The Future of Internet Applications: A Survey of Future Internet Projects

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Abstract. For the past decades, the internet has become the most important technological invention and the infrastructure of our digital society. However, the constant growth and massive use had also increased its complexity exposing weaknesses that were not considered by the original design. As a result, international efforts are being made on a clean-slate design for the *future internet* to overcome current challenges and to guarantee future requirements. Many of these initiatives are deploying testbeds and infrastructures to conduct experiments for the future internet applications, and some of these architectures are software-based defined networks to address the challenge of adaptation during runtime. This survey presents a timeline summary and analysis of these initiatives, an overview of the most recognized testbeds, technologies, experiments and results, and finally a compilation of some of the software applications prospects proposed by research groups, academia and industry, and a classification of the extracted requirements.

Keywords: Future Internet, Smart Internet, Smart Applications

1 Introduction

The first network, the ARPANET, was launched in 1969 by the Advanced Research Projects Agency (ARPA) implementing TCP/IP protocol for packet switching with four university nodes interconnected across United States. But over time and with the inclusion of more collaborators and some standardizations, this network grew to became what we known today as the Internet. Since then, the internet has being accessed by millions of users around the world becoming the most successful technological invention, Balzic *et al.* in [1] called the internet, the most important infrastructure of the digital society due the relationship between users, businesses, government, academia and human life activities in general.

Subsequently, the internet had being exposed to constant changes and enormous evolution through the last decades, having grown not only geographically as a distributed resource expanding its coverage, but also its size related to data, services, users and technologies. Not to mention the inclusion of certain type of online services that critically rely on internet like businesses' daily operations, stock market, emergency systems, healthcare or international projects, had added some constrains over the internet. Moreover, the introduction of wireless and mobility was the origin for user's presence as a new paradigm of the internet intensifying the demand and the evolution of this network.

Part of the evolution belongs to the definition of the internet of things that states how users and devices are connected to internet interacting with each other [2] exchanging information, and operating through the same internet platform. Beyond this internet of things there is a vision for a self-managed internet for devices, users and applications in which fundamental functions are automated, and decisions are made based on built-in knowledge like policies and past learning [3].

A consequence of this evolution and the future vision of the internet of things, software developers have being trying to keep up the speed releasing temporary patches, newer versions, drivers, and many other temporary and sometimes limited solutions that at the end had added even more complexity to the internet in the form of incompatibilities, obsolescence, orphan connections and applications, lose of privacy and control, security holes enabling cyber-attacks, and many others. In brief, many of these critical downsides are related to non-functional requirements like security, flexibility and manageability and the current efforts are not being enough.

Furthermore, under this conditions seems very hard to prepare internet for future requirements and adding the *uncertainty* and *dynamicity* of the context and the users requirements to the already current state of the internet, international researchers, academia and industry, have been working into the consideration of a clean-slate conception for the future internet. In this survey we are exploring the current state of those initiatives to recover insights and prepare the future research roadmap smart applications theme.

Under the most recognized initiatives studied here are included FIRE (Future Internet Research and Experimentations), GENI (Global Environment fot Network Innovations) , G-Lab (German Lab) and SAVI (Smart Applications on Virtual Infrastructure) due to their progress on the creation of the future internet. On these initiatives there is evidence of testbeds deployed and ongoing experiments and results. This survey is focused in those initiatives that are on the *Software-Based Defined Networks (SDN)*. With SDN the two main concerns of the network management are separated, control and data packages, with the purpose of adding dynamic capabilities of the network during runtime. In order to give networks this capability, there have been some advances in hardware and software as well like OpenFlow protocol which is the inclusion of a standard interface to control network switches, and NetFPGA network cards with high capacity of processing.

In our exploration and analysis of the worldwide initiatives we measure their maturity according to their progress in one out of three phases: (1) the definition of the future internet concept, requirements and design, (2) the implementation of the architectural layer infrastructure, and (3) the deployment of software applications. Many of the current projects are placed in the second phase which indicates that there is a global common conception of the definition for what the future internet should be. It is out concern the exploration of the third phase as our interest in the development of Smart Applications for the future internet.

1.1 Scope

In 2011 Paul *et al.* in [4] presented a study dedicated to the architectures for the future internet in which describes the worldwide initiatives that where more recognized at the moment highlighting the different networking approaches. I their survey, the state of those initiatives where in a stage of creating consortia to work on the networking challenges like security and routing. Since then, many of these initiatives had progress in their research and we explored their current state among others.

Our main goal is to focus in a higher level and study the state-of-art of the future internet projects from the point of view of the application layer while keeping in mind the current progress of the networking layer as the infrastructure for deploying future internet applications.

This survey presents an overview of the most significant worldwide active projects focusing on those with experimental testbeds results, and also those over software-based defined networks. Moreover, it also describes some software application projects prospects with the purpose of showing some insights on the gaps for future internet software applications proposals and experimentations.

The contributions of this survey include: (1) A time-line analysis of the worldwide future internet projects making explicit the relationship among them. This analysis proposes a life-cycle of three phases to help in the measurement of maturity of the projects. (2) A summarized table of the active projects and their networking technologies towards the implementation of software defined networks, (3) Observations and analysis of the current testbeds experiments and results, (4) A compilation of some software application prospects for the future internet proposed by different research and development groups, academia and industry, and finally (5) A classification of general requirements to envision software applications for the future internet.

1.2 Methodology

This survey follows a systematic literature review (SRL) as proposed by Kitchenham *et al.* in [5]. In brief, according to this methodology we define: *(i)* the research questions, *(ii)* the search process that includes academic and non-academic literature, *(iii)* the assessment process to subtract relevant literature and sources, and *(iv)* the study results of the information (i.e., collecting and analysing the data).

The collecting of sources included academia-related search engines like Google Scholar, IEEE Explorer, ACM Digital Library, SpringerLink, Science Direct and Elsevier, using the following keywords: internet of things, future internet, new internet, future networks, new generation internet, new generation networks. For the selection of relevant publications we applied a 3 layers filter: Firstly (i) a conceptualization of the objective of search by relating the same future internet concept under different words. The next step (ii) is narrowing the sources to those related to the future internet active projects, and those related with software-based defined networks. Finally, (iii) a selection only focused on key elements relevant for this survey: testbeds, experiments, and future internet applications.

Other sources included the projects' websites looking for official, but yet not academically published information like testbed call for experiments, and software application projects and proposals. In the selection for official websites we chose those related to academic literature as well as those part of recognized consortia. It is possible that this selection might had excluded emerging and independent initiatives, therefore, we can not assure that we made an exhaustive search of every project towards the future internet.

1.3 Research questions

Based on the scope of our survey we have formulated the following research questions:

- RQ1 What is the current state of the future internet worldwide initiatives? Where are the most advanced projects?, and What are their results?
- RQ2 What technologies are being implemented for the infrastructure of their testbeds?
- RQ3 How are they evaluating their network infrastructures?
- RQ4 What kind of applications are they intending to deploy in the future internet?

1.4 Organization of the document

The remaining of this document is described as following: Section 2 presents an overview for the current internet challenges conceived by different initiatives around the world, the definition of the internet of things, and key elements of software-based defined networks as relevant concepts for this survey. Section 3 describes the more significant worldwide future internet projects, testbeds and experiments, a time-line analysis and a graphic representation of the relationships among those projects. Also, describes the technologies associated with software-based defined networks and summarizes the projects implementing those technologies. Section 4 presents some application proposals and actual projects for the future internet, and highlights general features for future internet applications in the form of general requirements. Section 5 presents a summary of this study. Finally, Section 6 presents the conclusions of the survey and some recommendation for future internet research in the application layer.

2 Overview

This section presents a description of the current internet challenges that are encouraging the clean-state design of the future internet according the worldwide initiatives. Additionally, a brief idea of the internet of things as a general vision of the future internet behaviour and structure. Finally, the conceptualization of software-based defined networks as an important approach for the new architecture of the future internet.

2.1 Current Internet Challenges

The current internet is facing problems of size, complexity, security, and mobility among others, because of the increasing and daily use of several online applications, social networks, ubiquity of devices, data control flow, old and obsolete internet traffic and the constant and unpredicted changes of the users and the requirements. In other words, the current internet is getting short very quickly over the actual demands.

Many other authors have presented a review of the challenges and possible trends towards the future internet pointing out the weaknesses and future applications and use for this envisioned resourced.

Siekkinen *et al.* in [6] present some architectural problems of the current internet that need to be considered for the future internet. For their vision, the concept of the future internet is the sum of many different networks (called realms) and their challenges are in matter of the concurrency, inter-communication, monitoring and management of all those realms.

Calic *et al.* in [7] present concrete challenges for the user-centric media phenomenon. Among them are: intelligent media, ubiquitous access, collaborative environments and governance.

Stuckmann and Zimmermann in [8] describe the European research motivation towards the future internet highlighting the importance of mobile and wireless access in the future development, as well as the collaboration among the different projects as the Future Internet Assembly consortia.

Levä *et al.* in [9] summarizes three findings as key trends to consider in the future internet by the description of an analysis scenario: (i) openness and network integrity, (ii) stakeholders' interests to build separated networks, and (iii) a new clean-slate design of the architecture.

Galis *et al.* in[10] present MANA as the architectural model for managing networks of the future internet . This architecture is based on nine capabilities related to research areas: General, Infrastructure, Control and Elasticity, Accountability, Virtualization, Self-management, Service Enablement, Orchestrations and Overall.

Terziyan *et al.* in [11] propose PROFI as a solution for interconnecting the future internet network elements using semantic languages. PROFI is a middleware to connect multidisciplinary approaches using declarative networking overlay architecture for programmable network components providing flexibility, openness and manageability.

Blazic in [1] introduces some challenges from the point of view of the evolution of internet identify as: Resilience, failure tracking and management, Availability and robustness to attack, Information security scalability, Resource accountability, Network-application coordination, and Scaling for more extreme dynamics.

Tan and Wang in [12] propose and architectural design for the internet of things as an approximation of the future internet architecture addressing security and privacy protection as one of the most important issues. In their proposal they expose four facets (Economical market, Technologies, Regulations and Socio-ethics) as key elements to address this issue.

Wu *et al.* in [13] proposed a five-layer architecture for the internet of things. Those layers are: Perception (to perceive physical properties by sensors), Transport (to transmit data through the network), Processing (to store and analyse information), Application (to develop diverse applications), and Business (to manage applications, releases and changes, along with business processes and requirements).

Chaparazada *et al.* in [3] report the evolution from IPv6 towards IPv6++ proposing some extensions like headers and management interfaces, presenting an overview of the Generic Autonomic Networking Architecture to achieve self-* behaviours.

Chen *et al.* in [14] summarizes some research trends challenges and concerns for the future internet as flexibility, security, mobility and manageability. In the same line, Chuberre *et al.* in [15] focus on characteristics of smart infrastructures to increase service performance, optimize operational cost, and enrichment of services capability.

Salamatian in [16] explains why the future internet should conciliate different architectural and networking stating two positions: (i) a polymorphic internet compatible with different networks and paradigms, and (ii) a network science to address a scientific approaches for solving design and development issues.

Heuser and Woods in [17] review some initiatives for the future internet pointing out that Europe had been positioned among the leaders creating a digital agenda for 2020 gathering industry, researchers and academia.

Coetzee and Eksteen in [18] analyses the application and potential of the internet of things in the vision for the future internet, pointing out challenges from conceptualization (i.e., business process , politics, partnerships) to technological requirements (i.e., privacy, scalability, interconnectivity).

Zhou and Zhang in [19] explore the human geography of the future internet as a factor for the development due the interaction between the real world and the technological one. Also, this geography impacts the evolution, and the multi-networking phenomena.

Jung and Koh in [20] overview the future internet challenges for the mobile environments making it the critical factor for the design of the future internet. Some of the challenges proposed include: dynamic capability of the hosts, and the identification structure of the mobile network, data management control, scalability and a common mechanism to deliver content due the heterogeneity of the elements in the network.

