Future Internet 2020

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PREFACE

Like other regions of the world, Europe has to reflect on the increasing role of the Internet as a driver of our economy and society. Already, in a few short years, the Internet has transformed Europe in a whole variety of ways. In 2009 no business can operate effectively without a website. Many European enterprises have gone much further, using the Internet to fundamentally change the way they do business and developing new offerings that make the most of online channels. In our personal lives, Europeans, from teenagers to senior citizens, enjoy the opportunities and interaction made possible by social networking. We work online, we shop online, we learn online, we play online, and we build communities online. Many of these services are today also available while on the move using mobile devices.

At the same time new developments are on the horizon aimed at rethinking and rebuilding the Internet from the bottom up. This 'Future Internet' will be much faster and smarter, more secure, embracing not just information and content but also services and real world objects ('things').

Why do we need to do this? Well, the truth is the Internet was never designed for how it is now being used and is creaking at the seams. We have connectivity today but it is not ubiquitous; we have bandwidth but it is not limitless; we have many devices but they don't all talk to each other. We can transfer data but the transfers are far from seamless. We have access to content but it can't be reused easily across every device. Applications and interfaces are still not intuitive, putting barriers in the way of the Internet's benefits for many people. And, since security was an afterthought on the current Internet, we are exposed in various ways to spam, identity theft and fraud.

In the Future Internet all of these limitations will be swept away. By 2020 the Internet will be both laid out as public infrastructures and dynamically created by the objects connecting to one another. **We need to see the Internet of the Future as this seamless fabric of classic networks and networked objects**. The content and services they facilitate will be all around us, always on, everywhere, all the time. It will lead the way to opportunities we never knew existed: new ways of working; new ways of interacting; new ways to be entertained; new ways of living. Next to these future applications today's Internet will look clunky and primitive. For instance, multimedia applications will move towards the bandwidth of human perception and beyond.

Of course, the future is notoriously difficult to predict. Yet it is clear something is brewing here around the Future Internet. This is not just marketing hype about the Next Big Thing. A constellation of technological, economic and societal factors is emerging which puts us in Europe on the brink of major developments which could be as significant as the original innovation of the Internet itself.

Europe is facing many challenges: an economic downturn, global competition, climate change, and an ageing population to name just a few. The Future Internet does not offer a panacea, but we firmly believe that it ***is*** part – and possibly a major part – of the solution in these and other areas. We must ensure that it develops in a way that respects our European values.

As Europe prepares to welcome a new Commission and a new Parliament, we take this opportunity to present our vision of what this Future Internet could contribute for Europe. We do this through a series of scenarios in terms which, hopefully, policymakers, industry leaders and citizens can relate.

Technological efforts have begun in Europe and elsewhere and must be intensified. We welcome, in particular, the Commission's initiative to launch the Future Internet Assembly bringing together stakeholders from the research community across Europe. We also fully support on-going plans to launch a Joint Technology Initiative (JTI) on the Future Internet, based on a public-private partnership, to better mobilise and coordinate European, national and industry efforts. As concerns innovation, education and entrepreneurship, we fully support the initiative of the European Institute of Innovation & Technology (EIT) for a Knowledge & Innovation Community (KIC) on future ICT.

But Europe could and must do much more. The opportunities in the Future Internet are huge and the threats are real. Already we see worrying signs that others are taking the lead in critical areas. It is time that the weaknesses of Europe are done with. The Internet space where we will reside in the future, provides us with a unique opportunity to overcome:

- Our competitiveness deficit, be it in technological or service aspects.
- Fragmentation and the absence of a fully developed Single Market for services.
- The lack of critical mass resulting from an inefficient use of resources.

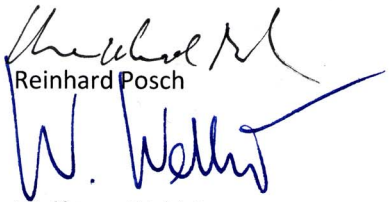
From the primitive networks of today, a new Internet will emerge where the economy of tomorrow will be invented. Employment and innovation opportunities will be plenty in Internet-enabled sectors such as manufacturing, energy, transportation, healthcare, education, and entertainment, where pervasive and massively-distributed and networked resources (sensors, actuators, communication devices, databases, etc.), will generate new economic and societal value chains.

Much as the intrinsic merits of a single EU currency have been demonstrated in the on-going economic crisis, time is now ripe for Europeans to show vision and leadership in the creation of a coordinated EU strategy for the Future Internet. We have no other choice but to strengthen our cooperation on research and development and innovation. We call on the European Commission, the Member States, and the European Parliament to take steps towards fostering the development of this EU strategy. We call on decision makers, industrialists, technologists, entrepreneurs, innovators and researchers to come forward with concrete plans aimed at creating an EU-shaped Internet economy responsive to the needs and ambitions of its citizens.

Europe must act now and act together to lead the new Internet age.

Jean-Charles Hourcade

Yrjö Neuvo



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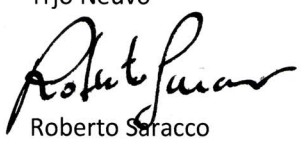

Roberto Saracco

Wolfgang Wahlster

1. INTRODUCTION

1.1 Internet: Past, Present and Future

The Internet as a driver of 21st century society …

Over the last 30 years the Internet has revolutionised our economy and society. From a purely academic network in the early 1980s, the Internet has grown into a truly worldwide open infrastructure for information, communication and commerce. Driven by the rapid diffusion of technology, in particular broadband and mobile, the Internet has become a powerful tool for creativity and innovation. It is now a central part of our lives in all sorts of ways, and in many activities is displacing traditional channels as people's first port of call. **The Internet is *the* global network of the 21st century**.

…reflected in rapid and sustained growth in internet traffic …

Evidence of this is clear for all to see in the statistics on Internet traffic growth. Data from various sources show a long-term growth trend in annual Internet traffic of around 50-60% per year[1]. This equates to around a 100-fold increase every decade. At the end of 2008 monthly Internet traffic worldwide was around 6500 petabytes (PB[2]). To put that into perspective, 1000 petabytes (or one exabyte) is equivalent to 50,000 years' worth of DVD-quality data. Trends such as peer-to-peer, video sharing and watching high-definition TV online will continue to drive traffic growth at exponential rates.

In Europe, the rate of growth appears to have eased recently with the economic slowdown, to around 50% per year[3], but the trend is still towards significant growth.

Some of the fastest growth is being seen in wireless. Worldwide the volume of mobile data is around 33 PB/month and is growing at over 100% per annum[4]. This is tiny compared to the wireline traffic worldwide – only around 0.5% of the volume – but the growth rate is much larger, and the value to users (and the prices they are willing to pay) is far higher on a per-byte basis. Nevertheless, with the mismatch in capacities, it will be some time before wireless traffic impacts on Internet backbones.

… reinforced by economic & societal trends

Behind these statistics are a whole mix of economic and social trends. Digital convergence has moved the tectonic plates, changing forever the business landscape for the IT, telecoms, consumer electronics and media industries. New technologies have brought a wave of user-generated content as well as the 'long-tail phenomenon' which means nothing is too niche or too obscure to find an audience online. New applications, such as social networking, are changing the way we communicate and, some would argue, re-engineering society in the process. New paradigms, such as software-as-a-service and cloud computing are emerging that open up a range of opportunities for innovation, efficiencies and collaboration in business and organisations. All of these factors add to the relentless growth in Internet traffic and continually raise the bar in terms of users' expectations of their online experiences.

Whereas a few years ago the only way to get online was through a computer, now a whole range of devices are Internet-enabled, from mobile phones and PDAs, to games consoles, TVs, GPS trackers, and industrial equipment. In particular, mobile broadband,

[1] Compilation of official and industry data monitored by Minnesota Internet Traffic Studies (MINTS), University of Minnesota. www.dtc.umn.edc/mints

[2] 1 petabyte = 10^{15} bytes; 1 exabyte = 10^{18} bytes (or 1 million trillion bytes)

[3] European Internet Exchange Association, 2008 Report, www.euro-ix.net and TERENA (European National Research and Education Networks), www.terena.org

[4] CISCO, Global Mobile Data Traffic Forecast, Jan 2009

which is just starting to take-off in Europe, will bring a whole new dimension, offering users the possibility of a 'personal Internet' on the move; at present this is constrained by a lack of services however. In parallel, everyday objects are becoming smarter, as ubiquitous connectivity and modern sensors allow them to communicate as part of a new 'Internet of Things'.

The Internet of the Future as a seamless fabric of connectivity

But this Future Internet will not be just an evolution of what we have already; it will not be more of the same. On the contrary, radically new approaches are needed: new architectures; new interfaces; new ways of managing data; new ways of integrating all the different Internet entities – devices, sensors, services, things and, of course, people. In the future, the idea that we have a network that reaches out to terminals will fade away. Rather, we are going to see that objects, including terminals, will have their local connectivity halo and this will be able to connect with other halos of connectivity, including the backbones, access rings, radio drops, etc. The Internet will be the sum of it all but this does not mean that the IP (the protocol) will be ubiquitous. Sensor and ambient networks are likely to be based on different more energy-savvy protocols.

Thus, any object will be able to have communications capabilities embedded within it and several objects in an ambient environment will create a communication network. This in turn will connect with other communications networks, locally and globally. This is a dramatic change and will have a significant impact since every industry, in practice, will have to learn to produce communicating objects and the functionalities of the objects will be influenced by these communications capabilities and by the context.

We need to see the Internet of the Future as this seamless fabric of classic networks and networked objects. In a way this is the Internet as it was conceived from the very beginning: a network of networks, but by 2020 these networks will be both laid out as public infrastructures and dynamically created by the objects connecting to one another. The content and services they facilitate will be all around us, always on, everywhere, all the time.

The Future Internet is essential to Europe's future

We are now witnessing the emergence of this next generation of the Internet, which will lead to a wealth of new services and will have an even greater impact on society and the economy than the Internet today. The future of the European economy and society is intimately bound to the Future Internet and will be founded on Internet-based business models. In fact, the Future Internet will be the essential part of Europe's future ICT infrastructure, which will be instrumental to fostering the internal market as well as to achieving the goals of the Lisbon agenda and ensuring growth, productivity, and employment in Europe.

1.2 The Developing Agenda

A developing European agenda

To realise these goals we must overcome the structural limitations in the current Internet in terms of scalability, flexibility, mobility, security, trustworthiness and robustness of networks and services. These issues are well recognised worldwide and research is underway aimed at avoiding the looming impasse.

Over the last two years the European Commission has undertaken a range of activities to explore and address the Future Internet problematic with stakeholders in industry, academia and EU member countries' authorities.

Its activities are first and foremost to foster the European RTD capabilities in this domain. The current ICT Work Programme supports a set of 90 projects which look at

various aspects of Future Internet developments. Increasing collaboration and coordination among these was the objective of the Future Internet Assembly (FIA), kicked-off at the Bled-Conference in March 2008[5] and united under the umbrella of the Bled Declaration on the Future Internet. The work of the Assembly was continued in seven working groups which produced white-papers for an FIA progress meeting in Madrid last December[6], and which continue to develop technical and non-technical requirements for the Future Internet.

The European Technology Platforms eMobility, NEM, NESSI, ISI and EPOSS are working towards a joint vision on the future of the Internet[7]. They jointly presented their work at the ICT 2008 Event in Lyon, which found a positive echo with EU member countries' representatives.

Member States have initiated their own Future Internet related activities, and the Forum of National Research Directors[8] and the ICT Advisory board have recently published reports about the Future Internet. The conclusions of the Telecoms Council of 27/11/2008 make explicit reference to the on-going FI activities: *"…The Council welcomes the Commission intention to consider public-private R&D partnerships concerning the Internet of the future, in compliance with the Bled Declaration of 31 March 2008…"*

Thus, the Future Internet is now established as a key theme for both the research constituency and for policymakers. Therefore Europe should prepare for a bold, visible programmatic approach towards the Future Internet with a coherent strategic vision in a 2020 timeframe.

