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The Internet of Services: Vision, Scope and Issues

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Abstract: The Future Internet and especially the Internet of Services have recently become buzzwords in the European ICT research community. Although the different stakeholders have generally been identified, the research on the Internet of Services is presently at a preliminary stage, fragmented and largely carried out in relative isolation of related areas. The aim of this paper is to support and encourage the development of the Internet of Services by providing an overview of current developments, analyses and insight. It is a contribution towards a holistic vision that encompasses all relevant stakeholders, initiatives and their interests.

Keywords: Services, Service-oriented technologies and paradigms, Future Internet, Internet of Services, Web technologies, Value proposition

1. Introduction

Over the past few years, we have seen a considerable acceleration in the importance of the Internet in our professional and personal lives. This acceleration has been fuelled by both its growth as an infrastructure and its diversity of use as an information delivery channel. The emergence of numerous new paradigms including Peer-to-Peer networks, Software as a Service (or more generally, "X as a Service" - XaaS), highly interactive social networking applications, and an explosion of the number of multimedia content providers add to continuous debates on how the Future Internet infrastructure may develop. In Europe and other parts of the world, the Future Internet is becoming a strategic focus of research. One of the newest and arguably most promising fields of research is the "Internet of Services" (IoS). This is the subject of the present paper, in which we argue that the IoS potentially constitutes a fundamental shift in terms of: (1) the Internet's technical structure; (2) the way in which the Internet will operate and serve its users; and (3) the business models for the provisioning of services, especially service infrastructures.

2. Objectives and Methodology

This paper aims to provide an overview of current developments linked to the concept of the IoS; it will identify and analyse the main issues at stake, and provide preliminary conclusions. It is intended to contribute to a shared understanding and vision of the role of services in the Future Internet. The paper provides the context to help answering major questions such as: What constitute(s) the layer(s) of the IoS? How will the IoS layer(s) relate to the overall Future Internet architecture and how will the different layers be inter-

related? How to ensure that the IoS will provide benefits to all stakeholders and have a positive social/societal impact? What are the optimal means to foster sustainable investment in the IoS? What if the research efforts fail? Would the IoS happen anyway?

Throughout the following, we use the term service to denote a software-based component that is delivered via public networks - notably the Internet (as opposed to the more generic sense of service as an economic activity, with a lesser focus on the capability of ICT[i]). We focus on services that are accessed purely electronically, involve interactions between the software systems of the provider and consumer (not excluding interfaces accessible by humans), and are consistent with the notion of services as defined by W3C and others [1]. In particular, we focus on those services that relate directly to the infrastructure of the IoS, as opposed to services offered on top of the infrastructure. We believe the former class of services are of most interest for laying the foundation of the IoS. In contrast, the latter class are more specific to end user needs, more likely to be dependent on the market strategy of a particular provider, and generally more ephemeral.

An underlying perspective of the paper is that the IoS is not just about technology, but also about usage, community building, deployment, business models and public policy – all of which need to be duly considered in bringing the IoS to life. We see four main dimensions to be considered for the IoS: Research and Technology, Business, Individuals and Communities, and Policy and Governance. These four dimensions are inter-related, and development in one impacts on others. However, they are currently being addressed in relative isolation. Therefore, this paper seeks to address these inter-related aspects in a holistic, integrated manner. It attempts to structure what currently is a fragmented landscape into cogent descriptions and arguments, towards a shared understanding of what are the key issues and what may be at stake. The paper addresses the following questions:

- What are the main initiatives, trends, drivers and issues for the IoS?
- What is the value proposition for the IoS and how does this relate to existing and emerging business models of multiple groups of stakeholders?
- What are the preliminary conclusions that can be drawn from the myriad of activities?

Answering these questions is a considerable challenge and so is describing the "big picture" of the IoS. This implies a multi-disciplinary approach which encompasses the sciences of Information and Communication Technologies, Management/Organisational and Services Sciences, Economic and Social Sciences, and potentially others. That approach should ultimately lead to the definition of a common vision for the IoS, which our analysis suggests is currently lacking.