Hu in [21] analyses the security issues of the future internet addressing different points of control in the network: secret keys in the sensors, encryption mechanisms, safety assurance and legal regulations.

Metzger *et al.* in [22] introduces four challenges from the point of view of service-oriented systems: (1) services life-cycle, (2) the services' technological foundations, (3) a multi-layer and mixed adaptive initiatives, and (4) a proactive adaptation to guarantee services' quality.

Finally, Natarajan and Wolf in [23] focus their discussion over security issues in the network virtualization, one of the future internet initiatives to address some challenges of scalability and flexibility. As their conclusion, network virtualization is vulnerable and therefore the architecture needs some redefinition in order to avoid attacks.

Many of these approaches had led the creation of many research initiatives to build the future internet. With the purpose of conceptualizing the future internet we summarized some of these research initiatives' information into three main concerns: *(i)* Architecture and Networking, *(ii)* Application and Services, and *(i)* Users and Devices.

Architecture and Networking

A very important non-technological issue is related with the *business model* of the internet. Some decision about , who is in charge, and who should decide the rules, standards and control over a worldwide resources, are major considerations that future internet researchers need to address. Locally, the ISPs are responsible for all the infrastructure and the users final edge. However, for some ISPs maintaining and upgrading the network infrastructure depends on budgets and expertise.

A very immediate challenge is the *IP addressing space* available and the IPv6 initiative is clearly a solution to expand that space [3,17]. However the migration process for IPv4 to IPv6 is not solved yet, and while waiting for a consensus, the internet traffic and demand for connection of devices keeps increasing.

Another issue related with the deployment of new services and applications is often considered *impractical*. This is due to the high costs, in terms of money and time, associated with the installation of new hardware. Network virtualization helps to overcome this challenge and some projects are considering it an essential architectural technology. Indeed, the hardware evolution and design play a very important role in the creation of the future internet.

For many of the approaches, *response time and security* requirements are common concerns that appear together. Newer applications (e.g., those based on video or with a time-critical dependency) require to process data efficiently but at the same some domains (e.g., banking, healthcare, security) require high privacy during transactions and storage, yet addressing both requirements is not an easy task. Despite the efforts on improving transmission and protocol techniques, the results are not being enough for a permanent solution [3,15]. Moreover, with the security requirements, more data is added to the network traffic that causally increases the size of transmission packages and therefore the response time is affected making these two requirements a twofold issue. Smarter infrastructures, those able to understand and react after changing situations and requirements, could perform adaptation and decide over a pool of policies and algorithms to solve this twofold but with proper hardware to support the network's own need to be smart-able.

Finally but not less important is the *scalability* of the internet. The ubiquity of devices, the fact that every new technology is also internet-able, that more developers are deploying services and more users are demanding them, is making the scalability prediction a very hard task. As a definition for the internet of things [18], in the future internet there will be more devices than people connected to internet, which means that in terms of scalability, there is a requirement for sensors and actuators for those devices that need to be considered. According to the Cisco Internet Business Solutions Group (IBSG), the internet of things (IoT) is that moment in technology evolution where the number of devices connected to the internet is bigger than the number of people [24]. Nevertheless, scalability also means connectivity everywhere and any time.

Applications and Services

A significant issue is related to the constant *amount of data* that is being generated by users and applications over the internet. The continuous flood of data requires more applications available to process it in order to guarantee accurate and useful information in real time for users and application owners [18]. Therefore, as this data generation is continually growing, the life span of data, the storage capacity and the data analysis are big issues that need to be considered for the future internet.

During the past years, the software engineering community has evolve the software development towards the conception of *self-adaptive systems* as a response of continuous new requirements, uncertain changing context conditions and real-time. The current internet users are demanding software applications capable to respond to their necessities efficiently and the current internet needs to collaborate with those self-adaptive systems and vice versa [22].

Another important and recalled issue is related with *standardization and compatibility* (e.g., drivers, sensors and actuators, devices, languages). With the technological diversity, and the interconnectivity those multiple devices need to guarantee the capability to communicate with each other and with internet. In the internet of things vision, the compatibility is crucial. Despite that software components combined with web-services, address this goal, exposing services in a standard way, there are challenges in the discovery of services and the proper composition.

Users and Devices

The current internet appears to be services- and applications-centric. The users presence over the internet is the sum of the username owned by one person on the different web applications without the possibility to share cross-information among them. In response, newer web application are trying to centralize the user's login by merging themselves with social networks, but it doesn't fully represent the user as one entity [7] and sometimes is limited only for the users in that social network. As a result, the current internet fails on giving the user an *unique identification* for all the applications and services.

Mobility is keeping people connected to the internet any time and everywhere [20,10,14]. These mobile devices also have good processing power and storage capacity, but the current internet still depend on the traditional *client-server* architecture without taking full advantage of the technological power in the users devices.

From the point of view of the user, that can be either a natural person or a company, the lack of control over his personal information in the current internet holds back the possibility of exploding better applications. Then *privacy and control* are also issues that the future internet needs to address [7] to make the traffic over internet more secure between the different nodes and from one service to another. This also includes the accuracy of the information that represents the user (i.e., updated information).

2.2 The Internet of Things (IoT)

Along with the growth of the Internet it also came the incorporation of new technologies such as radio-frequency identification, that enabled things to have an identity and connection capabilities with the Internet. Soon, this new paradigms turned into the concept of the Internet of Things (IoT). In other words, the Internet faced the necessity to interconnect not only people but also multiple devices, able to talk to each other to exchange valuable information. Indeed, handling this amount of data requires certain degree of wisdom [24].

According to Cisco Internet Business Solution Group (IBSG), the number of devices has increased 100 times and it is estimated that each person will hold approximately 4 devices around the world by 2015 [24]. Certainly, this situation rises concerns in the way data is being handled.

A significant insight of the IoT is the different requirements in the matter of resources that all these devices and applications need. For instance, different domains require internet access, but at different service level agreements. For example, video streaming in healthcare applications, such as tele-medicine, requires special availability conditions than home video streaming.

Consequently, individual networks are created for each of these things to provide the services with the adequate quality they all require. However, the downsides relies on the management effort and shifting conditions of the network and the devices as they both keep growing. The goal is to develop intelligent devices directly connected to the internet, but capable to self-manage the needed resources, and negotiate service level agreements with other devices according their needs.

The proper use of sensors play an important role in the development of the IoT. Alcatel-Lucent touch tag service and Violet's Mirror gadget provide a pragmatic consumer-oriented approach to the Internet of Things by which anyone can easily link real world items to the online world using RFID tags [25,26]. According to Peter Hartwell from HP Labs: *With a trillion sensors embedded in the environment connected by computing systems, software, and services it will be possible to hear the heartbeat of the Earth, impacting human interaction with the globe as profoundly as the Internet has revolutionized communication [27].*

Initiatives of IoT

In comparison to other projects, Europe considers IoT one of the prime concerns while developing new internet. Particularly, the project community CORDIS have as an objective not only extension of the current internet but also, the deployment of new independent systems capable to operate with their own new infrastructures. Furthermore, this project community defines the IoT as a combination protocol of thing-to-person communication, thing-to-thing communication or machine-to-machine communication [28].

Similarly, other Europe project, European Research Cluster (IERC) is subdivided into: the IoT Architecture and Technologies, IoT Communication Protocols, Physical-Virtual Worlds interoperability, Things Coding and Naming, Energy Saving Issues, Harmonized Global IoT Standardization, among many others [28]. Finally the project CASGARS2 is responsible for finding experts from all over the world to explore the needs of IoT clusters architecture and networking [29].

2.3 Software-Based Defined Networks

Software-Based Defined Networking (SDN) allows to separate the concerns of the control plane from the data plane . This capability generates great interest among researchers. On the one hand, the *control plane* system is in charge to make the decisions about where the traffic is being sent. On the other hand, the *data plane* forwards the traffic to the selected destinations [30]. This separation of concerns allows the network to be programmed, automate, and controlled effectively to meet the application requirements.

In this changing scenario, from PC's to cellphones and other smart devices. There is an enormous need of virtualization of networks with greater bandwidth. SDN gives an abstraction layer for virtualization of networks. SDN provides virtualization where multiple network operation system can control *slices* of the same hardware device [31].

Moreover, SDN gives freedom to network administrators to implement policies and changes at runtime, which traditionally was hidden and fixed inside the switching and routing hardware. Furthermore, SDN describes the capability to provide programmable interfaces within the network switches to enable high level of automation while providing services [30]. Developing and implementing open source SDN tools and platforms has opened the gates of innovation for internet infrastructure [32]. Additionally, SDN provides an abstraction layer for virtualization of networks in which multiple network operation system can control slices of the same hardware device [31].

SDN, OpenFlow and NetFPGA

Traditional networking devices implement packet forwarding and routing decisions both on the same device. The OpenFlow implementation can be either at the level of the hardware or the software, while at the same time separating control and data traffic. OpenFlow is a protocol that allows network configuration to enable the communication among the control and data planes. OpenFlow is commonly mistaken equivalent with SDN [33]. On the one hand OpenFlow is a mechanism while SDN is a concept definition. Even though they are compatible with each other, SDN can have other mechanisms like OpenFlow.

OpenFlow is an open API to configure network switches enabling remote control of the forwarding tables in network devices (i.e., switches, routers, and access points). In general, OpenFlow is the combination of three elements: (1) a *flow table* that specifies how to process the flow, (2) a *secure channel* to communicate the switch to the controller, and (3) the *OpenFlow protocol* that specifies an open and standard communication mechanism [34].

In comparison, NetFPGA is a platform for prototyping networking devices. Currently, there are two platforms available namely NetFPGA-1G (1G) and the NetFPGA-10G (10G). These platforms are open source, and its hardware provides high speed networking systems. The hardware consists of a PCI express board with 4x10 Gigabit Ethernet ports and FPGAs. This open source project provides an approach to design and implement a router and their policies. It provides custom user module platform in which a user can place their own logic and data processing functions in FPGA [35,36]. This works best with an approach of Software based defined network which also separates data and control plane.

Tools and Platforms of SDN

There are a number of projects running in the Open Networking Research Center (ONRC) Lab at Stanford University which are continuously innovating SDNs. Some of the tools that are being developed in the lab are listed below [37]:

- **Beacon** is a Java based OpenFlow controller which supports both event based and threaded operation. Its a fast, open source and cross platform controller.
- **Nox and Pox** are cross platform and Open Source OpenFlow controllers written on C++.
- **Flowvisor** is a transparent proxy between OpenFlow switches and multiple OpenFlow controllers.
- **Mininet** is a simulation tool to create multiple nodes of OpenFlow networks using Linux processes in network namespaces.

The benefits of application deployment over SDN

Current applications are demanding higher bandwidth and better response time while being exposed to dynamic behaviour. SDN implies the reduction of the operations and management complexity to overcome the needs of current applications. Moreover, SDN's flexibility is provided with tools that automate many management tasks which are done manually by network administrators[30].

Additionally, these tools reduce operation overhead, decrease network instability and support Infrastructure-as-a-Service models. Moreover, some applications design for the cloud can run with smart management orchestration and provisioning systems, thus reducing some operational overhead without sacrificing the business agility [38].

The SDN infrastructure can adapt dynamically to the users needs by taking advantage of higher-level applications capability to manage network information and centralized control. For example, using OpenFlow, video applications would be able to recognize at runtime the bandwidth availability and automatically adjust the video transmission [30].

3 Future Internet Worldwide Initiatives

Among the projects towards the future internet there are two types of policies: One is in which the private sector is independent to create its own devices for the future internet, and in the other the government, academia and business had gathered together to create a collaborative research agenda [17]. With both policies the different projects had made interesting progress.

Despite the differences, all these worldwide initiatives converge to describe the main problem of the current internet as how the original design is not longer enough to support the actual and future challenges. Nevertheless, within time and to overcome the challenges many solutions had been implemented as patches weighting the internet with only temporary and partial solutions increasing the complexity and altering the structure. Therefore, from the point of view of the infrastructure there is a natural challenge for these initiatives to create a simpler and flexible architecture for the future internet.