1.3 The High-Level Panel

A panel of diverse experts

To help prepare the ground for a new approach to public-private partnership in this area, the Commission invited a panel of high-level European experts to develop scenarios on the Future Internet topic. The invited experts were from different but complementary backgrounds, which ensured insightful discussion and a cross-fertilisation of ideas.

Guided by their experience and knowledge and by any information deemed relevant, the experts were asked to develop a set of scenarios for the Future Internet post-2020, covering applications and technology uses. The Panel was encouraged to use a multi-disciplinary approach with regards to the many technological and service domains that will characterise the Future Internet.

Scenarios for exploring multi-dimensional aspects

In developing the scenarios, the experts were invited to consider questions such as:

1. To what extent is Europe capable to contribute to this scenario? What if Europe does not contribute to make this scenario a reality? What is at stake for Europe? Which are the obstacles (market, regulations, technologies etc) to the realisation of this scenario? What needs to be done to overcome such obstacles?

[5] http://www.fi-bled.eu

[6] http://www.fi-madrid.eu

[7] http://www.future-Internet.eu/fileadmin/documents/reports/Cross-ETPs_FI_Vision_Document_v1_0.pdf

[8] http://www.future-Internet.eu/fileadmin/documents/reports/FI_Rep_final__281108_.pdf

2. Which are the strengths Europe could draw upon to build this scenario? Is our industrial and academic base adequate to deal with the issue? What should Europe do to ensure its contribution to this scenario? Should the efforts in Europe be placed on the technological developments associated to the scenarios or should they be placed on the development and testing of applications? How to better stimulate the creativity and innovation of European actors?

3. To which degree and how can the competitiveness of Europe be strengthened should the scenario become a reality? Which concrete actions should be undertaken? Explain what should be done to ensure that Europe benefits from these developments. Are there specific reasons as to why European efforts required building the scenario, needing to be consolidated?

The Panel met on three occasions during March and April 2009 and also corresponded by email and a social networking space.

1.4 The Scenarios

With a suitably European cast of characters, the scenarios show how the Future Internet could, and possibly will, shape the lives of all Europeans in or around 2020.

A new network infrastructure

- **The Future Internet infrastructure will need to be architected differently:** The first scenario is about seamless mobility. In *Network 2020: Information on the Move* Matti moves effortlessly between his home, car and office interacting with family, friends and work colleagues as he goes, and always with his whole world of personal information at his fingertips.

  The scenario illustrates how in the Future Internet our personal information, content and services will be available to us anywhere, at any time. Our everyday environments will be context-aware: systems and devices will be able to sense how, where and why information is being accessed and respond accordingly. The Internet will be our **personal global network.** This new world of seamless applications, services and content requires a new network infrastructure, which must be built from the ground up. In particular, it requires truly ubiquitous wireless network capacity that can handle orders of magnitude more data. Advanced features such as semantics and trustworthiness must also be built in.

Internet-based services reshaping our economy

- **The Web-based Service Economy will bring new ways to create value:** The next set of scenarios is about services. In *Pierre goes to the Gym,* on a leisurely Sunday Pierre uses a variety of applications and devices to access services, many of them video-rich, tailored to his personal preferences. In a second scenario, *Like my car? I designed it myself!* motor enthusiast Helga customises a new car purchase by changing its physical attributes.

  The scenarios emphasize that the impact of next-generation services on Europe's economy and society will be widespread. Service convergence will reshape sectors such as media, broadcasting and telecoms. Products will morph into services, with profound implications for traditional organisations and value chains. Relying closely on the Internet with Things, the **new Web-based Service Economy** will merge the digital and physical worlds opening up a multitude of niches and value propositions. Many of these services will be media-rich, but also bandwidth hungry and cost sensitive.

The physical and digital worlds converging

- **The Future Internet will increasingly include Things:** The next set of scenarios is concerned with the 'Internet of Things'. In *The Smith Family Goes Skiing* a family takes a winter vacation made possible by a large-scale realisation of the 'Internet of Things'. In *Talking to the Laundry* Mario uses a smart household appliance – a washing machine - to access a whole variety of advanced services related to a specialised washing task. And in *The Personal Mash-up* Anna sees the real and virtual worlds merge on a shopping expedition to her local high street.

  The scenarios show how embedding sensors, communication and computing capabilities will enable a whole variety of physical objects to seamlessly gather and use information throughout their entire lifecycle. By capturing and interpreting user actions, Smart Items will be able to perceive and instruct their environment, to analyse their observations and to communicate with other objects and the Internet. This new Internet will co-exist and be intimately bound up with the Internet of information and services. It will be an ***Internet with Things*.**

New challenges for regulation and ethics

- **Technological spaces and regulatory spaces are diverging:** In the final scenario, *My Personal Blackbox*, Václav utilises information collected via his mobile phone and other devices to create a personal memory space, enabling him to 'relive' memories and conversations. With Václav's permission, it also serves his doctors as a diagnostic tool.

  The scenario shows that the Future Internet presents new challenges for regulation, which is evolving at a much slower rate than technology. The complex web of services created in the Future Internet requires that privacy and security be built into each service. New businesses will evolve to leverage personal information, making data tracking and ownership a key concern. Important issues also arise in relation to accountability, governance and ethics. All of these create **new regulatory spaces**.

1.5 Action Areas and Recommendations

Focus areas

Based on this analysis, we see the following as areas requiring attention by European policy-makers and decision-makers in industry, public authorities and governments:

- Investing in **long-term research and innovation** necessary to rethink the Internet architecture as the spinal cord of 21st century society.
- **A major push in socio-economic research** to ensure societal and economic factors are taken into account in Future Internet development.
- **A focus on standards** so as to ensure interoperability in the Future Internet and realise economies of scale essential for widespread deployment of new applications.
- **Promoting take-up of the Future Internet within key sectors** so as to create a strong home market for Future Internet technologies and services.
- **Creating a supportive regulatory environment** that fully reflects the new reality of the Web-based Service Economy and the Internet with Things, and in

particular balances the needs of businesses, consumers and citizens in relation to trust and privacy.

- **A pooling of efforts** on the Future Internet at private, European, national and international levels.

Time to act

Specifically, we recommend:

1. **The European Commission** should: strengthen current R&D efforts on Future Internet within the EU Framework Programme; step-up activities within the Future Internet Assembly (FIA); and request FIA members to earmark specific resources to contribute towards a European FI strategy.

2. **The European Commission and industry** should: establish a public-private partnership on the Future Internet within key end-user application sectors; this PPP should follow an open eco-system approach, allow for the active participation of end-user application developers, have a strong experimental component, and address the evolution of educational needs.

3. **The EU Member States** should: take bold steps towards a deeper and stronger cooperation across existing and planned national Future Internet initiatives; and jointly develop a coordinated policy-driven strategy for activities in this field.

4. **Europe's Future Internet Community** as a whole should address the challenge of global collaboration by striving for a world-leading role in all fields. It should promote international co-operation in research and set the pace in regulatory co-operation.

2. LIFE ON THE NET: THE PERSONAL GLOBAL NETWORK

2.1 Network 2020: Information on the Move

In Helsinki, Matti's bedside display wakes him at 6.45 a.m., a bit earlier than usual because his calendar includes a telemeeting at 8.00 a.m. in the office. The clock display shows him a reminder of the meeting.

After getting ready, Matti takes his electric car to drive to the office. The car's communications system reminds him of missed calls. Matti calls his colleague while driving using the hands-free communication system. For the rest of the trip, he listens to his personal music channel. The 99-channel music from his home system is adapted to the 6-speaker setup in the car to create a perfect acoustic rendering of the conditions of the original recording.

When he gets to the office Matti hooks the car up to the company's recharging point. His car is sufficiently intelligent to be able to negotiate with the energy company so as to take power at the cheapest rates. As demand varies during the day so does the price and Matti asks the car only to take power once the price is below a set level, providing he has enough power in the batteries to get home. It's a windy day, so there is likely to be a surplus of power from the newly-installed wind energy capacity.

In the office Matti takes a seat in the meeting room in front of a terminal, which serves as a 3D desktop allowing documents to be felt by touch and moved around. The system automatically recognises him from his biometric data and calls up relevant documents. At the same time, his phone switches to silent work mode. During the telemeeting, Matti shows a presentation to all participants, shown on the big display in all meeting sites. Another participant makes notes on a shared whiteboard.

After the meeting, Matti opens his office terminal and starts to work on a shared document from another colleague on his 3D desktop. As Matti is immersed in work, his phone remains in silent mode. Matti can opt to leave his real desk to enter into a shared virtual space where he can communicate with other members of his workteam. He observes that two of his team members are visiting a customer, one is immersed with browsing a specification document, and one is having a networked work session with a colleague.

Matti's phone rings - his boss was notified of Matti's status change to 'pause mode' and uses the opportunity to give him a call where they discuss the results of a lab test. A record of the call, with a context record including links to relevant documents, is placed in both Matti's and his boss's work diaries.

During mid-afternoon, Matti peeks into his Home Sizzle Channel to see that his daughter is in a café with her friends after school and his son is at home. He is also reminded that his wife will be working late, and Matti is expected to pick up Chinese takeaway for the family dinner while commuting home. Matti places an order for the food. The ordering system gives him a personalised recommendation, but for variety Matti changes one of the suggested courses. Driving home, near the shopping mall Matti gets a friendly reminder to stop for the food.

At home, Matti again plugs the car into recharge with instructions to watch the dynamic pricing.

After dinner, Matti decides to edit the video material from his son's birthday party. He opens the video editor using his home office terminal, and fetches the video files from the family's online digital storage. He is happy the files were automatically synchronised there from the camera - big relief compared to the past! While working on the video, Matti listens to music and news from another of his favourite subscribed channels. After editing the video, he publishes it for access by the boy's grandparents and other close family. He observes that his mother has commented a photo journal published previously, and spends a moment peeking into the notes left.

Later, Matti joins his wife in the living room to watch an episode of their favourite TV show, recorded in the family's media storage. Then he watches a real-time football match of Italian Premier League. He enjoys the 3D webcast: during a penalty kick he places his viewpoint between the goalposts, guessing where the penalty is aimed. He can also stop the game for a replay from any viewpoint. Using a wireless keyboard, he also chats with a Dutch colleague who is watching the same match, as Matti saw in his Social Sizzle Channel. They place a bet on the number of goals in the match; Matti loses! They agree to share another match viewing in two weeks.

After the match, Matti peeks into tomorrow's work schedule using the living room display. There will be a customer visit in the afternoon, so he looks at its context record. He reminds himself to ask about how the art project of the customer's spouse Tiina has progressed.

In bed Matti reads another chapter of his Chinese language course using his lightweight wireless reading terminal. The terminal speaks the sentences to him, and when he recites them back it records them and corrects his pronunciation and intonation which is especially important in Chinese. While Matti is reading, the display of the terminal is adapted to the ambient lighting of the bedroom.

Before dozing off, Matti reflects on how much easier life is with information at his fingertips the whole time. He wouldn't have it any other way.

Why is this scenario important?

Content available everywhere, for everyone

Matti's world is one where his personal information is available to him anywhere, at any time. We see elements of this already, with developments such as cloud computing, 3G+ phones and wi-fi hotspots. But Matti's world is more seamless than anything we have today. There is no lost connectivity, no waiting for logons, no poor quality content, no systems that don't talk to each other. What's more, all environments (Matti's home, office, car) are context-aware: systems and devices are able to sense how, where and why information and content are being accessed and respond accordingly. Such approaches will be essential in making sure systems are accessible to everyone, so avoiding digital divides.

Key features include the following:

- **Many terminals, shared content**: Matti's phone, video camera, living room display, reading terminal, home office terminal, work terminal(s) all use and share the same information. Content is automatically synchronized between systems and adapted to each device.
- **Ubiquitous social interaction**: Social networks (contact lists) are shared between services and terminals, which are embedded everywhere.
- **Shared digital assets**: Similarly, digital assets – documents, video, contact data – are shared seamlessly across various settings, from the home, to the car and the office.
- **Context sensitivity and adaptation**: Matti's context is disclosed according to contextual privacy policies and settings. This opens the door for opportunistic communications, such as the phone call from Matti's boss and the chat session with the Dutch colleague during the football match.
- **Interactive and adaptable content**: Content is interactive and able to adapt to the different formats and settings in which it is used.

