POSITION PAPER

FUTURE NETWORKS

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1 Context and Trends

When considering the evolution of the Internet, a number of important observations can be made:

- The Internet is becoming an immersive medium that will support a natural interaction between people and their environment.
- The Internet will become the service platform of the future and it will take over large parts of the functionality and intelligence that is currently provided on personal platforms.
- The Internet will connect billions of people and trillions of devices.
- The Internet will become the unifying platform for many application areas (eHealth, Media, Transport, Energy, Education, Entertainment, ...).

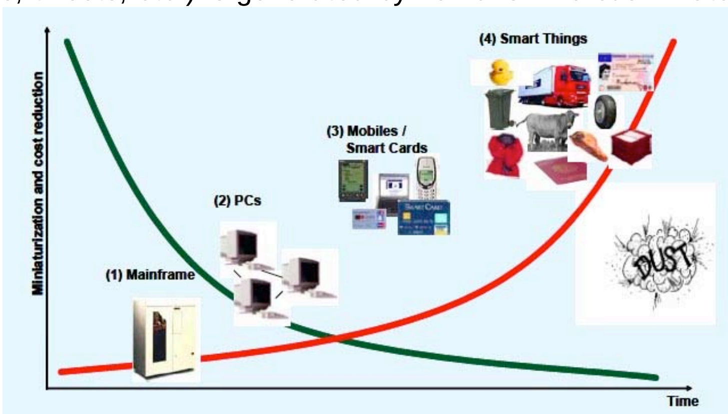
1.1 The Internet as an immersive medium

The way people are interacting with each other and with their environment is drastically changing. Traditional interaction is gradually shifting towards ubiquitous computing and embodied interaction in which interacting with a system is accomplished by communicating with our environment and with other people in our vicinity. This evolution is driven by the increasing amount of tangible objects that have computing capabilities and sensors integrated. Originally a text-only medium, the Internet evolved to simple graphics, photographic images, audio, video, and synthetic 3D (still somehow troublesome) as technology matured. The trend is towards better synthetic 3D, but also towards stereoscopic, multiscopic, multi-view, free-viewpoint, omnidirectional, ... in short “immersive” 3D imagery, meant to provide a spectator a feeling of “being there”. This trend is already clear in high-end markets such as digital cinema, and is emerging in home entertainment (stereo- and multi-scopic TV systems, consumer level stereo shutter glasses and graphics accelerators and applications supporting it). It is not only the way the environment is displayed to us but also the way we trigger this environment. The traditional keyboard is gradually replaced with touch screen, natural language processing, gesture and haptic interfaces and eventually with a brain computer interface.

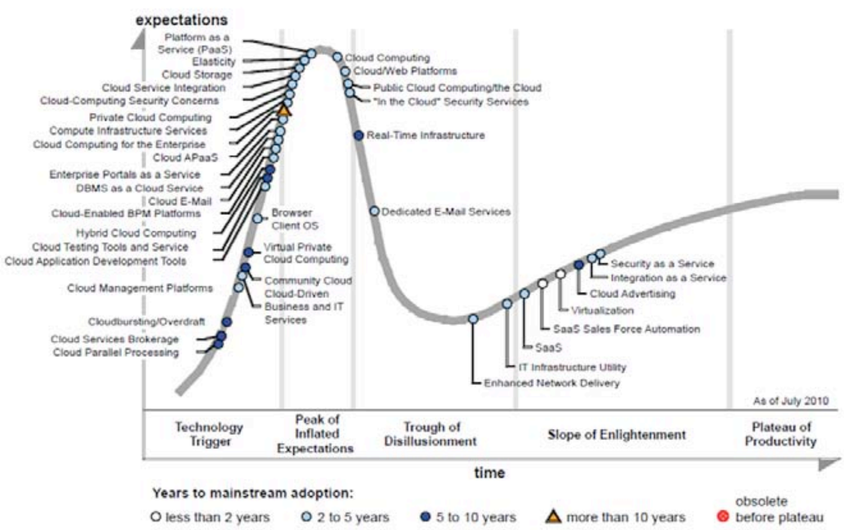
This is clearly visible in modern game consoles such as the Ninetendo Wii, XB0x 360 Kinect and Playstation Move/Eye. It will carry on to the Internet. Novel highly personalized but shared immersive Internet experiences will emerge, that put the participant at the very center, and that will blur boundaries between social networks, entertainment, information retrieval and communication. The “home page” of today will evolve into a “home space”.

