more fine-grained and real time description of the massively growing amount of content that is generated daily and stored in dispersed digital archives in the web will allow the creation of novel processes for content creation and curation, the delivery of content in a more personalized way according to user's needs, and a wider reuse of high quality and more valuable content.

3.1.2 Internet of Things

The Internet of Things underpins the Future Internet ecosystem with the capability of collecting data from highly distributed and capillary sources.

Moving beyond the challenges and their interaction, FIWARE Mundus identified a number of cornerstone technologies that will empower their resolution. A summary is offered in the following sub-challenges and technological solutions.

Short-term

- **Virtual objects**. Following on the need to foster interoperability, virtualization of objects will also be needed to separate real and resource-constrained objects.
- **Security and privacy.** This is a cross-cutting issue as it relates not only to the security of radio communications, but also to the security of IoT-generated data to ensure good levels of trust and privacy.
- **Machine learning for decentralized reasoning.** As IoT functionality gets virtualized and distributed, besides orchestrating the use of resources there will also be need to coordinate decision-making and achieve conflict resolution for the actuators that are involved in achieving a common goal.

Long-term

- **Cognitive Computing**. Widespread availability of monitoring data will require good algorithms for interpretation and data to knowledge transformation.
- **Tactile Internet**. Tactile Internet will require the instantiation of very low-latency cognitive loops for sensing, processing and actuating within milliseconds.

- **IoT function virtualization.** IoT function virtualization will be opening-up new opportunities where hardware ownership will not be necessarily a requirement for producing IoT services.
- **Autonomic Management of IoT Platforms.** This element of the roadmap relates to solutions that will ensure devices can be fully operational with simple and little involvement of the users, if need be.

In relation to the roadmap presented, FIWARE should focus on short term evolutions that are key to commoditize FIWARE services. FIWARE should provide means to describe objects with associated metadata that can be used not only in the search and discovery of these objects as we scale up and move away from manual configurations, but also in ensuring data content can properly be parsed by the retrieving applications. Another important evolution for FIWARE relates to the introduction of Edge Cloud and the leverage on that to execute / move as appropriate algorithms for data processing close to the source or away from it. Security is also a factor that FIWARE IoT Service Management Chapter should target to ensure the security and the privacy of the sensed data. Finally, the support for additional protocols is key: FIWARE IoT Generic Enablers (GEs) should evolve towards supporting those communication interfaces that will indeed become used by the growing community of IoT makers (notably IETF-based ones).

3.1.3 Big Data

Big Data, in its wider acceptation covering novel technology beyond relation databases, is a key enabler in the creation of a Future Internet ecosystem. This document discusses the characteristic value chain of Big Data and about those related levers (e.g. regulations and standards) that may support or block the creation of a Future Internet ecosystem.

Cornerstone technology evolutions foreseen in the FIWARE Mundus roadmap in the short-term are:

- **Enhanced privacy**: A better privacy taking into consideration that anonymization does not solve the problem.
- **Evolved Map & Reduce**: With more and more applications requiring real-time Big Data the increase of processing optimization is required.
- **Stream-based programming paradigms**: Exploiting the current computational capabilities in order to deal with the huge amount of data being processed will require not only high-performance-computing innovation, but also developing new programming languages and paradigms conceived specifically for Big Data processing.

And the 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.
- **Real-Time Big Data**: there is an emerging need for real-time big data and analytics capability in order for organizations to trigger business decisions immediately. This has a direct impact on the deployment needed to collect and process the information, but also in the existing business tools that will have to react to instructions dictated by the analytics results in real-time.
- **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 with video analytics is the huge amount of data linked to video signals.

Concerning the **FIWARE evolution**, this roadmap raises some suggestions that will 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.

3.1.4 Cloud Computing

Cloud Computing is a key technology in the Future Internet panorama to speed up and ease the development of new Internet based business in Europe, lowering the entry barrier to new providers and supporting the commoditization of enabling technologies.

Moving beyond the challenges and their interaction, FIWARE Mundus identified a number of cornerstone technologies that will empower their resolution. A summary is offered in the following sub-challenges and technological solutions.

Short-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).
- **Data Tracing**: Enabling data tracing, requires Cloud data control probes that provides at any time information on the status, access and localization of data.

Long-term

- **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.
- **Fast 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).
- **Edge Clouds**: 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 travel, thereby reducing transmission costs, shrinking latency, and improving the QoS.
- **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.

Concerning the evolution of FIWARE in the Cloud Chapter, there are a number of short term evolutions from current FIWARE Cloud Generic Enablers that are key to commoditize FIWARE services. A broader support for developers in term of simplified creation of Cloud native FIWARE-based applications is needed. This requires having more advanced means of orchestrating FIWARE micro services and automating their self-healing and self-management. FIWARE should as well support the ability to trace data into the Cloud at least in terms of Object storage solutions, introducing Cloud data control probes that provides at any time information on the status, access and localization of stored Objects. FIWARE recently adopted containers, but more work is required to ensure their adoption (spanning from the network management level to the consistence multi-tenancy of "container" hypervisors).

3.1.5 Communication Networks

The enhancement and evolution of Communication Networks is a technological ambition with elevated repercussion at global scale, not only stating a notable impact on ICT, but also affecting vertical market trends. Infrastructures are the main carriers of services and applications, being the basis of the Internet itself. The faster, more flexible and more robust the networks can become, the more efficient the services will perform and further expectations will be reached.

The development of new communication networks is dependent on the emergence of globally accepted standards in order to ensure interoperability, economies of scale with affordable cost for system deployment and end users.

Moving beyond the challenges and their interaction, FIWARE Mundus identified a number of cornerstone technologies that will empower their resolution. A summary is offered in the following sub-challenges and technological solutions.

Short-term

- **Network APIs**: Management and Data Planes require easier and uniform interaction means, through more powerful and rich APIs.
- **Terminal Virtualization**: Network virtualization must not be limited to the infrastructure providing connectivity, but should be extended to the end-user device.
- **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.

Long-term

- **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.
- **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.

Concerning the future of FIWARE, 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.

For FIWARE Providers, it is proposed that 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. In addition, connecting and managing FIWARE instances opens up multiple possibilities. Apart from the initial achievements from FIWARE Ops[16], FIWARE can act as the technology enabler of future use cases. Current 5G market segments are a valuable reference to follow in this sense.

For 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.

3.2 Dependencies on infrastructures innovations

The realization of the abovementioned Future Internet roadmaps 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 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*" 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.

[16] FIWARE Ops. http://www.fiware.org/fiware-operations/

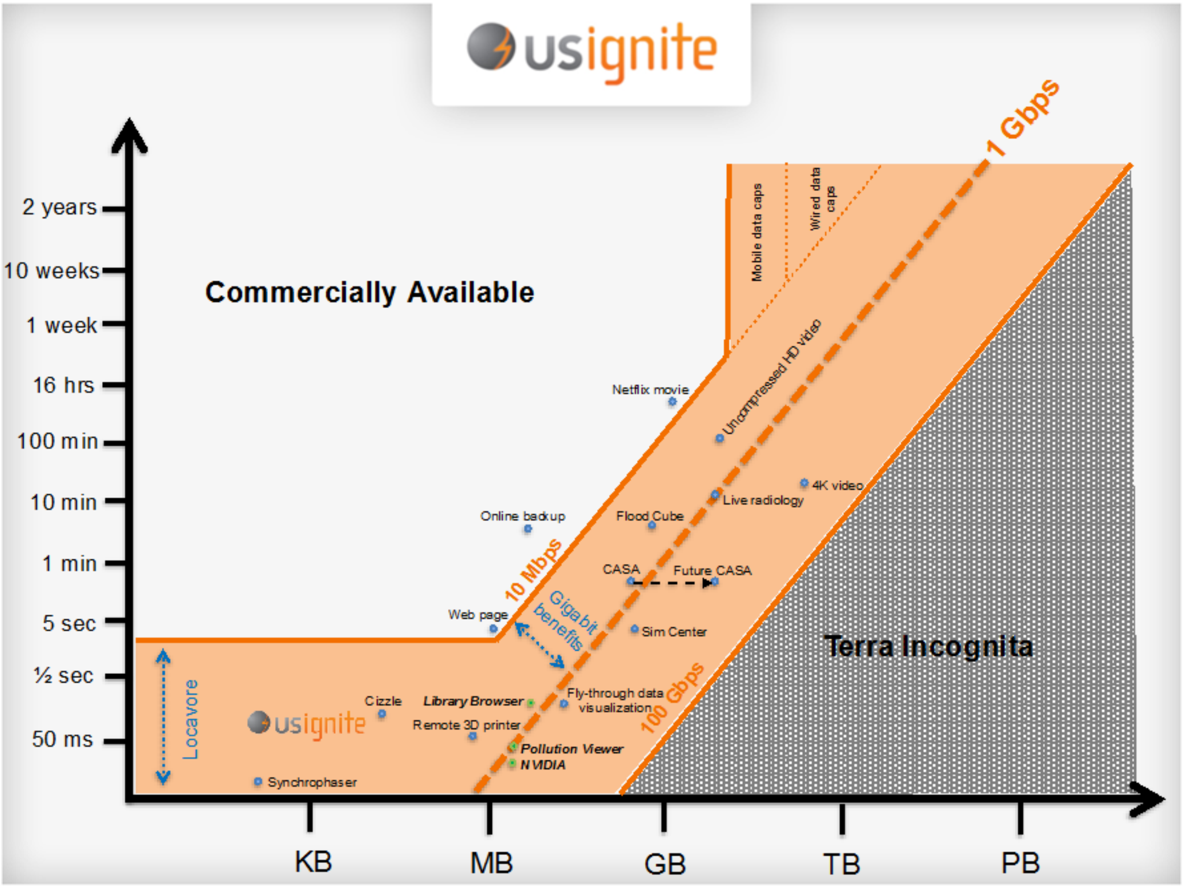

Figure 7: The gigabit Internet frontier, courtesy of Glenn Ricart and US Ignite[17]

Another example of infrastructure innovation is the proposal from the 5G Infrastructure Public Private Partnership (5G-PPP)[18] 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 up new innovation opportunities.

---

[17]Gigabit apps by Glenn Ricarthttp://www.slideshare.net/KCDigitalDrive/glenn-ricart-gigabit-apps-panel

[18] The 5G Infrastructure Public Private Partnership: http://5g-ppp.eu/

Figure 8: 5G-PPP's Key Challenges

As can be seen in Figure 7, 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.

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.

4 BUSINESS ROADMAP FOR THE FUTURE INTERNET EVOLUTION

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.

4.1 European Future Internet Ecosystem Vision & Roadmap

Rather than a monolithic or tightly vertically integrated architecture, the European Future Internet industry vision is based on the interoperation of many players that together form a European Future Internet ecosystem.

The five technological drivers (Internet of Things, Big Data, Cloud Computing, Communication Networks and Media Internet) are deeply intertwined and cross-dependent.

While the technical issues needed to create the Future Internet Industry are substantial, little attention has been given to the behavioural, organizational and business issues that are necessary for a better understanding of the adoption, usage and impact of Future Internet technology drivers.

Managing complexity in the provision of business services through Internet technology is regarded as the key success factor to establish services in the Future Internet. Numerous actors from different domains, working in different business settings and using heterogeneous IT technologies have to be integrated according to the business strategy identified.

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 the 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, where in the *push* models the people are seen as passive consumers (even when they are producers like workers on an assembly line) whose needs can be anticipated and shaped by centralized decision-makers, whilst in the *pull* models the people are treated as networked creators (even when they are customers purchasing goods and services) who are uniquely positioned to transform uncertainty from a problem into an opportunity.

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.

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 focus of the 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.

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

This section describes the list of elements that affect the Future Internet Ecosystem Vision enactment. They are generally similar in every economic ecosystem and have been tailored for each of the technology domains analysed throughout the FI-LINKS project execution and account for experts feedback following the release of white papers at [1]. The structure of this section foresees a brief analysis of these catalysts and potential barriers, namely *standardisation* which brings different organisation together pushing for a common agenda; *regulation*, which can affect what is and isn't acceptable from the policy makers point of view; *critical mass*, which is the threshold after which the evolution of a technology becomes sustainable; *awareness* which promotes the definition of synergies for a common R&D agenda which opens new business opportunities; *investment* is a clear element that will affect the evolution of the Future Internet ecosystem and relates to the clarity and confidence new technologies and associated impacts can be formulated to potential investors; *sustainable business models*, where relationships amongst various parties need to be defined, especially in multi-sided business contexts; *IPRs and Technology Transfer* goes hand in hand with the previous one, especially when IPRs might be related like it might be the case in a whole ecosystem; *Research and Innovation* as the enabler that guarantees foresight, which might be more or less present according to the state of evolution a technology is at.

4.2.1 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 the commoditization of formerly custom processes."[19]

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 ones most broadly accepted - the "de facto" standards.

There are several standardization initiatives into which FIWARE provided contributions and which are widely adopted, e.g.:

- OMA NGSI, in the context of Internet of Things;

[19] https://en.wikipedia.org/wiki/Standardization

- DMTF Open Virtualization Format in the context of Cloud Computing.

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

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. Standardizing too soon will mean stunted advancement for an industry that shows enormous promise for changing the way we live, connect and operate.

We can conclude that the development of new technological standards will influence how markets will evolve opening access to new players, especially to SMEs.

4.2.1.1 Media Internet

The Media Internet encompasses a large number of technologies. The main standardization initiatives relate to: content format, encoding and transmission over CDNs, SLAs, advertising integration, and application development and marketplaces. For example, online social networks rely on FOAF[20] to describe people and relationships; computer systems use WSDL[21] to describe distributed software-based services; GoodRelations[22] 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.

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

4.2.1.2 Internet of Things

There are several standardisation initiatives which underpin the monetisation potential within each of the IoT value chain layers. IoT is particularly characterised by the existence of too many different standards, given the applicability of IoT in many different application domains burdened by existing standards. On the lower "device-level" there are initiatives dealing with low-energy protocols for communication with the devices, for managing these and ensuring sensed data can be extracted and sent across to remote applications. At a higher abstraction level there are initiatives pursuing a "thing-level" standard, which are more concerned with how the sensed data is structured, including semantic descriptions, application specific data models, etc.

While there are tens of standardisation activities in IoT, the most relevant ones for the FI-PPP vision are:

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

Standardisation is also important for value to be extracted at the system integration level; large and generic deployments need open platforms based on standards. In any case, it has to be kept in mind

[20] http://www.foaf-project.org/

[21] http://www.w3.org/TR/wsdl

[22] http://purl.org/goodrelations/v1

that this is a highly crowded context, where the landscape may change quickly following the emergence of de-facto standards fostered by market use and adoption rather than technology / industry pushed initiatives.

4.2.1.3 Big Data

There are two layers of standardization activities applicable to Big Data: on a lower layer, standardization about the structure and contents of the data that is to be extracted and loaded (including multimedia standards, such as Web RTC) and, on a higher layer, standards about the syntax and semantics of the data that is stored and analysed (including OWL and RDF).

4.2.1.4 Cloud Computing

Standardization may be a key factor in support of market adoption of technologies. There is a large number of underlying technologies within the generic umbrella of "Cloud Computing" and, associated to many of those technologies, there is a number of competing standards and standardization initiatives. Despite the reality is that Cloud Computing market is mostly dominated by de-facto standards (e.g. Amazon AWS APIs[23] or OpenStack[24]) that often are not aligned with standardization initiatives, the following table summarizes some standardization initiatives related with Cloud Computing.

Standardization Body	Standards	Comments
DMTF	CIMI, Cloud Audit, OVF	Cloud Infrastructure Management Interface, Open Virtualization Format
Open Grid Forum	OCCI	Protocol and API for cloud management tasks
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

Table 5: Standards for the Cloud

Two of the most relevant standardization initiatives for FIWARE are:

- ETSI Cloud Standards Coordination Initiative[25], promoted by the European Commission;
- DMTF Open Virtualization Format[26], to which FIWARE initiative has contributed notably.

[23] http://aws.amazon.com

[24] https://wiki.openstack.org/wiki/RefStack

[25] http://csc.etsi.org

[26] https://www.dmtf.org/standards/ovf

Indeed FIWARE founds its Cloud Computing platform on OpenStack that can be considered as a widely adopted de-facto standard. The active participation by FIWARE to the OpenStack Community is key in order to stay aligned with such a de-facto standard and try to influence it. It is then suggested for the future an even larger contribution of FIWARE on the aforementioned community.

4.2.1.5 Communication Networks

There are countless standards, organizations and initiatives related to network technologies that will impact Future Internet innovation. Among all of them, two important sets shall be noted:

- Network standards related to the interaction and integration to Cloud Computing, such as Software Defined Networks and Network Function Virtualization. The IRTF's Software Defined Networking Research Group[27], ETSI Working Group on NFV[28] and the IEEE SDN[29]are great examples of these activities.
- Network standards related to the increased capacities required by new market opportunities and demands, for instance the 3GPP[30].

4.2.2 Regulation

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

- Economic regulations - trying 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.

One aspect impacting FIWARE and the Future Internet is the regulation of private data since it is dependent on each specific Country, and this impacts, for example, on the distribution and localisation of data (in the case of data hosting and cloud computing). For example, it can be the case that data has to be maintained in the specific Country generating the data, while computation capacity could instead be moved outside; however, data shall need to remain within the specific Country.

Therefore cloud computing and BigData, technologies should take into account such specific issues.

4.2.2.1 Media Internet

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

[27] IRTF Software-Defined Networking Research Group (SDNRG). https://irtf.org/sdnrg

[28] ETSI Network FunctionsVirtualisation. http://www.etsi.org/technologies-clusters/technologies/nfv

[29]IEEE Software Defined Networks. http://sdn.ieee.org/

[30] 3rd Generation Partnership Project (3GPP). http://www.3gpp.org/

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.

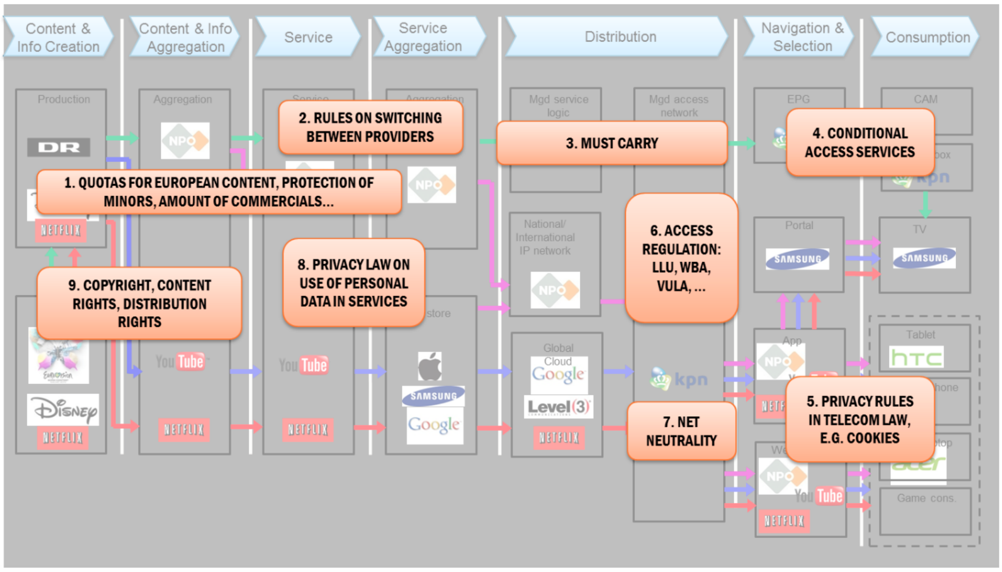

Figure 9: Regulations that Affect Video Services in the Converged Value WEB (TNO Innovation for Life)

4.2.2.2 Internet of Things

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 Low-Power, Wide-Area (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.

4.2.2.3 Big Data

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. Similarly to IoT, the issue of inferred knowledge derived from low-level data through Big Data algorithms is to be properly regulated to prevent loss of privacy.

4.2.2.4 Cloud Computing

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. 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 fragrantly transfer personal data to countries with inadequate data protection laws. The picture below gives a snapshot of the current EU legal framework with respect to the technical evolution. Recently (May 2016) the EU promulgate the processing of personal data and the free movement of such data regulation so as to have a uniform legislation throughout Europe. Technologies and business models adopted by FIWARE in the context of Cloud Computing can take advantage of this simplification.

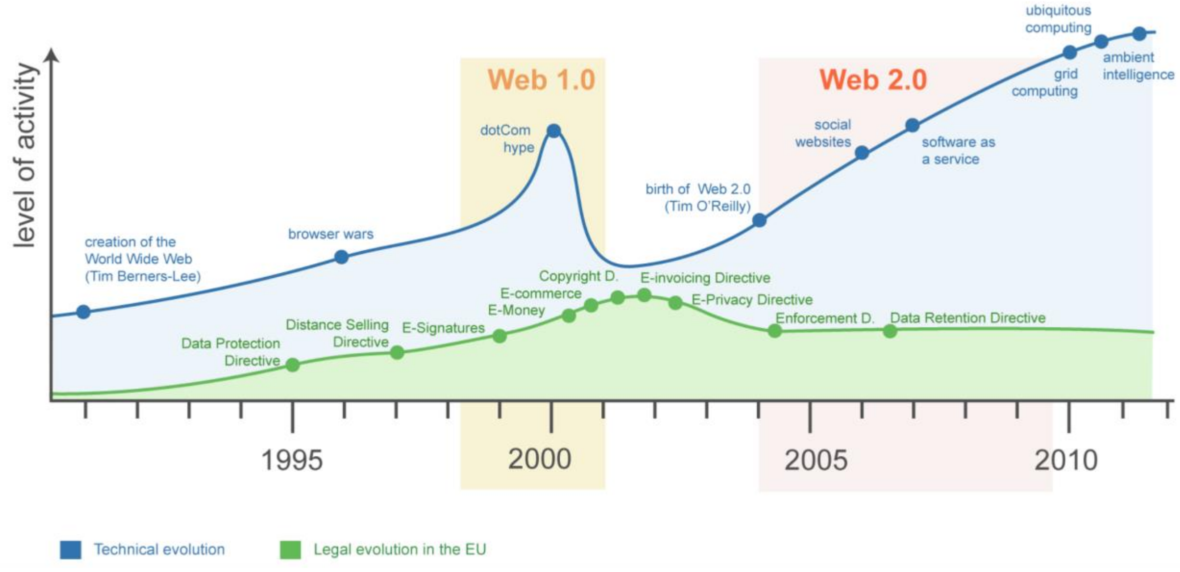

Figure 10: Cloud Computing legal issue (DLA Piper Brussels)

4.2.2.5 Communication Networks

The European telecom sector is facing significant challenges in terms of rapidly emerging technologies and new forms of competition as well as business models. 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 exigent issues which require steps to be taken to modernize the regulatory situation. When defining the path towards regulatory modernization, Europe shall avoid going for incremental improvement and rather taking aim at an ambitious scenario and step into a "*Virtuous Circle*" model, based on innovation, investment and smart regulation *("Regulation 2.0")*.

4.2.3 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 Rogers [25], 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 decelerating [26]. In a collaborative environment it outlines at which point the user involvement - in the 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 Wagner [27] 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 involved [28].

4.2.3.1 Media Internet

Digital content market spans and covers a variety of different players and market segments to be considered a "digital ecosystem" that includes all actors involved in the production, consumption and exchange of content and information within a unique and shared digital environment. The real current barrier to further market expansion is thus not the lack of critical mass but rather market fragmentation that prevents full interoperability and cooperation among different players working in the whole ecosystem. Internet Media permeates and covers in any case the whole Internet value chain, from content production to end users, impacting and involving different key online services and related enabling technologies and all network-related infrastructures, as well depicted by A.T. Kerney in its Internet Value Chain representation.