3. Development and Perspectives towards an IoS Vision

3.1 Scope, Synergies and Complementarities Regarding Future Internet Research

Future Internet research is at the heart of many large initiatives worldwide. The current wave of activities started in 2005 with the US National Science Foundation (NSF)'s announcement of the GENI experimental facility (Global Environment for Network Innovations). GENI originated from the observation that the current Internet infrastructure presents too many limitations which seriously hinder future developments such as mobility, dynamicity, 3D and quality features. The initiative focuses on a US continental-scale, programmable, heterogeneous, networked system driving a "clean-slate" infrastructure and enabling "real experiments with real applications and users". More recently, the Future Internet Design (FIND) initiative, also under the umbrella of the NSF, has started to fund projects and adopts a multi-disciplinary approach for reaching its objectives. There are other national initiatives, such as the AKARI Project and the New Network Architecture Forum in Japan and the Future Internet Forum in Korea. In Europe, of note is the German national "lighthouse project" THESEUS which has the strategic goal to develop products,

business models and markets, for enabling consumers and enterprises to access services, contents and knowledge anytime from anywhere. THESEUS seeks to contribute to the creation of a new Internet-based knowledge infrastructure. Already in the late nineties, the French "Réseaux de recherche et d'innovation technologiques" (RNRT) launched working groups on the future of the Internet, with a specific call in 2007 to address major issues under the topic “Rupture”. While the scope of these national initiatives varies, there is clearly synergy between them. NSF encourages researchers outside the US to participate in GENI and FIND. In an effort to coordinate Future Internet R&D among countries in Asia and other continents, the Asia Future Internet Forum (AsiaFI) was founded in 2007.

The European Union has accelerated the pace of its actions regarding the Future Internet since 2006, following consultations and publication of “The Future Networked Society” by the EIFFEL Think Tank [2], a voluntary initiative created under the auspices of the European Commission. Under the EU’s research programme, some 70 projects of FP6 and FP7 now fall under the Future Internet umbrella [3]. These projects, together with the relevant European Technology Platforms (ETPs), have signed up to The Bled Declaration to further actions on the Future Internet through a European Future Internet Assembly (FIA) [4]. The five ETPs active in the ICT domain (eMobility, EPoSS, ISI, NEM and NESSI) are developing a common vision and exploring joint work. Various FP7 Support Actions are stepping up their community building activities. The EIFFEL Support Action, for example, is creating a pan-European community of scientific/technical experts. All these initiatives present manifold different features in their approach. Coordination at the European level (via, for example, the FIA) would be a challenge.

From the research work available so far, a core debate of the Future Internet is evident, with two major schools of thought for designing the Future Internet. The first is based on a clean-slate approach with radical and disruptive innovation, promoted notably by GENI/FIND[ii] and investigated in FP7 projects such as 4WARD and Trilogy. The second is based on an evolutionary approach, i.e. building the Future Internet on top of the current Internet through incremental enhancements, which has been linked, for example, to the FP7 Future Internet Research and Experimentation (FIRE) experimental facility[iii]. The EIFFEL Support Action strongly recommends a smart combination of these two approaches to design the Future Internet. To complete this context overview, it is of interest to mention the Future Internet “dimensions” as envisioned by the European Commission: the Network of the Future, Internet of Services, Internet of Things, 3D Media Internet, Trust and Security, and Experimental Facilities. Development of the IoS therefore is intrinsic to achieving the full vision of the Future Internet. All these developments underline the need to define a common, holistic view of the IoS.

3.2 Trends and Developments

Recent visions of next generation technologies from a wide variety of viewpoints include connectivity layers and Next Generation Networks (NGN) [5], Grid Computing and Grid Services [6], Semantic Web [7], Service Web [8], Service Wave [9], BPM/ebXML and other application developments enabled by “Web 2.0” technologies. These visions all share a common core view: that the notion of services will play a key role in new architectures and deployment. The trends seen in each of these areas collectively point to: increased automation of software processes (encapsulation of functionality), increased modularity and interoperability (open interfaces and seamless machine-to-machine interaction) and increased flexibility/agility (dynamic software configuration and service composition). These trends are evident in the current state-of-play. For example:

- The complex web of emerging news sharing systems based on RSS syndicated news streams, feed processors and readers – which can be seen as a simple service-based system. News sources increasingly syndicate their content via continuously updated

XML based “feeds” which contain snapshots of new content. Other systems such as feed-burners and feed-readers process this output in order to extract and forward items relevant to specific topics and integrate them for users. Yet other services aggregate posts emerging on the same topic in meta-feeds and so forth. In this case existing Internet and Web protocols provide the service infrastructure.