As one of the definitions of the *internet of things*, which is the basis for many of these worldwide initiatives, the future internet is about interconnecting not only users and their personal computer devices but also all the things (*e.g.* emergency vehicles, home supplies, or building accesses) [2] [39]. That massive expected integration requires standardized communication protocols and languages. Indeed, another common interest to build a generic service platform to provide better integration between the internet and all the devices connected to it.

On the other hand, from the point of view of the applications, these initiatives are moving to create services more network-aware which means those able to self-adapt according the changes in the network during execution [10]. That type of services will move the internet application layer towards self-management systems providing autonomy and automation to enhance user's experience.

These worldwide initiatives include research groups, forums, consortia, academia and industry affiliations, government projects and international collaborations, working on different categories on interest (e.g., Networking, Multimedia, Security) and we have them summarized in Appendix A as a reference for future exploration. The following are some of the most recognized projects:

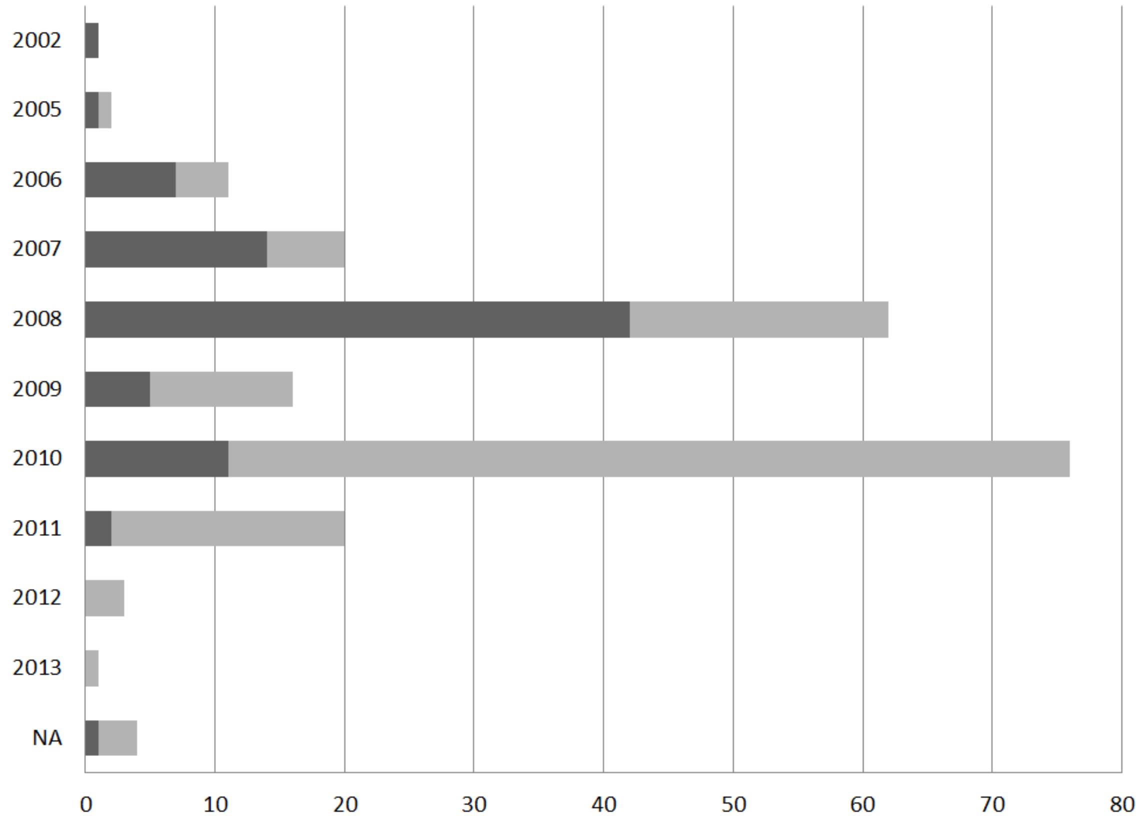
- The *Smart Applications on Virtual Infrastructure (SAVI)* is a Canadian partnership to design and deployed future applications on a flexible infrastructure [40]
- The *Future Internet Testbeds Experimentation between Brazil and Europe (FIBRE)* main goal is to design, develop and validate two research facilities located in Brazil and Europe for the future internet [41]
- The *Global Environment for Network Innovation (GENI)* is a US project to deploy new technologies based on an OpenFlow Testbed [42]
- The *Future Internet Research and Experimentation (FIRE)* [43] its an European initiative to create testbeds for the future internet experiments. As a result of a consortium, there are many projects associated to FIRE. Some of the projects are research facilities, experimental testbeds and others are just definitions and goals for future projects.

- *The Autonomic Redesign of the Internet Future Architecture (TARIFA)* is a research group active since 2007 that proposes a clean slate network architecture based on services and a context-awareness [44]
- The *German Lab (G-LAB)* started in 2008 with the purpose of creating an experimental facility for the new technologies and applications all across Germany research groups. [45]
- The *Future Internet Engineering (FIE)* is part of the Poznan Supercomputing and Network Center in Poland, and aims to develop a replacement for the current IPv4 with the purpose of solving the future internet networking issues [46]
- The *Future Internet Forum (FIF)* in Korean initiative to review the research and development direction for th e future internet. This Forum has five working groups with different focuses: Architecture, Wireless, Service, Testbed, and Security [47]
- The *New Generation Network (Akari)* is a program in Japan that aims to design and implement a new architecture for the worldwide future internet as well as the migration from the current one [48]
- The *Open Networking Research Center (ONRC)* is an academia and industry US affiliation to design and implement *Software-Design Networks* based on OpenFlow and other technologies [49]

Figure 1 presents the summary of projects according their creation date as well as their current state. As noted in the figure the year 2010 signified an explosion of projects, most of them are still active projects. The reason behind is related with the complete definition of the future internet conception and the creation of individual projects to work on particular challenges.

Figure 2 presents the summary of the projects according the research category. Despite the fact that some projects work in more that one of these categories, we categorized them according the most significance of their work. As noted in the plot, the *networking* area has the majority of projects which implies that the primary challenge to be address while building the future internet is towards the architecture and networking Followed bu this, in second place is the testbed, which indicates the natural creation of experimental infrastructures for the future internet experiments and evaluation.

Figure 3 shows the relation between the amount of projects according the most representative location of it founders. In this chart it is evident that how Europe is the leader taking advantage of the consortia of Europe-wide countries to create significant amount of projects to address particular challenges but at the same time keeping the connection among each other.

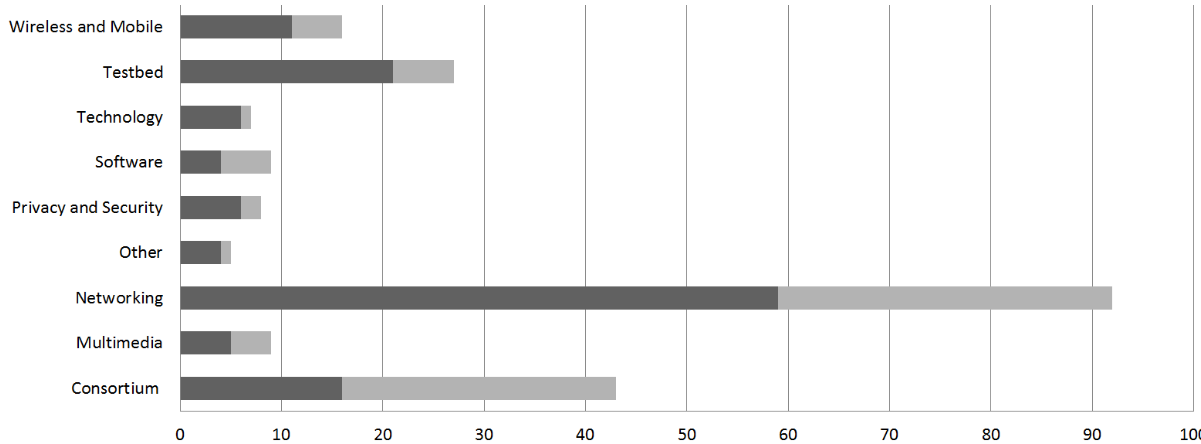


	NA	2013	2012	2011	2010	2009	2008	2007	2006	2005	2002
Terminated	1			2	11	5	42	14	7	1	1
Active	3	1	3	18	65	11	20	6	4	1	

Fig. 1. Total of projects created per year and current state of those projects.

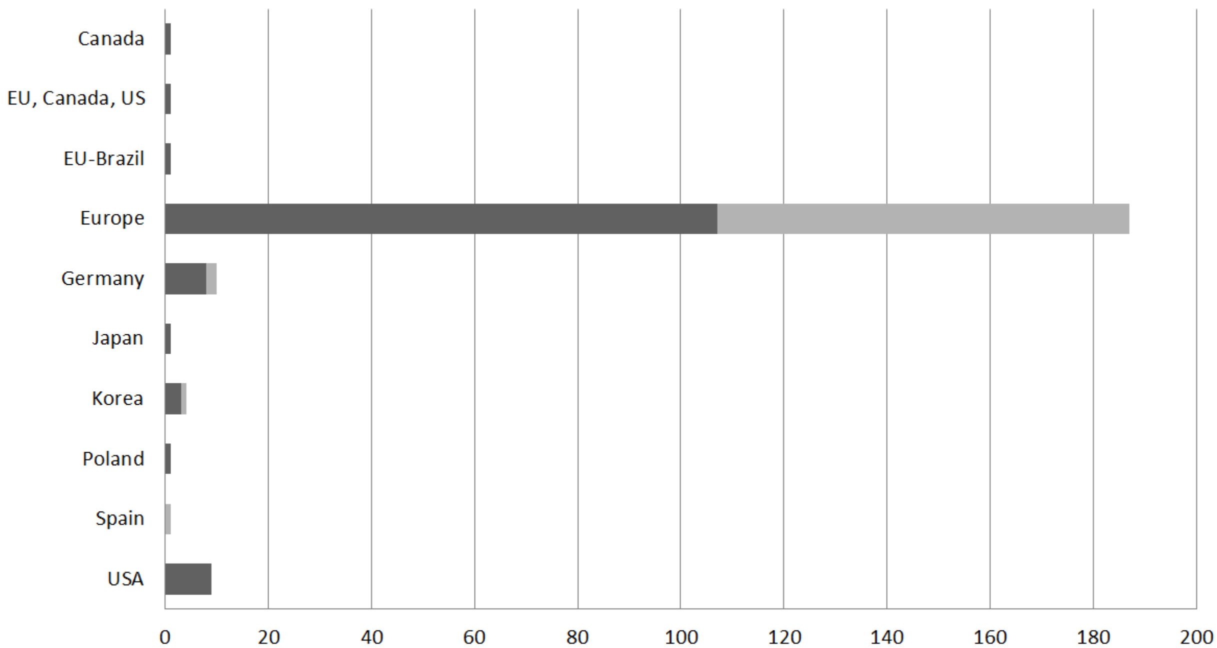
Figure 4 shows the relationship graph of relevant projects revised in this survey making explicit their affiliation, associated projects and testbeds. In the figure the *triangle* shape are related to testbeds, the *circle* shape to consortia, and the *rectangles* are projects in general. This figure only summarizes the most recognized active projects.

As a consequence of this exploration we can identify that all these projects are part of a lifecycle based on 3 levels in the construction of the future internet: The first level corresponds to the *definition of the concept for the future internet*, in which the project is focused on defining the requirements, the challenges and the scope of the future internet. Most of the projects in this level are the pioneers and usually are conformed by a consortia of universities, research groups and industry. The second level is the *design and deployment of the architecture and networking,* in which the project is focused in the definition and creation of new technologies, techniques and mechanisms to address the mos



	Consortium	Multimedia	Networking	Other	Privacy and Security	Software	Technology	Testbed	Wireless and Mobile
Active	16	5	59	4	6	4	6	21	11
Terminated	27	4	33	1	2	5	1	6	5

Fig. 2. Total of projects for research category and current state of the project.