1.2 The Internet as an intelligent application engine

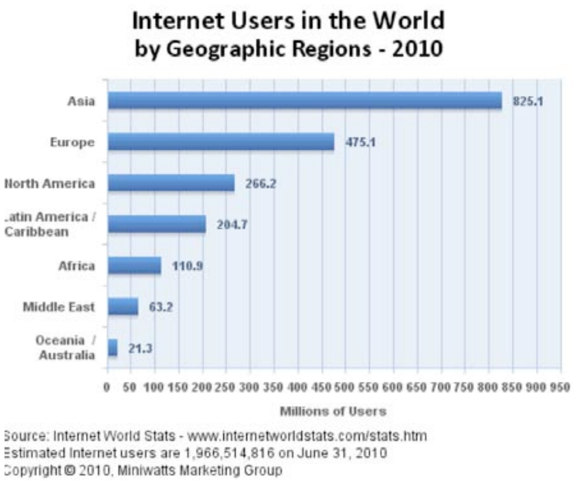
Initially the Internet was conceived as a communication infrastructure that allowed the exchange of e-mails and files using traditional protocols such as SMTP/POP, HTTP and FTP and hardly any intelligence was provided (looking for information on a web page was initially only possible when the URL was provided). An initial step towards more intelligence was the introduction of search functionalities in order to have easy access to the increasing amounts of information available on the World Wide Web. In the mean time this has been further expanded towards many other intelligent services and applications provided by the Internet of Services (e.g. networked games, e-Learning platforms, e-Commerce applications, e-Government information, etc). But this is only the beginning: today most information on the Internet (video's, photo's, blogs, tweets, etc.) is generated by humans whereas in future a massive amount of information will be added that is generated by sensors (used to measure energy consumption, position, motion, health status, emotion, traffic density, building status, etc.). One of the tasks of the Internet will be the provisioning of novel services that will use these massive amounts of information in a smart way (the Internet of Things).



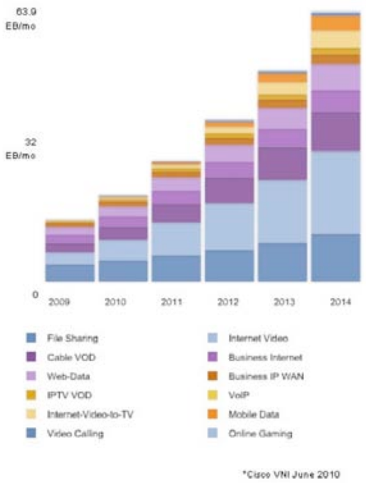
The emergence of novel user interfaces and the convergence of services in the Internet will also take away the need for local personal functionality and infrastructure (the disappearing computer). Indeed computing power, storage capacity and software applications will no longer be a personal asset that you have to carry with you all the time but it will be replaced by Internet services that will be available anywhere and anytime. This is currently happening with the advent of cloud computing services (Infrastructure as a Service or IaaS, Platform as a Service or PaaS and Software as a Service) and consumer grids. Although the basic concepts were already invented in the sixties, it is only now that people start to see the real benefits of these technologies.



1.3 The Internet as a unifying communication platform



It is clear that the Internet has also to fulfill its first mission, namely providing a communication infrastructure that is able to connect the world population and their environments, and supporting a wide range of applications. This is still a big challenge as illustrated by a rapid increase[1] in the number of users (in July 2010 nearly 2 billion users), the total consumed bandwidth (increase by about 50% per year) and the number of services offered. Since its inception, the type of Internet traffic evolved drastically from e-mail and simple web-access, to peer-to-peer file exchange, to video streaming and real time interactive video communication (as used in for example virtual presence applications or interactive gaming). Video is definitely becoming the major part of the content transported over the Internet. In addition, over the last decade mobile access to applications and services has become an essential part of our lifestyle resulting in mobile networks connecting half of the world population. Mobile Users expect a Quality of Experience similar to the one experienced in a fixed network environment. But not only people get connected through the Internet, as mentioned before there has been a trend where more and more tags, embedded control devices and many sensors get connected to the Internet as well, resulting in the "Internet of Things" and allowing the Internet to become a smart environment. A hundred-fold increase in end-devices is currently projected, but even higher numbers are envisaged.