Reaching critical mass therefore comes as a lower priority goal compared to existing fragmentation of the whole technology ecosystem.

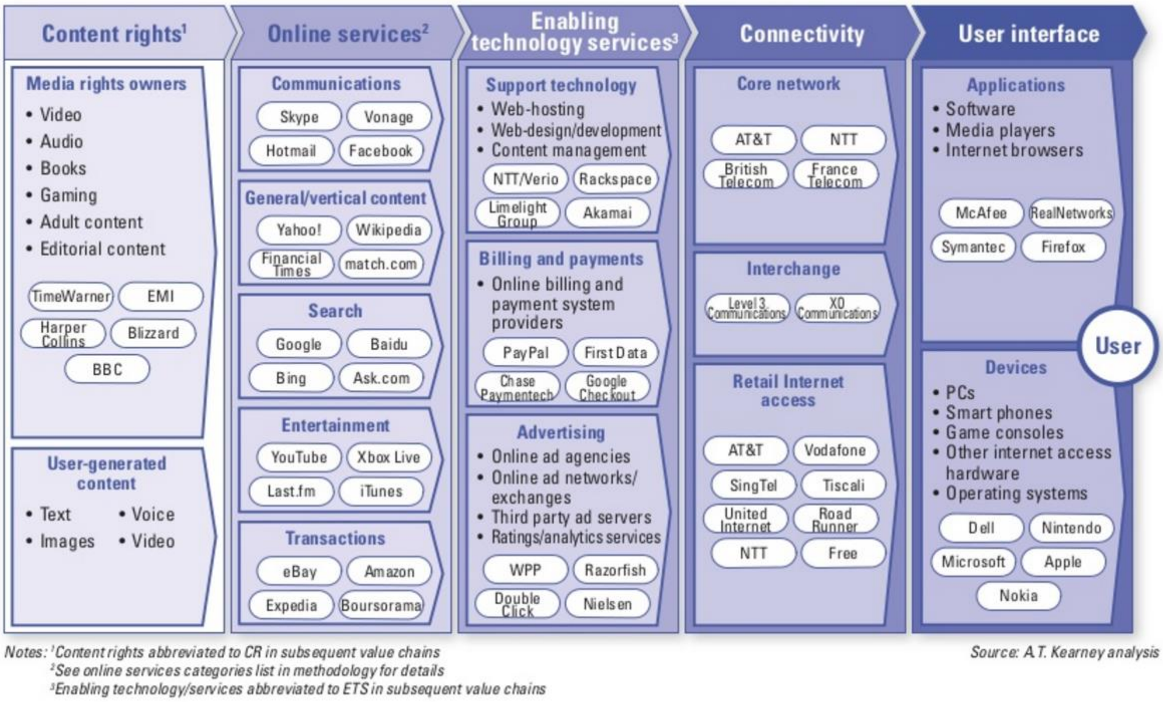

Figure 11: Internet Value Chain (Source: A.T. Kearney)

4.2.3.2 Internet of Things

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

Critical mass is also difficult to achieve also due to high fragmentation of the offer, across many different application domains and with many standard and many more players populating a crowded market. One of the largest deployments of IoT technologies existing at EU level already launched is indeed related to the 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, started in 2014, the French company Sigfox will deploy more than 4,000 base stations connecting 30 cities in the United States, and effectively making it the largest IoT deployment.

While these are initiatives aimed at building critical mass, the sustainability of these is still under scrutiny due to the above-mentioned fragmentation. The EU promoted AIOTI recent initiative goes in this direction, but the jury is still out as to whether or not this will be successfully sustaining IoT “made in Europe” to reach critical mass.

4.2.3.3 Big Data

The latest statistics show 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. 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. Furthermore, 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.

4.2.3.4 Cloud Computing

Critical mass is a determining factor for the creation of an ecosystem. The number of Cloud Computing adopter is clearly increasing, but the peace in Europe is still lacking beyond compared to other industrialized countries such as US.

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. The following figure shows the usage of Cloud Computing in Europe.

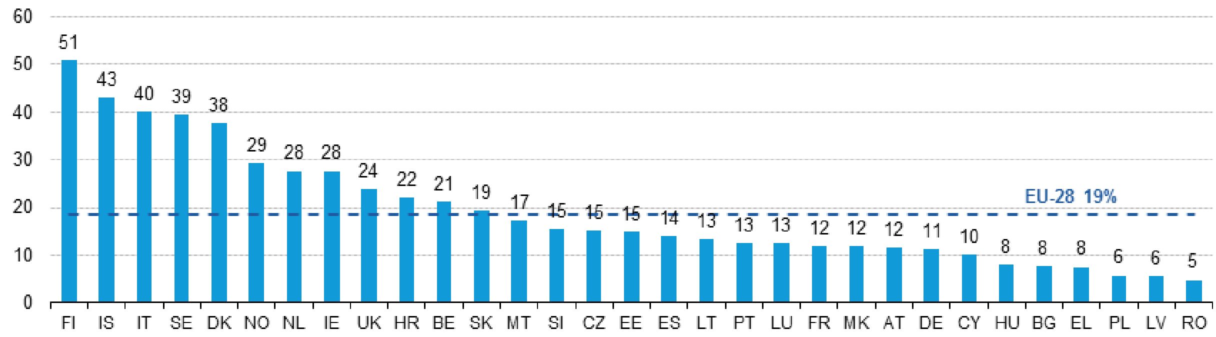

Figure 12: Use of Cloud Computing services, 2014 (% of enterprises) (Source: Eurostat)

As far as Cloud Computing is concerned, FIWARE adoption is relevant throughout Europe: FIWARE Lab offers a multi-region Cloud based on OpenStack covering many European countries and currently used by more than 6000 users of which more than 1000 can be considered as "business" users. The recent Open Call for new FIWARE Lab nodes and the launch of the so called "commercial" FIWARE Lab nodes will surely improve the adoption and the business footprint of FIWARE.

More generally Could Computing can increase its "critical mass" if SMEs and developers are made aware of the potentialities of cloud-native applications and of the advantages that moving their applications on the Cloud entail.

4.2.3.5 Communication Networks

The transformative impact of digitization in the mass adoption of 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. On the other hand, the "over-the-top" (OTT) players -media services such as Netflix and Spotify that piggyback for free on telecom infrastructures- are gaining in number and popularity, making the traditional operators' landscape much more difficult.

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

4.2.4 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.

4.2.4.1 Media Internet

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, suggesting "awareness" is not one of the biggest concerns for the future of this technology.

4.2.4.2 Internet of Things

European Future Internet initiatives about the Internet of Things are particularly well-known throughout the EU and beyond by 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 annual *IoT Week* event, the IoT Expo, IoT World, and other private initiatives are representative examples of these awareness-creating actions.

4.2.4.3 Big Data

Actions raising awareness should be handled carefully. On the 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.

4.2.4.4 Cloud Computing

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. Unfortunately, most of these events are located outside EU, limiting the increase of awareness in Europe. Nevertheless many FIWARE dissemination and communication initiatives have been put in place in order to increase its awareness: in particular the Cloud Computing offering has been disseminated in the last OpenStack Summits (Tokyo 2015 and Austin 2016) and the plan is to do the same in next Summits. Participation to other Cloud related events or organization of Business/Developer weeks can also contribute to increase the knowledge of FIWARE and the business advantages offered by its Cloud technologies.

4.2.4.5 Communication Networks

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.

4.2.5 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.

4.2.5.1 Media Internet

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%).

4.2.5.2 Internet of Things

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

The plan approved at the end of the last year by Jean-Claude Junker, President of the European Commission, 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.

This is not enough: as said in the last EIB conference, Europe needs to mobilise 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 largest investment comes from municipalities modernising to Smart Cities. From the private perspective, a few Smart Industry deployments still outnumber the many long-tail opportunities.

4.2.5.3 Big Data

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. In this context, the ability to interpret and derive knowledge from low-level data is behind a useful expansion of Big Data, where actual usefulness of applications sustains investments in this rapidly growing area. Public investment is focused still on longer term objectives such as R&D initiatives, etc.

4.2.5.4 Cloud Computing

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 this 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.

4.2.5.5 Communication Networks

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 90s, but since then has fallen behind in investments in networks. Despite the EU’s leading role in standardization and development of LTE (4G), in 2012 the EU’s share of global LTE investments was only 6%, compared to 47% in the USA, 27% in South Korea and 13% in Japan.

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 (i.e. the USA, 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.

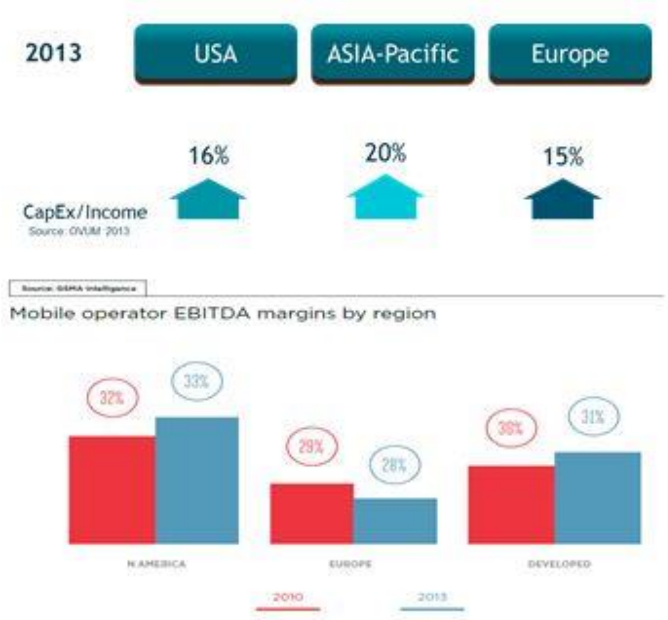

Figure 13: Investment levels led by financial returns (Source: ETNO)

4.2.6 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.

4.2.6.1 Media Internet

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:

- Crowd sourced 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)

- Crowd sourced and location based news (nunki, storyhunter, newstag)
- Targeting for reach and scale (newsatme.com, 8bit, feedspy, wordlift, buzzfeed)

Keeping monitoring evolution of activities in these domains is of paramount importance to make sure impact of Media Internet activities is not jeopardised by the lack of sustainable Business Models.

4.2.6.2 Internet of Things

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 so that business models can more easily be elaborated. Efforts towards building standards-based solutions are emerging; nonetheless, such efforts need to be further refined to ensure that solutions are future-proof.

Traffic tariffs are another parameter in the sustainability equation. The networks over which particular IoT data will be carried will have to be selected according to issues such as access location, bandwidth, latency, reliability, privacy and security. The subsequent choices will have an impact on the cost of transporting the data and on the tradeoffs from adopting edge-cloud solutions for minimising network usage.

4.2.6.3 Big Data

Applications with a 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 on public administration data sources and platforms and aim at providing value to cities and citizens.

4.2.6.4 Cloud Computing

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 services are being evaluated.

Activities on Cloud Computing technologies and models offered by FIWARE are governed and managed by the FIWARE Open Community and the FIWARE Foundation that have been established in order to make FIWARE ecosystem sustainable.

4.2.6.5 Communication Networks

The business model of a Network Provider heavily depends on the initial investment required to setup the associated infrastructure. Traditional telcos manage legacy and capabilities that facilitate the launch of any new innovation, whereas new entrants face an access barrier.

Figure 14: Market indicator of sustainability (Source: Telefonica)

The negative outlook on European telecom revenues, despite a strong traffic increase, reveals a structural problem in Europe. 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 15: Fragmented European Market (Source: Telefonica)

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.

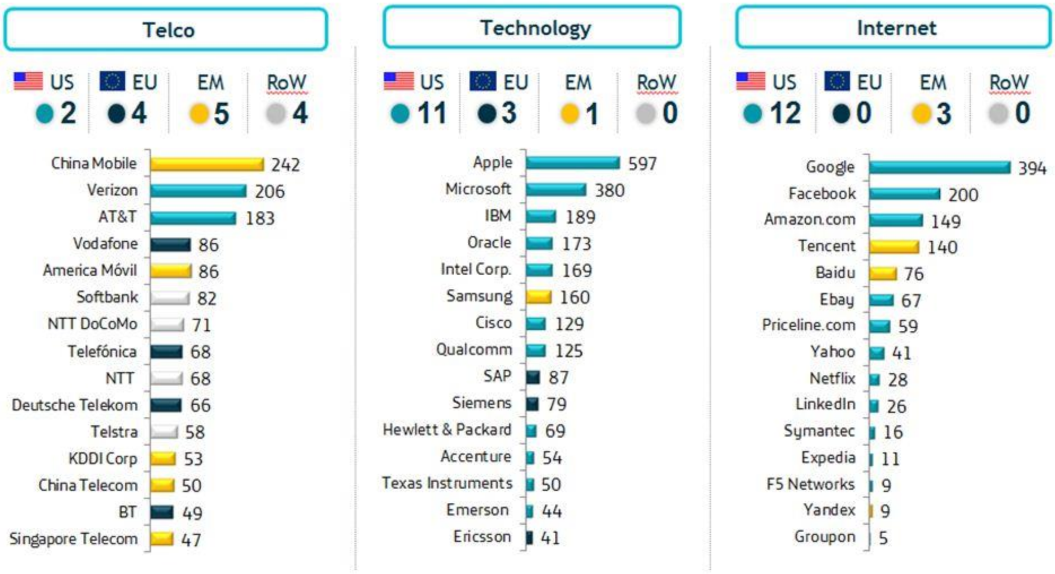

Figure 16: Data Market Cap (Source: Bloomberg, October 2014)

4.2.6.6 Overall Business experts' feedback

The effort has been made as 985 SMEs / startups have already adopted FIWARE (sustainability). In order to continue on this roadmap, the FIWARE Foundation is being established. FIWARE Foundation will address key issues such as alliances, targeted market, sales model, and so on. The sustainability of FIWARE platform is, in fact, ensured by the sustainability of the business adopters themselves. Therefore, FIWARE sustainability shall rely on the soundness of each adopter' business model. What needs further attention is the orchestration of various companies' interests towards common "ecosystem goals" that highlight a fruitful path to follow.

4.2.7 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.

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 terms[31].

4.2.7.1 Media Internet

As shown in **¡Error! No se encuentra el origen de la referencia.**, IPRs for content (copyright) are a fundamental element in Media Internet innovation. This differs from the other technological drivers in

[31] http://itlaw.wikia.com/wiki/F/RAND

which IPRs for technology (patents) are the most relevant. Patents are also very relevant in Media Internet underlying technology, such as CDNs or Codecs.

4.2.7.2 Internet of Things

There is a well-established patent base in IoT. The main owners of the IPRs are hardware manufacturers, and component providers: the two areas where Europe is less active in the overall IoT market. This particular enabler has therefore limited importance in a European context.

4.2.7.3 Big Data

Many companies now fight in 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.).

4.2.7.4 Cloud Computing

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.

Regarding FIWARE Cloud Computing Chapter, software and tools are mostly offered with Open Source licensing model.

4.2.7.5 Communication Networks

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.

4.2.8 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 in opposite directions.

4.2.8.1 Media Internet

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).

4.2.8.2 Internet of Things

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.

IoT enjoys a prominent focus in the Horizon 2020 work programme 2016-17 with particular focus on interoperability solutions and on the IoT ecosystem that future solutions will enable and sustain.

4.2.8.3 Big Data

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

4.2.8.4 Cloud Computing

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 centers and the merging with software defined networks. Moreover, the emergence of lightweight container-based runtimes has enabled rapid innovation in building novel platforms with greatly improved agility and developer experience (e.g. Docker, Amazon Lambda). Finally, domain-specific Clouds are the subject of research in many fields, such as in the Telco domain. The H2020 programme covers extensively the foundation R&D activities on Cloud Computing and its adoption in specific domains (e.g. 5G-PPP).

4.2.8.5 Communication Networks

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.

4.3 Current and short term Business Markets

Throughout the Phase 3 of the programme (2014-2016), a clear go-to-market strategy has been encouraged through the creation of new business markets around the platform, where the FIWARE Accelerator programme[32] has been the main reference by bringing together 16 different business accelerators on different vertical sectors: **Smart Cities**, **eHealth**, **Cleantech**, **Energy**, **Agrifood**, **Media & Content**, **Manufacturing**, **Learning & Training**, **Industry 4.0** and **Social Impact**. The mission of this initiative has been focusing on boosting new and promising ideas, products and services developed with FIWARE by entrepreneurs, startups and SMEs, being supported through direct funding, mentoring, training and networking.

The Accelerator programme has successfully achieved to attract over 8,000 submissions to their open calls and grant more than 1000 ideas, where a great part have already developed their market-ready products. The figure below summarizes the main numbers, quantifying the impact on both the Business and Consumer Markets.

[32] https://www.fiware.org/accelerators/

Figure 17: FIWARE Accelerator Programme outcomes (July 2016)

IDC and other companies [29] produced an interesting analysis about the initiative:

- The majority of the business ideas (59%) target a B2B model, whilst only 20% have the consumers as end-users (the remaining 20% follow a hybrid approach);
- 28% of the sub-grantees are focused on the Smart City area, including solutions for intelligent transportation, connected healthcare, open data initiatives and urban smart grids;
- The Top 5 countries have been Spain (22.54%), Italy (11.27%), Germany (11.27%), The Netherlands (6%) and UK (6%);
- Among the Top ICT solution adopted we can find Mobility (367 ideas), Big Data (311), Cloud (287), IoT (264) and Social Media (140);
- By 2017, over 1000 new or fast-growing small enterprises, part of the FIWARE Accelerator Programme, will be key actors in the most innovative markets, offering disruptive apps, IT solutions and web based services. Horizon 2020 will be the next keystone in this process;
- By 2020, a revenue of more than €330 million is expected around the SMEs leveraging the FIWARE platform. They will be serving at least 1.5 million business customers and reaching a market of more than 20 million consumers.

The study by IDC et al. [29] also analyses the adoption of FIWARE Generic Enablers by participants to the FIWARE Accelerator programme. This analysis provides interesting insights into the maturity and relevance of FIWARE platform components. In particular, the most adopted FIWARE Chapters are: Data/Context Management (53%), Security (52%), Advanced Web-based User Interface (45%) and the Cloud Hosting (44%).

4.3.1 Predictions of strategic investments by companies in relation to FIWARE technologies

IDC [29] predicts that companies' strategic investments in IT will be built on introducing or strengthening the third platform[33], technologies. The third platform, also known as SMAC (Social Mobile Analytics Cloud), consists of the inter-dependencies between what IDC calls "4 pillars": Mobile Broadband Network, Cloud Computing, Social Media, and Big Data; and additionally the Internet of Things.

Mobile Broadband Network. As mobility is part of business digital innovation, a great amount of SMEs are strategically investing in mobile solutions and apps to generate revenues and extend their reach. IDC expects mobile solutions to increase in the short-term since as many as 67% of the companies will invest in mobile strategies to boost productivity and strengthen collaboration by 2015.

280 out of the 725 initiatives (39%) are paying attention towards mobile enablement.

Big Data. Big Data is developing in Western European countries and is a fast growing market. In Western Europe 20% of the companies are already using Big Data and 19% will introduce such solutions by the end of 2015.A large number of proposals that have been granted funds by the FI-PPP Phase III are focusing on this technology.

241 out of the 725 initiatives (33%) are deploying Big Data solutions.

Cloud. Cloud solutions are growing rapidly but there is plenty of space for improvements in adoption across Western European countries as Cloud IT spending is still limited. According to IDC, 58% of the Western European companies are using Cloud, but although the market is expanding rapidly, investments are contained.

236 out of the 725 funded initiatives (33%) are adopting Cloud technologies.

IoT (Internet of Things). The Internet of Things is one of the most important drivers for innovation for the growth and expansion of IT-based value. The IoT explosion took place with the constant growth of connected devices to create a “smart” ecosystem (smart cars, homes, industry equipment, wearables, etc.).

213 out of the 725 selected projects (29%) are IoT initiatives.

Social Media. Social Media usage is generally high, but compared with other innovative technological drivers its use appears still limited. A large share of these organizations operates in the telecommunication and media industries, where Social Media is highly correlated to their core business.

4.4 Future business markets

To achieve further positive impact of the FIWARE initiative, it is important to bring innovation offered by FIWARE and the FI-PPP Programme beyond their current business scope.

After reviewing some references of emerging technologies (e.g., Gartner’s yearly Hype Cycle for Emerging Technologies[31] and Imperial College’s Timeline of Emerging Science and Technology[32]), four science & technologies have been selected as Future Internet business drivers that could provide mutual growth of Future Internet technologies and FI-PPP business sectors:

1. 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

[33] https://en.wikipedia.org/wiki/Third_platform

overall quality of lives (e.g., biochips lifelog, DNA Internet). The organization Research and Markets [33]estimated in 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 2020.

2. CleanTech (i.e., green technology) and FI are influencing each other and make co-petition between traditional sectors (e.g., manufacturing, automobile industry) and the Internet industry that leads to business evolution and innovation for each other. There are strong driving forces in the CleanTech industries, such as demographic change, urbanization, globalization, scarcity of resources and the challenges of climate change. 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 yearly, and it is expected to more than double (€4 trillion) in size by the mid-2020s according to new research commissioned by the German government [34].
3. 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, new interfacing with pervasive ICT). 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.
4. 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 all the way down to the so-called ‘smart dust’. 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.

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 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. The below table show how the current FI-PPP sectors, the FI technology drivers (Media Internet, Internet of Things, Cloud Computing, Big Data and Networks), are connected to the selected services and applications that converge with Bio, CleanTech, Neuro and Nano science & technology fields.

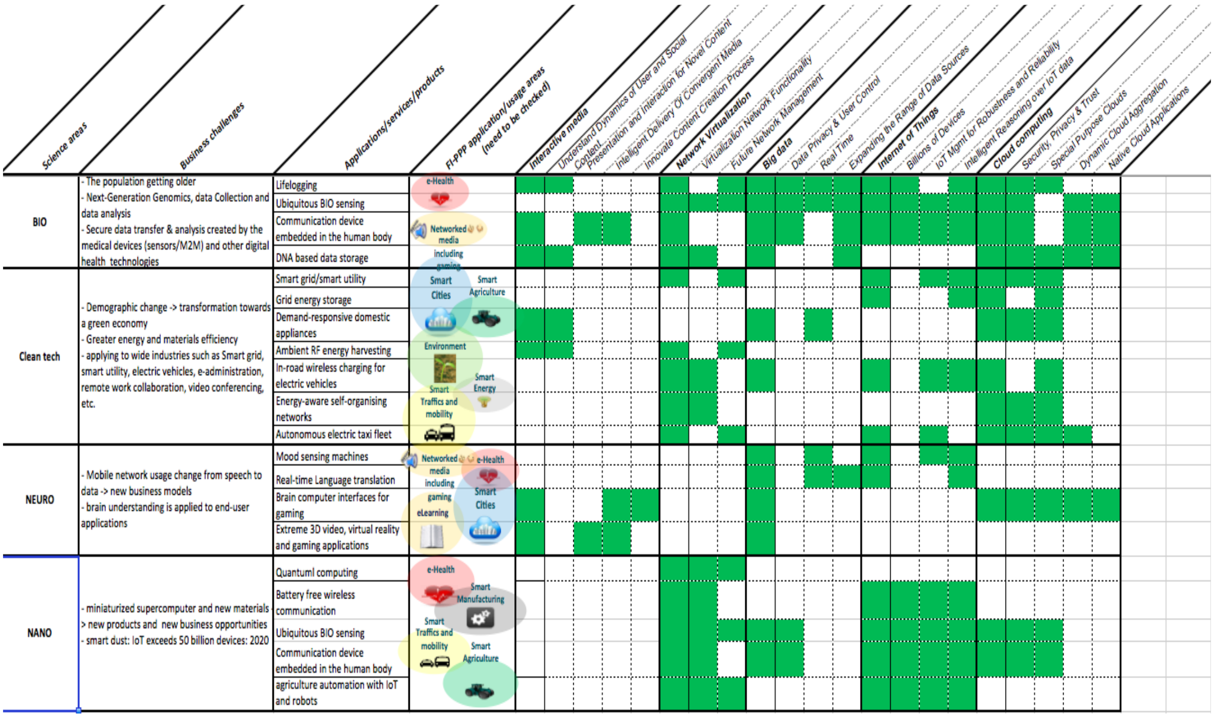

Table 6: Connection between FI technology and services related to with Bio, CleanTech, Neuro and Nano science & technology fields

5 CONCLUSION AND FUTURE RECOMMENDATIONS

This roadmap outlined different directions for the challenges which the FIWARE Mundus team believe will be the most relevant ones for FIWARE in the future, spanning from short- to long-term.