The driver of the change is end-user value. Matti's company uses wholly virtualised services, requiring near-zero investment in infrastructure and its maintenance. At home, nearly all services are virtualised and subscribed from several service providers. Matti invests only in the terminal(s), some of which may come bundled with the service(s). In some cases the terminals might even be given away and users pay just for the services.

2.2 What are the Enablers?

While the present technologies are still far from being capable of implementing the scenario in its entirety, Matti's world represents a natural evolution from current trajectories. Developments in the IT, telecoms and media industries are already moving in a direction that could, potentially, realise the scenario described. This is far from assured, however, and there are likely to be major roadblocks along the way.

Technological barriers

One set of roadblocks will be technological, including:

- **Differential rates of technology development:** The key system building blocks are subject to differential rates of development. As is well known, Moore's law says processing power grows at ~1.5x/year. Less well known are Kryder's law for mass storage (~2x/year) and Butter's law for optical networks (~2x/9 months), and there are others. The differences in rates are significant and their impacts accumulate over the years.

- **Optimising spectrum usage:** This scenario (as in fact the other scenarios) is highly dependant on wireless connectivity and mobility. This is an area where radical new architectures and technologies are needed in order to cope with the massive exchange of data across the many data-hungry network nodes. As the radio spectrum is a limited resource, advanced new concepts are needed. New multi-access wireless architectures are needed. Advanced wireless radio technologies implemented on high-performance and low-cost microelectronics platforms will be another key enabler of this scenario.

  However, eventually we will still need a further enabler - a new wireless spectrum usage paradigm. A significant portion of the most valuable spectrum is underutilized today. Or put another way, we foresee that modern technologies would allow the development of methods that would increase the capacity of radio spectrum many fold. A highly relevant direction to be pursued is to develop principles and policies and eventually protocols that would create **a real-time location-sensitive spectrum trading market**. Research activities on cognitive radio provide a starting point for this important development.

- **Optimising energy consumption:** Another factor that must be overcome is the increase in power consumption, which is escalating rapidly. Large data centres typically consume several megawatts (for cooling as well as running the equipment). With concerns about energy and environmental impacts on the rise, optimising power sourcing and reducing consumption may become one of the driving principles of network design. Many of the efficiencies can be achieved through software (e.g. low-power algorithms and protocols).

- **Open standards:** If the new wireless networks are to simplify everyday life, provide additional convenience and save energy and time, the technology has to

be extremely low cost. The only way to achieve this is to agree common architectural principles in global cooperation and based on these create the open standards needed to guarantee global interoperability.

Market barriers

Other roadblocks stem from the incompatible positions and strategies of the various stakeholders in the relevant value chains. In particular, each of the incumbents is endeavouring to hold its control point and leverage it to control the entire value chain. The unsuccessful attempts of the media industry to gain widespread control over digital assets through IPR enforcement are an example of this. With the likely future development of Internet traffic, leading to the emergence of the "memory wall" and the "middle mile" as bottlenecks constricting potentially useful applications, the inefficient market structures will become even more severe problems. Policy-makers and regulators should exploit technology (such as watermarking and communications) to encourage new business models, not block content usage.

Regulatory barriers

Lack of regulatory harmonisation presents a further barrier. As we move around Europe we still encounter many different regulatory regimes and legal cultures which must be harmonised for information and content to be fully mobile.

Hence, the key challenges are economic and regulatory, as well as technological. To counter these strategies, and to create a level playing field, regulators and public policymakers should strive for open standards, open interfaces, and federated architectures. Adherence to these principles should be a mandatory requirement for developers of public Internet services.

3. THE MARKET OF ONE: THE WEB-BASED SERVICE ECONOMY

3.1 Pierre Goes to the Gym

It's Sunday morning. Pierre gets up earlier than the rest of the family, since he wants to go to the gym. He takes breakfast in the dining room. As he sits at the table, he takes his two-page flexible display and reads his personalised Sunday newspaper. The paper has been delivered by iMedia&News with whom Pierre has taken out a personalised subscription. The newspaper is tuned to Pierre's interests and in the morning offers especially politics and sports news. Pierre reads a message about the Formula 1 racing taking place in Canada today and the newspaper also contains video links to the results of the qualifying from Saturday.

He touches a video link, but the newspaper's display technology - based on e-ink - only provides a reduced frame rate, which is not adequate to capture the fast action of the race. So Pierre decides to view the video on the ultrathin ambient high-definition (HD) display on the dining room wall. This display normally shows an art calendar. Pierre can easily jump through the scenes just by using appropriate eye and head movements; the camera sensor technology of the house alarm in the room recognizes these movements and translates them into actions. Since his son Henri is also an enthusiastic race fan, Pierre reserves an interactive 3D HD transmission of the live event for this evening with guaranteed service quality for optimal enjoyment. The personalised newspaper mash-up has automatically been integrated with the service platform of Pierre's infrastructure provider and therefore the reservation is processed seamlessly in the background.

Since the 3D event should come as a surprise to Pierre's son, he connects to the ambient poster display in his son's room and temporarily overwrites it by an animated wall display of the racetrack which the newspaper offered. In addition, he activates the animation with sound from the race to be automatically started when his son wakes up later; again this will be registered by the house alarm's movement sensors. These configurable real-world aware services are all part of the new house management system.

Pierre drives to the gym, where he starts with a workout. All the machines are instrumented. Doing his exercise on the elliptical trainer Pierre can use the mounted display to access his business emails. The communication is secured by a login based on his small secure RFID-based iKey. Pierre uses this as a universal key for entering his house, car and office, and also as a badge to enter the gym. For this situation, it also stores his fitness plan and monitors his progress. Pierre needs to answer an urgent message and therefore uses the new "almost speech sensor" for sub-vocal speech transmission to the context-dependent speech-recognizer of his email client in order to not disturb his surroundings.

Back at home and in the early evening, Pierre and Henri enjoy the live broadcast of the Formula 1 race on the big-screen 3D cinema display in the living room. They are able to choose their preferred viewpoint on the race focused on the position of their favourite driver. Suddenly, the bell rings and the pizza service delivers their favourite pizza – they always have pizza and coke for Formula 1! The personalised shopping service of their iHome service package had ordered it after Pierre booked the special race broadcast in the morning. It knows about the usual behaviour and had only requested a confirmation by Pierre.

Henri was so excited about the race that at the end he buys the current race data for the drivers and vehicles involved. This allows him to recreate the race on his favourite car racing game and to swap drivers and cars. The game service platform always provides him with the latest bug-free version and allows him to choose his favourite 3D rendering device to join a game. Henri meets his friends in their favourite social networking space and arranges a hot race with them to be played in the evening via the network by driving virtually against the best riders of today's race. Henri's best friend, Jean, is still in a car on his way home from an outing with his parents. But he can also join the network game by using his stereoscopic 3d-enabled smartphone.

Being Sunday evening, Henri realises he needs to catch up with his homework before going back to school. He accesses his class's shared learning space and watches the video message from his teacher explaining the history assignment – to write an essay about Napoleon. The teacher has also left video messages in response to questions from his classmates. Henri follows up the links to virtual museums and other sites suggested by his teacher, but he also finds a 3D re-enactment of the Battle of Waterloo on a history networking site. Resisting the temptation to actually join in, he studies the battle, writes his essay and then files it in his teacher's in-tray for her to look at before the class.

Why is this scenario important?

A new world of Internet-enabled services

This scenario illustrates how next-generation services delivered via the Internet could have a dramatic impact on our society and economy.

Wherever Pierre and his family are throughout the day, Internet-enabled services are never far away. From the personalised newspaper subscription and bookable HD broadcast facility, to the universal RFID key, automatic pizza ordering, and automated purchasing and play of a customised network game: all of these tasks utilise services tailored to the user's personal profile and needs. Most of the services rely on rich video content, whether for communication, information or entertainment.

The Internet of Services (IoS) relies largely on a service-oriented architecture (SOA) – a flexible, standardised architecture that allows various applications to be combined into interoperable services. The IoS also uses semantic technologies that understand the meaning of information and facilitate the accessibility and interconnection of content. Thus, data from various sources and different formats can easily be combined and processed toward a wealth of innovative web-based services. The IoS also relies closely on the Internet of Things (Section 4), which merges the digital and physical worlds by enabling real-world objects to communicate and interact with each other.

Key features evident in Pierre's scenario include the following:

- **Really high broadband access** to the Internet, according to specific quality of service (QoS) criteria, will be available everywhere.
- **Interactive broadcast media** will be established, as well as **service providers offering additional add-on services** to be integrated into associated applications like games.
- **Adaptable smart home systems** with well-defined APIs for the integration of services and functionality will become industrial standard.
- **Display technology** will further develop and will produce thin, flexible, HD and 3D-enabled display devices to be integrated smoothly into the environment or specific gadgets.
- **Multimodal interaction** concepts and ubiquitous user interfaces achieve a widespread use, since good user experience is a key to reach a relevant acceptance level of new value-added services.
- **Platforms for value-added services** regarding daily living and leisure activities will be available and they integrate well with the sensor-enhanced infrastructures and context-providing services of the Internet.

Video-rich services everywhere

One of the main beneficiaries of these developments – as shown in the scenario – will be video.

Ultra-high bandwidth opening the wave to video-rich services …

By 2020 broadband fibre-based networks will offer up to 10 Gbits/sec to homes, while broadband mobile networks will offer shared access close to 1 Gbits/sec. Most of this bandwidth will be consumed by video-rich services. Indeed, we expect fixed Internet to become the primary mode of distribution for TV and video delivery services. This allows all video-based services to be distributed to the same devices, through the same networks, accelerating service convergence.

These video-rich services will be primarily in three areas or service clusters:

1) **Personal communications and social networking**: Visual communication is an important part of human interaction. Traditional telecommunications has offered a poor substitute to real life communication, but the increased bandwidth opens up possibilities that are much closer to real life. Visual communication, messaging and chat will be mainstream, with or without the adjunct of virtual environments. Social networking – or perhaps we should call it *presence networking* – will cover many overlapping circles, be it with business colleagues, friends, family, neighbours, or members of common interest groups. Terminals seamlessly adapt to the services and the context.

2) **Entertainment:** The huge extension of available bandwidth will allow TV programmes to be distributed through the Internet, as well as any other form of film, video or music content. This remains true even when the resolution of the content (and therefore its size) moves from standard and HD TV to super-high resolution formats, like 4K stereoscopic[9]. Most content is available in all meaningful formats, and only the one fitting best with the service, the terminal, and the consumption context will actually be used.

3) **Information and finding:** New kinds of search and information services will emerge, leveraging on advances in data analysis. Search engines will morph into 'answer engines' able to provide direct answers to precise questions rather than just lists of references. Indeed, systems will have advanced to such a stage that they pass the Turing Test, where the intelligence is such that the user does not know whether they are interacting with a human or a machine[10]. The 'new search' is multimodal, able to work not only with text but also with pictures, sound and video. This will allow, for example, to search for an individual using their picture, and to browse all accessible video data across the world including surveillance video.

Semantics – the ability to understand meaning from data - will be a key enabler for all of these clusters.

..with major implications for value chains

Arguably the most important evolution will be that these three clusters strongly converge, exploiting strategic, technical and commercial synergies. Such developments

[9] 4K Stereoscopic is an emerging high-resolution format with higher dynamic range and faster refresh rate, providing better quality than 24x36 photographs with perfect motion rendition.

[10] The Turing Test was advanced in 1950 by British computer scientist Alan Turing.

would have major implications, especially in sectors such as media, entertainment, broadcasting and publishing:

- Digital Cinema could shrink to a smaller market as it struggles to compete with home entertainment. The economic importance of the box-office therefore will diminish, but theatres remain essential as a marketing tool for studios, and as a reference for the wider entertainment industry.