[1] www.Internetworldstats.com, www.cisco.com, www.emc.com

1.4 The Internet as a smart society platform

Today we are confronted with a large number of societal challenges where the Internet promises to be a key enabler to come to sustainable solutions. A number of these challenges are:

- Energy: Climate change, scarcity in natural resources and energy cost created a strong "energy awareness" in our society. By 2020, the EU wants to reduce the greenhouse gas emissions by 20%, increase the percentage of renewable energy usage to 20% and improve the energy efficiency by 20%. This will be impossible without the wide adoption of Internet technology in energy grids, energy efficient buildings, smart cities, etc.
- Healthcare: An ageing population, decrease of workforce in the healthcare sector and sustainability questions in view of healthcare economics are predominant in many EU countries. Adequate Internet services, such as telemedicine, telemonitoring, distant coaching, decision support and smart ambient assisted living (AAL) solutions will be key in a more sustainable and qualitative healthcare system.
- Mobility: Efficient mobility systems play a key role in our economic ecosystem and are more and more relying on Internet technology to increase efficiency, improve safety and reduce cost. Intelligent transport system, multimodal planning, advanced tracking, personal information services are a few examples.
- Education: Internet services will be widely deployed in education, such as distributed serious gaming, interactive intelligent learning, virtual instructors, interactive whiteboards at school, and distance learning.
- Other important examples are collaborative working, media, culture and entertainment.

2 Challenges & long term vision

Based on the observed “Context and Trends”, we subscribe to the following long-term vision of the Future Internet:

“The Future Internet should provide an open platform
that will support the natural interaction between humans and their environment,
enabling services in a wide range of application domains and
interconnecting the world
in order to obtain a sustainable smart society”

When analyzing this long-term vision we observe the following high level challenges:

- The *Future Internet should provide an open platform* in order to allow creativity and innovation. This has been a basic requirement from the beginning of the Internet and has been one of its major success factors.
- The *natural interaction between humans and their environment* requires the development of novel human computer interfaces and the possibility to enter in an immersive 3D environment.
- The *seamless enablement of novel services* requires novel service engineering approaches and the embedded intelligence to obtain autonomic operation.
- *Interconnecting the world* will only be possible by the combination of high performance fixed and wireless networks.
- The Future Internet platform should support a *sustainable smart society* by enabling scientific and technological breakthroughs in different *application domains*: energy, transport, health, education, etc.

It is clear that these challenges need to be tackled from an interdisciplinary point of view. Many of the challenges will require the set-up of multidisciplinary teams, combining networking expertise with other technology knowledge (e.g. security or media processing), application expertise (e.g. health care) and user interaction (e.g. user requirement analysis).

The technical challenges can be summarizes as follows:

1. Future fixed network infrastructures should be able to support ever increasing bandwidth requirements, real-time and interactive services, quality-of-service, reliability and energy-efficiency. Various aspects should be addressed: design of novel multilayer network architectures, advanced networking algorithms and novel network layer and transport layer protocols. Open research questions that arise in modern home and access networks are a consequence of the changes in traffic type, size and pattern. Professional private networks should evolve from simple IT networks to high reliable, high throughput networks supporting large amounts of video streams and private clouds. In order to interconnect the many home and private professional networks, a next generation high throughput, flexible and reliable multilayer core network is required that will be able to support the high amount of mainly video traffic, a diversity of traffic requirements, real time interactive services, etc.