In this document 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 Communication 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.

Concerning the recommendation on the business side we can summarise them as:

- It is advisable FIWARE follow-up and related Foundation should promote a bigger impact with regard to standards. Standards should become an active part of the Work programme and included in all the future-looking activities of the organisations involved in FIWARE.
- Concerning regulation, in many cases, technology is moving too fast with respect to real regulation efforts. In other words, regulation tends to lag behind the actual deployment of FIWARE technologies, which could be a hindrance on the path to easy adoption of Future Internet technologies. It is advisable that FIWARE can play a role in the policy directions concerning regulations for the Future Internet technologies.
- A lot of effort must be put into ensuring FIWARE gets adopted and reaches critical mass that sustains its adoption in the future not only as an innovation enabler, but also as a business ecosystem enabler. Critical mass is therefore crucial in order to guarantee that FIWARE is moving and impacting also at business level, and not only at a technological level. Therefore the creation of a sustainable community of global users and developers if key.
- A proper analysis of where the current investment is going, as well as the prediction of where the investment trends will go to (in particular, what needs to be specified is to choose vertical areas where financing is appropriate and investments more likely to occur), is a critical fact towards the use of FIWARE, as investors are interested in the verticals, i.e. the use of FIWARE for different applications and services.
- Any further development in FIWARE and Future Internet should have clear Intellectual Property Rights.
- Convergence with other EU-wide initiatives. A number of new programmes, following the success of the FI-PPPP programme, are starting in the last 12 months, including a programme on Big Data value and one 5G. Outcomes of FIWARE should be largely reused in those programmes, both in term of technology, ecosystems, and best practises.
- Inclusion of cutting edge technologies in the platform. FIWARE needs to maintain its novelty as way to distinguish from other platforms and compete with them. To do so, it needs to always scout for the most promising technologies and include them as part of the platform: e.g. Blockchains could be a great solution to provide novel means for trustful management of distributed data in the Cloud.

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 the audio-visual content market.
- 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.
- 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.
- 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.
- Communication 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.

On the business side we illustrated what enablers will need to be boosted and what impediments might be found on the road that leads to a successful adoption and impact for Future Internet technologies.

All activities surrounding the FIWARE initiative tend to suggest that the process is still in the market validation phase, instead of in a market adoption phase. For this transition to be made successfully efforts should be increased to raise awareness and consequently critical mass adoption. Without reaching high numbers for these two key performance indicators, FIWARE cannot claim to be having real market success.

How fast are the initiatives surrounding Future Internet able to adapt or to include new trends that are coming out from other developers and research organisations is a key question that needs answering. Therefore, there should be side investments for FIWARE to keep scouting and eventually adopt new and emerging trends and technologies for the Future Internet, following an open innovation scheme. In addition, further investment in R&I in FIWARE is critical to adapt to such new trends.

To set the activities of the Foundation on a right course it would be useful to set measurable KPIs with respect to the FIWARE market adoption so that corrective actions can be taken on the way to better achieve this important goal. Example of these could be revenues, jobs created, or perhaps simply the survival rate of the sub-grantees as compared to the survival rate in other programmes and those outside any schemes or programmes. A tendency to have higher mortality rate of start-ups compared to general rates might be an indicator that many proposers are simply there for the survival budget itself, rather than for using it to fuel their ideas and market share in existing business landscape or because they are start-ups that would have invested that money anyway even if it didn’t come from FIWARE programme.

REFERENCES

[1] FIWARE Mundus website. https://www.fiware.org/mundus/

[2] Map of technologies and business challenges for the Future Internet: https://www.fiware.org/mundus/#roadmap

[3] Phaal, R., Farrukh, C. and Probert, D. (2001). Technology Roadmapping: linking technology resources to business objectives. Centre for Technology Management, University of Cambridge.

[4] The 5G Infrastructure Public Private Partnership. http://5g-ppp.eu/

[5] "SDN and NFV Strategies: Global Service Provider Survey". Infonetics Research. March 2014

[6] "A Survey of Software-Defined Networking: Past, Present, and Future of Programmable Networks". January 2014

[7] "The Real Cloud. Combining Cloud, NFV and Service Provider SDN". ERICSSON White Paper. February 2014

[8] "Network Functions Virtualization - Challenges and Solutions". Alcatel-Lucent White Paper. 2013

[9] ETSI NFV. http://www.etsi.org/technologies-clusters/technologies/nfv

[10] N. Wainwright et al., “Future Internet Assembly Research Roadmap”, 2011

[11] Engineering Secure Future Internet Services: A Research Manifesto and Agenda from the NESSoS Community, by NESSoS project.

[12] E. Simperl et al., “Future Internet Roadmap”, 2009

[13] S. Modafferi et al., “Initial Future Internet roadmap and proposals for sustainability”, 2012, INFINITY

[14] T. Nagellen, D. Ferrer, C. Pena, “Future Internet Technologies Roadmap for Transport and Mobility”, 2012

[15] O. Vermesan et al., “Internet of Things Strategic Research Roadmap”, 2012

[16] H. Schaffers et al., “Landscape and Roadmap of Future Internet and Smart Cities”, 2009, FIREBALL

[17] M. Hirabaru et al., “New Generation Network Architecture AKARI Conceptual Design”, 2009, NICT

[18] S. Mattoon: “Creating a Roadmap to Cloud Computing”, April 2013

[19] M. Hogan et al. “NIST Cloud Computing Standards Roadmap”, 2011.

[20] L. Schubert et al. “A Roadmap for Advanced Cloud Technologies under H2020”, 2012

[21] L. Kart, Gartner, Big Data Industry Insights, Sept 2014.

[22] Info-communications Development Authority of Singapore (IDA), "Infocomm Technology Roadmap (ITR) 2012"; http://www.ida.gov.sg/Infocomm-Landscape/Technology/Technology-Roadmap

[23] Ovum, 2014 Trends to Watch Big Data, 24 Oct 2013

[24] F. Facca et al., "Map of technology and business challenges for the Future Internet", 2015

[25] E. M. Rogers, "Diffusion of innovations", 5th edition. New York: Free Press, 2003

[26] P. Oliver et al., "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

[27] P. Prasarnphanich et al., "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

[28] M. Witt et al., "Gamification of online idea competitions: Insights from an explorative case", INFORMATIK 2011 - Informatikschafft Communities, vol. 192, 2011

[29] IDC et al., "Ex Ante Impact Assessment and Forecast" Deliverable D2.3.

[30] Ricart G., "Gigabit apps". http://www.slideshare.net/KCDigitalDrive/glenn-ricart-gigabit-apps-panel

[31] Rivera J. et al., "Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor", Gartner. http://www.gartner.com/newsroom/id/3114217

[32] Alex Ayad, "Timeline of Emerging Science and Technology", Imperial College. http://www.imperialtechforesight.com/future-visions/87/vision/timeline-of-emerging-science-and-technology.html

[33] Research and Markets, "Biopharmaceuticals – A Global Market Overview", 2013.

[34] James Ayre, "Global Cleantech Market Expected to Expand to €4 Trillion by 2020, Germany to Capitalize", CleanTechnica, 2012. http://cleantechnica.com/2012/09/17/global-cleantech-market-expected-to-expand-to-e4-trillion-by-2020s-germany-to-capitalize/

APPENDIX A - A FUTURE INTERNET ROADMAP FOR THE FIWARE ECOSYSTEM: MEDIA INTERNET

EDITORS	Fabio Antonelli *(Create-Net)*
AUTHORS	Federico Alvarez *(Universidad Politécnica de Madrid)*, Monique Calisti *(Martel Consulting)*, Federico M. Facca *(Create-Net)*, Estanislao Fernandez *(Telefonica)*, Raffaele Giaffreda *(Create-Net)*, Jose González *(Universidad Politécnica de Madrid)*, Eunah Kim *(Martel Consulting)*, Timo Lahnalampi *(Interinnov)*, Martin Potts *(Martel Consulting)*, Elio Salvadori *(Create-Net)*
EXTERNAL EXPERTS	Stuart Campbell *(Director and CEO at Information Catalyst)*, Alex Gluhak *(Lead Technologist for Internet of Things, Digital Catapult)*, Lutz Schubert *(IOMI Head of Research, University of ULM)*, Richard Lloyd Stevens *(Research Director Government Consulting)*, George Wright *(Head of Internet Research & Future Services, BBC).*

1 EXECUTIVE SUMMARY

Media Internet combines two distinct but related dimensions: on the one side, the "digital content" and all related capabilities for content creation and management, on the other side "content distribution and access", i.e. all means for delivering, accessing manipulating, sharing and experiencing content through the Internet. Future Internet technologies have the potential to strongly impact all processes involved in digital content/information creation and distribution. The Future Internet can impact and change the structure of costs needed to handle all these processes and, as such, it has the capability to enable new potential business models for the media sector. Novel devices for content creation and access, new environments for interaction and consumption of content, social media, etc. can also open new possibilities for the creation of new valuable products and services for consumers, impact and change people's habits. We can recognize and foresee part of these ongoing changes looking at the transformation that the market of digital content has experienced in recent years: convergence among traditional content delivery platforms and the Internet has already opened a new strong competition among traditional players and newcomers. Each of these players (Telcos, content providers, broadcasters, internet service providers such as Google or Facebook, device manufactures such as Samsung, Apple, etc.) are trying to take advantage of their assets by offering their technological platforms to end users and third parties to become leading platform providers around which services and application can be delivered and monetized. At the same time, SMEs have the opportunity to foster innovation capabilities offered by an "open" Internet and to become creators of innovative services and applications and individuals, playing the role of "prosumers" (thanks to social networking and social media services) become active players in the market. The Media Internet domain is therefore an evolving ecosystem where technological factors can disrupt the equilibrium among existing players.

"The Media Internet offers interesting challenges with huge take-up by end users, very high expectations from these users (QoE, QoS, reliability, uptime) alongside a heterogeneous ecosystem in Europe – bounded by geographic borders for content production and distribution, and a multi-actor environment - with a highly regulated system, hybrid (broadcast and Internet) distribution, alongside

an increasingly dominant 'OTT' (Internet Only) set of newcomers who can act in an agile way, and offer services direct to users."

George Wright, Head of Internet Research & Future Services, BBC

In this perspective, this document aims at identifying a roadmap for the evolution of Future Media Internet technologies addressing and supporting market innovation needs. The analysis starts from the description of the characteristics of the Media Internet value chain and about related levers that may support or block the creation of the ecosystem around it. It presents then a summary of current Media Internet related developments in FIWARE. The document then focuses on presenting a high level roadmap of Media Internet technologies in relation to FIWARE current developments. The document concludes with some hints, derived from the roadmap, in relation to FIWARE and the future H2020 work programmes.

2 MEDIA INTERNET VALUE CHAIN AND LEVERS

Within the European industry part of the Future Internet ecosystem, the Media Internet sector and technology are strongly depending on market and technological developments of other ICT areas such as Network, Cloud Computing and Big Data, as already highlighted in the FIWARE Mundus general white paper.

2.1 Value Chain

The Value Chain of the Media Internet builds on **5G Networks & Backend IT** and **Platform as a Service** providers to commoditize the underlying infrastructure capabilities enabling capacity and scalability of media services, integrating and leveraging on different **Platforms** to create, adapt and combine existing digital content, test, develop and deliver new services making them available for **Integration & Application development** beneficial for providers/resellers and end users.

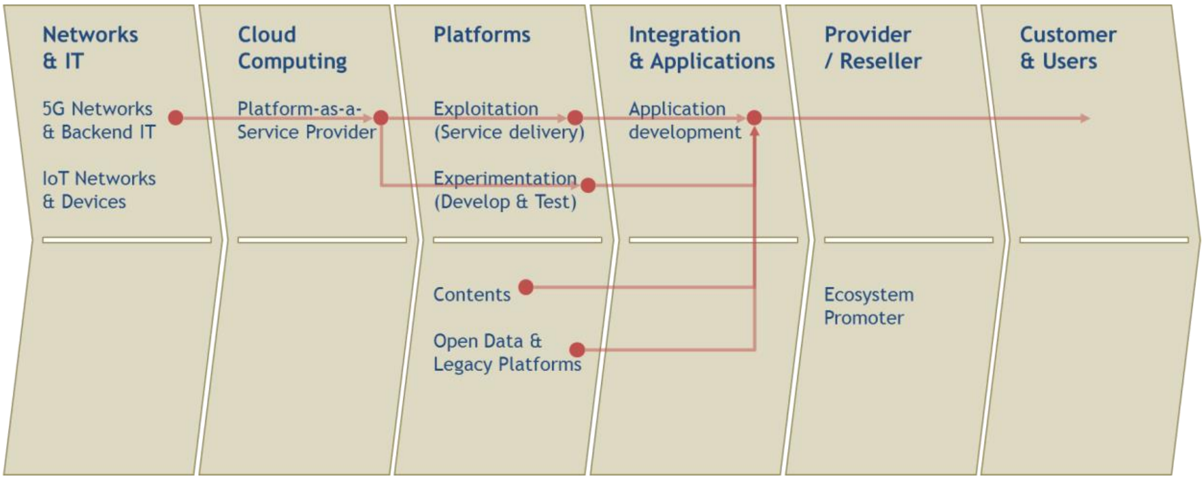

Figure: Media Internet detailed value chain

2.2 Levers

This section describes the list of elements that affect the interoperation of elements to support the creation of the Future Internet ecosystem within respect to the Media Internet market segment.

2.2.1 Standardization

The Media Internet encompasses a large number of technologies that are reflected in the plethora of standardization initiatives. The main standardization initiatives relate to: content format, encoding and transmission over CDNs, SLAs, advertising integration, and application development and marketplaces. For example, online social networks rely on FOAF[34] to describe people and relationships; computer systems use WSDL[35] to describe distributed software-based services; GoodRelations[36] is used to mainly describe products; and business-to-business systems use ebXML to describe transactions, orders, and invoices. On top of these existing standards, Linked USDL (Unified Service Description Language) describes services in a comprehensive way by providing a business or commercial description. 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.

FIWARE adopts USDL to describe applications and services offered in its application management suite.

Another relevant initiative supported by FIWARE is WebRTC: an interesting development that has a role to play in the Media Internet. WebRTC is a free, open project that provides browsers and mobile applications with Real-Time Communications (RTC) capabilities via simple APIs. The goal of WebRTC is to enable rich, high-quality RTC applications to be developed for the browser, mobile platforms, and IoT devices, and allow them all to communicate via a common set of protocols. The WebRTC initiative is a project supported by Google, Mozilla and Opera, amongst others. Even if the roadmap towards standardization of WebRTC has been only partially addressed IETF and the W3C and it is still an ongoing process, the current WebRTC support offered by most popular web browsers represents a great opportunity for innovation that has been already embraced by a large number of developers that will push to converge towards standard solutions overcoming current existing browser interoperability issues.

2.2.2 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 they apply.

[34] http://www.foaf-project.org/

[35] http://www.w3.org/TR/wsdl

[36] http://purl.org/goodrelations/v1

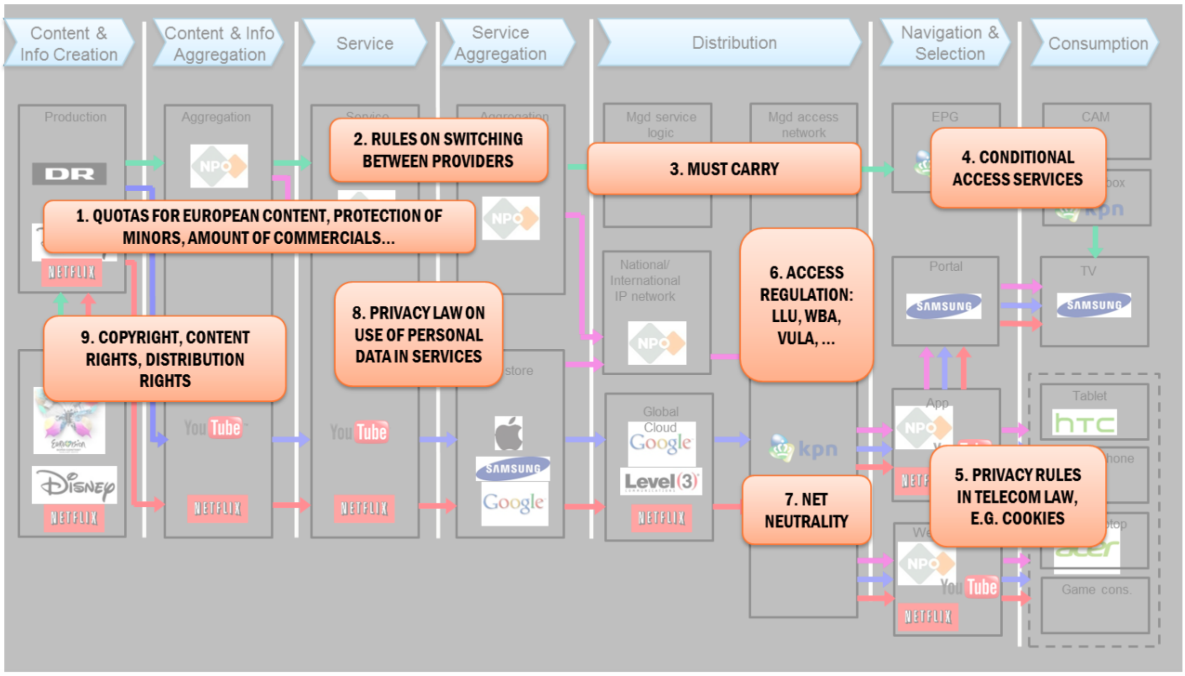

Figure: Regulations that Affect Video Services in the Converged Value WEB[37] (TNO Innovation for Life)

2.2.3 Critical Mass

The digital content market spans and covers a variety of different players and market segments creating a "digital ecosystem" that includes all actors involved in the production, consumption and exchange of content and information within a shared digital environment. The real current barrier to further market expansion is thus not the lack of critical mass, but rather the market fragmentation that prevents full interoperability and cooperation among the different players working in the whole ecosystem. The Media Internet permeates and covers the whole Internet value chain, from content production to end users, impacting and involving different key online services and related enabling technologies and all network-related infrastructures, as depicted well by A.T. Kerney in its Internet Value Chain representation.

[37] http://publications.tno.nl/publication/34611843/NhocfJ/TNO-2014-R11482.pdf

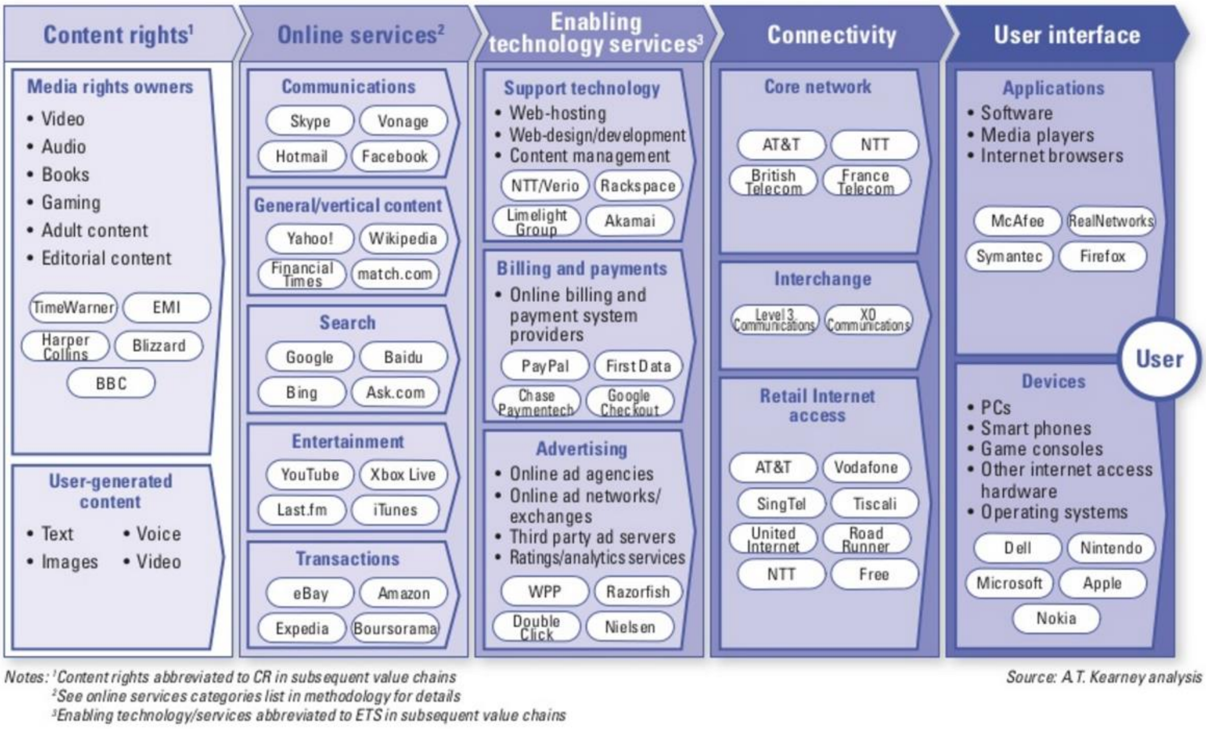

Figure: Internet Value Chain Economics38 (Source: A.T. Kearney)

2.2.4 Awareness

The Media Internet adopts Future Internet technologies 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.

2.2.5 Investment

Investment in new Media Internet 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 B2B Content Marketing Report by Spice Works[39] identifies *lead generation* (59%) as, "…. by far the number one goal of content marketing, followed by *thought leadership and market education* (43%). *Brand-awareness* (40%) is the third most mentioned goal …". *Customer acquisition* was considered as a "top-3 goal" by 28% of the survey respondents.

---

[38] https://www.atkearney.com/paper/-/asset_publisher/dVxv4Hz2h8bS/content/internet-value-chain-economics/10192

[39] http://www.spiceworks.com/marketing/b2b-content-marketing-report/

2.2.6 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 the ablest to target, repackage and programme creative content.

The new media consumption paradigms are often criticized for being non-sustainable (e.g. 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)

2.2.7 IPRs &Technology Transfer

As shown in **¡Error! No se encuentra el origen de la referencia.**, 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.