- TV channels are distributed as other Internet services, and do not need terrestrial or satellite broadcasting anymore, except in isolated areas. TV channels, in their 'linear programming' form, remain important because enough people still appreciate the comfort of being guided and driven in their entertainment experience, at least for a certain amount of time. The programming is however tailored to best fit the viewer's preferences, while staying within the editorial line of the channel producer.

- TV competes with other forms of video-based entertainment, like access on-demand to huge banks of films, videos, TV series, archives of all sorts and all formats, and user-generated content. The whole spectrum of delivery services is available: direct search, passive linear TV consumption, and a wide variety of intermediate propositions that add value by aggregating and presenting various types of content to the consumer at various degrees of quality.

- Video games reach a level of sophistication which makes the gaming experience an extremely compelling entertainment experience. Most games offer symbiotic experiences with social networking, allowing one to invite friends and relations within a game – as Henri does here - and conduct a social experience where the frontier blurs between game, social networking, and business. In this respect, video games will be an extremely serious and strategic business, accounting perhaps for more than 50% of the total entertainment industry across all categories. They shape many areas of social life, through the communication frameworks they propose to the users of these social/gaming services.

- Traditional information sectors (newspapers, magazines, radio, etc.) can expect major disruption. They must transform themselves into new broadband information services, bringing a strong editorial differentiation while embracing the innovative forms allowed by the new broadband Service Economy. Non-commercial – and in many cases non-organised – groups will also be information providers, through media such as blogs and community resources (like Wikipedia). Such open source efforts provide a quasi-universal, real time, audio and video coverage of events across the world.

3.2 Like My Car? I Designed It Myself!

Helga is excited – she's going to buy a new car today! She drives to the car showroom and after entering its broad expanse approaches a sales person. Helga tells him what she is looking for – she's done her homework online and is well prepared. However, she soon discovers that the options are almost limitless. The salesman asks how fast she would like the car to go, its top speed and also maximum acceleration. The new car's engine is completely computer operated, so can be tuned as required within the maximum performance limits.

As she mostly drives around town, Helga opts for a lower performance so as to pay less in sales cost, insurance and taxes. But she knows she can always change her mind later on and will be able to get a wireless upgrade to achieve better performance. Of course, she will have to pay for downloading the new performance limits into the car's computer and can even opt to request those increased limits for just a short period. Next weekend she has a long journey to visit her mother, so would welcome the extra power on the autobahn. The price charged will be proportional to the increase achieved and to the time Helga will be using that extra performance. Part of the money will go to the car manufacturer, part to the dealer, part to the insurance company, and part in taxes (including environmental taxes).

Looking through the dealer's computer screens, Helga realises that the list of options attached to a car and the related services (provided by different companies) are now so numerous that there are no two cars alike on the road.

The dealer explains that insurance companies may be willing to charge less to insure Helga's car if she is prepared to disclose her driving habits in real time. They will effectively charge her for the risk that she is generating as she drives and as the car is parked in a particularly risky area of town. Helga tells the dealer that despite living in a dodgy neighbourhood she has access to a secure car park, so that would cut the insurance costs considerably.

Helga's son Helmut sometimes borrows her car but he is a new driver and so more expensive to insure. The insurance company offers her an option to automatically downgrade the performance when he is driving, which also saves her money.

After waiting for a while for her options to be uploaded, Helga drives her shiny new car home. She's looking forward to telling her family how she designed it herself!

Why is this scenario important?

Products morphing into services

Products becoming platforms for services

In the new Web-based Service Economy, as this example shows, *everything* becomes a service. The fact that Helga can ask for new features and to change existing ones (such as performance) transforms the car into a service. Similar transformations can be envisioned for all sorts of physical products: clothes, appliances, garden furniture, books, home decorations – the list is endless. And existing services, such as energy, transportation, and entertainment, can be delivered in new ways.

For instance, Helga could be offered tax incentives to restrict her journeys outside of commuter hours, or if she regularly carries passengers, all of which would be communicated by the car itself. However, it also calls for a series of data protection features to safeguard the driver's personal details. For example, Helmut may wish to use his mother's car but may not want her to know where he has been.

…leading to highly personalised markets

So much flexibility and personalisation results in a 'market of one'. Information gets morphed with the user's profile and changes to become a unique offering, tailoring the product to the user's exact desires and inclination.

Personalisation clearly provides additional value to the market and is in the interest of both the producer and the consumer. Mass market leverages on the decreasing cost brought by economies of scale, which is advantageous to customers since it makes products affordable. But along with affordability comes compromises: one has to get what the others get.

The shift towards customisation is a double-edged sword: it increases product appeal and focuses activities at the customer (or retail) site so that a company can reach its customers independently of the location. But at the same time it will enable other enterprises to easily and effectively compete in a company's home market.

Since it involves the end-user, a lot of effort will be required to simplify the customisation process. Person-machine interfaces will play a key role and those companies that provide the easiest and most captivating interfaces may win the market.

Changing relationships with customers

Restructuring value chains

This morphing of products into services has profound implications for organisations. In various respects it makes them more open.

Perceiving an offering as a service rather than a product creates a different and more direct relationship with the producer/manufacturer that skips the reseller. This process of 'disintermediation' – removing the middleman – is an existing trend which is likely to accelerate radically as value chains evolve. From the user perspective, most of the value may shift from acquisition to operation. This significantly changes the relationship between the consumer (user) and the enterprise selling the goods. Actually, the customers are really becoming consumers, and they will tend to pay on the basis of what they use, when they use it and how they use it.

In addition, this direct relationship and personalisation of the service lead to the possibility of fine-tuning over time through new releases (service updates) and by tailoring the service to the user's needs based on usage patterns. This latter would require the user's permission to disclose usage data to the service/product provider. In most cases it would be in the customer's interests to do so as the provider would monitor the usage and take responsibility for proactive maintenance.

In cases where the product is a shell - in other words is able to host a variety of other services or hardware add-ons offered by different providers - the situation becomes far more complicated. Each of the providers would be competing for the customer's attention through advertising, and would have their technical requirements and legal responsibilities. A solution could be for one entity to take care of the whole package being offered and used on that particular product. It might go even further, since the experience of that service/product will be embedded in a wider environment, such as the home. An independent entity may offer its services to manage and orchestrate this complexity, delivering seamless operational simplicity and maintenance, taking care to interface with all the required parties.

So while traditional intermediary functions, such as distribution, may decline, new entities will emerge whose market space is the integration of offers and the creation of

seamless customer experiences. As a customer and user we will, most probably, have relationships with both the producer, who will provide releases of new services and fine-tune them to a general profile, and certain third parties, who will help us make the best of our particular personal environment. For instance, they could suggest service add-ons to increase performance and/or cut costs.

3.3 What are the Enablers?

Trust, security and identity as key issues

The new Web-based Service Economy will only rapidly reach a critical mass in Europe if the benefits are widely understood among business and private users and if there is real trust in the new technologies. In essence, it must be clear that existing European standards for security and data privacy will apply in the Future Internet. We see a constellation of related issues here around trust, security and identity:

- **System-wide trust & security**: As virtual markets, ICT-supported services and ICT-controlled supply chains increase, security measures at infrastructure level become even more important. In particular, identity management will be essential for establishing and managing trust and for safeguarding privacy, as well as for designing and implementing business security models and policies. Compliance across the whole software development and service lifecycle will be necessary to ensure the quality and effectiveness of security measures. Also, methodologies for secure implementation and operation of software systems will have to be advanced to systematically achieve security and dependability of applications.

- **Alternate identities:** The new Service Economy will require frequent verification and exchange of identity information. Identity will become a critical part of social life, i.e. of "real" life. People will wish to manage their identities in different ways, sometimes opting for full disclosure, at other times disclosing only in an anonymous way that preserves their privacy. Alternative identities (such as avatars) and levels of visibility will be needed.

- **Identity as a service:** The management, custody, and authentication of identity profiles could become a critical service. This can only be managed by highly trusted third parties, and such security providers will in turn need to rely on an ultimate trusted party (for example to authenticate the identity certificates of all agents in the chain). At the root of this **chain of trust** should be a permanent, non-commercial entity able to act as the ultimate guarantor of the security of the system. This could be a public entity at the European level.

Other issues

In addition, the following are prominent issues in the context of the Service Economy:

- **Architectural changes and choices**: It will be important to establish a proper balance between fixed and mobile networks. Both network architectures will share a full logical IP infrastructure, however their costs of ownership and operation differ broadly, as does their use of scarce resources like radio frequencies. Fully-optical fibre-to-the-home (FTTH) and mobile networks each have advantages and disadvantages in areas such as power consumption and operating cost. All of these trade-offs should be looked into at infrastructure level. Storage and computing services have also to be monitored, as the energy consumption will represent a growing challenge.

- **Localisation of production**: The on-site production made possible by simplified and cheaper production processes will reverse the paradigm of the last two centuries of progressively aggregating production in a few areas. Bits will be travelling the world, bringing instructions for the construction of goods everywhere. If well managed, localisation of production could bring social and environmental benefits throughout Europe by decreasing waste and pollution, saving energy, and providing specific solutions to specific needs. The complexity lies in having effective production technologies that overcome the loss of efficiency with respect to large-scale mass-market production, and in the management of diversity.

- **A new role for standards**: Standards will be essential to ensure interoperability and realise economies of scale. A crucial step will be a Service Description Framework (SDF) to handle the transformation of a technical service into a tradable and interoperable good. This SDF will be at the heart of the Future Internet. Standardisation will also be required to turn core business-critical knowledge (in the form of ontologies) into automated business processes for providing, trading, integrating and consuming services.

- **Governance becomes a political issue**: Governance issues will be critical in securing identities, privacy, and more generally security, to a point where political attention is absolutely required. Driving the transitions in network architectures towards socially positive, and environmentally friendly solutions is also an area where political attention is legitimate.

At a technology level, many of the research challenges described in relation to the Internet with Things (Section 4) also apply here. In particular further progress in semantics technologies, in interfaces and in personalised service mash-ups will also apply to the Internet of Services.

4. ATOMS AND BITS: AN INTERNET WITH THINGS

4.1 The Smith Family Goes Skiing

The Smith family is going on a skiing holiday. After getting into the car the vehicle's on-board information system welcomes them and they interact with it to plan their journey.

Carla is driving today, and she gets a description of the route depending on her preferences. Alternative routes are explained as well and the main differences in relation to the selected one are highlighted, including information such as traffic conditions and estimated fuel consumption. Her husband Peter and the children, Emily and Paul, experience the trip as an interactive journey. The in-car system gathers information on interesting points along the road and explains things on the way, really bringing the journey to life. Unfortunately, Peter missed the opportunity to take a picture of the castle they just passed. But he uses the car's vehicle-to-vehicle communication facility to ask one of the cars behind them to take a picture and send it to him. Emily and Paul also enjoy the trip, while communicating with their friends back home on their in-car terminals.

The family arrives safely at the winter sports area. After checking in at the reception they go to their room. Carla and the children are impressed by the colouring of the spacious hotel room, which resembles their colour scheme at home. In addition to colour adjustment of the iTapestry, the room has adjusted the temperature, lighting and the configuration of the television to their preferences by checking back with the appliances at their home. The hotel got permission to check back and to access user profiles from Peter's mobile phone lying on the reception desk during check-in.

A little bit tired from travelling and before going to dinner, Peter decides to take a shower and shave. While he is in the bathroom the mirror offers the possibility to check email and displays information Peter is interested in, such as financial news and politics, and whether everything is alright with his mother staying at home.

After a delicious dinner in one of the local restaurants the family returns to their room to prepare tomorrow's ski runs. The hotel's entertainment system provides suggestions for the next day based on their individual fitness profiles and forecasts of slope conditions. These forecasts are based on sensor data from biodegradable smart dust deployed in the winter sport area. They are able to visualize their routes in high-definition 3D on the ambient displays integrated in the room's iTapestry.