	USA	Spain	Poland	Korea	Japan	Germany	Europe	EU-Brazil	EU, Canada, US	Canada
Active	9		1	3	1	8	107	1	1	1
Terminated		1		1		2	80			

Fig. 3. Total of projects for their main geographically location representative and current state of the project.

suitable infrastructure for the future internet challenges and requirements. In this level, the projects create experimental platforms and open their facilities for testing The last level is the *design and deployment of future internet applications*, in this final phase the

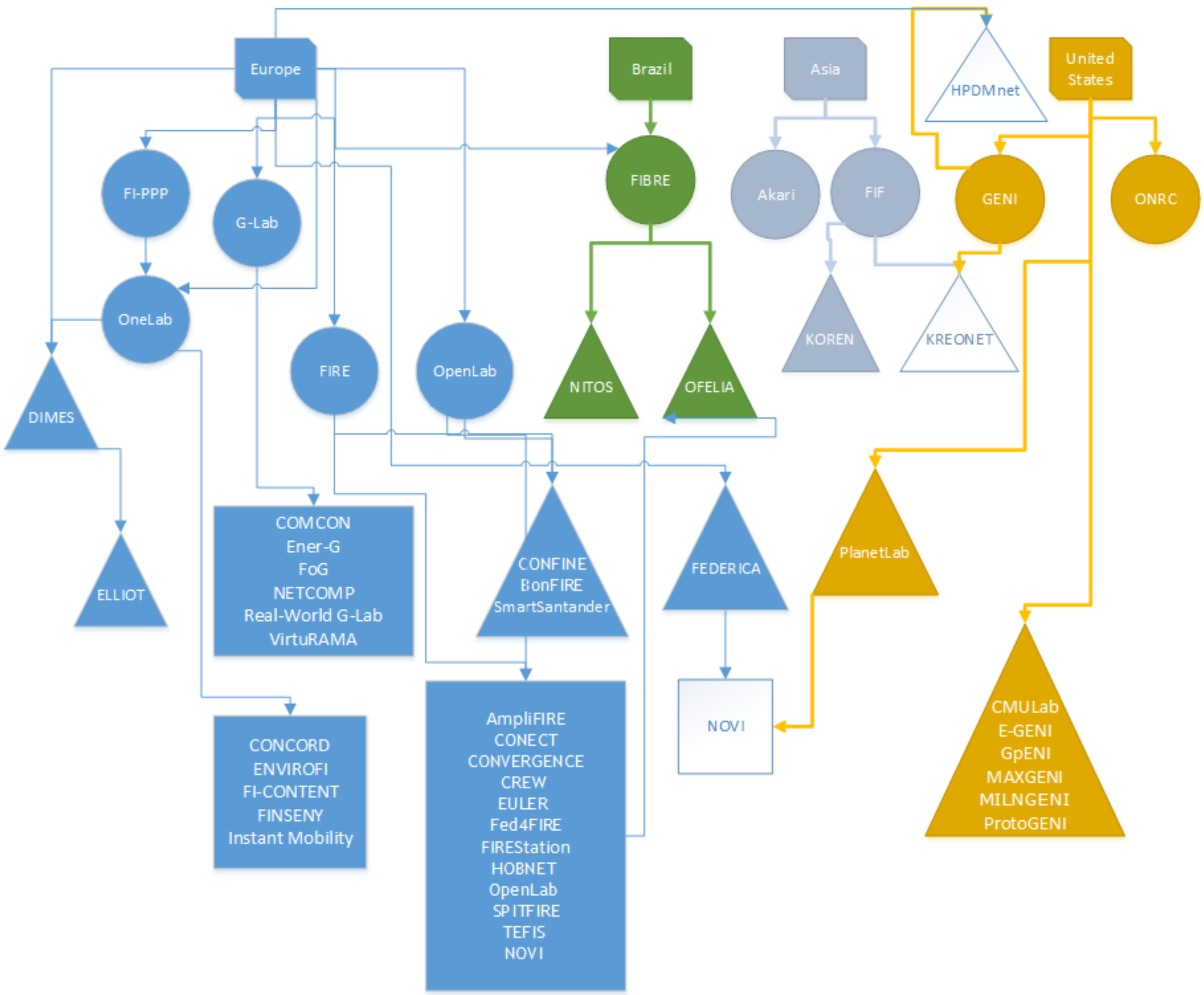


Fig. 4. Future Internet worldwide initiatives connections map

projects are ready to create applications to meet the new requirements taking advantages of the infrastructure and the platform of the new internet. After this study we conclude that for the most recognized projects, their lifecycle is at the end of completing level 2. The evidences are all the deployed testbeds, experiments conducted and evaluation of results to gather data to move for the next step of building software applications.

3.1 SDN Projects, experiments and results

The network is the back-bone of the internet and while we talk about clean slate approach for developing new internet, network is foremost concern. According to this survey, most of the projects are using OpenFlow or software defined networking to make better networks for future. Software Defined Networking has emerging as a most powerful technology in networks as it take decisions intelligently to decide where and how the data should be sent. It separates the data plane or forwarding plane with control plane.

Below Table 1 gives an overview of projects using different technologies for networks.

Table 1. SDN Projects and technologies

Country	Project	Technology	Comments
Canada	SAVI	OpenFlow, NetFPGA, Openstack	
USA	GENI	OpenFlow, NetFPGA, Openstack	
ITALY	Information centric Networking(ICN)	OpenFlow, NetFPGA	
BRAZIL	FIBRE, OFELIA	OpenFlow, NetFPGA	Different Testbeds
Germany	German Lab	OpenFlow	
EUROPE	CHANGE	OpenFlow	
KOREA	MediaXLabs	OpenFlow, GPUs	Alliance with GENI

The following sections describe an specific overview of some of the recognized worldwide projects, experiments and results from the interest of the Software Defined Networks (SDN).

Global Environment for Network Innovations (GENI)

GENI is one of the biggest and successful projects so far in developing and deploying future internet strategies. GENI is sponsored by NSF(National Science Foundation), lead by BBN technologies—which was responsible of the project ARPANET) in 1969. Indeed, GENI is a consortia of different partners and researches to experiment on networks, services and applications on a heterogeneous shared infrastructure.

GENI is working on a slice based strategy in which different researchers can request for a slice of resources with service requirements—such as, bandwidth, delay and computing power—to experiment in different locations. Researchers can remotely configure, program, debug, operate, and distributed systems established across the parts of the GENI suite. Moreover, it provides a virtual infrastructure, an extended virtualization abstraction to routers and links, and WiMAX sites for wireless aggregates with programmable base and mobile stations [42].

Additionally, GENI Racks is a subproject to address the computation and storage elements to build GENI. Some of the requirements of these racks are in the scope of the software, integration, monitoring, production, local aggregate owner, and experiment. Moreover, GENI Racks projects include OpenFlow features to provide connections to the GENI backbones via regional access networks.

GENI Racks is divided into three campus categories: ExoGENI, InstaGENI, and Starter Racks. ExoGENI uses some flexible technologies such as OpenFlow. Additionally, OpenFlow supports multi layer network slicing, creating virtual network slices that can be defined by any combination of physical layer, link layer, network layer and/or transport layer flow rules. OpenFlow network virtualization consists of two components: (1) the *Aggregate Manager*, an OpenFlow controller that can control a subset of the network resources as defined by the local administrator, and (2) the *FlowVisor* which virtualizes a physical OpenFlow switch into multiple logical OpenFlow switches, that can be controlled by different experimenters. In fact, for the GENI project it is critical to be able to allow multiple experimenters to run independent experiments simultaneously in one physical campus network, thus this implementation of racks [50].

The Open Resource Control Architecture(ORCA) is a framework implemented by RENCI and Duke University for ExoGENI, which provides virtual networking systems. It is integrated with OpenStack, Eucalyptus and xCAT to support virtual machines and baremental nodes [51]. The ORCA framework is meant ot be deployed in the BEN testebed and it will act as a small version of the future GENI testbed. BEN is a regional experimental testbed managed by RENCI , Duke University and North Carolina University. It consists of segments of dark fibre and also works with optical plane and packet forwarding plane in network [52].

Nevertheless, due to the increased number of wireless devices, there is a need to develop and deploy WiMax technologies to allow researchers to experiment with open and programmable 4G Wireless systems. GENI WiMAX sites are deployed to be used by local and/or remote administrators to conduct experiments [53].

GENI experimenters' Diverse Outdoor Mobile Environment (DOME) testbed is a network of buses consisting of WiFi cards. The DOME testbed is built to collect real data for mobile systems through the WiFi cards, 3G modem, VMs and other hardware and software available. The buses can talk to each other within the same range and also provides data for researchers on the DOME testbed [54].

DOME has a web portal for submitting experiments, which can be distributed to all buses installed with the DOME hardware automatically. The web portal also provides schedules for starting and stopping the experiments automatically [55]. Each instance of a Xen Virtual Machine which is also called a *brick* is installed on the buses. Then, the researchers submit the experiment on the DOME portal by creating the disk partitions that are mounted by the Xen VM.

The following experimental facilities—or research labs—are researching on future internet by either creating or supporting testbeds, or doing some research in extension of OpenFlow or some other protocols:

- *PlanetLab* is a large community of researchers formed from different geographical areas to provide a distributed platform for deploying, evaluating and accessing planetary scale network services. In PlanetLab each group of researchers and universities contributes with hardware resources and in return they have the opportunity of accessing one or more isolated slices of PlanetLabs global resources [56].
- *OneLab* focuses on a federation of PlanetLabs and plans to widen it by adding testbed nodes behind links that are not typical research network links [57].
- *Emulab* provides integrated access to a wide range of experimental environments, from simulated to emulated to wide-area network testbeds. Emulab is a universally available time- and space-shared network emulator which achieves new levels of easy use. It has virtual nodes, for running experiments using virtual resources rather than physical machines. Researchers can also use wireless testbed of Emulab.[58]
- *Teagle* is a project which gives access to all the testbeds build in the European community. Teagle portal provides information about all testbeds and also allows you to manage a Private Virtual Test Lab which is composed of hardware and software components existing in other testbeds across Europe. This lab provides a prototyping environment of testbeds [59].

Future Internet testbeds experimentation between Brazil and Europe (FIBRE)

Also Known as FIBRE [41], this research project is about building a testbed across Europe and Brazil to experiment over the future internet infrastructure and applications. This project is described in a set of objectives in which many subprojects had been created.

The most relevant issue about this partnership is that the research projects in FIBRE can use the testbeds in both sides to perform experiments. Right now there are two testbeds available: OFELIA based on OpenFlow technology, and NITOS based on commercial WiFi cards and Linux drivers.

The *Network Implementation Testbed using Open Source* platforms (NITOS) consists on open source software wireless nodes. It is part of the OneLab project [60] from the European Commission FP7. This testbed operates with two servers; one to scheduling and control of the users, and the other one to run the experiments in the testbed [61].

The *OpenFlow in Europe: Linking Infrastructure and Applications* (OFELIA) is a testbed in which researches can dynamically control the network. This facility is based on OpenFlow technology that enables the virtualization and control of the network [62]. OFELIA is composed by a set of islands that provide a diversity of technologies and layers for experimentation. These islands are in Germany(TUB), Belgium(IBBT), Switzerland (ETH), Spain(i2CAT), UK (UNIVBRIS), Italy (CNIT, CREATE-NET) and Brazil (UFU). OFELIA is divided into three phases in which first phase is to set up the islands with openflow controlling the network slice, second phase is to interconnect all these islands with the IBBT(citation needed) virtual walls and last but not the least experimentation using different use cases and customization of the Facility provided by OFELIA to FIRE and other projects researchers around the world.

Resources in each island of Ofelia consists of ORBITS/ICARUS nodes for wireless testbeds. These are very powerful wi-fi nodes also used in NITOS testbed. Each wired testbed/island uses at least OpenFlow NetFPGA servers, OpenFlow switches, Emulab server which is FIBRE virtual server.