2. The emergence of new wireless technologies and standards has led to a multitude of different wireless networks (covering different ranges and using different spectral bands) and has triggered the appearance of many wireless and/or mobile devices, ranging from very small, embedded devices like wireless sensors up to more powerful devices like mobile laptops. This evolution leads to a number of important technological challenges. First, we are faced with an increasing number, and consequently increasing density, of wireless and mobile devices. In particular wireless sensor networks incorporate a huge number of heterogeneous devices supporting diverse applications. Secondly, there is an increasing heterogeneity of mobile and wireless networks with devices competing for the same spectrum. Thirdly, unlike wired networks, the capacity of wireless networks is unstable and often asymmetric, due to interference, user mobility, (dis)appearing devices… Special attention should go to mobile networks (involving users on the move), wireless sensor networks (consisting of heterogeneous devices supporting various applications), self-organising virtualized networks (enabling dynamic interconnection of distributed devices over heterogeneous underlying network technologies) and cognitive networks (dealing with heterogeneous co-located wireless devices competing for the same resources).

3. As the Internet will become an intelligent application platform, it will be important to introduce autonomic system technologies. Autonomic systems in general are systems that exhibit self-* properties (self-managing, self-healing, self-optimising, …), being able to adapt their behavior to changing execution contexts (e.g. user demands, partial infrastructure failure) and that are governed by high-level policies, typically representing business goals. More specifically, for large and complex distributed systems, autonomic behaviour is a key enabler to realize well-performing systems at low operational cost. The scale and complexity of currently deployed distributed systems is becoming prohibitive for pure human intervention, because of the cost associated with such interventions. Also, guaranteeing optimal behavior (e.g. in terms of system throughput, or quality offered to end-users) in changing environments requires interventions beyond the possibilities of human actors.

4. As the Internet infrastructure will become the key resource platform for many applications, novel service platforms will play a major role in the flexible development and deployment of all kinds of applications in C2C, B2C and B2B environments ("the Internet of services"). Service platforms will be using basic service building blocks from

different software vendors and parties and will allow the composition of complex applications. This will require technologies for multi-party service choreographies, automatic deployment and resource assignment for complex service workflows and technologies for service compositions. Dynamic service deployments will become a reality by using semantic descriptions of the services and introducing advanced reasoning support, based on gathered knowledge and information. This knowledge management will rely on efficient representation of the knowledge, modeling of uncertain relationships between concepts, scalability optimizations to deal with large-scale, distributed knowledge bases and the development of intelligent reasoning processes. As the Internet will become the underlying service engine of our information society, service dependability will be a key issue. This requires management of reliable connections between the service components, redundant placement of the different service components, dependable code generation, advanced failure detection and correlation techniques at multiple layers and appropriate restoration strategies.

5. Another key challenge is making the Internet further media-rich by providing the right technologies and platforms to handle media. A major limitation of today is the lack of technology to capture, manipulate, distribute, render and display real-world 3D objects, subjects and environments, by non-expert internauts using commodity appliances, and with appropriate real-time versus high-quality trade-offs. In this context, it is important to address stereo-scopic, multi-scopic and general depth-enhanced imagery as well as navigatable environments (causing a sense of “being there” by allowing the spectator to look around and/or roam around freely at will). Some detailed challenges are realism-preserving acquisition, modelling and representation of dynamic 3D and immersive content using multi-camera acquisition set-ups; manipulation and processing of immersive video, including retouching, segmentation, annotation, tracking, registration, compositing, animation, montage, color/appearance filtering; intelligent delivery of the content; rendering of delivered 3D and immersive content on a large variety of devices and screen sizes, taking into account user interaction and finally the identification and realisation of the most useful immersive display and interaction modes.

6. Last but not least is the development of novel human-computer interaction paradigms especially tailored towards networked usage. For these interactive systems, communication between the human user and the system is crucial for the application to fulfil its mission. In a number of situations users are collaborating and communicating about the cooperative tasks or actions. To assist the user in natural individual interaction with the system, as well as effective collaborative deployment of interactive environments, single-user interaction techniques and specific (collaborative) multi-user interaction should be explored. In addition context-aware and adaptive UIs to personalize interaction in a variety of dynamic application contexts such as mobile systems, ambient intelligent environments and virtual environments are required. Besides research results focusing on end-user support, designers’ and developers’ support to facilitate the realization of emerging interactive systems will also be a key challenge. By using User-Centred Software Engineering, one will effectively bridge the gap between software engineering and HCI inspired development methodologies (e.g. user-centered design) for complex interactive systems.