Early the next morning, after Peter and Carla have dropped the children in ski school, they take different ski-lifts to their chosen routes, but agree to meet in one of the ski-huts for lunch. New materials in their clothing not only help to regulate the body temperature during sport activities, but also change colour depending on their activity or mood. So Peter's gloves serve as an ambient display, reminding him when it's time to meet his wife for lunch.

Back in the hotel room after a long day, the children are in bed. Peter and Carla take the opportunity to show each other some descents they have taken during the day. From the data gathered by micro-sensors in their skis – such as location, acceleration, and velocity - the entertainment system recreates their personal routes, allowing them to share their experiences and excitement. Meanwhile, the system is updating their fitness profiles and personal digital memories with pictures and movies automatically captured from tiny little cameras integrated in their helmets and geo-tagged during the first day of their holiday.

Back at school after the holiday, Paul accidently finds his ski-pass in his sports bag. By putting it on his smart school desk he can show his schoolmates where he went on vacation, showing off how good he was on the slopes. He's looking forward to going again next year, but in the meantime he can relive the runs he made as often as he wants. It's like a year-round holiday!

Why is this scenario important?

Atoms and bits converging

The Smith Family's winter excursion was made possible by a large-scale realisation of the 'Internet of Things'. The sensors along the road, the iTapestry in the walls, the smart dust feeding back slope conditions, the location and movement sensors in their skis: all these are examples of real-world objects collecting data which is then processed and used either to provide information or to make decisions.

Embedding sensors, communication and computing capabilities into physical objects enables them to seamlessly gather and use information throughout their entire lifecycle. By capturing and interpreting user actions, Smart Items are able to perceive and instruct their environment, to analyse their observations and to communicate with other objects and the Internet.

The Internet of Things will not be a separate entity in parallel with our human world of Internet information. The two will co-exist and, as our example shows, be intimately bound up with each other. It will be an ***Internet with Things*.**

The definition and perception of "objects" change here since the object is no longer made of pure atoms but is a seamless mixture of atoms and bits. We will perceive the whole – both the physical and digital parts - as one. Furthermore, this layering of bits (information and services) will be made possible by the way the physical object is designed and by third parties that will piggyback on it to deliver their services. This generates new business opportunities and stimulates service creation and offering in an ecosystem marketplace.

Key features for this scenario are the following:

Augmenting human memory

Digital memory on a wave of innovation

Upcoming technologies will allow almost every object to have an associated memory, just like a digital diary. In addition, such objects provide the possibility to provide additional information automatically when the user is looking at or interacting with an object. Taken to its logical conclusion, objects become anthropomorphized, able to behave in a human-like way. Regular point-and-click interfaces will co-exist with novel mechanisms, which allow the user to communicate with the object only, e.g. by performing gestures with or talking to the object.

Human decision-making typically takes into account personal experiences made in the past. In support of the dialogue between human and machine, an intelligent assistant can mimic such behaviour by means of a "digital memory". By recording the interaction between user and environment, a digital memory can be constructed in an automated manner, which enables diverse innovative application fields.

Digital memories may be assigned to a specific user and thus embody a digital extension of human memory. This idea is related to research on long-term capturing of human behaviour, up to capturing an entire lifetime. Since user preferences and habits may change with time, information stored in such a personal digital memory should not be affected by subjective interpretations. In contrast, user support based on memory content requires a presentation matching the user's preferences, opinions, and plans.

By linking smart items with a digital memory objects will be able to learn how they are used and instruct users in their application. This promising extension to tangible user interfaces has even more potential in support of product lifecycle management and

product quality monitoring. Semantic memory content enables the communication of product-related information along the whole value chain from production to consumer, via the natural act of handing over products. A smart label attached to a product package may implement such a digital memory; sensors embedded in the label and environment fill this memory during the product's lifecycle on a per-object basis.

Improving business processes

Smarter products and processes as a key way to compete

Collecting and making information available - for example about an object's origin, location, movements, physical properties, usage history, and context - can help enterprises improve their business processes and create new ones. Existing business processes may become more accurate since information taken directly from the point of action can be used to manage processes and related decision-making procedures. The continuous evolution of embedded and ubiquitous computing technologies, in terms of decreasing costs and increasing capabilities, may even lead to the distribution of existing business processes to the 'network edges' and can overcome many limitations of existing centralised approaches.

Moves to integrate smart devices into packaging, or better into the products themselves, will allow for significant cost saving and increase the eco-friendliness of products. Following the current trend in the fields of production, logistics and transport, these technologies will permeate into every field of our daily lives. Some examples include:

- In energy, abundant sensory information will enable unprecedented optimisation of power grids by applying predictive instead of reactive control. This will eventually reduce the need to invest in improved grids and new power plants.

- In e-health, improving the design of systems that support and can be supported by healthcare workers and integrated from the supply chain to the bedside. In addition, new efficient diagnostics combined with nanotechnology will enable lab-on-a-chip technologies to open a complete range of novel opportunities for new treatments and prevention of serious diseases. Smart *in-vivo* equipment will assist in drug dosage closer to the affected organs, thus reducing the amount of reagents needed and diminish the risk of adverse effects.

- In the area of ambient assisted living, smart environments open up new possibilities for the elderly to live longer and safer at home, an especially important issue in view of the demographic trends facing Europe.

4.2 Talking to the Laundry

Mario is getting ready to do the laundry. He doesn't like doing it, but it has to be done. Although many of his clothes are now made of self-cleaning nanofabric and no longer need washing, some still require the use of a washing machine. In any case, it's easier now than it used to be since textiles got 'smart'.

Many new clothes are made of sophisticated textiles embedded with active parts that are far beyond "silk, wool, cotton or rayon". How should he wash the active screen, that touch pad, the nanocarbon fibre that can stretch the fabric to fit his driving activity and reshapes the shirt once he is out of the car and back to the office?

To cope with these complex demands, the clothes talk to the washing machine, which in turn talks to the clothes manufacturer and the detergent manufacturer. The detergent manufacturer tells Mario's machine that it would be advisable to use a special washing programme that has been specifically developed for this situation. It asks Mario whether he would be willing to pay 1 euro for it? Only too happy to have the peace of mind, Mario consents to the payment. The machine then downloads software from the detergent manufacturer along with an insurance certificate protecting Mario from any problem with the washing.

The washing machine is able to talk to the ecosystem in this way because it is part of the Internet, and it is able to talk to Mario thanks to its interactive screen with all the jingles that make conversation easy and captivating.

Unfortunately, Mario realises there is a problem with the washing machine; one of the buttons is broken. He calls the repair centre, which sends out an engineer to look at the problem. When the engineer arrives she downloads the geometry of the broken part from the manufacturer's database and makes a replacement on-site using a 3D printer she has brought with her. The replacement part matches the original in every way, and once integrated Mario's washing machine is as good as new.

Why is this scenario important?

Value in the most mundane tasks

In this scenario a simple household chore – doing the washing - has resulted in a series of related interactions and transactions that add value to the task. The washing machine and clothes manufacturer, detergent provider, insurance company, telecoms provider are all involved – and in a blink of an eye. It gave Mario peace of mind, it enriched the ecosystem by one euro, and gave the opportunity to those players in the ecosystem to talk to him.

Some features of this scenario are:

Connectivity everywhere

Ubiquitous communication

This example relies on fast and low-cost communication. Mario isn't prepared to wait for the various systems to talk to each other, and doesn't expect to pay a fortune for them to do so.

Communication infrastructures should provide ubiquitous connectivity in the presence of a significantly increased traffic load and should be very efficient so as to decrease the cost per bit. Network architectures will probably need to adapt and transform from a point-to-point and point-to-multipoint model to multipoint-to-multipoint communication. So in the scenario, all the service providers need to be able to talk to Mario's machine at the same time and know what the others are saying. Replication of data and service delivery may be necessary to distribute traffic load and to cut delays.

Many of the local connections are naturally wireless as that is the most cost-efficient and convenient way to make these numerous connections.

Product platforms

Open platforms as the basis for new business models

Business models are important here. The washing machine is no longer just a household appliance but a platform for a whole variety of services. In doing so, it has become a source of revenue not just for the machine manufacturer but for all the other actors in the 'laundry value chain'.

Product platforms and the application layers associated with object-embedded computers need to be open so as to stimulate the creation of offers by third parties. Security also needs to be assured. This requires a different approach to the design of products, to transform them into platforms supporting third-party services. Companies that can deliver this kind of "product-platform" will benefit from the increased value derived from third party investments.

The Internet as a design studio

3D printing as a new production paradigm

Just as in the eighties people were first able to print text, and in the nineties to print photos, so the next wave will be 3D printing. Three-dimensional printers able to produce limited size objects with materials like plastic, metal, and ceramic will be readily available, including in the home.

These 3D printers and related ink technology are likely to come in two main forms. One will allow limited scale production, the other providing single one-off object production. The latter will be used within a home environment while the former will be used for decentralising production of certain goods. Indeed, technology for small-scale production could become so advanced that we will see more and more plants producing goods locally. In some cases these production plants will be in the retail shop itself (or other customer-facing facility such as Mario's repairman), enabling local suppliers to deliver customised items in real time.

3D printing may sound far fetched, and probably is slightly ambitious in a 2020 timeframe. But machines capable of 'printing' three-dimensional parts have already been demonstrated and with advances in production and materials technologies, as well as ICT, local and even home-made production is a real possibility.

Control of ownership

With so many different providers interacting it has to be clear who owns what. This is necessary so the various parties can share both the revenues and also the responsibilities. Thus, control of ownership and of what information and services are overlaid on an object will be crucial to the success of the Internet with Things.

4.3 The Personal Mash-up

Anna loves shopping, especially since stores became personalised boutiques.

As she steps into her local clothes shop Anna is recognised as a VIP customer – in other words, one who is prepared to share part of their personal data to get a loyalty card. As she gets closer to the racks of dresses tiny LEDs light up to indicate those dresses that would fit her size, with some colour coding to signal special discount, just for her. She goes to a dressing room where a mirror-like screen recognises her and presents her with a choice of dresses to try on, virtually. Knowing her size, the shop's computer can easily do the trick of dressing her image reflected by the screen. Anna finds one she likes and asks a sales assistant to get her the real thing.

As she tries it out, the mirror reflects her image and starts proposing some accessories. Some of them are not sold at the store but are offered by other merchants. Her image becomes a mash-up to advertise products. Anything that she is able to click through, by touching the mirror, will generate some sort of revenue for the shop.

Anna's friends can join in too. With the new social retailing applications she asks her friend Katie to take a look and provide advice, even though she's not there in person. Her friend can access the mirror through her own devices, be it a television, or a mobile phone, or a navigator screen. Anna chats through the options, and since the dress has an Internet address Katie could even try it on (virtually) as well. Or she may wish to choose a different colour, a different fabric from the store inventory, or see how it fits and how it looks if they were to walk together to a party.

Why is this scenario important?

An infrastructure for mash-ups

Mash-ups require instant information

The concept of mash-ups – the reconfiguration of content and services from different sources - is the crucial business enabler when considering the Internet with Things. A dress can be mashed up with offers of necklaces or wrist cuffs, purses or backpack, watches, coiffeur, gym (if we are selecting some sports outfit). It may generate suggestions of dancing schools, travel agencies, nightclubs, etc.

These mash-ups require supporting platforms which open the market and allow a flow of information and service offers based on the objects concerned. Access to information and services associated to an object needs to be a seamless and rewarding experience. Anna would not have stayed in the shop long if the system couldn't find relevant accessories. She expects reaction times below 0.5 seconds and one-click transactions.

Free is the ideal price point

Users like Anna expect an attractive price for these new services – which for at least part of the portfolio means free. In some cases information and services could be provided on a pay-per-use or subscription basis and the price will depend on the value perceived by the user. But to stimulate the market, a significant amount of information and some services should be made available for free.