2.2.8 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).

3 FIWARE AND MEDIA INTERNET

While there is no specific chapter of FIWARE aggregating all Media Internet technologies, within FIWARE platform there are different enablers relevant for the Media Internet domain. A part of them belongs to the set of Generic Enablers while another part belongs to the set of specific enablers for the Media Internet domain developed[40] in order to support domain-specific features focusing on three application areas: social connected TV, Smart City services and pervasive games. Figure maps Media Internet related enablers on FIWARE reference architecture, highlighting their logical positioning in the current FIWARE enablers portfolio.

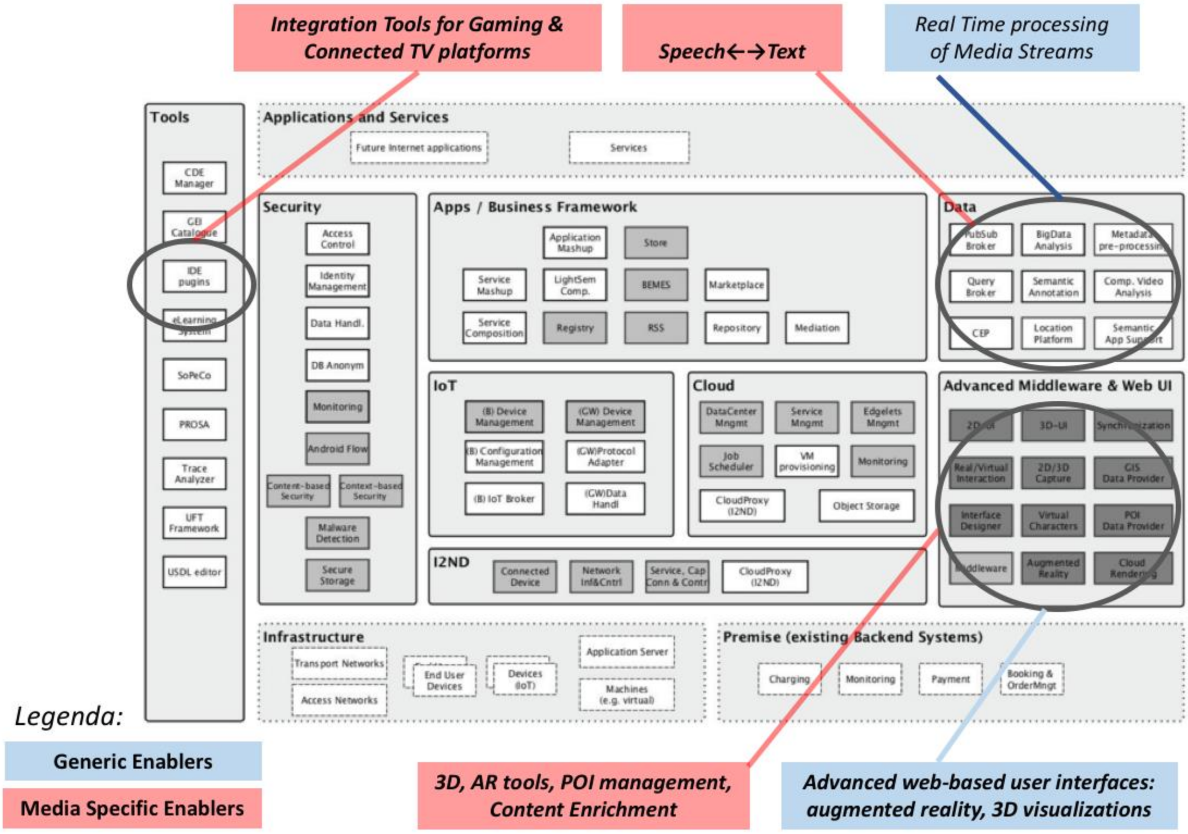

Figure. Media Internet related enablers and FIWARE

A wide set of enablers (both generic and specific) deal with *Advanced Middleware and Web User Interfaces*, others deal with media *Data* handling. In addition, specific integration enablers with gaming and Connected TV (HbbTV) platforms area available in order to support and speed-up the process of development of innovative media applications through the FIWARE platform.

Generic enablers have been made available and validated in the FIWARE Lab[41] – a live instance of the FIWARE platform, while Media Internet specific enablers have been made available and validated in the FIWARE Media & Content Lab[42].

---

[40] See FI-CONTENT FP7 project and specific enabler catalogue described at http://mediafi.org

[41] http://lab.fiware.org

[42] http://lab.mediafi.org/

4 ROADMAP FOR MEDIA INTERNET TECHNOLOGY BEYOND FIWARE

In the previous white paper on "Future Internet Challenges" [24], we presented a number of challenges that we believe to be key in the evolution of Media Internet technology.

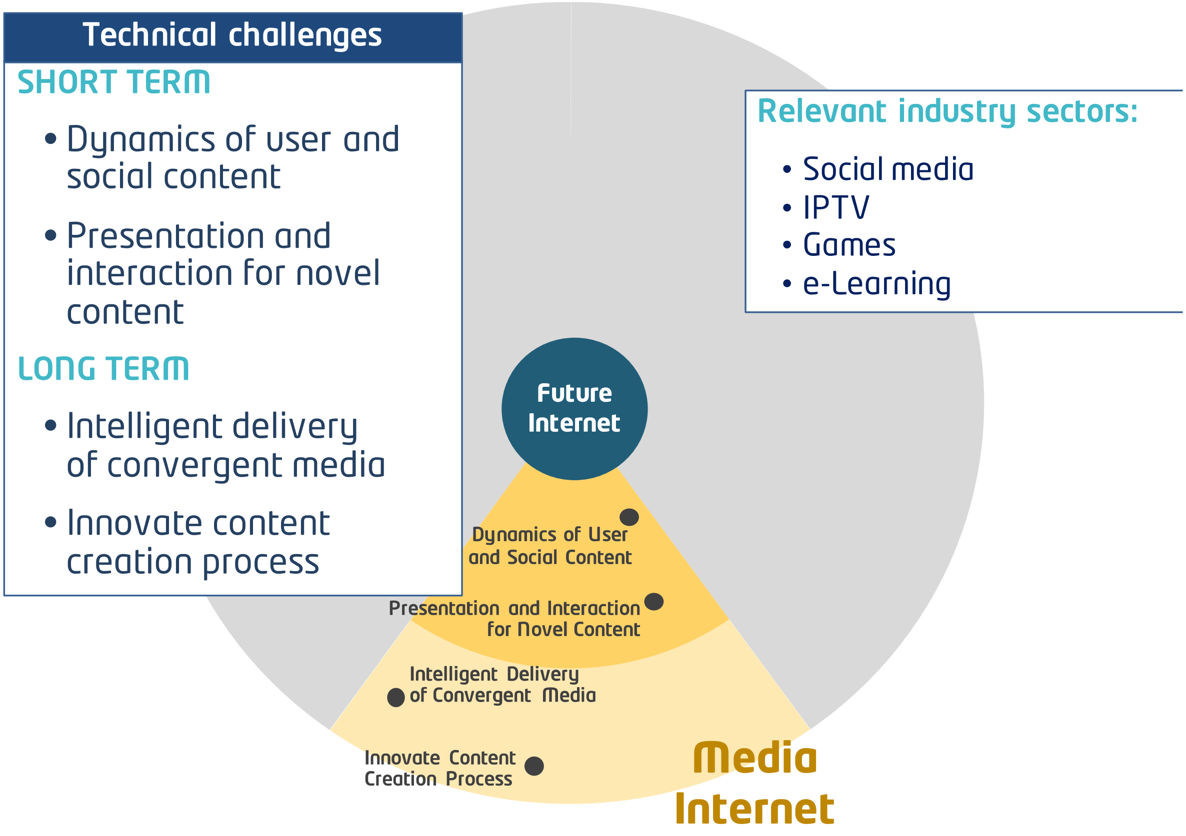

Figure. Media Internet's challenges conceptual map.

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

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

The following analysis and identification of challenges originate from the current FIWARE roadmap, in conjunction with a number of existing roadmaps produced by European initiatives ([1]), by studies from EU governmental [5] and non EU governmental organizations [3], and market insights papers [4].

4.1 From challenges to technology solutions

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

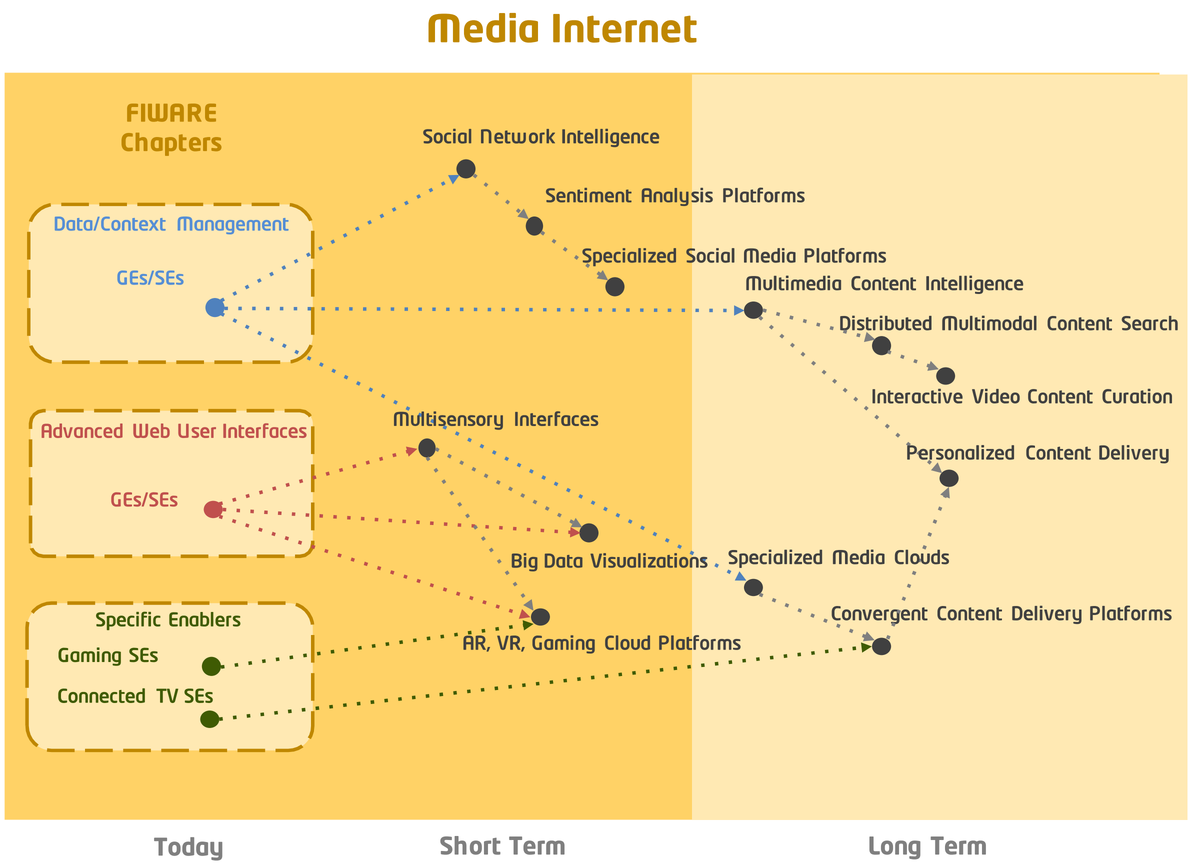

Figure. High-level Roadmap for Future Media Internet and Relations with FIWARE

Short-Term

- **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 Platforms**: 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.

- **Specialized Social Media Platforms**: 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.
- **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.

Long-Term

- **Multimedia Content Intelligence**: According to Cisco forecasts[43], "every second, nearly a million minutes of video content will cross the network by 2019". The amount of audio-visual content 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-

[43] Cisco Visual Networking Index: Forecast and Methodology, 2014–2019

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 manly 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 Communication Networks roadmap, the availability of customized context-aware networks is a prerequisite to tailor content delivery to the user context.
- **Specialized Media Clouds**: the continuous grow 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.
- **Convergent Content Delivery Platforms**: the strong competition existing on the market among different players (broadcasters, telcos, TV manufacturers and OTT players) has leaded 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 be 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.

4.2 FIWARE evolution in the context of the wider Media Internet ecosystem

Current FIWARE architecture and roadmap focus has been the setup and creation of a core platform of the Future Internet that includes generic enablers having specific added-value for the creation of media-related application, and a meaningful set of domain-specific enablers addressing requirements for specific domains part of the Creative Industries sector (specifically: connected TV, Smart City services and pervasive games).

In a short term perspective for FIWARE evolution in the context of the Media Internet domain, two main additional directions should be addressed in order to facilitate the take-up of innovative and added value services within the FIWARE ecosystem:

- on one side, a stronger integration of existing immersive technologies (devices, platforms as described in the *Integrated Multisensory Interfaces* topic) for augmented reality, virtual reality and gaming will enhance user experience and offer more intuitive ways to interact with content (new enablers and integration of *Augmented, Virtual Reality and Gaming Platforms*);
- on the other side, a smarter social media and *Social Network Intelligence* will allow to design, build and structure new and more profitable relationships among companies and their target audiences.

In a longer term perspective, technologies that allow to gain a deeper knowledge, a more fine-grained and real time description of the massively growing amount of content that is generated daily and stored in dispersed digital archives in the web (*Multimedia Content Intelligence*) will allow the creation of novel processes for content creation and curation. This will allow also the realization of tools and solutions addressing the delivery of content in a more personalized way according to user's needs (*personalized and content-aware delivery*), and a wider reuse of high quality and more valuable content.

At the same time, evolution of FIWARE infrastructure on other technical chapters will be beneficial to Media Internet scalability at delivery level (networks and edge clouds), at processing level (specialized media clouds) and at content level (big data analysis for media content), allowing the creation of smarter, more effective and more efficient platforms for a convergent and ubiquitous delivery of audio-visual and social media services.

5 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK PROGRAMMES

The roadmap presented in the previous section proposes some promising future directions that technological evolution of FIWARE should address in order to ensure a proper evolution of the Future Internet ecosystem.

In the current H2020 work programme, the Future Media Internet (FMI) is addressed in 3 main initiatives:

- ICT13-2016 (Future Internet Experimentation) calls for large-scale experimentation on FMI services fully integrated with broadcasting, with a focus on high mobility scenarios and its impact on communication and storage infrastructures;
- ICT19-2017 (Media and content convergence) calls for Innovation Actions in topics such as immersive environments, advanced personal audio-visual services, augmented reality, content aggregation, media sharing and recommendation, etc.
- ICT-20-2017 (Tools for smart digital content in the creative industries) calls for the creation of tools maximizing the potential for re-use and re-purposing of all types of digital content of

digital content and offering novel ways to produce and manage content in different creative industries domains.

Current work program objectives aim at strengthening Europe's Media Sector technological positioning and at enlarging technology adoption to new audiences in the creative sector in order to face more effectively competition coming from global players, stimulating the creation of new business models and fostering the creation of a European Digital Single Market. Current H2020 work programme already focuses on most of the technologies mentioned in this document and future work programmes should continue on this path addressing, supporting and fostering the integration, development and validation of all the above mentioned technological solutions in order to offer put in the hands of digital market players tools and technologies capable to speed-up and simplify the creation of media applications, enhancing the quality of produced content and capable to enable new user experiences. In particular, a more integrated approach for the creation, provisioning and delivery of new technologies for the Media sector should be addressed in any case: this may foster the delivery of these technologies in a more scalable and accessible way (through cloud scalability and service "API-fication"), the possibility to leverage more effectively on big data capabilities to gain a better understanding and knowledge of content structure enabling new potential ways for content reuse and monetization; leveraging also on future network evolutions (especially in the mobile domain) a more effective ubiquitous media service convergence and delivery will be possible. The availability of current open infrastructure offered by FIWARE represents a relevant asset to evolve towards this direction.

At the same time, future work programme should focus on strengthening the collaboration among research and business domains supporting the creation of a meaningful ecosystem of actors coming from different sectors of the Creative Industries capable to collaborate and validate the usage of the provided Future Internet open platform and technologies in industrially relevant contexts and environments, driving real adoption of the provided solutions by the market.

6 REFERENCES

[1] Future Media Internet Research Challenges and the Road Ahead, Future Media Internet-Task Force – Whitepaper from NextMedia, Apr 2010.

[2] Position Paper on Future Research Directions - Opportunities for an Innovative Europe, NEM Sept 2011.

[3] Info-communications Development Authority of Singapore (IDA), "Infocomm Technology Roadmap (ITR) 2012"; http://www.ida.gov.sg/Infocomm-Landscape/Technology/Technology-Roadmap

[4] Internet Value Chain Economics, Gaining a deeper understanding of the Internet economy, A.T. Kearney, paper;

[5] La catena del valore e i modelli di business dell'ecosistema digitale; SCREEN Research

APPENDIX B - A FUTURE INTERNET ROADMAP FOR THE FIWARE ECOSYSTEM: INTERNET OF THINGS

EDITORS	Raffaele Giaffreda *(Create-Net)*
AUTHORS	Federico M. Facca *(Create-Net)*, Federico Alvarez *(Universidad Politécnica de Madrid)*, Fabio Antonelli *(Create-Net)*, Monique Calisti *(Martel Consulting)*, Estanislao Fernandez *(Telefonica)*, Raffaele Giaffreda *(Create-Net)*, Jose González *(Universidad Politécnica de Madrid)*, Eunah Kim *(Martel Consulting)*, Timo Lahnalampi *(Interinnov)*, Martin Potts *(Martel Consulting)*, Elio Salvadori *(Create-Net)*
EXTERNAL EXPERTS	Stuart Campbell *(Director and CEO at Information Catalyst)*, Alex Gluhak *(Lead Technologist for Internet of Things, Digital Catapult)*, Lutz Schubert *(IOMI Head of Research, University of ULM)*, Richard Lloyd Stevens *(Research Director Government Consulting)*, George Wright *(Head of Internet Research & Future Services, BBC).*

1 EXECUTIVE SUMMARY

According to the IEEE definition [1], "*Internet of Things envisions a self-configuring, adaptive, complex network that interconnects 'things' to the Internet through the use of standard communication protocols. The interconnected things have physical or virtual representation in the digital world, sensing/actuation capability, a programmability feature and are uniquely identifiable. The things offer services, with or without human intervention, through the exploitation of unique identification, data capture and communication, and actuation capability. The service is exploited through the use of intelligent interfaces and is made available anywhere, anytime, and for anything taking security into consideration.*"

This comprehensive definition leads to the consideration that the Internet of Things and the Future Internet will be part of the same ecosystem, with the former heavily relying on infrastructure enablers and technological advances being achieved in the latter. This intertwined evolution will be instrumental to fulfil the predictions about future IoT applications where billions of connected devices will have a tangible impact on our society in the domains of health, utilities, transportation, logistics etc.

"the Internet of Things (IoT) has finally left the research labs to enter the main stage of today's technology world. It is now at the heart of the next technology revolution that will shake up all industries in the decades to come"

Dr. Alex Gluhak, Lead Technologist (Internet of Things), Digital Catapult UK

The Internet of Things will exploit the Future Internet lower level enablers, becoming eventually an integral part of its ecosystem. FIWARE supports this vision by making the Internet of Things one of the central chapters in its architecture. The FIWARE Internet of Things chapter provides "cloudified" enablers to support the management of devices and integrates them into the Data Management chapter and the Application and Service Delivery chapter.

This paper briefly introduces the value chain associated with the Internet of Things and related levers (e.g. regulations, standards, …) that may support or block the success and uptake of this technology and associated applications. This general discussion is followed by a summary of current IoT related development in FIWARE. The document then focuses on presenting a high level roadmap of IoT technologies in relation to FIWARE current developments. The roadmap moves on from the 3 keys challenges identified in the FIWARE white paper: "Map of technology and business challenges for the Future Internet" [24]. The document concludes with some hints, derived from the roadmap, in relation to FIWARE and the future H2020 work programmes.

2 INTERNET OF THINGS VALUE CHAIN AND LEVERS

The Internet of Things, with its unprecedented wide-scale and distributed sensing capabilities underpins practically all visions about how our lives will look in the future. In order to make it become a reality, it is important to assess what its value chain looks like and how the various stakeholders are related.

2.1 Value Chain

The figure below illustrates the various IoT Value Chain stakeholders on the whole delivery path between data sources and IoT application users.

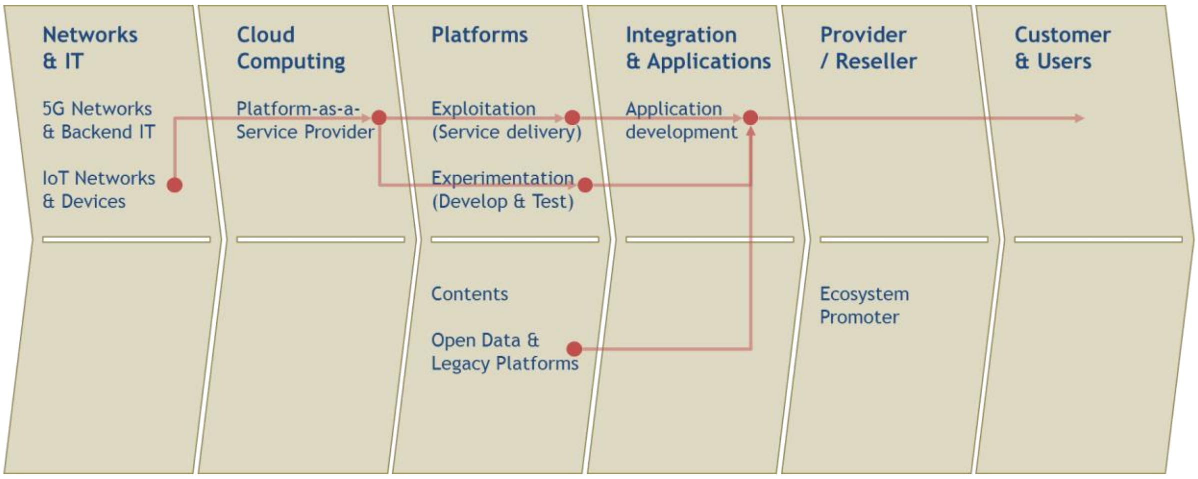

Figure: IoT detailed value chain

While devices and connectivity can be viewed as commodities with consequently low value appropriation, applications, platforms and services are the places where the value lies. That is where the 'brain' that transforms data into knowledge resides, as opposed to the connected limbs and veins that represent devices and connectivity. Value clearly increases as we move to the right side of the picture below.

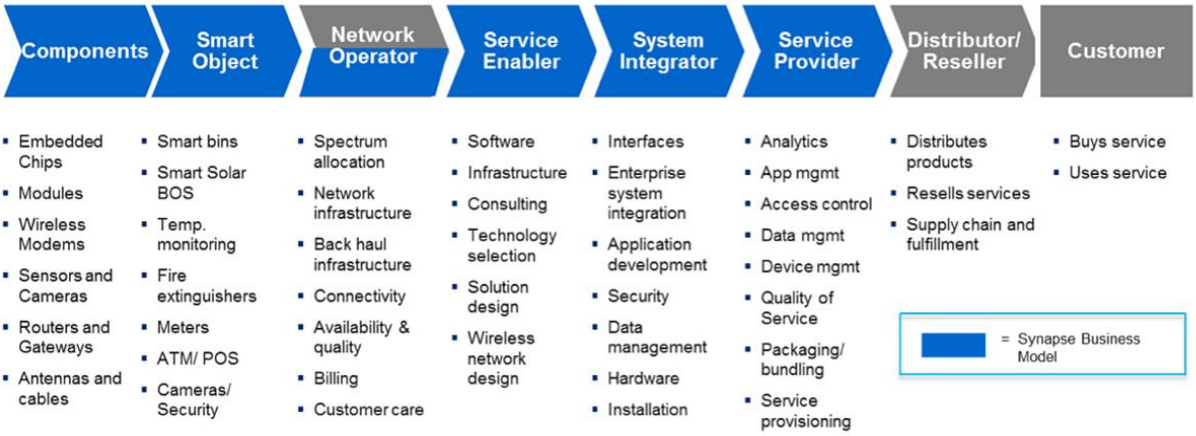

Figure: IoT value chain by Synapse Wireless Inc.