- Large-scale scientific grid deployments such as EGEE already contain hundreds of services, providing a variety of different types of high capacity computing power, data storage and processing. Highly specialised infrastructure systems support high capacity data transfer, caching, monitoring and other features with value-added systems such as workflow tools. Lastly, domain specific data sources and processing services are available for experiments in areas such as e-Science and e-Health.
- Intra-company focused deployments of current SOA technologies that rely on deployed service infrastructures based on standards such as XML, SOAP, WSDL, UDDI and WS-Security for basic interoperation and BPEL, BPML, WS-CDL, XPDL and others for workflow and coordination. These are often combined with vendor specific add on tools from large organisations such as SAP, ORACLE, Microsoft and others. Businesses are able to progressively expose more and more internal functionality between units and departments for quick re-use.
- The rapid adoption of infrastructure services provided by companies such as Amazon, Google and others, with total traffic by volume to Amazon's S3 and EC2 Web Services even eclipsing global traffic to all other Amazon web properties by Q4, 2007.
- Rapidly emerging new services such as Twitter – which provides a rapid-fire personal micro-bloging service broadcasting short messages; generating well over 50% of their traffic not from their central website, but via a multitude of third party plugins connected to programmatic APIs.

Such developments point to a vision of the Future Internet comprising not just billions of users (compared to the 1.3 billion of users today or 20% of world population; source: Eurescom), but also billions of services, applications and devices; over a multitude of converged networks that are fixed, mobile, hybrid and virtualised; enabling potentially limitless sharing and exchanging of collaborative, user-generated contents both 2D and 3D; and all within trusted as well as trustworthy environments. A fundamental challenge in the current state-of-the-art is to tackle “cross domain” issues in a paradigm of convergence towards a “multi-faceted” Future Internet [10]. For example, in preparation for the Future Internet Assembly, the “Post-Bled” services and software working group has initiated the following cross domain topics: Management & governance; Architectures & infrastructures; Trust at scale and high granularity; and Lifecycle management for Future Internet applications [11]. The IoS should pursue the achievement of a “Continuity of services”, encompassing “perfect interactivity” for service consumers (i.e. permanent, transparent, seamless and trustworthy services) and new approaches to service management for service providers (i.e. a move from the complexity of the central control principle to the simplicity of keeping the consistency of each service) [12].

Various players in the telecom industry, on the other hand, have concluded that the current Internet has too many limitations which prevent the convergence of networks and services and the deployment of converged services for delivering “the unified experience” centred on the customer. Specifically, “in order to succeed the FMC (Fixed-Mobile Convergence) must be translated into a new service layer concept and not a new technology” and “future services will be highly individualised, and demand strict quality parameters in terms of latency, jitter and bandwidth” [13]. Orange/France Telecom, for example, has described Future Internet services as those that “focus on user-centric service delivery, with a tight coupling of IMS (IP Multimedia Subsystem) and the Web” [14].

3.3 Towards a Vision for the IoS: Issues for Consideration

At the present juncture of developments as described above, it would be impossible to lay down definitive requirements for the IoS. What seems clear is that the IoS is highly likely to be a fusion of ideas, technologies, practices, and communities. The software industry and the telecom industry are obvious stakeholders, but there are others such as their existing customers, Web 2.0 companies and communities, whose interest should not and cannot be ignored. The convergence of technologies emphasises the need to provide varieties of differentiating services. Our survey of the state of play suggests that there are likely to be one or more service "layers" in the overall architecture of the Future Internet, though the composition of the layer(s) is presently unclear, as is the intersection or intertwining of the network and service layer(s). "User centricity" is another key aspect (see, for example [15]), but what this entails is not sufficiently precise yet. Some of the research orientations to date point to a distinction between the service infrastructure of the IoS and the innovative, value-added services that such an infrastructure supports and enables[iv]. However, there is currently no common view on the definition of "infrastructure" in the context of Future Internet services, let alone what this infrastructure may comprise. Research on these issues is likely to be pursued by different groups of researchers in the coming years. On the other hand, while new technical models, mechanisms and techniques will undoubtedly be developed, will such solutions be able to accommodate billions of users, services and devices? What if the research community fails to produce radically new infrastructures, architectures and platforms? Would the IoS happen anyway? Is there anything that needs to be done to ensure a level playing field for all stakeholders? What are the bottlenecks for and who are the gatekeepers of service development?