The age of social retailing

Social networking hits the high street

In the bricks and mortar world shopping has always been a social activity. Shops and shopping centres have become gathering places, watering holes for people to have fun. As the scenario shows, this could also be the case with online retailing too. A generation brought up on social networking sites – such as Facebook, MySpace and Bebo – will be

more than ready to embrace such experiences on the high street. The Internet with Things could add a nice twist to the social retailing experience.

4.4 What are the Enablers?

The Internet with Things will generate an enormous market space and this market can be filled, in principle, by enterprises and individuals independently of their physical location. Furthermore, the Internet with Things will change significantly the way an enterprise can reach a customer, accelerating the transition from products to services.

Competing through open platforms

Developments such as the Apple Store, Google's Android Market, RIM's Blackberry AppWorld and Nokia's OVI already offer add-on applications for products – many of them developed by users themselves - and are very popular with consumers. This situation is likely to be replicated a thousand-fold in the future as most products will allow third parties, including users, to develop applications and increase their value.

Europe should aim to ensure that such future platforms are open, so as encourage innovation and facilitate interoperability between the many new applications and services. By being the first to open their products, European industries can attract a wide range of players around them offering layered services, so increasing their products' perceived value.

In the meantime, we see a variety of issues that need to be addressed:

- **Location and environmental awareness**: An Internet with Things requires that the 'things' can be identified in various ways. A variety of technologies and schema are available for this, dependent on the specific object. For objects related to location, image recognition coupled with localisation may be appropriate. Localisation is relatively straightforward but requires a massive effort to integrate location tags into the physical environment (roadsigns, monuments, tourist sights, etc.). Coupling this to Europe's Galileo system should also be investigated. In addition, high-resolution indoor positioning needs to be developed (e.g. based on RFID) and integrated seamlessly with outdoor systems.

- **Unit costs**: For objects related to mass distribution, identification is tied to the management of production and distribution. Here unit costs are a key factor. To be economically viable, costs would have to be below one cent per package (including the packaging). The adopted technology should also be usable at the point of sale, as bar codes are today. RFID may be the technology of choice, particularly if created via printed electronics. Indeed, printed and polymer electronics could emerge as a very important industry with implications across a wide range of sectors: production, distribution, retail and customer care.

- **Data retrieval & cheap connectivity**: Capturing the object and exploiting it within a system requires devices that are able to retrieve the raw data and connect to service centres where the data are converted into information and services. Ubiquitous, cheap connectivity – including mobile connectivity - is very important when addressing the mass market.

- **New regulatory frameworks**: A sound regulatory framework will be essential for an Internet with Things to blossom. The situation is similar in certain aspects to

that pertaining in telecoms: the Internet with Things involves a sharing of infrastructures. A product produced by an enterprise becomes a shared resource when a third-party exploits it by layering information and services. Europe must create a regulatory environment that establishes trust and promotes fair sharing of revenues among all participating actors. The issue of responsibility is also a potential stumbling block. Here the push should be towards the monitoring and resolution of controversy, rather than trying to avoid controversy by blocking the mash-ups of services on products.

Research needs

In terms of technology, the key research needs are in:

- **Reliable & secure application platforms**: New privacy-respecting architectures and protocols need to be developed on the conceptual level and tested. A major part of the 'intelligence' described in the scenarios comes from the ability to run code fragments retrieved opportunistically and dynamically from the Internet. The whole service needs to be trustworthy and its operations controlled and authorised according to set data profiles. In some cases, direct access to profile information on the user will also be required, even on the first (random) encounter. A careful balance must be struck here – too tight control would inevitably reduce the platforms' utility and diminish the innovation potential.

- **Semantic technologies**; Semantic technologies allow data from real world objects to be interpreted in a way humans and machines can understand. Existing research on semantics in distributed information management should continue with an emphasis on semantic cooperative systems.

- **New interfaces:** As smart things encroach more deeply into our personal spaces, there is a need to think about and develop new interfaces and advanced interaction mechanisms. This research should be inter-disciplinary, integrating results from areas such as neuro-science, cognitive science and human-computer-interaction.

- **Major effort on integration**: In the future we can envision interfaces based on *ad-hoc* federations of devices that self-assemble from essential components distributed in the near environment, for instance worn by the user either as accessories or clothing. These devices will be scalable, multimedia and multimodal, and exhibit self-configuration and self-maintenance features. Such configurations present major challenges in terms of integration.

- **Public acceptance**: An important area for research relates to public acceptance, which depends on the right balance between security and privacy aspects. Ideas, concepts and methods must be communicated and discussed to avoid experiences already made by the retail industry in their pioneer RFID-applications, where consumers blocked the adoption of electronic tags. One of the central questions that must be answered is: Who owns the data in networked systems?

5. PUSHING THE HORIZON: NEW REGULATORY SPACES

5.1 My Personal Blackbox

Václav is terrible at remembering stuff. But fortunately, now that streams of bits can be easily captured, stored and processed, he doesn't have to. His life experiences are mirrored in bits – and it's all safe and secure.

The storage capacity of mobile phones is now measured in terabytes[11] (TB), which is more than enough to store all Václav's life's data. With this in his hand, actual conversations on the phone can be recorded and stored so that he can listen to them later and search sentences for "meaning". Some phones come with the option of recording any surrounding sound as well, so that everything that is said and heard is captured and stored. It is a tangled web of personal experiences.

When Václav makes a purchase the store's payment mechanism flushes the money from his mobile phone or whichever other device he happens to be using. At the same time it records the transaction and the nature of the purchase. Information on what Václav has bought, in the form of a unique identity, is stored in his personal memory space. That identity comes in handy when he needs the set of applets that will allow him to make best use of his purchases. For instance, he may wish to use his mobile device as a remote control, which will require information on his video and audio systems. Or he may need to access information to allow his kitchen appliances to connect seamlessly together.

These days everything Václav buys becomes part of his personal information space and 'lives' in this virtual space, thus allowing interconnection with all the rest. Some of these interconnections will be used in the virtual space; others will result in actions from the virtual to the real worlds, thus enabling communication and cooperation among devices to serve his purposes.

This wealth of information is there for Václav to exploit. Just browsing through his memories might be fun but basically impractical and only usable on very limited occasions. However, by using advanced speech and video retrieval methods, he has access to his whole life's data. This information can also be harvested by special applications, delivering value.

One such area is healthcare. Václav's doctor, and ultimately his drug company, are able to tailor pills to fit his health requirements based on the data they are able to download from his 'blackbox life recorder'. This provides information on his lifestyle and on his hidden pathology. His data becomes a very important diagnostic tool, allowing medication and treatments to be personalised to his exact needs. And in the event of an accident, rehabilitation can be greatly improved by accessing the blackbox, since it will be possible to finely tune the rehabilitation process looking at how Václav was before the accident. Memory supports are also available: faces Václav sees are associated to a name that is projected on his glasses and this reinforces his memory.

Why is this scenario important?

Sharing and protecting our digital selves

The Future Internet will be part of the fabric of our lives. For Václav, being able to share his digital self is a key part of being connected – and understood. Sharing our digital blackbox makes work more effective since our individual work experiences can be shared and leveraged by team mates. Similarly, our social networks derive benefit from having access to (parts of) this 'digital shadow'.

Here the Internet is both a communications network – which we no longer perceive since it is embedded and accessible everywhere – and a suite of services provided by a

[11] 1 terabyte = 10^{12} bytes or 1000 gigabytes

variety of parties. Bandwidth is no longer an issue, since most information is floating nearby, in our mobile phones, our cars, our home information systems. This information is, most of the time, pushed in our vicinity based on personal profile. It creates a context and communication is taking place in a contextualised way.

Opportunities will arise in a variety of sectors beyond those described above:

- In education, for example, we would be able to sift through our experiences and tailor new knowledge and the way it is delivered according to our preferences and learning styles. We will be able to gain new knowledge a morsel at a time, when we need it most and are most receptive to it.

- In retailing, we can benefit by knowing exactly what we bought before. This can steer our buying and the way we customise new services and products. As flexibility in the offer increases, it is more and more relevant to be able to use our profile in the customisation of the offer. This profile will be extremely rich as more and more information becomes available.

Specifically, this scenario emphasizes various aspects:

Privacy and security must be built in

Identity as a basis for dynamic security

The Future Internet will comprise a complex web of services which requires each service to be accompanied by inherent security and identification guarantees. These should include information about governing legislation, responsibilities, service levels, etc., integrated in protocols and communications. They would also be context sensitive, revealing only the level and extent of personal data necessary to fulfil a specific service or transaction. Only with frameworks that allow such integration and context-sensitivity will it be possible to automatically and dynamically connect and integrate new services to enhance service web applications.

Just as today we are able to access all kinds of information over the web, in the future we will be able to access, use and deliver identity information as needed by the process, and to build security upon such identity information. At the very large scale, identity is a combination of technology, processes and semantics. These principles need to be combined within a framework and integrated into the Service Economy.

Such a framework would enable applications and services to set their own security and identity requirements and claims, freeing the user of that responsibility while not infringing on their privacy. This would not inhibit any traffic or service, it merely affirms and positively flags those services that ensure the required security. The situation is analogous to traffic flows, where the rules of the road ensure all drivers follow the same assumptions and rules. It is still possible to go off-road but that is the driver's explicit choice and at their own risk.

Data protective services

One approach could be data protective (as opposed to 'data protection') services where accountability is built into the services themselves. Under a generalised eID/attribute concept a trusted third party, rather than the service provider, would hold subscribers' personal data, and would be accountable for how it is used. Such an approach would introduce greater transparency throughout the value chain.

So the situation here is not the secure or trusted 'islands' based on proprietary solutions. Rather, a sustainable open Internet requires a secure mainland, and where

identification and control features meeting the requirements of this mainland's legislation regarding trust are built in.

New businesses will evolve to leverage personal information

Services to manage our personal information

Major businesses will develop around this Internet of personal information. New companies will emerge offering services to capture, analyse, structure and store the personal information in our digital blackboxes. These enterprises will be intermediaries for a variety of personal information and services. Some of them will be our trusted parties; others will just be service providers to whom we disclose part of our data in exchange for the service. Of course, this disclosure part will be a service in itself and will be provided by a trusted party.

Ethical issues come to the fore

Ethical issues are of a different order

Important ethical issues will also emerge. We may be prepared to deal with the dangers, as we have in the past with issues such as Internet fraud. But the ethical issues here are new and more complex. What happens, for instance, if we lose part of our digital blackbox? Will or should our digital blackboxes outlive over physical lives? What if, after being incapacitated by a stroke, we are confronted by someone who impersonates us, even if it's just in bits? Again, 'data protective' (i.e. proactive rather than reactive) approaches should be encouraged.

5.2 What are the Enablers?

Accountability, governance and sovereignty

Every actor should be accountable

In the Service Economy, where there is no longer any structural difference between consumer and service provider, accountability becomes a basic need. Mechanisms (protocols) are needed through which it is possible to assign accountability to every player and entity on the Internet.

Technically, such accountability could be achieved in a variety of ways. The concept of an open and secure "mainland" Internet (discussed above) requires that the defined protocols are "conservative", such that when applied the security and identification/ accountability assumptions do not change. Such protocols would not exclude any communication or application but would define and maintain security status including the legislation that can be applied. Also these protocols would make the user or the application aware when the security status is about to change.

For example, virtually entering a jurisdiction that does not provide for tracing and legal co-operation in child protection would return a status where the service becomes flagged as accountable for such violations, unless the communication is registered with a recognised filtering authority to prevent such adverse behaviour. For areas where there is no confirmation/co-operation, voluntary escort services that offer the user the necessary accountability might be an option.

Such flagging and filtering needs protocols that do not infringe with privacy, as the virtual entering of a "unsafe" area is not a dubious activity by itself. Similar assumptions can be built into the cross-jurisdiction and cross-domain traffic to safeguard follow up of spam violation and other legally agreed elements.

Challenges to nation states

Another issue that comes to the fore is sovereignty. In cyberspace, where does one national border end and another begin? The sovereignty of states is already being undermined by increasing use of the Internet and in the Service Economy this threat will escalate dramatically without proper systems for identification and authorisation. It affects all areas of economic and social life, from the tracking and prosecution of criminal activity, to the payment of taxes and the protection of data and intellectual property.