2.2 Levers

2.2.1 Standardisation

There are several standardisation initiatives which underpin the monetisation potential within each of the illustrated layers in the value chain. On the lower "device-level" there are initiatives dealing with low-energy protocols for communication with the devices, for managing these and ensuring sensed data can be extracted and sent across to remote applications. At a higher abstraction level there are initiatives pursuing a "thing-level" standard, which are more concerned with how the sensed data is structured, including semantic descriptions, application specific data models, etc.

While there are tens of standardisation activities in IoT, the most relevant ones for the FI-PPP vision are:

- ETSI 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

Standardisation is also important for value to be extracted at the system integration level; large and generic deployments need open platforms based on standards. In any case, it has to be kept in mind that this is a highly crowded context, where the landscape may change quickly following the emergence of de-facto standards fostered by market use and adoption rather than technology / industry pushed initiatives.

2.2.2 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 Low-Power, Wide-Area (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.

2.2.3 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 sufficiently cost-effective to gain wide acceptance. The challenge for the embedded-devices 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 [2], the value of a network is equal to the square of the number of devices connected to it.

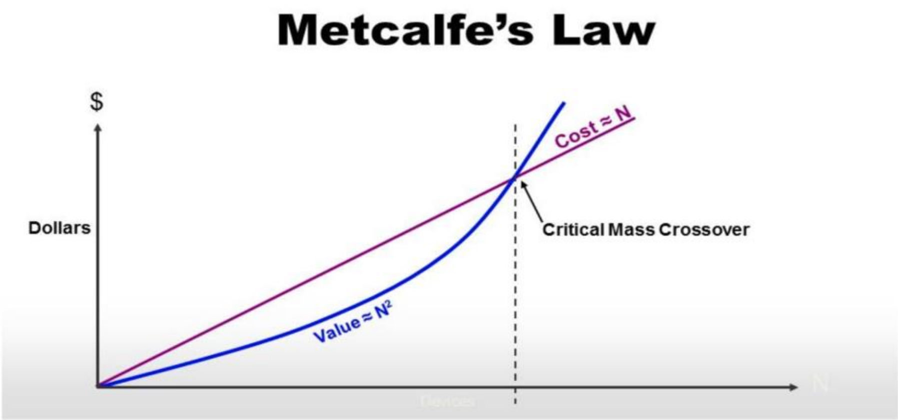

Figure: "The Value of a Network is Equal to the Square of the Number of Devices Connected to It"

One of the largest deployments of IoT technologies already launched is indeed related to the 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, started in 2014, the French company Sigfox will deploy more than 4,000 base stations connecting 30 cities in the United States, and effectively making it the largest IoT deployment.

2.2.4 Awareness

European Future Internet initiatives about the Internet of Things are particularly well-known throughout the EU and beyond by 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 annual *IoT Week* event, the IoT Expo, IoT World, and other private initiatives are representative examples of these awareness-creating actions.

2.2.5 Investment

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

The plan approved at the end of the last year by Jean-Claude Junker, President of the European Commission, 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.

This is not enough: as said in the last EIB conference, Europe needs to mobilise 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 largest investment comes from municipalities modernising to Smart Cities. From the private perspective, a few Smart Industry deployments still outnumber the many long-tail opportunities.

2.2.6 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, nonetheless, such efforts need to be further refined to ensure that solutions are future-proof.

Traffic tariffs are another parameter in the sustainability equation. The networks over which particular IoT data will be carried will have to be selected according to issues such as access location, bandwidth, latency, reliability, privacy and security. The subsequent choices will have an impact on the cost of transporting the data.

2.2.7 IPRs &Technology Transfer

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

2.2.8 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.

IoT enjoys a prominent focus in the Horizon2020 work programme 2016-17 with particular focus on interoperability solutions and on the IoT ecosystem that future solutions will enable and sustain.

3 FIWARE AND INTERNET OF THINGS

IoT is a central element in the FIWARE platform that provides a set of Internet of Things micro services based on the OMA NGSI Context Management standard [1]. Additional related services are covered in different FIWARE related projects (e.g. FI-Space[44], FITMAN[45]) where a number of vertical IoT-based PaaS have been developed.

FIWARE IoT chapters consists of two main service typologies, one providing the *backend functionality* (IoT Backend in Figure) and one providing the *gateway functionality* (IoT Edge in Figure).

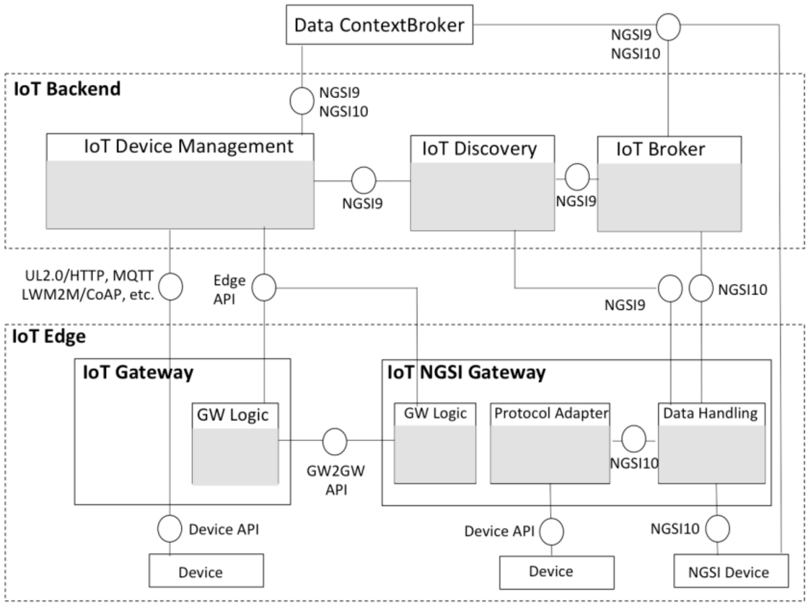

Figure: FIWARE IoT Services Enablement architecture

- **IoT Backend.** As far as IoT Backend functionality is concerned, the three envisaged building blocks all have relevance to the two main challenges identified for IoT in the aforementioned white paper: "Map of technology and business challenges for the Future Internet [24] that identifies the challenges of dealing 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. *IoT discovery* is poised to play a central role within the broader context of ensuring scalable registration and discovery of IoT services in general can be achieved. Both *IoT Broker* and *Data Context Broker* are instead mostly related to being able to execute intelligent reasoning over IoT data and produce knowledge.
- **IoT Edge.** The *IoT Edge* part is mostly designed to deal with the functions envisaged to address interoperability, heterogeneity of devices as well as *data handling* and *protocol*

[44] http://fispace.eu

[45] http://www.fitman-fi.eu

adaptation. This is poised to also play an important role as technology for virtualising objects and more in general, IoT services.

4 ROADMAP FOR INTERNET OF THINGS BEYOND FIWARE

In the white paper on "Future Internet Challenges" [24], we presented a number of challenges that we believe to be key in the evolution of IoT technology.

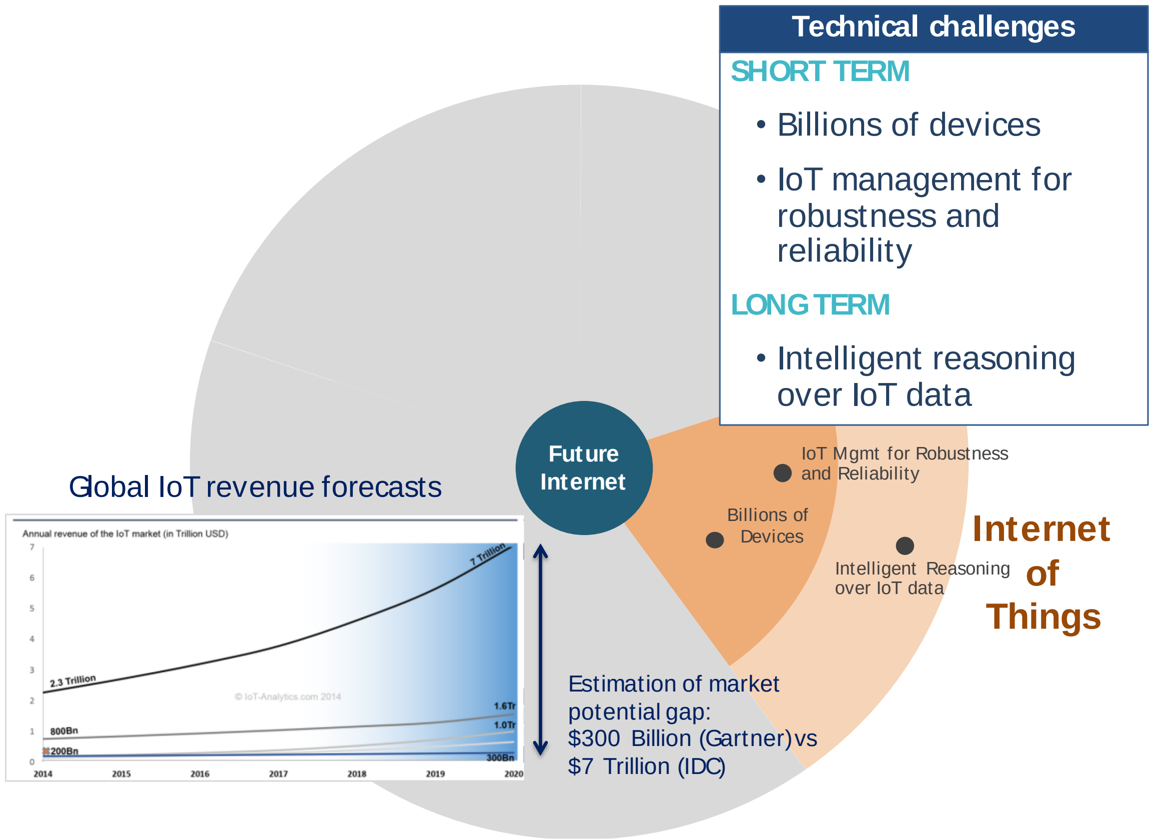

Figure: IoT's challenges conceptual map.

The three major challenges in the field of IoT are presented in Figure, and summarised as follows:

- **Billions of devices** (short-medium term): the sheer scale of connected devices and the type of traffic these generate (compared to humans' devices) will have substantial implications on the current Internet as we know it today.
- **IoT Management for Robustness and Reliability** (short-medium term): This second macro-challenge is concerned with supporting reliability and dependability of services that rely on IoT data.
- **Intelligent reasoning over IoT data** (medium-long term): This challenge relates to the availability of general purpose machine-learning based solutions that can be re-used to address the wide variety of situations in which similar IoT services and applications could be applied.

In this white paper we present a roadmap that, taking into account existing development in the FIWARE roadmap, provides highlights on the evolution of IoT technologies that will address the above highlighted challenges.

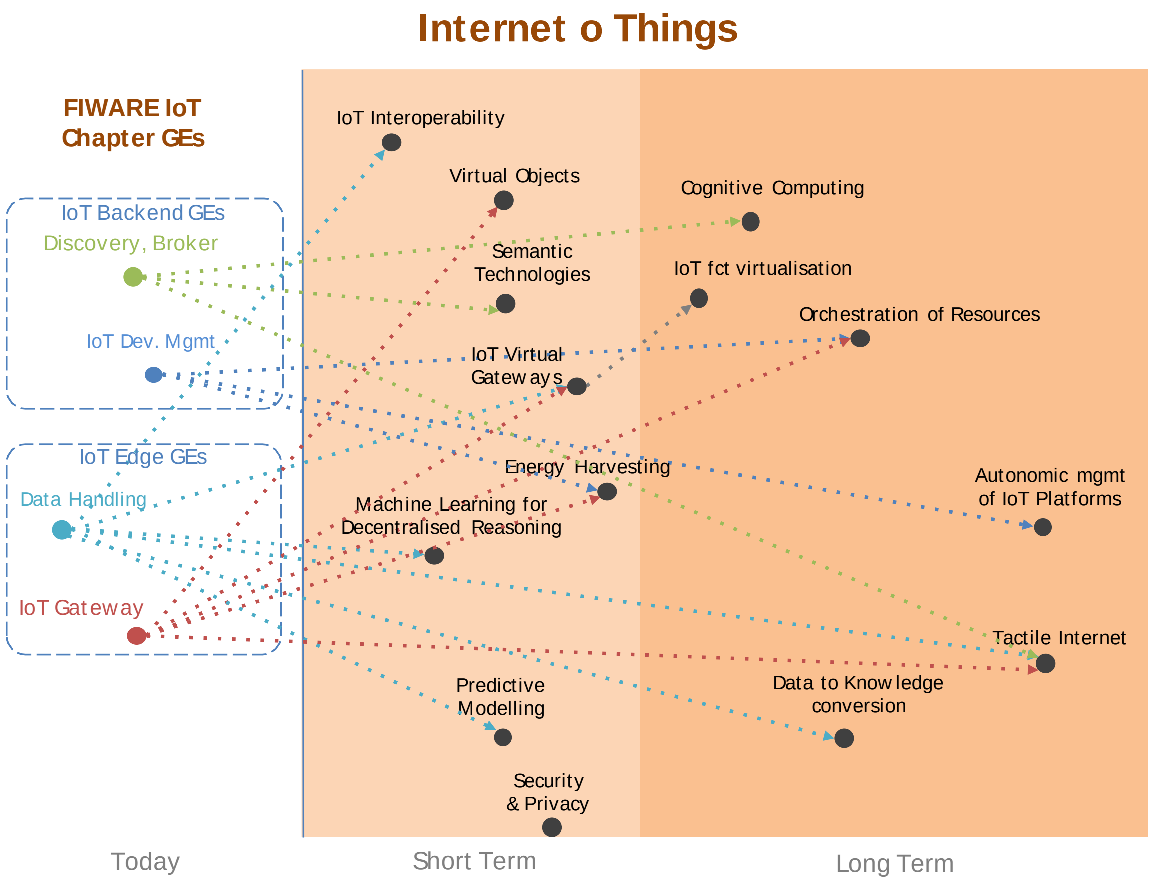

Figure. High-level Roadmap for IoT and Relations with FIWARE.

The challenges proposed originate from the analysis of FIWARE and a number of existing roadmaps, including the ones envisaged through the yearly publications of the IERC, the cluster of IoT European collaborative projects.

4.1 From challenges to technology solutions

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.

Short-term

- **IoT Interoperability**. Besides the common aspects of underlying technologies that have enabled short-range connectivity and the miniaturisation of devices that have paved the way towards the success of IoT, current applications have been evolving as a collection of vertical silos often deployed with different standards. To fully unlock the potential of having billions of connected objects, cross-use of data across application domains will be needed. Solutions that foster interoperability and reduce barriers between application silos will therefore have a strong role to play.

- **Virtual objects**. Following on the need to foster interoperability, virtualisation of objects will also be needed to separate real and resource-constrained objects from their virtual counterparts in order to minimising energy consumption, facilitate interaction with applications as well as address the challenges of scalability and those of empowering single objects with flexible added resources from the "wired and resource intensive world".
- **Semantic technologies.** As more and more data gets collected through IoT devices, to ensure a more automated selection of the appropriate end devices to be associated with IoT services and applications, IoT data will have to be modelled according to given structures and properly annotated. Semantics help in this respect; so this challenge is part of the broader data interoperability problem though it encompasses besides "finding" the right data also the ability of fostering automated translation between data structures in different ontology domains
- **IoT Virtual Gateways**. This challenge is about implementing software-defined functionality in virtual gateways, such as the ability of processing data close to the place where it is generated or on its way to the requesting application, in order to avoid unnecessary use of network resources, as well as reduce the amount of data that has to be processed for analytics purposes. It includes challenges like data aggregation, stream processing, CEP, etc.
- **Energy harvesting.** To ensure long duration and usefulness of connected objects, given also the limitations of battery evolution compared to processing power and spectrum efficiency, it will be essential to design hardware and systems that can operate for long time without need for battery replacement / recharging. Integration of energy harvesting techniques also falls in this category.
- **Machine learning for decentralised reasoning.** As IoT functionality gets virtualised and distributed, there will also be a need to coordinate decision-making and achieve conflict resolution for the actuators that are involved in achieving a common goal.
- **Distributed / decentralised reasoning and data to knowledge conversion.** While the previous challenge is about why we should decentralise reasoning, at least with IoT generated data, this challenge is about how this has to be achieved. With IoT set to become the underlying monitoring fabric of future smart-x applications and with trends suggesting we will soon have more devices than we can dedicate attention to, getting data across to applications will have to be better managed on the end-to-end delivery path, introducing new ways for distributed data interpretation which accounts for the locality of data, the need to compress it to meet application requirements (i.e. latency, quality, etc.) and network capacity.
- **Security and privacy.** This is a cross-cutting issue as it relates not only to the security of radio communications, but also to the security of IoT-generated data to ensure good levels of trust and privacy. On this front, not only solutions that address these issues are needed, but also solutions that - at a management level - can detect attacks and contain them.

Long-term

- **Cognitive Computing and Data to Knowledge conversion**. widespread availability of monitoring data will require good and general purpose algorithms for interpretation and data to knowledge transformation.
- **IoT function virtualisation.** The IoT functionality is currently solely supported by ad-hoc hardware (i.e. communication of sensed-data, domain/sensor specific gateways, etc.). IoT function virtualisation will open-up new opportunities where hardware ownership will not be necessarily a requirement for producing IoT services.
- **Orchestration of resources.** This challenge relates to the ability of assessing dependencies between sensing, networking and computing resources and how these components contribute

to the Quality of Experience (QoE) and reliability of the end-to-end application being supported. Issue of dependability becomes important if one has to leverage on the advantages of the IoT also within mission-critical systems and / or simply more dependable services.

- **Autonomic management of IoT platforms.** The rapidly increasing number of connected objects will not be met by a similarly progress in human's ability to set them up, configure them, manage them etc. this element of the roadmap relates to the need of solutions that will ensure devices can be fully operational with simple and little involvement of the users, if need be.

- **Tactile Internet.** This challenge relates to the IoT evolving towards becoming able to support very low-latency reasoning loops for "Tactile Internet" applications. This involves the ability to instantiate data processing instances dynamically and close to data sources, besides addressing redesign of communication protocols for speed.

4.2 FIWARE evolution in the context of the wider Internet of things Ecosystem

Tackling all the technological evolutions described in the previous section is beyond FIWARE scope. Nevertheless, there are a number of short term evolutions from current FIWARE IoT Generic Enablers that are key to commoditise FIWARE services. These include:

- Providing the means to describe objects with associated metadata that can be used not only in the search and discovery of these objects as we scale up and move away from manual configurations, but also in ensuring data content can properly be parsed by the retrieving applications. This relates to the *Virtualisation of objects* and *Semantic modelling*.

- Leveraging on edge cloud advances for executing / moving as appropriate algorithms for data processing close to the source or away from it. This relates to *Machine learning for decentralised reasoning*.

- Ensuring security and privacy of the sensed data can be guaranteed by having proper protection at data transmission level as well as regulation compliant storage procedures. This relates to *Security and Privacy*

- Multi-protocol interfacing: it is unthinkable that the plethora of existing wireless / wired communication standards and heterogeneous devices will eventually merge into a single standard. FIWARE IoT Generic Enablers (GEs) should evolve towards supporting those communication interfaces that will indeed become used by the growing community of IoT makers (notably IETF-based ones). This relates to *IoT Interoperability*.

5 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK PROGRAMMES

The roadmap presented in the previous section proposes a few indications for the path that the current development of FIWARE technology should follow to ensure a proper evolution of the Future Internet ecosystem.

FIWARE driven innovation, as evidenced, needs to focus on short term technologies that will improve the adoption of IoT services in the market. These relate in a nutshell to addressing the interoperability, security and complexity problems associated with a growing number of heterogeneous connected objects.

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 as this enables the "scaling-up" everyone keeps talking about without the involvement of humans in the loop. One such Call for Proposals is announced in the 2016-17 work programme: ICT-03-2017: “R&I on IoT integration and platforms”.

Substantial progress on large-scale and interoperable solutions is expected to be realised with the 2016-17 work-programme execution, through 5 specific so-called “Large Scale Pilots” (IoT-01-2016) for:

- Smart living environments for ageing well
- Smart farming and Food Security
- Wearables for smart ecosystems
- Reference zones in EU cities
- Autonomous vehicles in a connected environment

These are “Innovation Actions” expected to use existing technologies as a stepping stone to address many of the short-term challenges identified earlier.

Lastly, the problem of end-user confidence and the issue of trust towards the perceived invasive nature of IoT will also attract a lot of attention. Beyond the 2016-17 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.

6 REFERENCES

[1] Towards a definition of the Internet of Things http://iot.ieee.org/definition.html

[2] B. Metcalfe, “Metcalfe's law after 40 years of Ethernet”, Computer, 46(12), 26-31, 2013

[3] Mobile Alliance, “NGSI Context Management”, 2012.

[4] F. Facca et al. “Map of technology and business challenges for the Future Internet”, 2015

[5] O. Vermesan and P. Friess, “Internet of Things – From Research and Innovation to Market Deployment”, 2014.

APPENDIX C - A FUTURE INTERNET ROADMAP FOR THE FIWARE ECOSYSTEM: BIG DATA

EDITORS	Estanislao Fernandez *(Telefonica)*
AUTHORS	Federico Alvarez *(Universidad Politécnica de Madrid)*, Fabio Antonelli *(Create-Net)*, Monique Calisti *(Martel Consulting)*, Federico M. Facca *(Create-Net)*, Raffaele Giaffreda *(Create-Net)*, Jose González *(Universidad Politécnica de Madrid)*, Eunah Kim *(Martel Consulting)*, Timo Lahnalampi *(Interinnov)*, Martin Potts *(Martel Consulting)*, Elio Salvadori *(Create-Net)*
EXTERNAL EXPERTS	Stuart Campbell *(Director and CEO at Information Catalyst)*, Alex Gluhak *(Lead Technologist for Internet of Things, Digital Catapult)*, Lutz Schubert *(IOMI Head of Research, University of ULM)*, Richard Lloyd Stevens *(Research Director Government Consulting)*, George Wright *(Head of Internet Research & Future Services, BBC).*

1 EXECUTIVE SUMMARY

There seems to be a consensus in the specialized media as well as in the reports from the most prestigious analysts' agencies on the fact that Big Data has reached, as of 2014, the "Peak of Inflated Expectations" according to Gartner's Hype Cycle.

At that point investment in Big Data was heavily increasing in different industries. According to Gartner [21] the industries that have most actively invested in Big Data so far (around half of the respondents' companies) are Communications/Media, Healthcare and Transportation. In addition, companies from Insurance and Utilities industries had even 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 still in the experimental phase, 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.