We believe that the IoS must first and foremost *have a positive impact on the capabilities of users; be they individuals, organisations, "things" (as in the Internet of Things), or other software-based services*. It must ultimately result in benefits to people in their different roles in society. This has several major implications in respect of the role of the IoS, the paradigm of the IoS, the openness of the IoS and the positioning of the IoS in the Future Internet, as follows:

- The IoS is an *enabler* both for service provision and service consumption, as well as interaction between provision and consumption including "pro-sumption". The technologies and services that comprise the IoS are means to serve the needs of users; they are not ends.
- At the service infrastructure level, the paradigm of the IoS must be any-to-any. The services at this level must be commonly shared, transparently discoverable, and capable of living in an open and dynamic environment. Accordingly, they must have properties that comply with those characteristics and consistent levels of performance that can be guaranteed to the user.
- The IoS infrastructure itself must be open, in the sense that: (1) it is not locked into any technology paradigm or service platform; (2) it is not owned or controlled by any entity; (3) its development and growth is based on participatory input, as opposed to being channelled through makers of the infrastructure; and (4) it has no bias towards business models or service ecosystems, existing or emerging.
- The IoS infrastructure is part of the Future Internet. It should enable and allow for seamlessness of information, applications, services, networks, provisioning and usage to the edge of the network. The IoS should not make a priori assumptions about function placement which restrict business model experimentations by providers or users.
- Just like the current Internet, the serendipitous and disruptive innovation predicted in a variety of Future Internet visions will not be borne out of chaos, but instead rest on a

combination of emerging common and standard infrastructures and the opportunity of creativity this enables.

The above general consideration of requirements strongly indicates that a holistic, multi-disciplinary approach to the IoS is needed. This is also supported by the examples given for the state of play in Section 3.2, which are notable for their variety. Nevertheless, common themes do emerge, including:

- A shift from today's human-readable systems towards facilitating increased machine-to-machine interaction between systems – both in terms of providing new programmatic interfaces to information and functionality and in terms of taking a more structured approach to defining the semantics for machine-to-machine interactions.
- A shift from design time to run-time/late binding of service, from static to dynamic service composition, and from interoperability by design to interoperation by discovery, reuse and on-the-fly assembly.
- A shift towards increased distribution of applications and encapsulation of information as well as functionality; shifting from "download and install" of software applications to "remote pay-per-use" access models and from moving large collections of data around to "always-on remote queries" of information. This change enables three things: the creation of new classes of distributed applications, the creation of new delivery models for functionality and data, and the emergence of new business and revenue models.
- A shift from closed and tightly controlled intra-organisational distributed applications to massively distributed applications functioning in open, public environments.
- A shift from static and standalone content, applications, usage scenarios and systems to dynamic, media-rich content; context-aware, collaborative and intelligent services; ad-hoc value networks and innovation ecosystems; and globally connected and always-on systems of systems.

4. Internet of Services Value Proposition and Related Challenges

The IoS is becoming a hot topic for research. But research for the sake of research is not enough. The question "Why do we need the IoS infrastructure?" has to be addressed. It is because the answer to that question will help determine the means of realising the IoS. In a world of finite resources and competing strategies, choices will need to be made as regards the means, from architectural design to business alliances. Ultimately, these choices are based on the perception or even conviction of the need. "Doing nothing" about the IoS or "let the market sort it out", for example, are themselves choices.

We believe that the rationale for the IoS lies in the value it offers to its users, actual or potential. In line with our vision, the value of IoS stems from the IoS' positive impact on the capabilities of users. In other words, the demand and supply value creation equation of the IoS must have a positive balance in favour of the demand side. Among others, this is the basis for the user centricity argument of the IoS already noted, and a main ingredient of the global momentum of Web 2.0 companies and related initiatives. User-generated content, user-generated services - and even user-generated service infrastructures - constitute a prominent strand of user centricity, and a source of business-economic friction (see below). "Pro-sumption", where service provision and consumption is blurred, is another.

The full ecosystem of the IoS is vast and still nebulous. Arguably, no definitive chart exists. However, for the purpose of value attribution and accretion, we may identify the users and providers of IoS, on the basis of what could be gleaned from the markets, though not necessarily what might develop in future. This is depicted in Table 1.

Just like the Internet, the IoS should serve equally the individual, business, government and other public environments. It has three main kinds of impact on users' capability: technical, economic and social/societal. *Technical capability* is traditionally the main focus

of ICT, where great strides have been made and are continuing in industry and in research (see examples in Section 3). It pertains to all four groups of users (see Table 1).