A framework for privacy and security

A comprehensive framework is required

The Future Internet will require a wide-ranging framework for trust, security and privacy embracing at least the following dimensions.

In technology:

- **Storage technologies and services**: **Storage technologies** are crucial in being able to capture and mine data at this ultra-large scale. In particular, there is a need for new storage technologies/approaches that are stable over the long term (i.e. for posterity). Established technologies, like flash memory and magnetic disks (where Europe has limited presence) will give way to new technologies, such as polymer memory, holographic storage, and nano-storage, that still offer significant entrance opportunities for Europe. Investing in basic technologies may payoff in the long term. Similarly, there are major opportunities in **network storage and storage services** ("managing the cloud"). US players dominate this emerging space at present. We cannot afford to let US players alone copy the world's information and leverage on that generating services and wealth.

- **Data collection and processing**: Devices to harvest data play a major role in this scenario. **Data accrual should be seamless and contextualised**. Mobile phones, cars, digital cameras, personal sensors (those in the medical domain) and ambient sensors (like those in a house) are all important. Standards and regulation will be required to pave the way for their diffusion and exploitation. Payment systems are a further, most important, stream of data collection. Also, as data become available from many sources, completely **new methods of data analyses** are required, based on statistical approaches. Investments in basic mathematics, information processing and visualisation techniques will be important foundations and activities should have a strong application focus. Leveraging on these analyses, new search methods should also be investigated (e.g. going well beyond the Semantic Web).

- **Privacy aware technologies**: Objects and controls that enforce security and privacy. This is a technology which is around with smart cards but we do not yet have a view how to map this into the online world. The challenge will be the seamless integration that ensures the functionality still allowing full featured applications.

From an economic point of view, key issues are:

- **Data tracking and ownership**: To take off, this scenario, particularly in Europe and particularly in terms of generating an environment fostering business, requires trust and security. Identity theft, prying on my information should be absolutely blocked. Research investment on protection and on tracking violation

is required, in the latter case to cover the impossibility of protecting information 100% of the time. Technologies should be able to transform any data/information into a snippet that is self tracking. Tracing the use of these snippets will also be essential for associating value and charging for it. Micro payment in the order of one-tenth of a cent must be technically and economically viable.

- **Business models**: A business perspective on how to leverage data (preserving all ownership rights including non-disclosure) is required. Although information can be considered 'the new gold' we have very little understanding on how to exploit it. Economic studies of the Information Society are required, in particular studies looking at micro value, distributed ownership, and incremental value provided by independent parties.

Finally, in terms of legislation and regulation:

- **Building in privacy controls**: The increasing number and diversity of Internet services – both professional and private – make the risks of participation unknowable and the consequences of revealing personal information untraceable. The Future Internet will need means to manage personal data that are user-centric, allowing users to regain control over their privacy. This may range from consent management, to domain-specific and context-aware disclosure.

- **Balanced regulatory framework**: Europe has a particular sensitivity on privacy issues; this can be considered both an advantage and a drawback. It is an advantage in the sense that it may lead to a regulatory framework that ensures the respect of privacy, and hence generates applications in line with this. The drawback is that this framework may block the creation of applications to exploit personal data, thus hampering both the benefit to the owner of those data and the development of a business space. Striking the right balance will not be easy; nevertheless a balance needs to be found.

- **Implications for society**: As technological barriers diminish, we should look at the implications of the digital blackbox on culture and everyday life. Such social studies should consider the stances of various societal groups (age, gender, race, education, etc.). The worst outcome would be for such services to be accepted and driven by a part of the population, resulting in changes in the way of living that are welcomed by a few but create adverse reaction from others.

6 CHALLENGES FOR EUROPE

6.1 Key Issues

The scenarios presented in this report show how the Future Internet could shape the lives of all Europeans in or around 2020. They emphasize how the Internet will continue to touch all areas of our lives – even more so than it does today - opening up exciting opportunities for individuals, businesses, and public organisations.

In addition to the commentary given for each scenario, we see a number of common and complementary issues across the scenarios, spanning from the infrastructure through to end-users and businesses. :

Additional network capacity and further research are both needed

- **Going beyond the limits of current technology:** In a number of areas current technology is reaching its natural limits and faces roadblocks. One roadblock is network capacity: the Internet was never designed as a general communications infrastructure. Yet, as noted in Section 1, Internet traffic is growing at exponential rates which is being exacerbated by trends such as video sharing and watching high-definition TV online. Without massive investments, some analysts predict that within a few years we will already see noticeable degradation in performance as the Internet traffic jam makes our computers less responsive. We may even see 'brownouts' where users lose service altogether for limited periods. For business purposes, such as delivering medical records between hospitals in real-time, this is a major problem. Internet

  From a research perspective, more important is the differential rates of development in the key system building blocks (processors, optical networks, mass storage) which are accumulating, with significant impacts on network performance. For instance, as the amount of data needing to be processed increases, the growing disparity in speed between the CPU and the memory outside the CPU chip – known as the 'memory wall' - becomes a critical problem.

  Current technology is challenged in other areas too. Seamless architectures that span from the personal to the global level; techniques to handle the data deluge; system-wide trust and security; and long-term digital storage are just some of the areas where radically new solutions are required.

Maximising a scarce resource

- **Spectrum must be valued**: Radio spectrum is one of **the** most valuable resources of the digital age. As more and more devices and objects become wireless-enabled – including the whole new universe of smart 'things' – congestion in relevant parts of the wireless spectrum is becoming a key bottleneck. We have to find ways to manage the spectrum more efficiently so as to maximise data throughput and minimise interference. These new approaches are likely to be both technological (e.g. squeezing more from the available bandwidth) and economic (e.g. dynamic charging for spectrum usage). Optimising energy usage across the array of wireless nodes is also becoming a key concern.

Trust and security as a foundation for the new online world

- **Trust and security are paramount**: Trust and privacy are a prominent theme throughout the scenarios. They will be key enablers in realising the potential of the new online world. The world of Atoms and Bits requires that the mass of data collected by smart things is used in ways that protect our privacy and allow

us to retain control. Life on the Net requires that as our digital assets follow us around, from home, to office, to car, to airport, etc., they (and we) are protected. The Market of One requires that our highly personalised information is only shared with organisations with whom we have chosen to do business and in ways appropriate to the service being offered. And as Pushing the Horizon points out, our digital footprint is continually increasing – lasting even beyond a human lifetime – giving rise to ever more complex regulatory and ethical issues.

Technology is moving at ever faster rates and regulation is struggling to keep up. Developments such as cloud computing, social networks, and service mash-ups require new approaches to regulation at a Europe-wide scale. This should be complemented by research into privacy-enhancing technologies where data protective features and services are built in from the ground up.

Benefits and risks of personalisation

- **Personalisation – a double-edged sword?**: The scenarios rely to a significant extent on information, services and content being personalised around the user and their stated preferences and needs. This may be something of a double-edged sword. On the one hand, a world of personalised and customised offerings brings huge benefits for users and major opportunities for businesses. However, there is also a risk that personalisation leads to an atomisation of society. The 'market of one' has advantages in terms of goods and services but in other areas there may be a risk that by not 'getting what the others get' we lose some of our shared values and culture.

Users important in both market and societal contexts

- **User-driven innovation shaping societal change**: The scenarios emphasize how users will play a prominent role in shaping winning applications and services, and these in turn influence societal changes. In the Future Internet the principles that have driven Web 2.0 - user participation, openness and the network effect - get amplified many-fold and enriched by new possibilities such as rich-media and advanced finding aids. This will unleash a wave of user-driven innovation that will become a major driver (and in some cases probably ***the*** main driver) of the innovation ecosystem. As well as users as consumers, the Future Internet will enable citizens to leverage collaborative, 'open source' efforts for a whole variety of real-world community projects. For the third sector and non-monetary economy it could be the dawning of a new age.

Businesses have to learn to play by new rules

- **Encouraging new business models**: The new world of digital services and things will change the rules of the game in many sectors: there will be new niches; new opportunities; new ways to compete. Services may be delivered from/to anywhere, with no regard for organisational or national boundaries. Helga might be in one country, the car manufacturer in a second, and her insurer in a third. Similarly for Mario and his washing machine; or Anna and her personalised dress and accessories.

  How can businesses balance the trend to become more open with the need to protect their intellectual property and know-how? How can they co-operate with others to develop new service offerings while controlling the value chain? Europe's businesses must have the confidence to experiment with new business models and be supported by a regulatory environment that encourages them to do so. Greater transparency is required in the Single Market for services, including measures which ensure accountability to the consumer.

6.2 What Should Europe Do?

Many questions arise here which are well beyond the Panel's remit. However, and so as to initiate a much needed debate around these issues, we offer the following comments on areas which, we believe, require attention by policy-makers and decision-makers in industry, public authorities and governments.

Investing in research and innovation

Long-term research with a strong application focus

To stay ahead, Europe needs strong and long-term R&D activities addressing the key technologies, platforms, and application concepts of the Future Internet. These should be complemented by equally strong and long-term application-driven innovation activities aimed at exposing users - proactively and at an early stage - to novel technologies and services so that cross-adaptation becomes possible. This requires new types of innovation platforms that facilitate the voice of the end-users to be heard. In particular, Europe needs large-scale testbeds and living labs where various stakeholders can meet and influence each others' work.

At the infrastructure level, we have to rethink the whole Internet architecture around the 24/7 high-performance spinal cord of 21st century society. This architecture should be able to boost and support the Internet applications innovation and be able to scale up with the exponentially increasing data traffic for several decades to come.

Other research priorities include:

- management of heterogeneous network architectures and the operational needs of massively distributed systems;
- high-speed fixed networks (core and metro scale);
- high-performance, ultra-low cost wireless network architectures & technologies;
- new radio spectrum usage based on cognitive and real-time on-demand needs;
- reliable and secure interoperable platforms for services and applications;
- advanced user interfaces for Internet-enabled services;
- semantic technologies
- privacy-enhancing technologies (e.g. protective data objects), in particular for social networking;
- new approaches to storage (technologies and methods);
- massively distributed and cognitive systems.

A massive effort on integration will be required to enable the various devices, components and services to work together. The resulting platforms will be highly complex and should be tested in applications with high societal value. Thus, activities should go beyond pure technological research to include a key focus on application-driven innovation. In addition, as systems scale energy efficiency is likely to emerge as a key design parameter throughout the entire system.

The socio-economic dimension

Shaping future developments to societal needs

The Future Internet will reach into all areas of our lives and have transformational effects, both for individuals and organisations. Yet up to now the focus has been primarily on technological research. A major push on socio-economic research is also required to ensure societal and economic factors are taken into account in Future Internet development.

Examples of this socio-economic research include (but are not limited to):

- economic studies of the Future Internet. Digital industries (IT, media, telcos) themselves warrant attention (the next steps in convergence), as well as transformational effects in traditional manufacturing & service sectors;
- new business models (micro-level studies, see below);
- implications for regional ecosystems (e.g. from localisation of production)
- inclusion issues in the new Service Economy;
- public acceptance, especially regarding security, privacy & ethics; and
- regulatory environment for the Future Internet;
- policy needs for distributed e-Services within the EU market space.

A new role for standards

Standards as a foundation for interoperability

Standards need to be created in many areas to ensure interoperability in the Future Internet and to realise economies of scale that are essential for reaching a critical mass for new applications. For example, there is a need for standards to ensure the unique identification of objects in the Internet with Things. For the Service Economy, a standard for a semantic-based Service Description Framework would be a key enabler.

If standardisation is industry-driven then open procedures, non-discriminatory access, and a transparent, legally certain, and well-balanced IPR policy must be ensured.

Promoting take-up

Building critical mass in key application sectors

To compete in the Future Internet Europe needs to create a strong home market for FI technologies and services that can be satisfied by European industry and later expanded to other parts of the world. Such an approach will benefit all players: manufacturers, developers, end-user enterprises, public administrations, and citizens. A sufficient scale and intensity can only be reached by combining the national efforts and encouraging co-operation, mobility and cross-fertilisation.