Big Data is covered in the FIWARE chapter called Data/Context and is central to the FIWARE architecture providing means to all the other FIWARE chapters (e.g. Internet of Things and application and service delivery framework) to manipulate data within the cloud.

"Mastering the generation of Value from Big Data will create a significant competitive advantage for European industry, creating economic growth and jobs"

Stuart Campbell, Director and CEO Information Catalyst

Big Data, in its wider acceptation covering novel technology beyond relation databases, is a key enabler in the creation of a Future Internet ecosystem. This document discusses the characteristic value chain of Big Data and about those related levers (e.g. regulations and standards) that may support or block the creation of the ecosystem. This general discussion is followed by a summary of current Big

Data related development in FIWARE. The document then focuses on presenting a high level roadmap of Big Data technologies in relation to FIWARE current developments. The roadmap moves on from the 4 keys challenges identified in the previous white paper: "Data Privacy and User Control, Real Time, Cloud-based Solutions and Expanding the Range of Data Sources". The document concludes with some hints, derived from the roadmap, in relation to FIWARE and the future H2020 work programmes

2 BIG DATA VALUE CHAIN AND LEVERS

It is clear that Big Data technologies have a great potential to generate valuable insights for 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.

2.1 Value Chain

The term Big Data covers a wide range of actors in the Future Internet value chain: from the providers of the technology that allows data to be discovered, extracted, transferred and loaded into the platform, to the technology used to analyse and visualize data, and to the context-specific applications used to derive conclusions or make decisions based on Big Data-enabled reasoning. Therefore the value chain could cover almost entirely the complete Future Internet technologies. However, with network technologies being increasingly commoditized below cloud computing standards, the most relevant actors in the Big Data value chain are highlighted with a red dot in in the chart below:

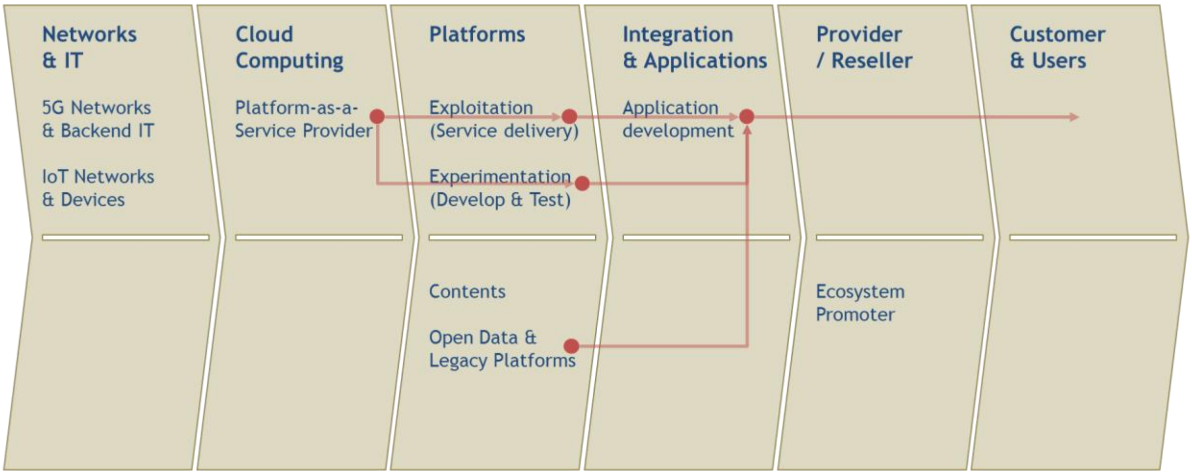

Figure: Big Data detailed value chain

From an activity - rather than technological - standpoint, the value chain introduced by Miller & Mork [2] can be found below:

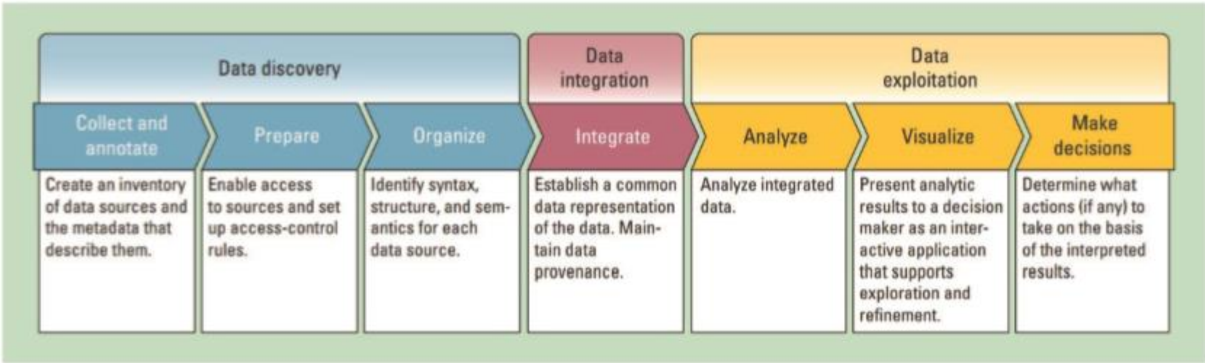

Figure: Big Data value chain (Miller and Mork, 2013)

2.2 Levers

2.2.1 Standardization

There are two layers of standardization activities applicable to Big Data: on a lower layer, standardization about the structure and contents of the data that is to be extracted and loaded (including multimedia standards, such as WebRTC) and, on a higher layer, standards about the syntax and semantics of the data that is stored and analysed (including OWL and RDF).

2.2.2 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.

2.2.3 Critical Mass

The latest statistics show 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. 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. Furthermore, 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.

2.2.4 Awareness

Actions raising awareness should be handled carefully. On the 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.

2.2.5 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.

2.2.6 Sustainable Business Models

Applications with a 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 on public administration data sources and platforms and aim at providing value to cities and citizens.

2.2.7 IPRs &Technology Transfer

Many companies now fight in 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.).

2.2.8 Research & Innovation

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

3 FIWARE AND BIG DATA

Data management technologies are a core ingredient of FIWARE architecture. The FIWARE platform provides a series of services that provide data and context management functionalities in support of development of advanced applications.

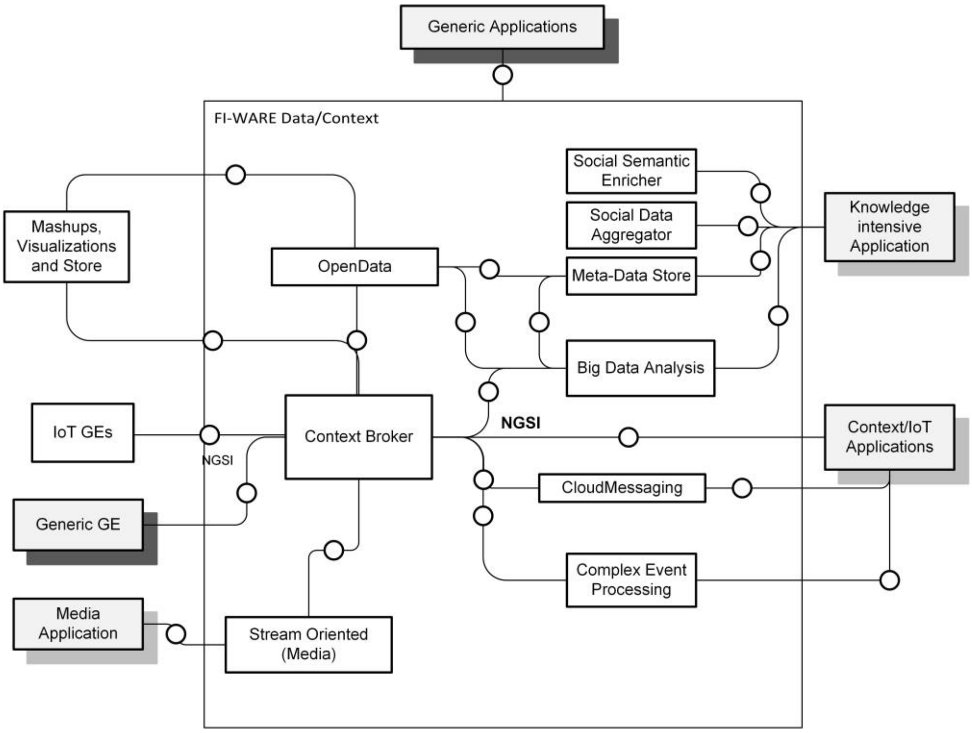

Figure. FIWARE Data/Context Chapter Architecture

The main Big Data functionalities are provided by:

- **Big Data Analysis – Cosmos**. Cosmos allows the deployment of private computing clusters based on Hadoop ecosystem and support OMA NGSI [10] standard for communication with other Data/Context Management Generic Enablers (GEs).
- **Open Data – CKAN:** FIWARE enhanced CKAN to support better interoperability with the rest of the FIWARE GEs based on NGSI.

Other FIWARE Generic Enablers providing Data/Context Management functionality include:

- **Context Broker – Orion**: allows publishing context information by the context producers and makes it available to context consumers using NGSI. It can work following two different models: request-response (pull) or subscription-notification (push).
- **Complex Event Processing – Proton:** The Complex Event Processing GE analyses event data in real-time, generates immediate insight and enables instant response to changing conditions.
- **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 GE is the Open API.

4 ROADMAP FOR BIG DATA TECHNOLOGY BEYOND FIWARE

We expect that in the next years, the following main challenges will need to be tackled in the Big Data area (cf. [24]):

- **Data Privacy and User Control** (short-term): In spite of Big Data's potential for enterprises it is a source of distrust for many individuals and organizations. Measures are being taken by regulators, e.g. EU directive on cookies, but users demand greater control on the information they consciously or unconsciously generate.
- **Real Time** (short-term): with which we refer to producing insights shortly after the data is received and allowing the target of the insights to react promptly meaningfully and profitably for the business.
- **Cloud-based Solutions** (short-term): enabling companies to quickly benefit from Big Data solutions without high upfront investment and without the need of highly specialized staff. Especially useful for SMEs or large companies wanting to test before investing.
- **Expanding the Range of Data Sources** (long-term): Currently most 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. However other types of contents are rather un-explored, for instance video and audio content.

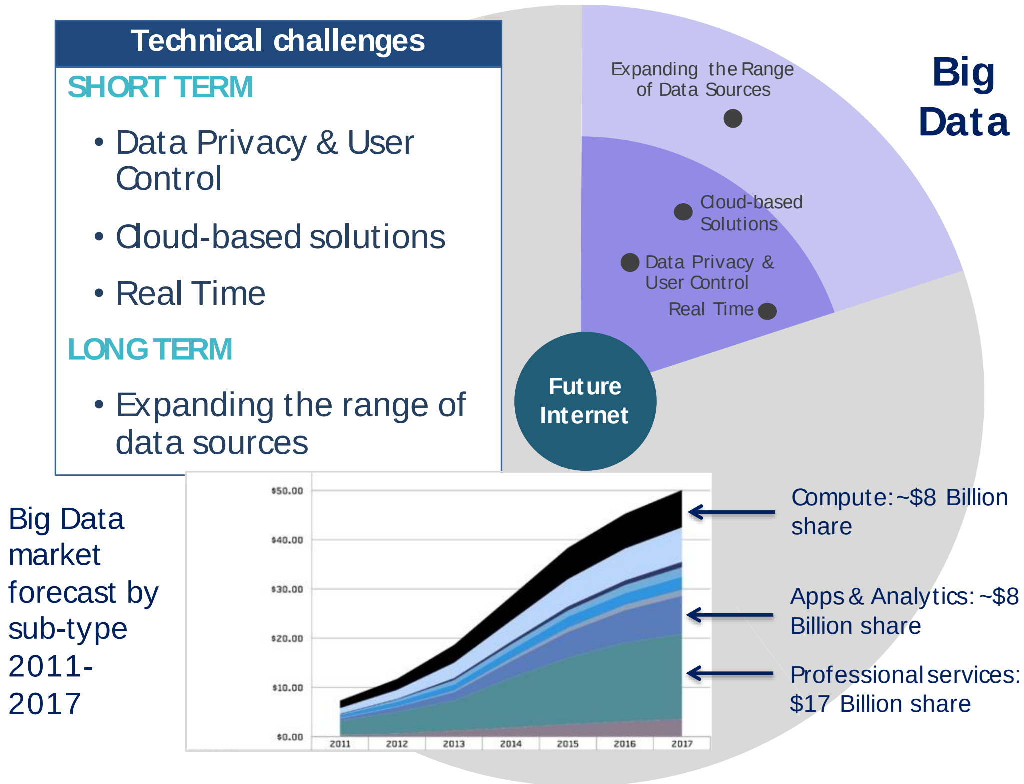

Figure. Big Data- Technical and Business Overview

Figure. High-level Roadmap for Big Data and Relations with FIWARE

4.1 From challenges to technology solutions

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

- **Effective Anonymization** & **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. 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 vulnerable 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://panopticlick.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 Montjoye[i] 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.

- **Batch Data Analysis** & **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 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 [3] back in 2004, which were key in the development of the Big Data area. In fact the Hadoop ecosystem relies on this technique. However, other emerging technologies seem to be aiming at reaching a much greater speed than Map&Reduce, for instance Spark [4], which claims to "run programs up to 100x faster than Hadoop Map&Reduce in memory, or 10x faster on disk", or Storm [5], 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 courier [6].
- **Stream-based programming paradigms.** Exploiting the current computational capabilities in order to deal with the huge amount of data being processed, will require not only high-performance-computing innovation, but also developing new programming languages and paradigms conceived specifically for Big Data processing
- **Image Analytics**, **Video & Audio Big Data**. Expanding the range of sources will imply using data from unstructured sources, such as images, video snippets and audio recordings, in order to extract useful insights from the vast media collections already existing.
- **Semantics**, **Natural Language Understanding** & **Automatic Translation.** The human brain uses semantics and Natural Language Understanding (NLU) to very efficiently use unstructured data. Computers are very good in processing structured data, but in order to understand unstructured data, computers need innovative brain-inspired technologies to acquire the ability to understand semantics. Big Data opens the door to a more effective translation of text which in turn results 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. This is a different approach from machine automatic translation, which is facilitated by Big Data technologies. Namely, machine automatic translation 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.

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 greater control. In this respect, control tools offered by the companies that control / analyse user data, will be certainly welcomed 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 lowering the barriers to entry. 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 Big Data.** There is an emerging need for real-time big data and analytics capability in order for organizations to trigger business decisions immediately. This has a direct impact on the deployment needed to collect and process the information, but also in the existing business tools that will have to react to instructions dictated by the analytics results in real-time.

- **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.

4.2 FIWARE evolution in the context of the wider Big Data ecosystem

The 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 fully exploit 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 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK PROGRAMMES

The Future Internet PPP has been one of the earliest initiatives that set the way forward for other 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 to note 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. The BDVA is not so much focused on the underlying technical challenges, which can be addressed in 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 the FIWARE Mundus 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. In 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 rely for a further technological evolution.

The four challenges identified in this roadmap are relevant to this vision as an enabler of a Future Internet Big Data laboratory, that facilitates the creation of new “value” from the technology: Cloud-based solutions eliminate the need for expensive infrastructure, a broader range of data sources allow for better richer decisions in new fields, and data privacy is especially relevant when datasets is made publicly available for experimentation purposes. Although not a requirement, approaching real time as much as possible is paramount to ensure scalable deployments with multiple users and tests being operated concurrently.

6 REFERENCES

[1] L. Kart, Gartner, Big Data Industry Insights, Sept 2014.

[2] Miller, H. and Mork, P. "From data to decisions: A value chain for big data", IT Professional 15, 2013.

[3] 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/

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

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

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

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

[8] Ovum, 2014 Trends to Watch Big Data, 24 Oct 2013

[9] F. Facca et al. "Map of technology and business challenges for the Future Internet", 2015

[10] Mobile Alliance, "NGSI Context Management", 2012.

APPENDIX D - A FUTURE INTERNET ROADMAP FOR THE FIWARE ECOSYSTEM: CLOUD COMPUTING

EDITORS	Federico M. Facca *(Create-Net)* Federico Alvarez *(Universidad Politécnica de Madrid)*
AUTHORS	Fabio Antonelli *(Create-Net)*, Monique Calisti *(Martel Consulting)*, Estanislao Fernandez *(Telefonica)*, Raffaele Giaffreda *(Create-Net)*, Jose González *(Universidad Politécnica de Madrid)*, Eunah Kim *(Martel Consulting)*, Timo Lahnalampi *(Interinnov)*, Martin Potts *(Martel Consulting)*, Elio Salvadori *(Create-Net)*
EXTERNAL EXPERTS	Stuart Campbell *(Director and CEO at Information Catalyst)*, Alex Gluhak *(Lead Technologist for Internet of Things, Digital Catapult)*, Lutz Schubert *(IOMI Head of Research, University of ULM)*, Richard Lloyd Stevens *(Research Director Government Consulting)*, George Wright *(Head of Internet Research & Future Services, BBC).*

1 EXECUTIVE SUMMARY

Cloud Computing, according to a widely shared definition by NIST [19] refers to a model for the self-management of computing resource (e.g., networks, servers, storage, applications, and services) that enables ubiquitous, convenient, on-demand network access to a shared pool of such resources. This technology traces its roots into Mainframes ('50s) and Computing Grids ('90s). The first public available platform for Cloud Computing appeared in 2006 with the introduction of Amazon EC2[46], which provided access and self-provisioning of virtualized resources within Amazon Data Centers.

Since then, Cloud Computing is more and more adopted by the industry spanning different sectors (e.g. retail, telecommunication, banking, manufacturing) and several commercial and open source solutions are available. Cloud Computing is often seen as a solution for reducing costs related to the management of ICT infrastructures and services (CAPEX savings), but its introduction, beyond that, supported different innovative scenarios such as: new business model (e.g. pay-per-use for online services like SAP Business One), higher service automation (e.g. automation behind eBay services), millions of users' social networks (e.g. Facebook), etc.

FIWARE, where Cloud Computing is a central paradigm, adopts a micro-service architecture designed to be hosted and run in a cloud platform. Central work within FIWARE covered enhancements to the state-of-the-art of Infrastructure as a Service (IaaS) and Platform as a Service (PaaS) solutions.

> *"The primary objectives of FI-PPP are focused on bringing cloud computing capacities and services to the masses for commercialization"*
>
> *Lutz Schubert, IOMI Head of Research, University of ULM*

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

Cloud Computing is a key enabler in the creation of a Future Internet ecosystem. This document discusses the characteristic value chain of Cloud Computing and about those related levers (e.g. regulations and standards) that may support or block the creation of the ecosystem. This general discussion is followed by a summary of current Cloud Computing related developments in FIWARE. The document then focuses on presenting a high level roadmap of Cloud Computing technologies in relation to FIWARE current developments. The roadmap moves on from the 4 keys challenges identified in the previous white paper: "Dynamic Cloud Aggregation, Native Cloud Applications, Customized Clouds, and Security, Privacy & Trust". The document concludes with some hints, derived from the roadmap, in relation to FIWARE and the future H2020 work programmes.

2 CLOUD COMPUTING VALUE CHAIN AND LEVERS

Cloud Computing is a key technology in the Future Internet panorama to speed up and ease the development of new Internet-based business in Europe, lowering the entry barrier to new providers and supporting the commoditization of enabling technologies. To foster such vision, it is important to identify the value chain of Cloud Computing (i.e. the stakeholders in the Future Internet ecosystem), and the levers that can push or block the creation of the ecosystem in the case of Cloud Computing.

2.1 Value Chain

In particular, Cloud Computing leverages on **5G Networks & Backend IT** and **IoT Networks & Devices** actors to build computing, storage and network self-provisioning capacities. **Platform as Service** providers adopt these capacities to commoditize the underlying infrastructure and offer platforms that allow **Application development** leveraging on different capacities:

- **Exploitation platform (service delivery) –** the micro-service based architecture that allows for storing, analysing and querying information from the IoT devices, and other sources of data.
- **Experimentation platform (Development & test) –** the platform where developers, data publishers and device providers can setup their systems to ensure that they can be seamlessly integrated in the overall system.
- **Open Data & Legacy platform** – the source of data (single or multiple) available for any particular application.
- **Contents** – as a particular case of the sources of data available to application in external systems, multimedia content usually requires specific treatment.

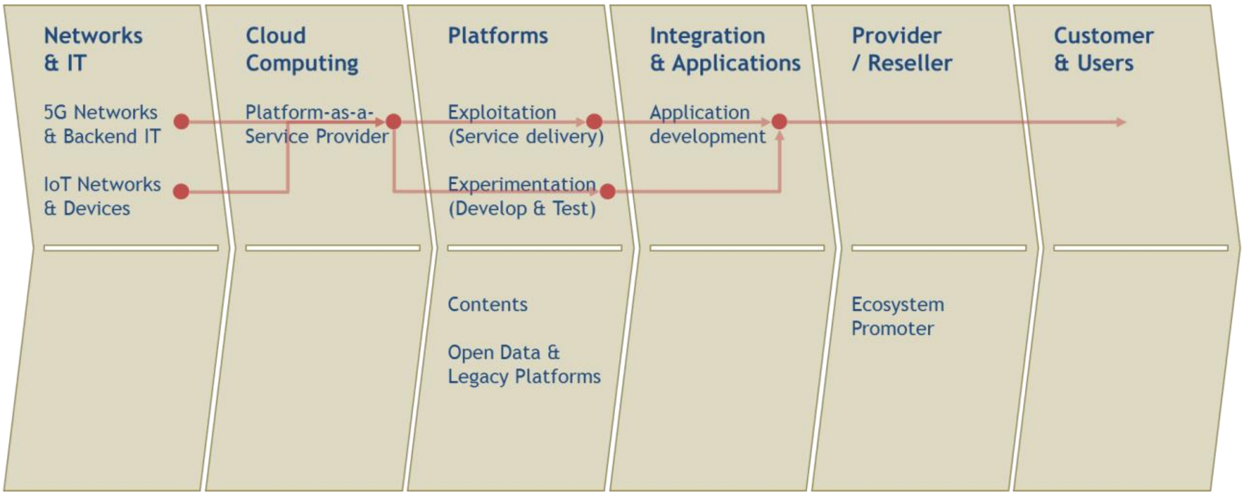

Figure: Cloud Computing detailed value chain

2.2 Levers

This section describes the list of elements that affect the interoperation of elements to support the creation of Future Internet ecosystem within respect to the Cloud Computing market segment.

2.2.1 Standardization

Standardization may be a key factor in support of market adoption of technologies. There is a large number of underlying technologies within the generic umbrella of "Cloud Computing" and, associated with many of those technologies, are a number of competing standards and standardization initiatives. The reality is that the Cloud Computing market is mostly dominated by de-facto standards (e.g. Amazon AWS APIs[47], or OpenStack[48])) that often are not aligned with standardization initiatives.

Standardization Body	Standards	Comments
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

[47] http://aws.amazon.com

[48] **https://wiki.openstack.org/wiki/RefStack**

Table: Standards for the Cloud (Jochen Friedrich, IBM)

Two of the most relevant standardization initiatives for FIWARE are:

- ETSI Cloud Standards Coordination Initiative[49], promoted by the European Commission;
- DMTF Open Virtualization Format[50], to which the FIWARE initiative has contributed notably.

2.2.2 Regulation

Cloud Computing enables the efficient and seamless access to data from everywhere. However, as a consequence, this means that data which could be considered personal or sensitive could be accessed without conforming to data protection laws. Therefore, regulation is necessary to ensure data is accessed in accordance with the data protection laws in place and that Cloud Computing is not abused to fragrantly access personal data from unauthorized third parties. The picture below gives a snapshot of the current EU legal framework.