Some experiments over OFELIA include processing capabilities, data storage and streaming media. However, these experiments had been made in the networking layer proposing protocols, transmission techniques and package streaming, and not from the application layer perspective. However, due to the maturity of the project OFELIA just finished its phase two out of three, and third phase in 2013 expects new partners that could propose application layer experiments.

German Lab (G-Lab)

G-Lab is a Germany wide project towards a reliable and secure network for the future. The mission of G-Lab is to create and maintain a facility where all the growing demands of new architectures, protocols and other research studies of the future internet components can be tested. Moreover, G-lab works on developing an architecture of future internet which includes a layer to design aspects, virtualization of network resources. G-Lab is also working on different naming and addressing schemes and what changes and alternatives are possible in routing field. G-Lab consists of various projects and research facilities which consists of around 170 nodes [45].

Some of major projects running in G-Lab are:

- *Future Internet Lab* is a network testbed which consists of 60 high performance node comprising of total 400 Gigabit interfaces. It provides a controllable environment in which experiments can be performed on arbitrary, user-defined network topologies. Additionally, programmable NetFPGA cards and high precision packet capture cards are integrated into the Lab. This lab also contains a wireless testbed which is using Gateworks Laguna boards equipped with 802.11n network interface cards and running OpenWrt [63].
- *Virtual Routers Architecture, Management and Applications (VirtuRAMA)* is a facility in G-Lab which works on establishing links and routers virtualizations. The high performance of virtual routers, extensibility and resource isolation are key factors in internet virtualization layer. This project is also working on mechanisms for transparently migrating virtual routers between physical machines. This is called *live migration* which will enable network management like energy conservation, load balancing and resources maintenance. An innovative work done by VirtuRAMA project is Network as a Service(NaaS) or network on demand. VirtuRAMA project takes advantage of Future internet testing LabVirtuRAMA [64].

Future Internet Research and Experimentation (FIRE)

The Future Internet Research and Experimentation (FIRE) initiative is creating a multidisciplinary research environment for investigating and experimentally validating highly innovative and revolutionary ideas for new networking and service paradigms [43].

FIRE has various testbed facilities which evaluates wireless sensor network applications. Three of them are very popular: Wisebed, Real-World GLab, and SmartSantander. *Wisebed* [65] and *Real World GLab* [66] provide a research platform for Internet of Things(IoT) through the integration of wireless sensors and meshed networks. They enable new kinds of applications based on real time, real world data. The *SmartSantander* [67] project aims to the creation of an experimental test facility for the research and experimentation of architectures, key enabling technologies, services and applications for the Internet of Things in the context of a city.

Asia Future Internet Forum

The Asia Future Internet Forum is a research network of the future internet among Asian countries—such as, Korea, China, and Japan—federated with other projects included

GENI. For instance, *K-GENI* is a testbed between Korea and the US to extend the GENI Project network connection to Korean GENI Project participants. Initially, they have deployed a GENI compatible OpenFlow core with access in Seattle, and a virtual core in Daejon (ASIA) which can be programmed. This experiment is to demonstrate programmable virtual network technology and also the federation of network operations [68].

Similarly, *DragonLab* is an independent autonomous project which has its own resources, and others also federated with others. Its focus is on very specific areas like traffic engineering research, measurement research and BGP researches. Also, it supports remote visualized and programmable experiments [69].

Smart Applications on Virtual Infrastructure (SAVI)

SAVI - Smart Applications on Virtual Infrastructure is a Canadian initiative for designing and developing the future internet which focuses on the networking architecture and applications. The main goal of SAVI is to identify the needs that future applications impose and in consequence, build the proper infrastructure for those applications to run and evolve efficiently.

The SAVI research project plan is into five themes supported by nine universities, namely: *(1) Smart Applications* to develop reusable frameworks to support data intensive, mobile, and media application; *(2) Extended Cloud Computing* to investigate on adaptive resource management such as, dynamic allocation of software, hardware, and network resources; *(3) Smart converged Edge* to develop a programmable network and computing infrastructure which provides virtualized resources and services; *(4) Integrated Wireless Optical Access* to design adaptive resource management methods at runtime capable to deliver QoE/QoS levels while fixing the capacity over demand ; and *(5) SAVI Application Platform Testbed* which is a shared activity to build an experimental testbed in the form of a smart-edge cluster that provides virtual resources in support of networking and applications[40].

The SAVI testbed will provide all the resources like NetFPGA, FPGA, GPU or any others needed by application from edge. These resources will reside in core but all edges can use it through virtualized environment. This will provide the capability for dynamically handling applications which will improve network bandwidth distribution, and lower the latency. One of the objective of SAVI is to improve resource utilization, by autonomously provisioning resources while monitoring the application's behaviour [70].

4 Future Internet Applications

Schönwälder *et al.* in [71] present a list of requirements for applications based on the premise that the future internet is a set of services available in the network and future applications should manage those services. An interesting proposal is to record users big portions of life as an alternate memory storage in the internet, in that way an user can replay his/her life by the use of internet. The challenge for this application is not the storage, but the information indexing and retrieval after user's request and specific circumstances, in an effective time and with precision. Let's say for example an user forgot the name of an acquaintance and want to recreate the moment when they met in order to get the name of the person. The storage of the information was based on a set of inputs that time (i.e., video, emails, voice records) and the future internet application should answer the question in proper time and accuracy.

In 2012 the European Commission posted nearly 300 project ideas for the future internet applications [72] and where classified according the objectives defined by them towards the future internet initiative. Among those classifications some areas include potential software applications where high bandwidth and low latency must be considered as relevant requirements (e.g., Services and Cloud Computing, Cognitive Systems and Smart Spaces, Symbiotic Interactions, Advanced computing, embedded and control systems, Smart energy grids),

Without a guarantee of the current state of the projects, the following list summarizes some of the projects proposal posted online and relevant for this survey in terms of software applications for the future internet:

- COMPOSITE MEDIA proposed by Helene Waters,British Broadcasting Corporation (BBC), Research & Development, United Kingdom [73]. This proposal envisions a new media content paradigm to invent new media formats and experiences by composing the continuous developing of online content related to the users interests and preferences in a way that the edition, adaptation and construction of online media depends of the consumers.
- AUGMENTED CONTENT ON VIDEO ONLINE proposed by Helene Waters BBC [74] In this proposal, augmented-reality-type overlays are provided under the users control to enrich video and bring interactivity in the experience of a an online video stream. With this idea, an user who is watching an online game sports could experience the elements as the player feels it (e.g., the distance of the field, the ball speed and perception, other players).

- SMEYEL: SMART MOBILE EYES FOR LOCALIZATION proposed by Kristof Csorba, Budapest University of Technology and Economics, Department of Automation and Applied Informatics, Hungary [75] This project is based on a smart camera network placed in the smartphones to process real-time video and create a redundant vision system of the environment. This idea would help to recreate 3D mappings of indoor environments, tracking of quadrocopter drones and other applications.
- SMARTPHONE APPLICATIONS FOR TRANSMISSION OF REAL TIME MULTIMEDIA proposed by Julian Beltran Droiders, Management, Spain [76] This project aims to build smart applications to transmit real time video and audio from smartphones to be used in scenarios like the eyewitness reporting. Also, this transmission would include geolocalization to address the source of the video from a browser.
- SMART MULTI-DEVICE APPLICATIONS proposed by Jacek Chmielewski, Poznan University of Economics, Department of Information Technology, Poland [77] This proposals intends to take advantage of the internet of things multiple device connections, and then creating applications that will not only use resources of the single device, but those closely connected to it, either to share or to gather information.

The European Technology Platform for communication networks (eMobility) had published an Strategic Applications Agenda [78] addressing 3 areas of importance in mobile and wireless communications towards future applications: Health and Inclusion, Transport, and Environment. In the report each area defines a set of challenges and project applications. The following list summarizes some of the most significant application proposals:

- WEALTHY is a project that integrates sensors, portable devices and computing techniques to process local information and give intelligent support to users on healthcare issues.
- DOC

  @HOME integrates telehealth for remote patients under long term treatments to gather data and effectively manage information with clinics to provide assistance at home.
- ENABLED is a project to develop techniques and tools to create real-time access of graphical content (as indoors and outdoors maps) to the blind and visually impaired through audio and hepatic representations, adaptable interfaces and wireless navigation.

– PEDESTRIAN DETECTION is a project to alert vehicle drivers of pedestrians activity in the nearby junctions as a traffic control mechanism.

In the same line of work, other research groups and software development companies had being working on ideas for applications in the future internet. In both cases, despite that some publications had been made about their initiatives, there are not details of the design nor the implementation and furthermore we can only highlight important aspects of their ideas. The High Performance Digital Media Network (HPDMNet) [79,80] is a consortium by Europe, Canada and United States research centers and universities. Their main goal is to develop and design experiments towards the future applications based on large scale streams of digital media under very flexible infrastructures and real-time requirements. This initiative take advantage of seven innovations in architecture some of those relevant for this survey as virtualization for network resources making availability more important, Infrastructure as a Service (IaaS) allowing flexibility and customization under changing requirements of the networking or the user, and Programmable Networks to dynamically reconfigure the resources.

Another source of information about future internet applications prospects are the developer's websites of technology vendors (i.e., Samsung, Goggle, Apple, Microsoft). These websites are available for developers to create their own applications, deploy, test, share and improve. These application stores turn into communities among those developers to exchange information, feedback and extensions of the applications. There is a considerations that the platform that makes all this possible is the current internet and future internet applications could also be addressed by these at-home developers that take advantage of new technologies specially mobile devices. In this scope, online gaming from mobile devices is one of the biggest markets for this type of application developments. On this scenario the low latency is a big requirement for the success of the applications, and in a mobile device, the changes in the location and bandwidth, represent a big challenge in the future internet.

4.1 Smart Cities

During this exploration, we have found significant approaches in the domain of smart cities. For many of this approaches smart cities are the largest source of data, devices, users and real-time applications. Additionally a smart city should be considered only with the appropriate technological support to process and deliver useful information based on huge streams of information to make the city sustainable and efficient. Indeed, smart cities should be in the scope of software applications for the future internet being this one the technological support to make that interconnection possible.

The ICT project, Generic event driven low cost service middleware for small smart cities proposed by Marko Bohar [81], aims for building solutions to create smart cities. In this case, the project intends to build a middleware whit real-time streaming capability to capture events from different subsystems of the city (e.g., traffic, energy, health services) and combine them to get relevant information for other subsystems in general. Another ICT project proposal is ADAPCITY: A Self-adaptive, reliable architecture for heterogeneous devices in Smart Cities proposed by Jesus Carretero [82], in this project the main goal is to provide the mechanisms required to make the devices in the smart city dynamically adaptable under changing conditions. In this project the heterogeneity of devices is crucial as well as the scalability of the data that is required to be processed.

In the same line SmartSantander by Sanchez *et al.* [83] expose a facility for interconnecting all kind of elements in the smart city. SmartEye by Pozza *et al.* [84] is one of the experiments deployed to manage the energy consumption of a testbed in the scale of a smart city. This experiment is relevant in the creation of the future internet applications due the share of resources and the flexibility of the future network.

The Massachusetts Institute of Technology (MIT) Media Lab, had created a City Science initiative to promote the design of technologies and analysis of big data to improve high performance urban environments [85]. The City Science initiative addresses 6 research themes related with the urban challenges. Despite that those themes are most related to the hardware than the software applications, we have identify some issues that could also apply. One issue is in the transporting scope; the city science project is aiming to build urban vehicles that are connected to a common network to share information. This information from the scope of future internet applications include the analysis of constant and real time data generated by those vehicles not only related to traffic but also by the user. In the future application for this vehicles, finding the best route is more that obvious, but also considerations related to the user's context like setting the car temperature is also relevant. Another issue is about the creation of customizable places like houses, offices and others according space, time and users. In this scope, future internet applications will gather relevant information about the user and the environment to perform those changes. However, those changes can be due time-critical information like natural disasters or health information about the person inside the place, therefore future internet applications must analyze big amounts of data in an efficient time.