Table 1: IoS Users and Providers

Users		
• Individuals/communities • Organisations/communities		• Things (as in the "Internet of Things") • Other software-based services
Example providers & their classification[v]		
Utility providers	Aggregators	Integrators
• Specialised software companies • Large companies with specialised service capabilities • Web 2.0 companies • Telcos, ISPs and other current web infrastructure providers • Hardware companies • Focused start-ups	• First generation B2B companies • Industry hubs • Large companies with specialised service capabilities • Web service hosting and management companies • EAI vendors • System integrators • Focused start-ups	• Software vendors • System integrators • Hardware companies • Web 2.0 type (user) communities

Economic capability relates to costs and benefits, usually though not exclusively expressible in monetary terms. It pertains to individuals and organisations as users. Productivity and (economic) growth are key examples. *Social/societal capability* is the most difficult to characterise; it ranges from recent concepts like collective intelligence/wisdom of the crowd to quality of life and eHealth, from eParticipation/eDemocracy to the latest Fifth Freedom of the EU – free movement of knowledge [18]. It pertains to individuals as users and the organisation of users into communities. Unlike the other two capabilities, it is least amenable to direct quantification. In all cases, however, the IoS produces impact on the capability of users through their *use* of the IoS. In this respect, the IoS is no different from other technology paradigms: its use might enable users to reduce efforts/resources; do existing things better; do new things which are judged to be "positive"; and/or reduce risks.

Many attempts are currently being made to characterise services for the Future Internet[vi]. Existing service ecosystems, commercial or otherwise - from Salesforce's AppExchange to Amazon's AWS to Facebook to Dopplr to Google's constellation of labs, codes and online communities - are already producing major improvements to users' technical capability as well as economic welfare. Some are "open" in the sense of publishing APIs, widgets and other technical functionality and making them available at low or even nil cost, leading to an explosion of new services from professional developers as well as seasoned "amateurs". Leading actors in the ICT industry and in Web 2.0 are also engaged in initiatives targeting service platform interoperability, inter-network service development and continuity, fusion between the physical world and virtual world and so on[vii]. The impact of technological convergence has been recognised especially in the telecommunication area; efforts are afoot to address seamless service delivery over different types of networks, including fixed, mobile and hybrid, as well as seamless services in Next Generation Networks. All these are important developments and would result in building blocks for the IoS. However, while they contribute to the value proposition of the IoS, they do not by themselves ensure a positive surplus on the demand side in the value creation equation. It is unclear whether or how they would enhance the capability of users - including which specific capability of the user - on a sustainable basis. Importantly, they might create a positive surplus of value for users *within* their own ecosystems. But these benefits are ecosystem dependent; they are lost as soon as users no longer belong to the ecosystem. In other words, the existing service ecosystems do not fully cover, let alone sufficiently address, the range of issues identified for the IoS in Section 3.3.

Given the existing service ecosystems in which major players are aggressively investing[viii], it might be thought that the IoS should be conceived as a global federation of such ecosystems – in other words, the IoS would "happen anyway". However, the technical challenges for service discovery, description, composition, negotiation and orchestration across service ecosystems should not be under-estimated, noting that future ecosystems are likely to mix telecoms, media and web capacities. Nor is not entirely clear how the issues identified in Section 3.3 would play out in this scenario. There is an even larger question mark over the commercial incentive for service ecosystem federation, including that for making services reusable in terms which are commercially attractive to the provider in any given business model[ix]. The competitive positioning of providers (see Table 1) in a nascent "IoS market" with an abundance of novelty fuelled by Web 2.0/X.0, an unclear trajectory of network effect, no sustained records of revenue streams, no clear market structures, and an eclectic population of potential providers spanning multiple industries/domains and those defying traditional classification, add to further uncertainty in the short to medium term. In sum, the business models for providing the IoS are presently at best unclear.

From the perspective of value proposition as described above, what distinguishes the IoS from the many initiatives on the market from Salesforce to Amazon are the specific characteristics of the IoS in creating and delivering usage and producing impact on users' capability. In the previous paragraph, we raised the fundamental question of business models for the IoS infrastructure providers. That, however, is different from the question of business models, which the IoS would enable in order to produce a value surplus for users. In accordance with our analysis in Section 3.3, IoS should not itself be biased towards certain business models of how it is to be used; a potentially unlimited multitude of business models should be supported by the IoS. This raises an important architecture issue of technical interface placement of services, assuming that the architecture be open: where and how should technical interfaces be defined, where economic players can compete (see [20] on the economics of next generation Internet architecture).