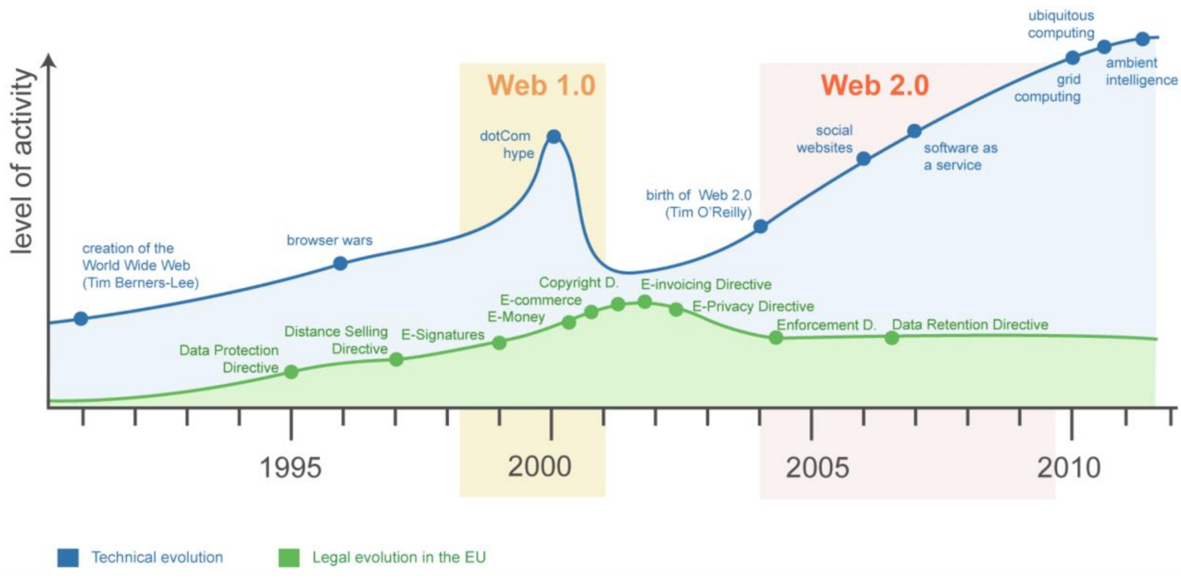

Figure: Cloud Computing legal issue (DLA Piper Brussels)

2.2.3 Critical Mass

Critical mass is a determining factor for the creation of an ecosystem. The number of Cloud Computing adopters is clearly increasing, but the pace in Europe is still lagging behind compared to other industrialized countries such as the US.

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

---

[49] http://csc.etsi.org

[50] https://www.dmtf.org/standards/ovf

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.

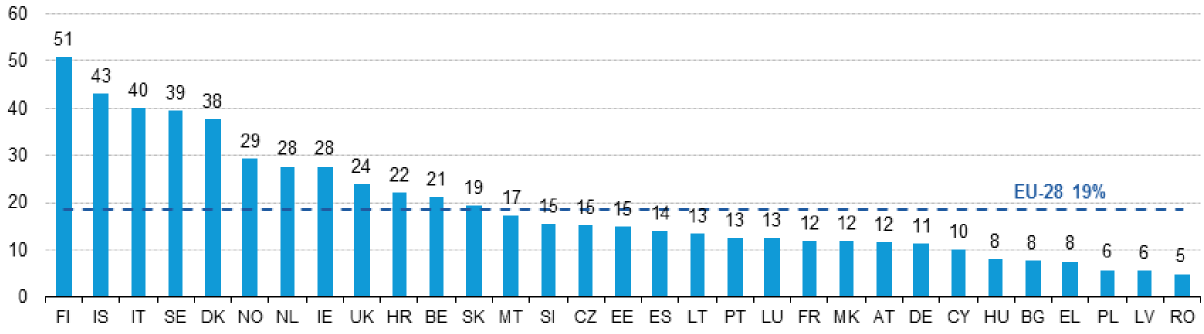

Figure: Use of Cloud Computing services, 2014 (% of enterprises) (Eurostat)

2.2.4 Awareness

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. Unfortunately, most of these events are located outside the EU, limiting the increase of awareness in Europe.

2.2.5 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 service 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[51] from 2013 through 2018 compared with 5% growth for the overall enterprise IT.

2.2.6 Sustainable Business Models

The advent of the Cloud Computing paradigm introduced a number of new business models in the enterprise infrastructure and software market, moving from a product business model to a service business model. Many companies are still transitioning toward these new model: Scalability, reliability, security and cost effectiveness are the parameters on which the available Cloud services are being evaluated. Nevertheless, many enterprises are starting to face the issue that the reduction of the costs of operations associated to ICT infrastructures corresponds also to a reduced customization

[51] Compound Annual Growth Rate

capability of such infrastructure that may limit businesses.

2.2.7 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.

2.2.8 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. Moreover, the emergence of lightweight container-based runtimes has enabled rapid innovation in building novel platforms with greatly improved agility and developer experience (e.g., Docker, Amazon Lambda). Finally, domain-specific Clouds are the subject of research in many fields, such as in the Telco domain. The H2020 programme covers extensively the foundation R&D activities on Cloud computing and its adoption in specific domains (e.g. 5G-PPP).

3 FIWARE AND CLOUD COMPUTING

Cloud Computing technologies are a key part of the FIWARE architecture. They provide the basis for the supply of FIWARE services belonging to the different chapters and their technologies have been validated in the FIWARE Lab[52] – a live instance of the FIWARE platform. Cloud Computing is mostly covered in the FIWARE Cloud chapter; nevertheless additional related components are covered in the FIWARE Ops chapter (the activity in charge of developing tools for the FIWARE Lab operation) and in different FIWARE related projects (e.g. FI-Space[53], FI-Content[54]) where a number of vertical PaaS solutions have been developed, following the trend well identified in the roadmap of the need for customized Clouds.

[52] http://lab.fiware.org

[53] http://fispace.eu

[54] http://mediafi.org

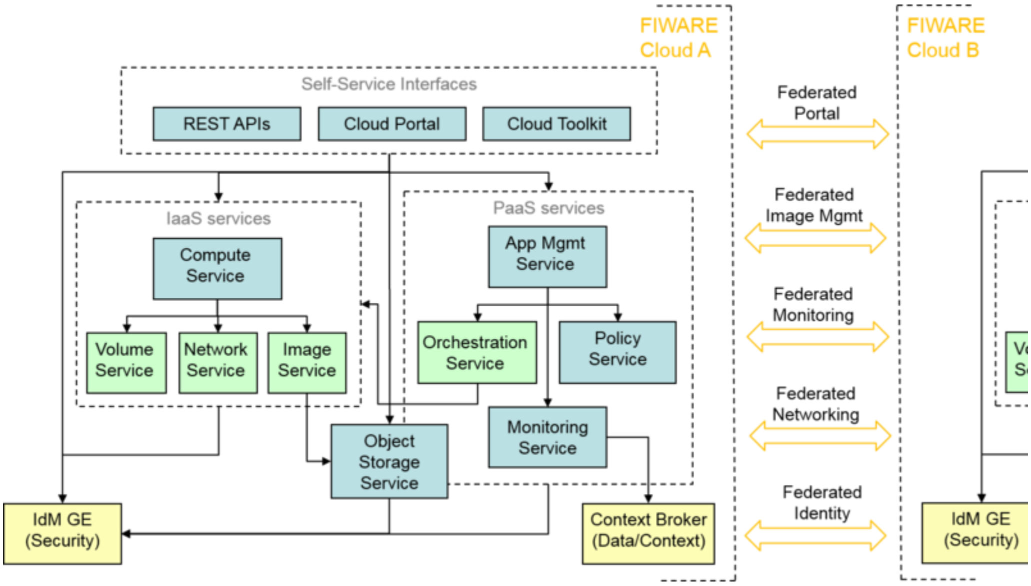

Figure. FIWARE Cloud Chapter Architecture.

The FIWARE Cloud chapter is based on OpenStack[55] and Docker[56], two of the most relevant Open Source products in the Cloud Computing market, and contributes to build the following key layers of the FIWARE Cloud chapter roadmap[57]:

- **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.

Beyond that, the ability to federate different FIWARE Cloud instances and support for federated identities have been introduced by the FIWARE Ops chapter.

4 ROADMAP FOR CLOUD COMPUTING TECHNOLOGIES BEYOND FIWARE

In the previous white paper on "Future Internet Challenges" [24], FIWARE Mundus presented a number of challenges that it believes to be key in the evolution of Cloud Computing technologies.

[55] http://openstack.org

[56] https://www.docker.com

[57] https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/Cloud_Hosting_Architecture

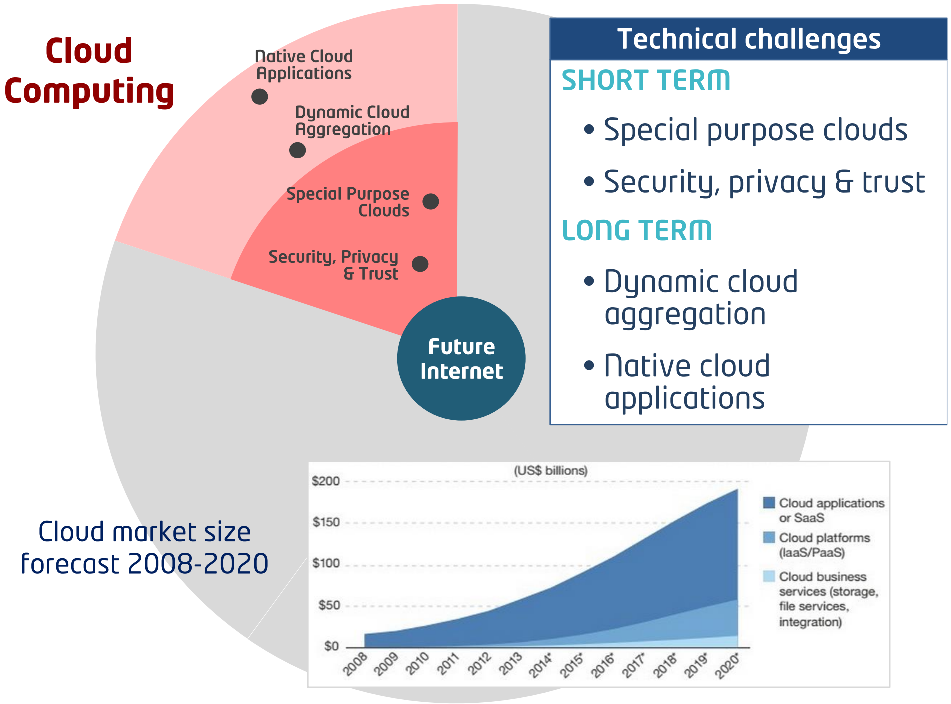

Figure: Cloud Computing's challenges conceptual map.

The four major challenges in the field of Cloud Computing, presented in Figure, can be summarized as follows:

- **Dynamic Cloud Aggregation** (medium-long term): This challenge refers to the general ability of composing and migrating resources across different Cloud platforms.
- **Native Cloud Applications** (medium-long term): This challenge addresses the needs for solutions that facilitate the development of Cloud-native applications and their interaction with the Cloud infrastructures (at any level: IaaS, PaaS and SaaS). This includes development and evolution of novel computing platforms based on lightweight containers (runtime, orchestration, monitoring, metering, image management, elasticity, etc), enabling the next generation of cloud-native data processing applications (e.g., event-based or stream-based).
- **Customized Clouds** (short-medium term): This challenge relates to the fact that Cloud is becoming adopted by different sectors and each sector is raising new requirements.
- **Security, Privacy & Trust** (short-medium term): This is the Achilles' heel of public Cloud offering adoption: most of the blocking issues for companies and users are related to security, privacy and trust issues.

In this white paper, FIWARE Mundus presents a roadmap that, taking into account existing developments in the FIWARE roadmap, provides a spotlight on the evolution of Cloud Computing technologies.

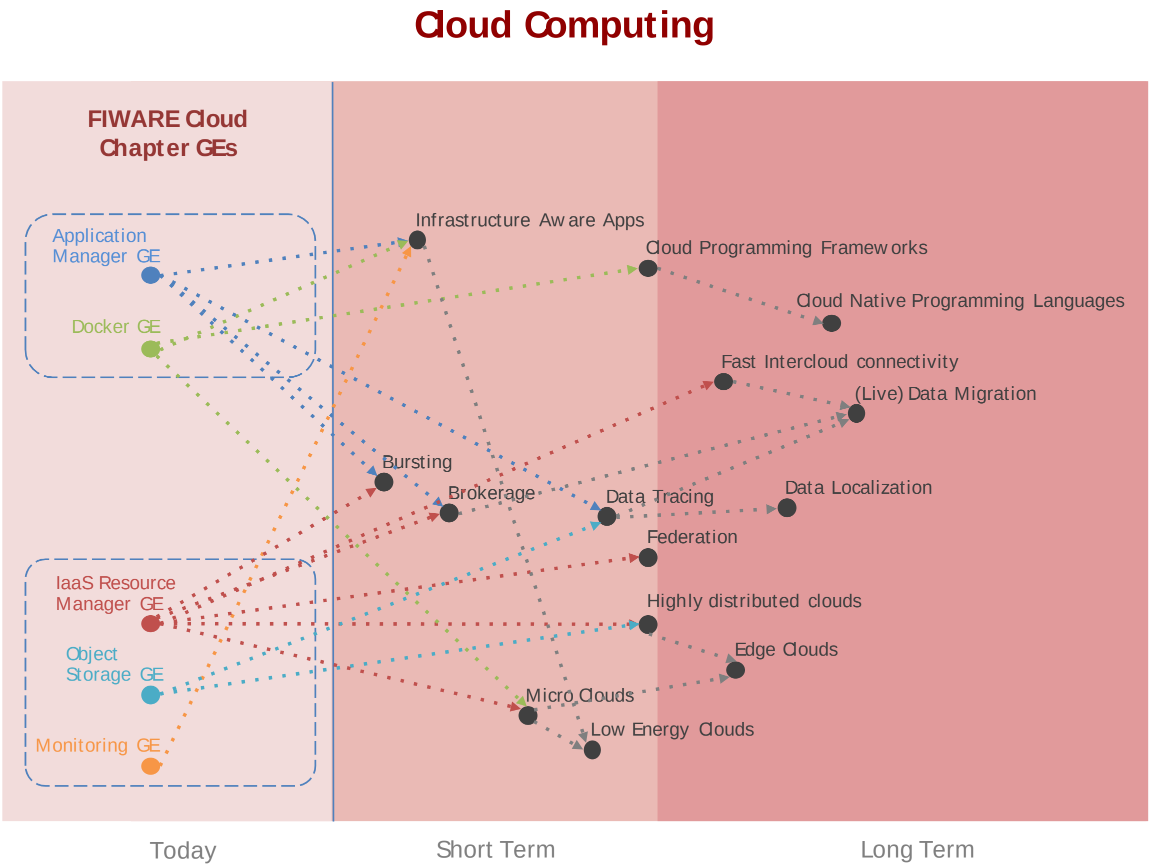

Figure. High-level Roadmap for Future Cloud and Relations with FIWARE.

The challenges proposed originate from the analysis of FIWARE and a number of existing roadmaps, including: Standardization Roadmaps (e.g. the NIST roadmap [19]) Industrial public roadmaps (e.g. the Oracle Roadmap for Cloud Computing [18]), European Research and Innovation Roadmaps [20] and Innovation roadmaps produced by other industrialized countries (e.g. the roadmap by the Singapore Innovation agency [22].

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

4.1 From challenges to technology solutions

Moving beyond the challenges and their interaction, FIWARE Mundus identified a number of cornerstone technologies that will empower their resolution. The following paragraphs discuss and use them as the starting point for the high-level roadmap (Figure).

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 leads to the requirement for cost-effective 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 increasingly 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 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 one 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 whether 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 challenge. 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**. Ever more data is hosted in the Cloud. For trust and privacy reasons it is very important for each user 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 ecosystem around cloud-native applications is rapidly growing (e.g., providing more and more tools to efficiently develop and manage micro-services based applications), it is still far from maturity, and further research is required to come up with the proper set of design, deployment and DevOps patterns suitable for Future Internet applications (e.g., IoT-enabled) – as well as frameworks and platforms that would enable such patterns. In parallel, new cloud-native paradigms emerge, such as 'serverless computing'[58] where the underlying platform takes care of all the aspects of infrastructure management (such as elasticity and high availability), and the developer only needs to provide the individual fine-grained 'functions' that comprise the application flow. This promising paradigm opens numerous opportunities, aiming at drastically higher agility and developer productivity in highly challenging data-intensive application domains such as those involving massive event-based processing and stream-based processing. In a sense, this paradigm overcomes the inherent limitations of existing PaaS solutions which are designed primary for traditional Web applications, and offers similar benefits targeting a much larger variety of applications, focusing on Big Data and IoT domains. Hence, FIWARE Mundus foresees the '*serverless*' and similar new paradigms to revolutionize the way cloud-native applications are designed, developed and operated – requiring fundamentally new *methodologies* (e.g., design patterns), *tools* (e.g., new generation of DevOps pipelines) and *platforms* (e.g., based on new kinds of lightweight containers).
- **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

[58] **http://thenewstack.io/serverless-computing-growing-quickly/**

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.

4.2 FIWARE evolution in the context of the wider Cloud Computing ecosystem

Tackling all the technological evolutions described in the previous section is beyond the FIWARE scope. Nevertheless, there are a number of short term evolutions from current FIWARE Cloud Generic Enablers that are key to commoditize FIWARE services. These include:

- Broader support for developers in term of the simplified creation of Cloud native FIWARE-based applications. This requires having more advanced means of orchestrating FIWARE micro services and automating their self-healing, as well as supporting emerging cloud-native paradigms such as 'serverless' computing.. This relates to *Infrastructure Aware apps* and provides the basis for *Cloud programming frameworks*.
- Enhancements to the ability to trace data into the cloud at least in term of Object storage solutions, introducing *Cloud data control probes* that provide at any time information on the status, access and localization of stored objects. This relates to *Data Tracing.*
- Extending the support of FIWARE service deployment and orchestration, beyond current FIWARE cloud hosting solution, further empowering developers to create advanced and mixed deployment scenarios. This relates to *Bursting* and *Federation*.
- Provide more advanced integration of containers in the current IaaS services. 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). This relates to *Micro Clouds.*
- 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. This relates in a more general way to the demands for *Customized clouds*.

5 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK PROGRAMMES

The roadmap presented in the previous section stems from the current development of FIWARE technology and takes into account that different levers will be in place to ensure a proper evolution of the Future Internet ecosystem.

FIWARE driven innovation, as evidenced, needs to focus on short term technology that will improve the adoption of Cloud based services in the market. Relevant technology evolutions in the short term should support the simplification of development and deployment of FIWARE-based micro-service architectures, their orchestration and automated management (e.g. scale-up and down, self-healing). This evolution should take into account not only the current FIWARE cloud hosting solution, but other competitive cloud hosting standards.

Beyond the short-term directions discussed above for the FIWARE community, the roadmap identifies a number of interesting technology evolutions. 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, FIWARE Mundus identified the following challenges as priority in the future H2020 work programmes:

- Cloud native programming frameworks (Software Technologies)
- Cloud native programming languages (Software Technologies)
- Micro-Clouds (Advanced Computing and Cloud Computing)
- Highly-distributed Clouds (Advanced Computing, Cloud Computing, 5G PPP)

6 REFERENCES

[1] S. Mattoon: “Creating a Roadmap to Cloud Computing”, April 2013

[2] M. Hogan et al. “NIST Cloud Computing Standards Roadmap”, 2011.

[3] L. Schubert et al. “A Roadmap for Advanced Cloud Technologies under H2020”, 2012

[4] Info-communications Development Authority of Singapore (IDA), “Infocomm Technology Roadmap (ITR) 2012”; http://www.ida.gov.sg/Infocomm-Landscape/Technology/Technology-Roadmap

[5] F. Facca et al. “Map of technology and business challenges for the Future Internet”, 2015

APPENDIX E - A FUTURE INTERNET ROADMAP FOR THE FIWARE ECOSYSTEM: COMMUNICATION NETWORKS

EDITORS	Jose González *(Universidad Politécnica de Madrid)*
AUTHORS	Federico Alvarez *(Universidad Politécnica de Madrid)*, Fabio Antonelli *(Create-Net)*, Monique Calisti *(Martel Consulting)*, Federico Michele Facca *(Create-Net)*, Estanislao Fernandez *(Telefonica)*, Raffaele Giaffreda *(Create-Net)*, Jose González *(Universidad Politécnica de Madrid)*, Eunah Kim *(Martel Consulting)*, Timo Lahnalampi *(Interinnov)*, Martin Potts *(Martel Consulting)*, Elio Salvadori *(Create-Net)*
EXTERNAL EXPERTS	Stuart Campbell *(Director and CEO at Information Catalyst)*, Alex Gluhak *(Lead Technologist for Internet of Things, Digital Catapult)*, Lutz Schubert *(IOMI Head of Research, University of ULM)*, Richard Lloyd Stevens *(Research Director Government Consulting)*, George Wright *(Head of Internet Research & Future Services, BBC).*

1 EXECUTIVE SUMMARY

The enhancement and evolution of **Communication Networks** is a technological ambition with elevated repercussion at global scale, not only stating a notable impact on ICT, but also affecting vertical market trends. Infrastructures are the main carriers of services and applications, being the basis of the Internet itself. The faster, more flexible and more robust the networks can become, the more efficient the services will perform and further expectations will be stimulated. The influence over the overall technical landscape is such that some valuable prospects are starting to fall behind due to the rapidly innovation and uptake by multiple stakeholders.

The development of new communication networks is dependent on the emergence of globally accepted standards in order to ensure interoperability, economies of scale with affordable cost for system deployment and end users. One of the most relevant activities in the international landscape is the European 5G Infrastructure Public Private Partnership (5G-PPP) [4], a 1.4 Billion Euro joint initiative led by the ICT industry and the European Commission which aims to revise the challenges and opportunities bound to current infrastructures and work to bring the next generation of communication networks.

"The future network should be increasingly more diverse, complex and able to cope with very different scenarios, and with very large heterogeneity"

NetWorld 2020 ETP. Mobility/Connectivity and Networking Layer Working Group

Such global requirements will be tackled in two main blocks throughout the 2015-2020 timeline:

- In the short-medium term, the challenges will be associated with the virtualization of network functionalities and the future network management.

- In the medium-long term, the major challenge will be associated with the foundation of software defined infrastructures.

Communication Networks play a fundamental role in the creation of Future Internet ecosystem. Network infrastructures are the ones delivering services, and their evolution is key to support the wide-spread deployment of the Future Internet. In this sense, while not being a primary concern of FIWARE, Communication Networks are key building blocks for FIWARE technologies interacting with Internet infrastructure (Cloud Computing, Internet of Things, Big Data, Data and Context Management, …)

This document assesses the main agents that will have an influence over this domain, as well as proposing a roadmap for network technology trends, identifying relationships among them and establishing a proper correlation with the current efforts in FIWARE and providing an outlook of challenges for future H2020 work programmes.

2 COMMUNICATION NETWORKS VALUE CHAIN AND LEVERS

The ICT sector is experiencing a major revolution that will seriously impact the way networks and services are designed, deployed and operated in the near future. Such a breakthrough will catalyse innovation in other ICT domains that strictly depend on the communication infrastructures.