4.2 General requirements for future internet applications

At this point, the surveyed approaches of the future internet do not present any applications as a final experience with compelling results. I seems like the maturity level for the worldwide future internet is in a stage focus on solving the architecture and networking issues before moving to the application layer and deploying future internet applications. Moreover, is in the plans of everyone's initiative some requirements are in the scope of network intensive applications, high demand of bandwidth and small response time, while keeping security and privacy and enhancing user experience. The following sections detail those requirements.

Low latency for real-time delivery of content

Low latency as stated in engineering, refers to the minimization on the response time of a system after a request. As mentioned for some of the proposals (e.g., transmission of real-time multimedia, smart cities traffic control) keeping a low latency is a very important requirement for the success of the application. In those cases effective response time sometimes is required to enrich users experience (e.g., online games or sports) and some other due the time-critical type of applications (e.g., stock market, healthcare, emergency system). Therefore, future internet application should be able to manage the processing to shorten response time taking advantage of the flexibility of the future internet network and architecture.

High throughput for large data processing

Throughput in software engineering is a non-functional requirement related with the capacity for processing. For the future internet applications the throughput requirement is due the amount of data to be process for the application itself to gather information that has to be delivered to the user (e.g., smart cities, multi-device applications, SMEyeL). One common requirement of the networking and architecture of the worldwide initiatives towards the future internet is the high bandwidth which is highly related with the throughput as equivalent to large scale data that has to be processed by an application in the future internet. These applications should take advantage of the network (i.e., virtualization, parallelization) to address the highest throughput by making the right decisions. These applications are not only smart, but also network-aware to be able to use and share available resources. Some of the applications related with high throughput include data center's management applications. With the explosion of virtualization and high speed networking servers are not longer required to be physically together, therefore the applications to manage those servers implies large amounts of data, for example, during service and machine migration.

Interactivity and identity for better user experience

Future internet applications reach for more personalized experience bringing to the end user interactivity with the applications, not only on matters of customization but also in the way the content is perceived. Some of this interactivity can be address by 3D graphics or augmented reality. This implies that the future internet should divide some of this processing between the core of the network and the end user's device. Some examples of this category are a third-person perception of a first person experience (i.e.,sports, online games) and telepresence (i.e., healthcare, emergency). Another way to reach user experience if by identifying the user once connected to the application (e.g, composite media) and deliver the proper content according its context and preferences. For this type of application a twofold in the personalization is the privacy and security to access such information from the user. However, taking advantages of the interconnection of the applications and the conception of integration through internet, gathering personal information to enrich the applications is a challenge that most current applications are addressing through localization and social networks.

Interconnectivity to workload balance

In the scope of the future internet, the interconnectivity of devices is being addressed. However, current applications are connected to each other through internet rather than the devices themselves. Then, future applications should include devices capabilities to empower the processing to be able to balance workload to reach its goal (e.g., gathering information, sharing information) as in the Smart Multi-device Applications proposal. Future applications could use nearby devices to collect information about surrounding context, or take advantage of already processed information instead of reaching a server in the cloud to get it (e.g., traffic and weather information, live online streaming, indoor mapping).

5 Summary

The future internet clean-slate design has been conceived as a worldwide concern for approximately the past 6 years, bringing together researchers from academia, industry and government to join efforts on building a most suitable infrastructure to address current internet challenges and future needs. Section 2 presents a summary of the current internet challenges grouped in three concerns *(1) Infrastructure, (2) Applications*, and *(3) Users*. In these concerns some challenges include *security, high bandwidth and ow latency demand, scalability , large amount of data analysis* and *mobility*. In the same section, we overview the *Internet of Things (IoT) and Software Defined networks (SDN)*, the first one as a vision that drove many of the initiatives to consider that the current internet is not suitable to overcome these necessities, and the second one as the new technology to manage networks dynamically. Hence, the internet of things is conceived as the massive, constant and unstoppable connection of users and devices to the internet to share and gather information to provide end-user better experience and better services by interconnecting all these elements. Moreover, Software Defined Networks changes the paradigm of traditional static infrastructure by providing capabilities to perform changes in the network at runtime.

As mentioned before, there are several worldwide initiatives working to build the future internet. Among all the efforts, some research groups and consortia stand out as pioneers of the initiative giving birth to hundreds of sub-projects aiming to solve some of those general challenges separately but keeping the internal correlation. Section 3 summarizes some of these initiatives and studies some aspects about the worldwide evolution of these approaches. In consequence, one of the contributions of this survey is a time-line analysis of the projects and the evolution of the worldwide initiatives. In this analysis, we had identified a lifecycle composed by 3 maturity levels: *(1) Definition of the future internet, (2) Architecture and Network design and implementation*, and *(3) Design and deployment of software applications*. With this measurement, we could state that the worldwide progress towards this initiative is the last part of the second level having testbed deployed to perform experiments, and new technologies ti build software defined networks for a suitable approach of flexible infrastructure for future applications.

As a significant contribution, this survey presents in Section 3 a summary of some of the mos relevant worldwide testbeds and SDN technologies, based on the relevance and importance while designing and developing future internet applications and summarizes a table to relate active project with SDN technologies. In this summary, OpenFlow and NetFPGA come on top of the technologies and the results of the testbeds being present in the most advanced projects of the future internet. Clearly, these technologies provide flexibility and high capacity to support the future internet applications.

In the last step of he future internet initiatives lifecycle, the deployment of applications on those testbeds is still in an intentionally stage, and therefore there is no evidence of actual applications deployment. However, as one of the contributions of this survey we present a summary of some of the prospect applications and a classification of general requirement that researchers and industry have proposed as future internet applications and are described in Section 4 as *(1) Real-time delivery of content, (2) Large data processing , (3) Better user experience,* and *(4) Workload balance.*

6 Conclusions

The internet is perhaps the most evolving technological invention that had changed the social structure of the world. Since the first design, there was an intention to interconnect geographically dispersed nodes to share information; and with no time, that interconnection spread from only universities to the inclusion of companies, homes and finally, to the last end of the user's hand with mobile devices. Indeed, the internet had evolved the way humans interact building a new digital society where rules of time and space are not longer a barrier.

However the high speed of evolution had also brought some disadvantages. The continuous fixes and patches to overcome new requirements, the creation of new technologies and devices, the amount of users connected to internet, and the new paradigms of the internet of things, had put over the current internet high complexity that computer scientists are trying to solve, from the physical layer (i.e., the hardware, the protocols and the structures of messages) to the application layer (i.e., the algorithms, applications, security mechanisms). Despite all the efforts to come up with solutions, there are additional requirements like time and obsolescence. As a result, worldwide communities had conveyed in a need for a clean-slate design for a new future internet that can address current challenges and can support future requirements.

For the past 6 years Europe had led most of the ongoing projects towards the future internet, making it the biggest consortium in the world. United States and Asia led in the second place. With the information surveyed for this paper, we have identify a maturity scale based on 3 levels: (1) Definition of the concept for the future internet, (2) The design and deployment of the architecture and networking, and (3) The design and deployment of future internet applications. After this study we conclude that for the most recognized projects, their lifecycle is at the end of completing the maturity level 2. Saying this, these project are deployed testbeds, conducted experiments and evaluating their results to gather data to move for the next step of building software applications.

As described in Section 3, the leading technologies of architecture and networking on the future internet are OpenFlow and NetFPGA. This technologies had being used to create software defined networks as one of the revolutionary elements in the new architecture of the internet providing flexibility and remote management networking elements, applications and services.

The natural progress of these initiatives is to move to the next maturity level to design and deploy future internet applications. However, the early stage only can provide prospects and initiatives for this applications rather that actual results. In this survey, as mentioned in Section 4, we have identify a set of requirements from those prospects that can guide us in the definition of future gaps and concerns. These requirements are in the matters of (1) Low latency for real-time delivery of content, (2) High throughput for large data processing, (3) Interactivity and identity for better user experience, and (4) Interconnectivity to workload balance.

The growth for future internet application development are not only in the hands of research centers, universities and industry. Technology companies (e.g, Samsung, Google, Apple, Microsoft) with market into smartphones and with a vision of all-device-interconnection had opened their API to at-home developers creating a community to constant develop and deploy applications with massive distribution and use. It is wise to understand that the future internet must face also, a massive sources of software development and the users requirements are as important as the developer's programming environments and availability to access the future internet. In conclusion, worldwide initiatives had made enormous progress in the development of the proper infrastructures and it is time to deploy future internet applications that take full advantage of these network technologies and architectures.

Acknowledgments

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A Worldwide Initiatives List

20-203DMedia - Active (2008) - Europe - Affiliation: FIA - Area of work: Multimedia - Website: www.20203dmedia.eu/

3DLife - Active (2010) - Europe - Affiliation: FIA - Area of work: Multimedia - Website: www.3dlife-noe.eu/3DLife/

4NEM - Terminated (2006) - Europe - Affiliation: FIA - Area of work: Networking - Website: www.nem-initiative.org/

4WARD - Terminated (2007) - Europe - Affiliation: FIA - Area of work: Networking - Website: www.4ward-project.eu/

ABC4Trust - Active (2010) - Europe - Affiliation: FIA - Area of work: Architecture - Website: https://abc4trust.eu/index.php/home/related-projects

ACROPOLIS - Active (2010) - Europe - Affiliation: FIA,ICT - Area of work: Wireless - Website: www.ict-acropolis.eu/

ADAMANTIUM - Terminated (2008) - Europe - Affiliation: FIA,ICT - Area of work: Networking - Website: www.ict-adamantium.eu/

AGAVE - Terminated (2005) - Europe - Affiliation: FIA - Area of work: Networking - Website: www.ist-agave.org/

Akari - Active (2010) - Japan - Affiliation: NICT - Area of work: Networking - Website: akari-project.nict.go.jp/eng/index2.htm

ALICANTE - Active (2011) - Europe - Affiliation: FIA - Area of work: Architecture - Website: www.ict-alicante.eu/

AmpliFIRE - Active (2013) - Europe - Affiliation: OpenLab - Area of work: Consortium - Website: www.ict-fire.eu/home/amplifire-project.html

ANA - Terminated (2007) - Europe - Affiliation: OneLab - Area of work: Testbed - Website: www.ana-project.org/

ANIKETOS - Active (2009) - Europe - Affiliation: FIA,FP7,ICT - Area of work: Architecture - Website: www.aniketos.eu/

ASPIRE - Active (2009) - Europe - Affiliation: FIA,FP7,ICT - Area of work: Technology - Website: www.fp7-aspire.eu/

ASSERT4SOA - Active (2010) - Europe - Affiliation: FIA - Area of work: Security - Website: www.ist-world.org/ProjectDetails.aspx?ProjectId=62c95d369d464a8abffe4665c91897ea

AUTOI - Terminated (2006) - Europe - Affiliation: FIA,FP7,ICT - Area of work: Architecture - Website: ist-autoi.eu/autoi/

AVANTSSAR - Active (2008) - Europe - Affiliation: FIA - Area of work: Technology - Website: www.avantssar.eu/

AWISSENET - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Wireless - Website: www.awissenet.eu/home.aspx

BonFIRE - Active (2011) - Europe - Affiliation: i2Cat,FP7 - Area of work: Cloud - Website: www.bonfire-project.eu

CARMEN - Active (2006) - Europe - Affiliation: FIA,ICT - Area of work: Wireless - Website: www.ict-carmen.eu/

CASAGRAS - Terminated (2008) - Europe - Affiliation: FP7,ICT - Area of work: Definition - Website: www.rfidglobal.eu/

CASAM - Active (2008) - Europe - Affiliation: FIA - Area of work: Tool - Website: www.casam-project.eu/default.aspx?page=home

C-CAST - Terminated (2006) - Europe - Affiliation: FIA,ICT - Area of work: Mobile - Website: www.ict-ccast.eu/

CHANGE - Active (2009) - Europe - Affiliation: FIA - Area of work: Networking - Website: www.change-project.eu/