That the Internet itself makes no assumptions about and is not biased towards particular business models is a critical factor for the serendipitous and disruptive innovation characterising its success. We believe that the Internet's tradition of being a virtuous circle of network reach (expanding number of users) and new applications (business opportunities) must be preserved and be carried through to the establishment of the IoS. The innovation argument rests on a set of more fundamental notions underpinning usage and impact, namely: *universality of services, accessibility of services and neutrality of services*. Together, they ensure that (1) usage of the IoS is unfettered and unlimited; (2) the pattern of use is in the control of the user; (3) development, growth and impact of use are directly channelled through users, as opposed to providers or makers (also known as the "generative" argument, see [21]). We believe these are the main ingredients for the value proposition of the IoS, and from which the characteristics of the IoS – such as any-to-any, openness, ownership and control – should be derived. Value creation should particularly focus on the edge of the network, where users are located. Benchmarking existing and emerging service ecosystems against these fundamental notions would eventually be a useful or even necessary exercise.

5. Conclusions and Summary Recommendations

In this paper, we have presented a perspective of the IoS and discussed a number of major issues. Tackling these challenges requires studying and further developing open service architectures and platforms, robust and stable utility-like service infrastructures, context-aware value-added services, methodologies for developing flexible and extensible services and networked applications, methods for experimentation and deployment, as well as (most importantly) models to deepen our understanding of how all these technologies and

research activities play together to enable the vision of the Future Internet Economy [22]. These activities need to be developed in a coherent and integrated way. They should also encompass non-technical perspectives in order to guarantee the success of their implementation, i.e. to bridge the future developments regarding the IoS with the activity of the economic actors to ensure that they will foster organisational innovation and as a result develop competitive advantages for the European economy.

While current research on SOA, Web/Enterprise 2.0/X.0, Enterprise Interoperability, Service Web, Grid Services and Semantic Web helps us address important bits of the IoS puzzle, none of these sufficiently addresses the overarching challenge of enabling and improving cooperation between service providers and consumers. Whilst breakthroughs may come in the form of individual projects, there is no obvious means to build up a critical mass of sustainable services and no significant progression towards truly open, universally accessible service infrastructures. The value proposition of the IoS raises fundamental issues about the business model for IoS provisioning. There is, therefore, an urgent need for a unifying perspective for research to position Europe as the leading actor in Future Internet Services. Aggregating all the different perspectives is one necessary step which will help overcome the current obstacles and enable advancement on the IoS challenge.

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[i] See, for example, the services' definition given by IBM including a description of business services, http://www.research.ibm.com/ssme/services.shtml (as of July 2008).

[ii] FIND invites the research community to consider what the requirements should be for a global network of 15 years from now, and how we could build such a network if we are not constrained by the current Internet - *if we could design it from scratch.* Some 40 projects are currently involved. See http://www.nets-find.net/.

[iii] The FIRE experimental facility is intended to support research for the Future Internet at different stages of the R&D cycle based on the design principle of "open coordinated federation of testbeds". See http://cordis.europa.eu/fp7/ict/fire/.

[iv] A perspective is given in [16], which emphasises the twin notions of utility and end-to-end for the IoS service infrastructure in order to create a level playing field with no technical barriers to market entrants, and to stimulate the wide provisioning of value-added services that are fine tuned to the needs of users, without being locked into particular "ecosystems". Another perspective is offered in [17], which identifies two aspects of the "Future Internet Infrastructure" with the greatest potential for Europe: (1) "Internet of Services – the service infrastructure" and (2) "Internet of Things – the integration of the physical and the digital world". [17] further proposes "a broadened concept of global and open Service Delivery Platform" for the IoS.

[v] The listing of example providers does not include so-called "prosumers" (end users as providers). It could be argued that prosumers should figure in any classification of providers.

[vi] Example list on trends and characteristics: Nomadic access becomes the norm; From ad hoc usage to always-on experience; From static information access to dynamic and time-critical services; From free-of-charge access to value-based transactions; Creating trust; Simplification of user interface; Increased M2M interaction [15]. See also the description of IoS in [12].

[vii] Most recent example as of May 2008: a technology consortium comprising Sprint Nextel, Google, Intel, Comcast, Time Warner and Clearwire to create a US$ 12 billion wireless platform targeting new Internet-based services.

[viii] Notably Google, Yahoo, Microsoft, Amazon, IBM and Sun; the infrastructures for such ecosystems are now popularly known as "clouds".

[ix] As evidenced by, for example, the on-going debates of IPR and the relatively small number of publicly available APIs and web services (reported to total respectively 802 and 27563 as of 6 July 2008 [19])