2.1 Value Chain

Figure 1 below graphically depicts the reliance on **5G/IoT Networks** and **Backend IT** throughout the whole value chain. Advanced communication infrastructures are needed to support and to operate both Cloud Computing and Service Platforms guaranteeing the interrelationships among the different global services they are composed of; for instance, communication networks link efficiently nodes in the FIWARE Lab federation across the globe or bridge the gap between Smart Cities and citizens. Hence, the different stakeholders of the value chain (including content owners, network operators, equipment vendors, and device manufacturers) shall work together to create attractive services and high quality user experiences.

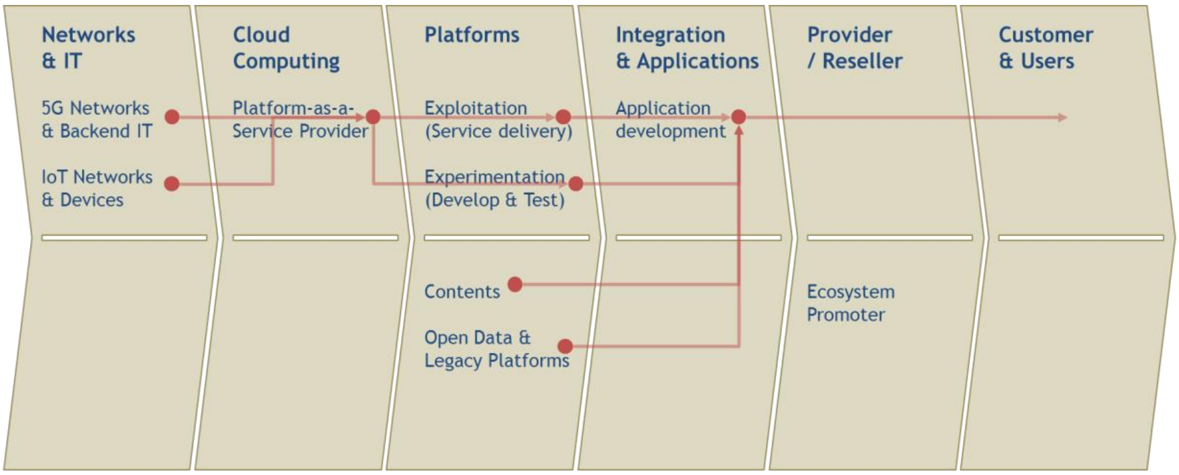

Figure: Communication Networks detailed value chain

2.2 Levers

2.2.1 Standardization

There are countless standards, organizations and initiatives related to network technologies that will impact Future Internet innovation. Among all of them, two important sets shall be noted:

- **Network standards related to the interaction and integration with Cloud Computing**, such as Software Defined Networks (SDN) and Network Function Virtualization (NFV). The IRTF's Software Defined Networking Research Group[59], ETSI Working Group on NFV[60] and the IEEE SDN[61] are great examples of these activities.
- **Network standards related to the increased capacities** required by new market opportunities and demands, for instance the 3GPP[62].

Standards are a way to guarantee interoperability among systems. At this layer, it is crucial that common standards are set and adopted to facilitate interoperation at higher layers in the service delivery chain (e.g. Internet of Things, Cloud Computing, …)

2.2.2 Regulation

The European telecom sector is facing significant challenges in terms of rapidly emerging technologies and new forms of competition as well as business models. 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 exigent issues which require steps to be taken to modernize the regulatory situation. When defining the path towards regulatory modernization, Europe shall avoid going for incremental improvement and rather taking aim at an ambitious scenario and step into a "*Virtuous Circle*" model, based on innovation, investment and smart regulation *("Regulation 2.0")* [10].

2.2.3 Critical Mass

The transformative impact of digitization in the mass adoption of 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. On the other hand, the "over-the-top" (OTT) players - media services such as Netflix and Spotify that piggyback for free on telecom infrastructures - are gaining in number and popularity, making the traditional operators' landscape much more difficult.

Telecom operators that have adopted aggressive digitalization strategies are generally faring better than their more conservative rivals, although the transition is not smooth. In some cases, early digital initiatives have been haphazard, and many Telcos 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.

[59] IRTF Software-Defined Networking Research Group (SDNRG). https://irtf.org/sdnrg

[60] ETSI Network Functions Virtualisation. http://www.etsi.org/technologies-clusters/technologies/nfv

[61] IEEE Software Defined Networks. http://sdn.ieee.org/

[62] 3rd Generation Partnership Project (3GPP). http://www.3gpp.org/

2.2.4 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 Low-Power, Wide-Area (LPWA) networks.

2.2.5 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 90s, but since then has fallen behind in investments in networks. Despite the EU's leading role in standardization and development of LTE (4G), in 2012 the EU's share of global LTE investments was only 6%, compared to 47% in the USA, 27% in South Korea and 13% in Japan.

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 (i.e. the USA, 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.

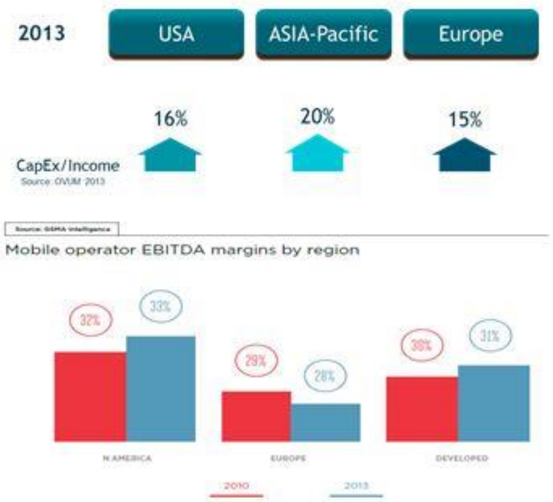

Figure: Investment levels led by financial returns (ETNO) (Telefonica, October 2014)

2.2.6 Sustainable Business Models

The business model of a Network Provider heavily depends on the initial investment required to setup the associated infrastructure. Traditional Telcos must manage legacy capabilities that hinder the launch of any new innovation, whereas new entrants face an access barrier.

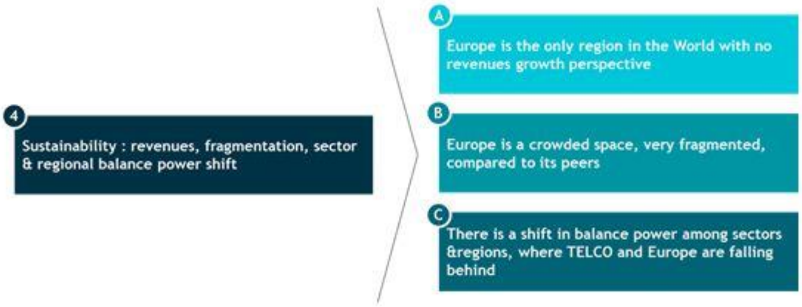

Figure: Market indicator of sustainability (Telefonica, October 2014)

The negative outlook on European telecom revenues, **despite a strong traffic increase**, reveals a structural problem in Europe. 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: Fragmented European Market (Telefonica, October 2014)

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

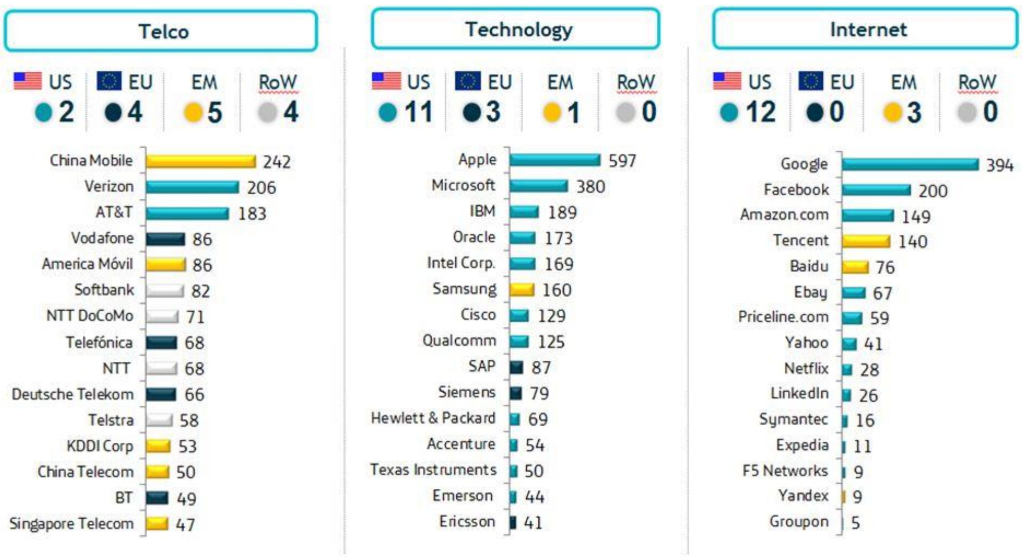

Figure: Data Market Cap (Bloomberg, October 2014)

2.2.7 IPRs &Technology Transfer

The list of existing network-related IPRs is vast, and Telcos, having been a key player and innovator over the last years, are owners of a large share of them. Alignment between national telecommunication network operation and national jurisdiction of IPRs is needed to alleviate the possibility of infringements and subsequent impediment.

2.2.8 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.

3 FIWARE AND COMMUNICATION NETWORKS

As introduced by the value chain, communication networks are fundamental in supporting FIWARE technology and ecosystem, even though not part of its kernel, and will hold a key role in future stages. Nonetheless, meaningful efforts have been already made to strengthen this bond.

The FIWARE Reference Architecture itself includes a dedicated chapter, the Advanced Middleware, Interface to Networks and Robotics (I2ND), that originally provided interfaces to run an open and standardised network infrastructure along with providing access to specific features. Current service maintenance is exclusively committed to the Advanced Middleware FIWARE Generic Enabler (GE), implementation of a modern communication middleware for efficient and secure applications, providing easy-to-use and extensible APIs.

Another significant milestone, where the communication networks have underpinned the evolution of

FIWARE, is the federation of cloud-based platforms that is FIWARE Lab[63]. FIWARE Lab is a non-commercial sandbox environment where innovation and experimentation based on FIWARE technologies can take place. Entrepreneurs and individuals can test FIWARE technologies as well as their applications within the FIWARE Lab, having also the possibility to exploit Open Data published by cities and other organizations. Each FIWARE Lab node maps to one (or a network of) datacentres on top of which a FIWARE Cloud Hosting instance has been deployed, federated and configured as a FIWARE Lab node (Cloud region) operated by a specific organization. For further details, see the specific white paper about running a FIWARE Lab node [9].

The connectivity of this multi-site testing infrastructure is supported by GÉANT, the pan-European research and education network that interconnects Europe's National Research and Education Networks (NRENs).

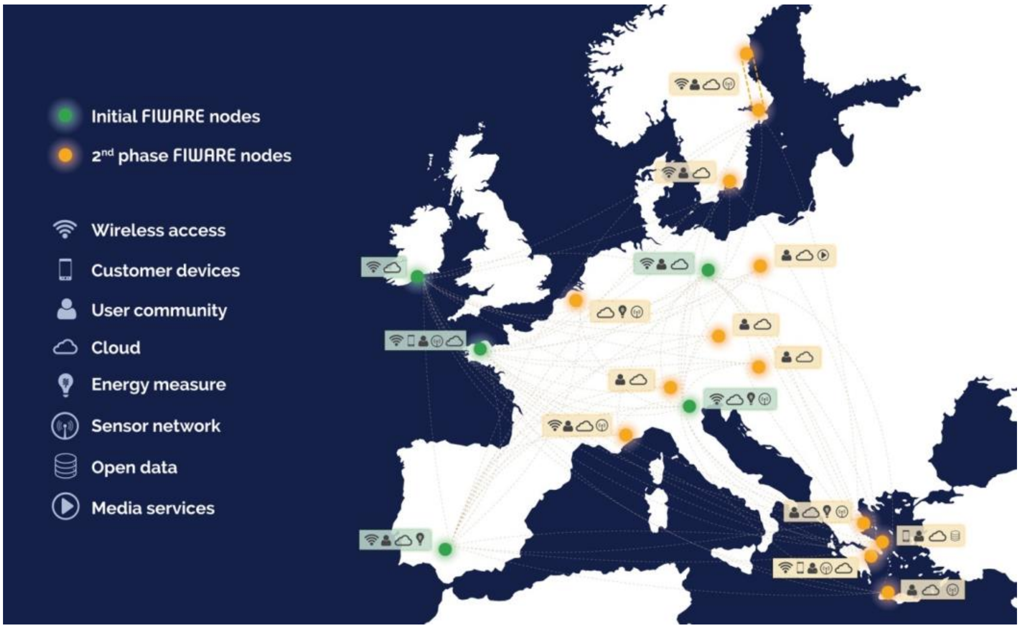

Figure: FIWARE Lab Nodes in Europe

4 ROADMAP FOR COMMUNICATION NETWORKS TECHNOLOGY BEYOND FIWARE

Software Defined Networks (SDN) and **Network Function Virtualization (NFV)** are the two main technological trends that industry manufacturers, telecommunication operators and service providers around the globe are currently moving toward. Worldwide service providers that control over 51% of global telecom CAPEX believe that SDN and NFV are a fundamental change in telecom network architecture that will deliver benefits in new services and revenue, operational efficiency, and CAPEX savings [5], [6].

[63] http://help.lab.fiware.org/

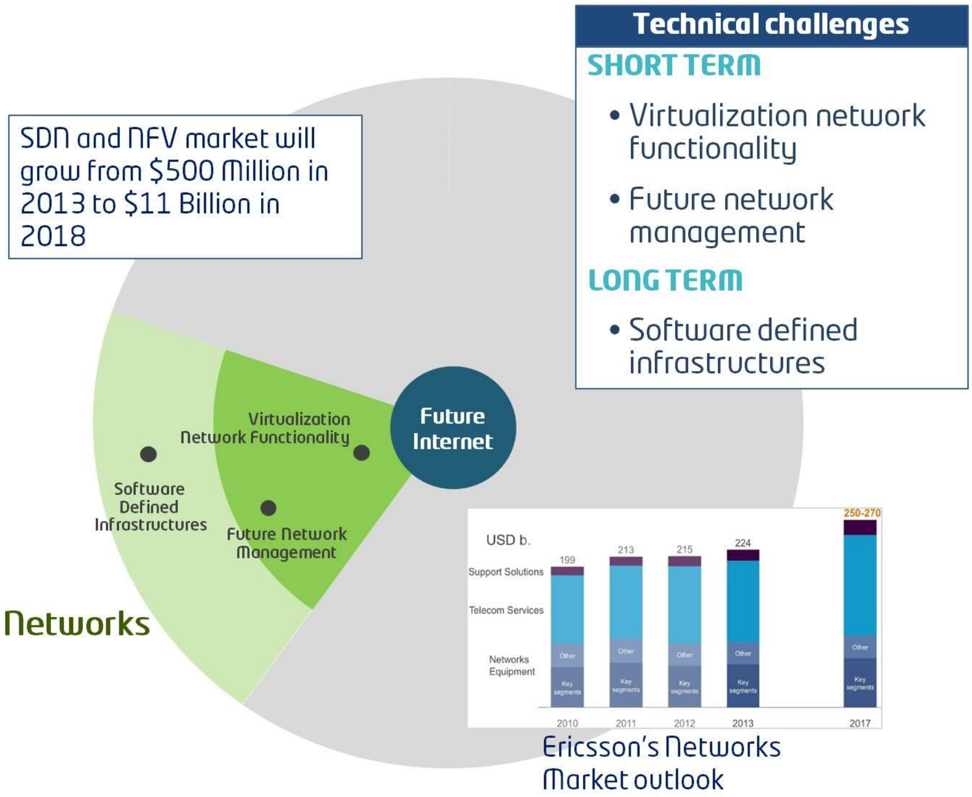

Figure: Network's challenges conceptual map

An assessment from a Future Internet perspective in the white paper on "Future Internet Challenges" [24], taking into consideration the fundamental changes in the evolution of network architectures, has identified **three major challenges:**

- **Virtualization of Network Functionality** (short-medium term): This challenge deals with the new ways paved by cloud computing to design, deploy and utilize network services;
- **Future Network Management** (short-medium term): This challenge considers the innovations that both NFV and SDN will bring to network architectures and that will require overcoming operational integration and high costs of managing the closed and proprietary appliances presently deployed throughout telecom networks; and
- **Software Defined Infrastructures** (medium-long term): the likely convergence with Cloud-based environments leads us to contemplate the concept of "Software Defined Infrastructures", where computing and network-based resources will be handled uniformly by interoperable multi-domain infrastructures.

Obviously, there are also other aspects to consider where effort is needed, such as the radio network architecture and the convergence beyond last mile. To evaluate a full-fledged assessment of Future Networks in its multiple areas, the **5G Infrastructure PPP** [4] is within the priorities for Europe in the context of Horizon 2020.

An overview on the evolution of Communication Networks is presented in the figure below, and further detailed in next section. The roadmap displays the influences among the different technology solutions throughout the time, taking as reference the current influences of FIWARE.

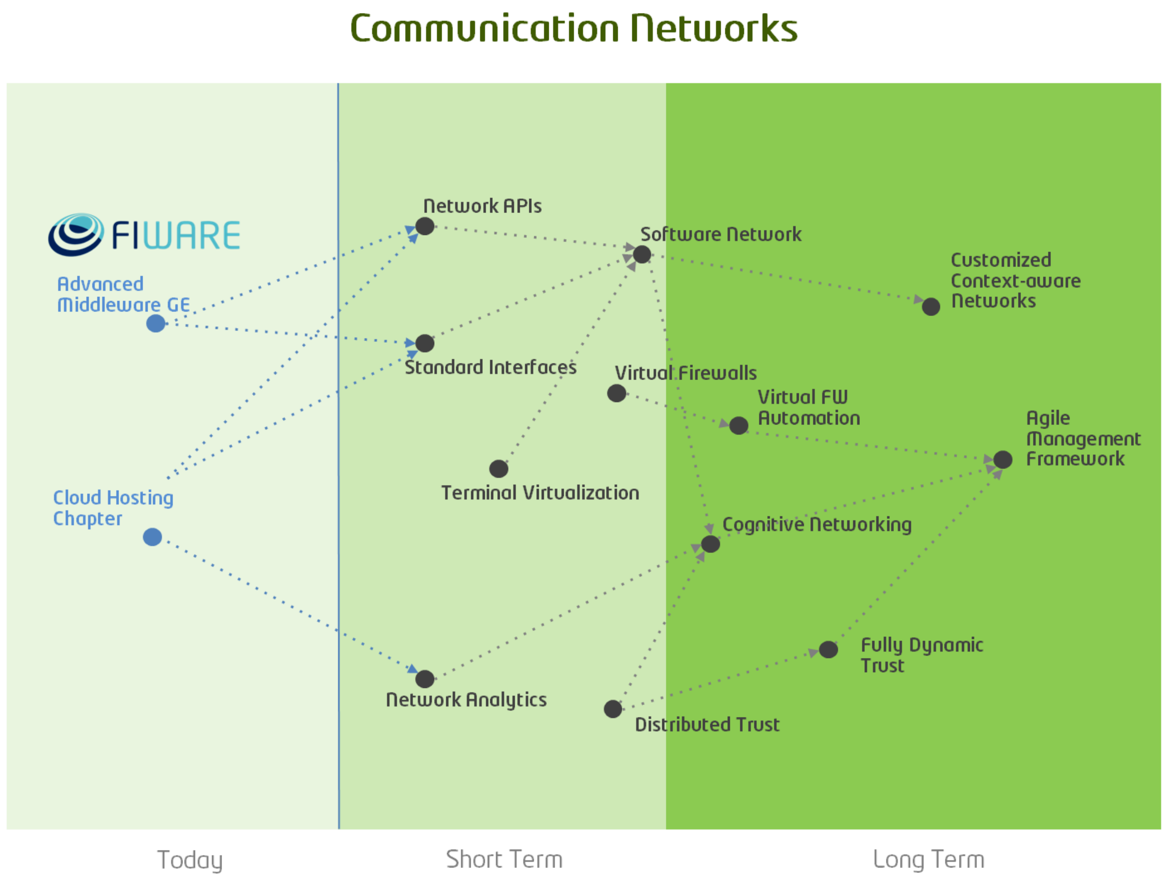

Figure. High-level Roadmap for Communication Networks and Relations with FIWARE

4.1 From challenges to technology solutions

The objective of this section is to present the expected technological solutions that will set the path throughout the defined timeline (both before 2020 and beyond), highlighting the foreseen links with the other technology roadmaps developed in FIWARE Mundus.

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' Quality of Experience (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
    - Free 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.

4.2 FIWARE evolution in the context of the wider Communication Networks ecosystem

While network functionalities and its management are not currently in the scope of the FIWARE community, a number of evolutions at the communication network layer offers interesting opportunities for the future of FIWARE. 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 Ops64, FIWARE can act as the technology enabler of future use cases. Current 5G market segments are a valuable reference to follow in this sense.
- 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 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK PROGRAMMES

This document aimed to identify diverse factors that have a direct impact on the evolution of next generation networks, discerning how they are related to major challenges in the short and long terms.

[64] FIWARE Ops. http://www.fiware.org/fiware-operations/

Communication Networks represent a very broad technological domain, covering multiple areas of investigation. Putting the focus on those aspects relevant to the Future Internet is only a partial assessment, and the reader shall be aware that there are some other research priorities in the global perspective.

One of the main conclusions of the assessment is the fact that FIWARE must leverage on networks rather than include them in its kernel. The recommendation for future steps is to strengthen the interfaces with the communication infrastructures, taking advantage of their evolution.

In this regard, the main outcome from this document is the definition of a roadmap that displays in a timeline the principal technology trends, relating one with each other. In the scope of the roadmap, FIWARE Mundus identified the following challenges as priority in the future H2020 work programmes.

In the short term:

- Network APIs
- Standard Interfaces
- Terminal Virtualization
- Network Analytics
- Distributed Trust
- Software Networks
- Cognitive Networking
- Virtual Policy Enforcement Points

Whereas in the longer term:

- Virtual Policy Automation
- Fully Dynamic Trust
- Customized Context-aware Networks
- Agile Management Framework

6 REFERENCES

[1] The 5G Infrastructure Public Private Partnership. http://5g-ppp.eu/

[2] "SDN and NFV Strategies: Global Service Provider Survey". Infonetics Research. March 2014

[3] "A Survey of Software-Defined Networking: Past, Present, and Future of Programmable Networks". January 2014

[4] "The Real Cloud. Combining Cloud, NFV and Service Provider SDN". ERICSSON White Paper. February 2014

[5] "Network Functions Virtualization - Challenges and Solutions". Alcatel-Lucent White Paper. 2013

[6] ETSI NFV. http://www.etsi.org/technologies-clusters/technologies/nfv

[7] S. Modafferi et al., “Initial Future Internet roadmap and proposals for sustainability”, 2012, INFINITY

[8] M. Hirabaru et al., “ New Generation Network Architecture AKARI Conceptual Design”, 2009, NICT

[9] F. Facca, “Running a FIWARE Lab node: What you need to know”, FIWARE Mundus White Paper

[10] G. Serentschy, “The Virtuous Circle”, 2013. http://www.serentschy.com/wp-content/uploads/2014/02/The_Virtuous_Circle_Buch-download.pdf

[11] F. Facca et al. “Map of technology and business challenges for the Future Internet”, 2015