CHIANTI - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Technology - Website: www.chianti-ict.org/

CHOReOS - Active (2010) - Europe - Affiliation: FIA,FP7,ICT - Area of work: Architecture - Website: www.choreos.eu/bin/Main/

CHORUS - Terminated (2009) - Europe - Affiliation: FIA - Area of work: Architecture - Website: old.ist-chorus.org/

CHORUS+ - Active (2012) - Europe - Affiliation: FIA,FP6,FP7 - Area of work: Software - Website: www.ist-chorus.org/homepage.asp

CHRON - Active (2009) - Europe - Affiliation: FIA - Area of work: Networking - Website: www.ict-chron.eu/

CMULab - Active (2010) - USA - Affiliation: CMU - Area of work: Testbed - Website: boss.cmcl.cs.cmu.edu/

COAST - Active (2010) - Europe - Affiliation: FIA,FP7,STREP - Area of work: Networking - Website: www.coast-fp7.eu/

COIN - Terminated (2007) - Europe - Affiliation: FIA,FP7 - Area of work: Definition - Website: www.coin-ip.eu/

COINALLIANCE - Active (2012) - Europe - Affiliation: FIA,FP7 - Area of work: Architecture - Website: www.coin-alliance.eu

COMCON - Active (2010) - Germany - Affiliation: Nokia,Docomo,Infosim - Area of work: Networking - Website: www.german-lab.de/phase-2/comcon/

COMET - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Architecture - Website: www.comet-project.org/

COMPAS - Terminated (2008) - Europe - Affiliation: FIA,FP7,STREP - Area of work: Architecture - Website: www.compas-ict.eu/

CONCORD - Active (2011) - Europe - Affiliation: FOI,FI-PPP - Area of work: Partnership - Website: www.fi-ppp.eu/concord/

CONECT - Active (2010) - Europe - Affiliation: FP7,STREP - Area of work: Wireless - Website: www.conect-ict.eu

CONFINE - Active (2011) - Europe - Affiliation: OpenLab - Area of work: Testbed - Website: www.confine-project.eu

CONVERGENCE - Active (2010) - Europe - Affiliation: FP7,STREP,ICT - Area of work: Networking - Website: www.ict-convergence.eu

CREW - Active (2010) - Europe - Affiliation: FP7 - Area of work: Wireless - Website: www.crew-project.eu

CuteLoop - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Definition - Website: www.cuteloop.eu/

DAIDALOSII - Terminated (NA) - Europe - Affiliation: FIA - Area of work: NA - Website: www.ist-daidalos.org/

Deep - Terminated (2009) - Germany - Affiliation: TU.Berlin,TU.Kaisersl,U.Duisb-Essen,FhG-Fokus - Area of work: Security - Website: www.g-lab-deep.de/

DEMONS - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Architecture - Website: www.fp7-demons.org/

DIMES - Active (2005) - Europe - Affiliation: OneLab - Area of work: Testbed - Website: www.netdimes.org/new/

E3 - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking - Website: https://www.ict-e3.eu/

eAccess+ - Active (2009) - - Affiliation: FIA, FP7 - Area of work: Networking, Applications - Website: http://www.eaccessplus.eu/node/1767

ECODE - Terminated (2008) - Europe - Affiliation: FIA,FIREworks,FP7 - Area of work: Testbed - Website: www.ecode-project.eu/

ECONET - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Technology - Website: www.econet-project.eu/

ECRYPTII - Active (2008) - Europe - Affiliation: FIA - Area of work: Security - Website: www.ecrypt.eu.org/

EFFECTS+ - Active (2010) - Europe - Affiliation: FIA - Area of work: Security - Website: effectsplus.eu/

EFIPSANS - Active (2007) - Europe - Affiliation: FIA - Area of work: Networking - Website: www.efipsans.org/

E-GENI - Active (2008) - USA - Affiliation: U.Stanford - Area of work: Testbed - Website: www.openflow.org/wk/index.php/E-GENI

EIFFEL - Terminated (2006) - Europe - Affiliation: FIA,FP7 - Area of work: Networking - Website: www.fp7-eiffel.eu/

ELLIOT - Active (2011) - Europe - Affiliation: FIA,FP7 - Area of work: Testbed - Website: www.elliot-project.eu/

EMANICS - Terminated (2006) - Europe - Affiliation: FIA - Area of work: Consortium - Website: www.emanics.org/

eMobilityNetWorld - Active (2009) - Europe - Affiliation: FIA,FP7 - Area of work: Wireless - Website: www.emobility-networld.eu/

ENDORSE - Active (2010) - Europe - Affiliation: FIA - Area of work: Privacy - Website: ict-endorse.eu/

Ener-G - Active (2007) - Germany - Affiliation: U.Passau - Area of work: Virtualization - Website: www.fim.uni-passau.de/en/fim/faculty/chairs/computer-networks-and-communications/research/projects/g-lab-ener-g.html

ENSEMBLE - Active (NA) - Europe - Affiliation: FIA,FP7 - Area of work: Definition - Website: www.ensemble-csa.eu

ENVIROFI - Active (2011) - Europe - Affiliation: FOI,FP7 - Area of work: Technology - Website: www.envirofi.eu/

ENVISION - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Networking - Website: www.envision-project.org/

ETICS - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Networking - Website: www.ict-etics.eu/

ETNA - Terminated (2007) - Europe - Affiliation: FIA,FP7 - Area of work: Definition - Website: www.etna-project.eu/

ETOMIC - Terminated (2007) - Europe - Affiliation: OneLab - Area of work: Testbed - Website: www.etomic.org/

EULER - Active (2010) - Europe - Affiliation: FP7,STREP - Area of work: Networking - Website: www.euler-fire-project.eu

EU-MESH - Terminated (2008) - Europe - Affiliation: FP7,ICT - Area of work: Networking - Website: www.eu-mesh.eu/

Euro-NF - Active (2007) - Europe - Affiliation: FIA,FP7 - Area of work: Architecture - Website: www.euronf.org/

EXALTED - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Architecture - Website: www.ict-exalted.eu/

EX-FI - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Definition - Website: initiative.future-internet.eu/

Fed4FIRE - Active (2012) - Europe - Affiliation: OpenLab - Area of work: Wireless - Website: www.fed4fire.eu

FEDERICA - Active (2008) - Europe - Affiliation: FIA,GARR,GN3 - Area of work: Testbed - Website: www.fp7-federica.eu/

FIBRE - Active (2011) - EU-Brazil - Affiliation: FIA,i2CAT,FP7,CNPq,BrazilGov - Area of work: Networking - Website: www.fibre-ict.eu/

FI-CONTENT - Active (2011) - Europe - Affiliation: FOI,FI-PPP - Area of work: Multimedia - Website: www.fi-content.eu/

FIF - Terminated (2007) - Korea - Affiliation: MIC,IITA - Area of work: Definition - Website: www.fif.kr/home.php

FIGARO - Active (2010) - Europe - Affiliation: FIA,FP7 - Area of work: Architecture - Website: www.ict-figaro.eu/

Finest - Terminated (2007) - Europe - Affiliation: FOI,FP7 - Area of work: Definition - Website: www.finest-ppp.eu/

FINSENY - Active (2011) - Europe - Affiliation: FI-PPP,FP7 - Area of work: Architecture - Website: www.finseny.eu/

FI-PPP - Active (2006) - Europe - Affiliation: FI-PPP - Area of work: Networking - Website: www.fi-ppp.eu/

FIRE - Active (2006) - Europe - Affiliation: FP6,FP7 - Area of work: Networking - Website: cordis.europa.eu/fp7/ict/fire/

FIREStation - Active (2010) - Europe - Affiliation: OpenLab - Area of work: Consortium - Website: www.ict-fire.eu/home/firestation.html

FITTEST - Active (2010) - Europe - Affiliation: FP7 - Area of work: Software - Website: www.pros.upv.es/fittest/

FITTING - Terminated (2011) - Europe - Affiliation: OpenLab,OneLab - Area of work: Testbed - Website: www.onelab.eu/index.php/projects/fitting.html

FLAVIA - Active (2010) - Europe - Affiliation: FIA - Area of work: Wireless - Website: www.ict-flavia.eu/

FoG - Active (NA) - Germany - Affiliation: ILMENAU - Area of work: Networking -

Website: www.tu-ilmenau.de/en/integrated-communication-systems-group/research/projects/g-lab-fog/

Freightwise - Terminated (2006) - Europe - Affiliation: FI-PPP,FP7 - Area of work: Architecture - Website: freightwise.tec-hh.net/

GENI - Active (2007) - USA - Affiliation: USA-Academia - Area of work: Consortium - Website: www.geni.net/

G-Lab - Active (2008) - Germany - Affiliation: BMFM - Area of work: Consortium - Website: www.german-lab.de/

GpENI - Active (2010) - USA - Affiliation: U.Kansas - Area of work: Testbed - Website: https://wiki.ittc.ku.edu/gpeni/Main_Page

HAMcast - Terminated (NA) - Germany - Affiliation: INET,U.Hamburg - Area of work: Architecture - Website: www.realmv6.org/hamcast.html

HOBNET - Active (2010) - Europe - Affiliation: FP7,STREP - Area of work: Networking - Website: www.hobnet-project.eu

HPDMnet - Active (NA) - EU, Canada, US - Affiliation: EU,Canada,US - Area of work: Testbed - Website: http://www.hpdmnet.net/

HURRICANE - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking - Website: http://www.ict-hurricane.eu/

I2Web - Active (2010) - Europe - Affiliation: FIA - Area of work: Tools for disabled and older people - Website: http://i2web.eu/index.html

ICTNET - Active (2010) - Europe - Affiliation: FIA - Area of work: Consortium - Website: http://www.ict-net.eu/

INFINITY - Active (2010) - Europe - Affiliation: FOI - Area of work: Consortium/Partnership - Website: http://www.fi-infinity.eu/

InstantMobility - Active (2011) - Europe - Affiliation: FI-PPP,FP7 - Area of work: Mobile - Website: instant-mobility.com/

INTERSECTION - Terminated (2009) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.intersection-project.eu/

IoT@Work - Active (2010) - Europe - Affiliation: FIA - Area of work: Architecture - Website: https://www.iot-at-work.eu/

IoT-A - Active (2010) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.iot-a.eu/public/front-page

IoT-i - Active (2010) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.iot-i.eu/public/front-page-1

IRMOS - Terminated (2007) - Europe - Affiliation: FIA - Area of work: Applications

- Website: http://www.irmosproject.eu/

I-SEARCH - Active (2010) - Europe - Affiliation: FIA - Area of work: Infrastructure - Website: http://www.envision-project.eu/

iSURF - Terminated (2007) - Europe - Affiliation: FIA - Area of work: Applications - Website: http://www.srdc.com.tr/isurf/

KOREN - Active (2010) - Korea - Affiliation: MIC,IITA - Area of work: Testbed - Website: yuba.stanford.edu/foswiki/bin/view/NetFPGA/OneGig/Projects/KOREN

KREONET - Active (2010) - Korea - Affiliation: MIC,IITA - Area of work: Testbed - Website: www.fif.kr/home.php

LAWA - Terminated (2009) - Europe - Affiliation: FIA - Area of work: Testbed - Website: http://www.lawa-project.eu/

MAXGENI - Active (2008) - USA - Affiliation: U.Meryland,BBN,NSF - Area of work: Testbed - Website: geni.maxgigapop.net/twiki/bin/view/GENI/WebHome

MEDIEVAL - Active (2010) - Europe - Affiliation: FIA - Area of work: Multimedia Application - Website: http://www.ict-medieval.eu/

MILNGENI - Active (2009) - USA - Affiliation: U.Washington - Area of work: Testbed - Website: groups.geni.net/geni/wiki/MillionNodeGENI

MobiWeb2.0 - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.w3.org/2008/MobiWeb20/

MOSQUITO - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.mosquito-fp7.eu/

MyFIRE - Terminated (2010) - Europe - Affiliation: FIA,ICT - Area of work: Definition - Website: http://www.my-fire.eu/

N4C - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Consortium/Partnership - Website: http://www.n4c.eu/

NANODATACENTERS - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.nanodatacenters.eu/

NAPA-WINE - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Network Applications - Website: http://www.napa-wine.eu/

NEFFICS - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Networking - Website: http://neffics.eu/

NESSI2010 - Active (2007) - Europe - Affiliation: FIA - Area of work: Definition, Architecture - Website: http://www.nessi-europe.com/

NESSoS - Active (2011) - Europe - Affiliation: FIA, FP7 - Area of work: Definition - Website: http://www.nessos-project.eu/

NETCOMP - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Cloud, Networks - Website: http://netcom.it.uc3m.es/research.html#media

NEXOF-RA - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://cordis.europa.eu/fp7/ict/ssai/docs/fp7call1achievements/nexof-ra.pdf

nextMEDIA - Active (2009) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.gatv.ssr.upm.es/nextmedia/

NisB - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Networking - Website: http://www.nisb-project.eu/

NITOS - Active (2011) - Europe - Affiliation: FIA,OneLab2,NitLab - Area of work: Testbed - Website: nitlab.inf.uth.gr/NITlab/

NOVI - Active (2010) - Europe - Affiliation: FP7,STREP - Area of work: Cloud - Website: www.fp7-novi.eu

OCEAN - Active (2010) - Europe - Affiliation: FIA - Area of work: Networking, Testbed - Website: http://www.ict-ocean.eu/

OEPI - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://oepi-project.eu/

OFELIA - Active (2011) - Europe - Affiliation: FIA - Area of work: Testbed - Website: www.fp7-ofelia.eu/

ONE - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Networking - Website: http://www.ict-one.eu/

ONEFIT - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Network, Applications - Website: http://www.ict-onefit.eu/

OneLab2 - Active (2010) - Europe - Affiliation: FIA - Area of work: Testbed - Website: http://www.onelab.eu/

ONRC - Active (2008) - USA - Affiliation: ONRC - Area of work: Networking - Website: http://onrc.stanford.edu/

OpenLab - Active (2011) - Europe - Affiliation: FP7, ICT - Area of work: Networking, Testbed - Website: www.ict-openlab.eu

OPTIMIX - Terminated (2008) - Europe - Affiliation: FIA, ICT, FP7 - Area of work: Networking, Multimedia - Website: http://www.ict-optimix.eu/index.php/Main_Page

OPUCE - Terminated (2006) - Europe - Affiliation: FIA - Area of work: Definition, Architecture - Website: ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/st-ds/opuce-project-story_en.pdf

OUTSMART - Active (2011) - Europe - Affiliation: FOI, FP7 - Area of work: Defintion - Website: http://www.fi-ppp-outsmart.eu/

P2P-Next - Active (2009) - Europe - Affiliation: FIA - Area of work: Multimedia - Website: http://www.p2p-next.org/

PARADISO - Terminated (2007) - Europe - Affiliation: FIA, FP7 - Area of work: Definition, Consortium - Website: paradiso-fp7.eu/

PASSIVE - Terminated (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Virtualization - Website: http://ict-passive.eu/about/

Peeroskop - Active (2010) - Germany - Affiliation: FIA, FP7 - Area of work: Networking - Website: http://peeroskop.realmv6.org/

PERIMETER - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.ict-perimeter.eu/

PERSIST - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Applications - Website: http://www.ict-persist.eu/

PetaMedia - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking, Multimedia - Website: http://www.petamedia.eu/

PHAROS - Terminated (2007) - Europe - Affiliation: FIA - Area of work: Multimedia - Website: http://www.pharos-audiovisual-search.eu/

PICOS - Terminated (2007) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.picos-project.eu/

PII - Active (2006) - Europe - Affiliation: FIA, FP7 - Area of work: Testbed, Architecture - Website: www.panlab.net/

PINCETTE - Active (2010) - Europe - Affiliation: FIA - Area of work: Network, Applications - Website: http://www.pincette-project.eu/

PlanetLab - Active (2008) - USA - Affiliation: NSF,DARPA - Area of work: Testbed, Architecture - Website: www.planet-lab.org/

PlanetLabCentral - Active (2007) - Europe - Affiliation: OneLab - Area of work: Testbed - Website: http://www.planet-lab.org/

PlanetLabEurope - Active (2008) - Europe - Affiliation: OneLab - Area of work: Testbed - Website: http://www.planet-lab.eu/

PlanetLabJapan - Active (2009) - Europe - Affiliation: OneLab - Area of work: Testbed - Website: http://www.corelab.jp/

PLAY - Active (2010) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.play-project.eu/

PPKL - Active (2010) - Korea - Affiliation: OneLab - Area of work: Testbed - Website: http://www.onelab.eu/

PrimeLife - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.primelife.eu/

PRISM - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking - Website: http://www.fp7-prism.eu/

ProtoGENI - Active (2008) - USA - Affiliation: U.Utah,HPLabs - Area of work: Testbed - Website: www.protogeni.net/

PSIRP - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking, Architecture - Website: http://www.psirp.org/

PSNC - Active (2008) - Poland - Affiliation: Polish Academy - Area of work: Networking, Architecture - Website: http://www.man.poznan.pl/online/en/projects/123/Future_Internet_Engineering.html

PURSUIT - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Networking, Architecture - Website: http://www.fp7-pursuit.eu/

REALMv6 - Active (2008) - Germany - Affiliation: FIA, PF7 - Area of work: Multimedia, Applications, Networking - Website: http://www.realmv6.org/

Real-WorldG-Lab - Active (2009) - Germany - Affiliation: Glab - Area of work: Wireless - Website: http://www.rwglab.de/

RESERVOIR - Active (2008) - Europe - Affiliation: FIA - Area of work: Cloud - Website: http://www.reservoir-fp7.eu/

ResumeNet - Active (2008) - Europe - Affiliation: FIA - Area of work: Networking, Architecture - Website: http://www.ict-fireworks.eu/fire-projects/resumenet.html

SafeCity - Active (2011) - Europe - Affiliation: FOI - Area of work: Definition - Website: http://www.safecity-project.eu/

SAFEST - Terminated (2011) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://ec.europa.eu/information_society/apps/projects/factsheet/index.cfm?project_ref=SI-2009-SIC-123931

SAIL - Active (2010) - Europe - Affiliation: FIA - Area of work: Neyworking - Website: http://www.sail-project.eu/

SAVI - Active (2008) - Canada - Affiliation: NSERC - Area of work: Consortium - Website: http://www.savinetwork.ca/

SCAMPI - Terminated (2002) - Europe - Affiliation: Scampi - Area of work: Networking - Website: http://www.ist-scampi.org/

S-Cube - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.s-cube-network.eu/

SEA - Terminated (2008) - Europe - Affiliation: FIA, FP7 - Area of work: Consortium/Partnership - Website: http://www.ist-sea.eu/

SecFutur - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Security - Website: http://www.secfutur.eu/

SELF-NET - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Definition - Website: https://www.ict-selfnet.eu/

SemsorGrid4Env - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Sensor, Applications - Website: http://www.semsorgrid4env.eu/

SENDORA - Terminated (2008) - Europe - Affiliation: FIA, FP7 - Area of work: Wireless Networks - Website: http://www.sendora.eu/

SENSEI - Terminated (2008) - Europe - Affiliation: FIA, FP7 - Area of work: Architecture - Website: http://www.sensei-project.eu/

SEPIA - Active (2010) - Europe - Affiliation: FIA - Area of work: Security Architecture - Website: http://www.sepia-project.eu/

ServFace - Terminated (2009) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.servface.org/

ServiceWeb3.0 - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Consortuim - Website: http://www.serviceweb30.eu/

SESERV - Active (2010) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.seserv.eu/

SHAPE - Terminated (2007) - Europe - Affiliation: FIA, FP7 - Area of work: Architecture - Website: http://www.shape-project.eu/

SLA@SOI - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Consortium/Partnership - Website: http://www.sla-at-soi.eu/

SMARTLM - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Applications - Website: http://www.smartlm.eu/

SMART-Net - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Architecture, Application - Website: https://www.ict-smartnet.eu/

SmartSantander - Active (2011) - Europe - Affiliation: FP7 - Area of work: Networking - Website: www.smartsantander.eu

SmoothIt - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking - Website: http://www.smoothit.org/

SOA4ALL - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.soa4all.eu/

SOCIALNETS - Terminated (2008) - Europe - Affiliation: FIA, FP7 - Area of work: Architecture - Website: http://www.social-nets.eu/

SOCIETIES - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Definition and Architecture - Website: http://www.ict-societies.eu/

SOCRATES - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Wireless Networks - Website: http://www.fp7-socrates.org/

SOFI - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Cloud - Website: sofi-project.eu/

SPARC - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Architecture, Networking - Website: http://www.fp7-sparc.eu/

SPITFIRE - Active (2010) - Europe - Affiliation: FP7,STREP - Area of work: Architecture - Website: www.spitfire-project.eu

SPRINT - Terminated (2010) - Europe - Affiliation: FIA, ICT, FP7 - Area of work: Security - Website: https://www.nics.uma.es/SPRINT/

SWIFT - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking - Website: http://www.ist-swift.org/

SYNERGY - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Consortium/Partnership - Website: http://www.synergy-ist.eu/

SysSec - Active (2008) - Europe - Affiliation: FIA - Area of work: Consortium/Partnership - Website: http://www.syssec-project.eu/

TA2 - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Consortium/Partnership - Website: http://www.ta2-project.eu/

TAMPRES - Active (2010) - Europe - Affiliation: FIA, ICT, FP7 - Area of work: Wireless and Security - Website: http://www.tampres.eu/

TARIFA - Terminated (2010) - Spain - Affiliation: i2CAT - Area of work: Architecture - Website: http://www.i2cat.net/en/projecte/tarifa-1

TAS3 - Active (2008) - Europe - Affiliation: FIA - Area of work: Architecture - Website: http://www.tas3.eu/

TCLOUDS - Active (2010) - Europe - Affiliation: FIA - Area of work: Cloud - Website: http://www.tclouds-project.eu/

TEFIS - Active (2010) - Europe - Affiliation: FP7 - Area of work: Testbed - Website: www.tefisproject.eu

ThinkTrust - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Definition - Website: http://www.think-trust.eu/

Trilogy - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Networking - Website: http://www.trilogy-project.org/

TWISNet - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Wireless,

Sensors - Website: http://www.twisnet.eu/
ULOOP - Terminated (2010) - Europe - Affiliation: FIA - Area of work: Wireless, Architecture - Website: http://cordis.europa.eu/fp7/ict/future-networks/documents/uloop.pdf
UNITE - Active (2010) - Europe - Affiliation: FIA, FP7, Vlab - Area of work: Consortium/Partnership - Website: http://unite-europe.gandi-sitemaker.net/
UniverSelf - Active (2010) - Europe - Affiliation: FIA - Area of work: Networking - Website: http://www.univerself-project.eu/
uTRUSTit - Active (2010) - Europe - Affiliation: FIA, FP7 - Area of work: Definition - Website: http://www.utrustit.eu/
VICTORY - Terminated (2007) - Europe - Affiliation: FIA - Area of work: Multimedia - Website: www.victory-eu.org
VirtuRAMA - Active (2010) - Germany - Affiliation: FMER - Area of work: Virtualization - Website: http://www.ikt.uni-hannover.de/virturama.html
VISIONCloud - Active (2010) - Europe - Affiliation: FIA - Area of work: Cloud - Website: http://www.visioncloud.eu/
VITAL++ - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Testbed, Architecture - Website: ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/fire/projects-vital-plus-plus_en.pdf
Webinos - Active (2011) - Europe - Affiliation: FIA - Area of work: Web Applications - Website: http://webinos.org/
WISEBED - Terminated (2008) - Europe - Affiliation: FIA - Area of work: Testbeds - Website: http://www.wisebed.eu/
WOMBAT - Active (2008) - Europe - Affiliation: FIA, FP7 - Area of work: Security - Website: http://www.wombat-project.eu/

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