A key requirement is to promote web-based services at national level, e.g. in public services, and to prepare key end-user sectors such as energy, automotive, finance, and manufacturing. Internet 2020 will be a pervasive infrastructure where users will have no perceivable limitation in terms of access, capacity and speed. Hence the various sectors of industry, agriculture, retail, and services like eGovernment, healthcare, education, tourism, need to be based on this infrastructure.

Other attractive markets with good growth opportunities will include: rich media games, and in particular the multi-player mobile segment; social networking, services supporting cooperative engagements; security management for identities and profiles; media-rich education, training and learning; and innovative “info-tainment” services.

New approaches to regulation and governance

A supportive regulatory environment

The Future Internet will only rapidly reach a critical mass in Europe if the benefits are widely understood among business and private users and if there is real trust in the new technologies. At present, consumers tend to mistrust new ICT applications, as the debate on data privacy issues related to RFID shows.

Europe must create a supportive regulatory environment that fully reflects the new reality of the Service Economy and the Internet with Things. A careful balance will need to be struck between users’ desire for privacy and the needs for innovation within a fast-

growing and rapidly-expanding business space. This means establishing trust and promoting fair sharing of revenues among all participating actors, as well as ensuring users maintain full control over the ownership of their data within networked systems. Existing privacy and security rules should be adapted to the Future Internet as appropriate and where necessary new rules created. Effective enforcement will also be essential.

Specific aspects include:

- Legislation to ensure eID of services, systems and users
- Users having the right to have, to get accepted, and to ensure confidentiality of any associated data.
- Obligations for service providers to be transparent in terms of use and security/privacy (security-enhanced 'Internet mainlands' rather than 'islands').
- Minimum security requirements for service classes (e.g. personal communications, social networking, mail, eBusiness, credit cards, use of eID)

As noted above, technology can also play a key role here by building in privacy controls at the architectural level and in a user-centric manner. The aim should be to create a European Digital Life framework, with all the relevant regulatory and technology platforms underpinning.

Pooling of efforts

Working together for the Future Internet

The Future Internet presents a massive challenge. To realise it Europe must pool its efforts at European, national and international levels. This requires:

- More effective collaboration amongst the EU's significant portfolio of research projects focusing on issues relating to the Future Internet.
- Better coordination between, and alignment of, national initiatives within the Member States on Future Internet research.
- Mobilising European industry around the Future Internet paradigm. This requires the forging of multi-stakeholder partnerships spanning the ICT industry and key application sectors for Internet-enabled services.
- Connecting into international efforts on Future Internet research, policy and legislation, based on a coherent and strategic European response.

6.3 Recommendations

The current economic downturn provides an opportunity to lay down foundations for the new world order, one where the Internet will be a key enabler. **This opportunity must not be missed**. Based on our analysis, the Panel offers the following recommendations:

Recommendation 1 addressed to the European Commission:

Strengthening and deepening the research base

Strengthen significantly the current R&D efforts within the EU Framework Programme and promote a holistic multidisciplinary approach to the development of the Future Internet and encourage the development of cooperation in the global context.

The Future Internet Assembly (FIA) launched by the EC in March 2008, has proven to be a useful and necessary instrument at the service of greater cohesion amongst R&D projects. The FIA should, however, **step-up its activities with a view to developing open approaches** catering for the multiple (and sometimes conflicting) interests of stakeholders in the Future Internet.

All projects, members of the FIA, should be requested to **earmark specific resources to contribute jointly to the development of a European strategy towards the Future Internet**. This strategy, once defined, should become the basis for the initiation of international cooperation partnerships.

Recommendation 2 addressed to the European Commission and Industry

Building partnerships between stakeholders

Establish with the support of industry and the research community at large, **a Public-Private-Partnership (PPP) initiative active in key end-user application sectors** such as manufacturing, energy, transportation, healthcare, education and entertainment, to fully explore the interrelationships between advanced networked and service technologies and massively distributed end-user applications.

The proposed PPP should provide for **the active participation of end-user application developers** who will be granted access to large-scale experimental broadband networked facilities (both fixed and mobile).

An open eco-system approach should be adopted, aimed at avoiding incompatible and non-interoperable implementations in the different application sectors, with a view to maximise the potential for innovation in the EU Single Market space. Attention should also be given to **the evolution of educational needs** in this area; the European Institute for Innovation & Technology (EIT), with a Knowledge and Innovation Community (KIC) on future ICT, will be a powerful vehicle here.

Recommendation 3 addressed to Member States

Facilitating co-operation between Member States

The Future Internet Forum of Member States which has been announced, is encouraged to take **bold steps towards a deeper and stronger cooperation** across the existing and planned national Future Internet initiatives.

Exposing the various initiatives to each other will lead to a better understanding of the:

a) requirements for interoperability;
b) specific privacy and security features;
c) best practices under development;
d) business opportunities in the European setting; and
e) opportunities for pre-commercial public procurement.

The Future Internet Forum of Member States, if appropriate with financial support from the Commission, should be tasked with the **development of a coordinated policy-driven strategy on the Future Internet**, with the aim of contributing to the acceleration of a public service market roll-out of innovative Internet technologies and services across Europe. We believe this report provides a starting point for such a joint strategy.

Recommendation 4: addressed to Europe's Future Internet community

Taking a world-leading role

The Future Internet will be a global phenomenon and Europe must strive for a world-leading role. On the one hand, this means **setting the pace in addressing global challenges**, such as governance, accountability and sovereignty within the Future Internet, in a way that reflects our European values. In addition, **research co-operation with international partners** should also be a key focus.

5. HIGH-LEVEL EXPERT PANEL MEMBERS

Jean-Charles Hourcade

Jean-Charles Hourcade, former *Directeur Général Adjoint (2004-2008)* and CTO (2000-2004) at Thomson , in charge of Technology, Research, Innovation and Intellectual Property, has previously held the positions of Vice President Strategic Planning at Thomson CSF (1993-1999), where he was in charge of Corporate Strategy, Alliances and Mergers and Acquisitions, and of Chairman & CEO of Canal+Technologies (2002-2003). He joined the Thomson group in February 1986, from the Institut National de l'Audiovisuel, where he had founded in 1982 the 3D computer graphics group. During the following years, he was the CEO of Thomson Digital Image (TDI), the world leader at that time in 3D computer graphics and animation. Jean-Charles Hourcade has served as Chairman of RIAM from 2001 to 2004, and of the european technology platform NEM (Networked Electronic Media), and is a member of the *Académie des Technologies*. In 2008, Jean-Charles Hourcade has created Red Cat Technologies, a strategy consulting and technology management company in the field of communication and digital media.

Jean-Charles Hourcade was born in Pau (France) in 1957, and graduated from the Ecole Polytechnique in 1978 and the Ecole Nationale Supérieure des Télécommunications in 1980.

Yrjö Neuvo

Yrjö Neuvo received his Ph. D, degree from Cornell University in 1974. Currently he is Professor and Research Director at Helsinki University of Technology. He was Chief Technology Officer and a member of the Group Executive Board in Nokia in 1993 – 2005. His responsibilities included managing mobile phones R&D. Before joining Nokia, he had a 19 year academic career as Professor at Tampere University of Technology, as National Research Professor at the Academy of Finland and as a visiting professor at University of California, in Santa Barbara, USA.
He has been Chairman of ARTEMIS JTI Governing Board 2007 – 2008, Bureau Member of European Science and Technology Assembly (ESTA) 1994 – 1997. He was General Chairman of the 1988 IEEE International Symposium on Circuits and Systems of the IEEE International Conference on Communications (ICC 2001). Currently he is Member of Governing Board (and its Executive Committee) of European Institute of Innovation and technology. He is also Board Member of two listed companies Metso and Vaisala as well as three high tech start-ups. He has received four honorary doctorates and is Life Fellow of the IEEE. Asteroid 1938 DN carries his name.

Reinhard Posch

Reinhard Posch was born on April 16th 1951 in Graz. After finishing school in 1969 he studied at the Graz University of Technology mathematics . In 1973 he received the „masters degree“. During 1971 until 1979 he worked at Graz Research Center in operating systems, networking and automated road construction, during which he recived his PhD in 1976. 1974 to 1984 Reinhard Posch served as assistant professor at Graz University of Technology in information processing. During this time he also worked with Sperry Univac (Roseville, MN, USA) researching in the field of physical network layers.

1983 Reinhard Posch got his „Habilitation“ in “Applied Information Processing and Communications Technology” and was appointed full professor at Graz University of Technology in 1984. In 1999 he became also Scientific Director of the „Austrian Secure Information Technology Center“ (A-SIT). Reinhard Posch was in charge of eGovernment in the task force e-Austria and became federal CIO (Chief Information Officer) for the Austrian government in 2001. 2007 Reinhard Posch got elected chair of the management board of ENISA (European Network and Information Security Agency).

Besides many publications in the field of networking, VLSI design, IT-security and eGovernment he conducted many national and international research projects concentrating on networking, computer security, smart cards and innovative advances of eGovernment.

Roberto Saracco

Roberto Saracco has been working for over 35 years in telecommunications on data networks, management systems, switching software. Since the end of the nineties he moved to research in the economics aspects of telecommunications. In 2001 he was appointed director of the Telecom Italia Future Centre where a group of international researchers studies new business models in the context of ecosystems enabled by technology evolution. He is Director of the COMSOC Sister and Related Societies, Member of the IEEE Strategy Group and Vice President of the Italian Telecommunications Association.

Wolfgang Wahlster

Professor Wolfgang Wahlster is the Director and CEO of DFKI and a Professor of Computer Science at Saarland University, Germany. Founded in 1988, DFKI GmbH is a private-public partnership between German government agencies and 13 companies including SAP, BMW, DaimlerChrysler, Deutsche Telekom, Deutsche Post, and EADS. With DFKI he helped to create 53 high-tech spin-offs companies. Dr. Wahlster received his diploma and doctoral degree (1981) in Computer Science from the University of Hamburg, Germany. He has published more than 170 technical papers and 7 books on language technology and intelligent user interfaces. His current research includes multimodal and tangible user interfaces, user modelling, ambient intelligence, embodied conversational agents, Car2X systems, and semantic web services. In 2001, the President of the Federal Republic of Germany presented the German Future Prize to Professor Wahlster highest scientific prize that is awarded each year for outstanding innovations. He was the first German computer scientist elected Foreign Member of the Royal Swedish Nobel Prize Academy of Sciences, Stockholm in 2003. In 2004, he was elected Full Member of the German National Academy Leopoldina that was founded in 1652. He has been appointed as chief scientific advisor for Information and Communication Technologies in the Research Union of the German government.

Michael Sharpe

Panel Rapporteur

Director of MS Consulting & Research Ltd, has broad experience at the business-policy-technology interface. He has worked with both public and private sector clients on innovation issues, and has been active in European research programmes since 1992. Over recent years he has been closely involved with the European ICT Programme on strategy, communication and evaluation assignments.

Mike has a keen interest in SME networks and was instrumental in setting up PIN-SME, a pan-European network of ICT SME associations. He is also an advisor to Advantage West Midlands, a UK regional development agency, on European research funding.

Prior to setting up MS Consulting in 1998, Mike spent twelve years with a large management and technology consultancy. He has a Master's degree in Science & Technology Policy from the University of Sussex, and a Bachelor's degree in Engineering from the University of Manchester.

FURTHER READING

ec.europa.eu/foi

This website is the first place to read about the many activities the European Union undertakes in the area of FUTURE INTERNET. The site links to the multitude of related

www.future-internet.eu

The European Future Internet Portal is a project initiative which hosts the Europe-wide debate on the Future of the Internet.

cordis.europa.eu/ict/ch1

Ongoing research and development activities in the area of Future Internet, links to activities, projects, work programmes, calls and events – held and upcoming.

FIA Conference Series

- Valencia, 14 April 2010
- Stockholm, 23 November 2009
  www.fi-stockholm.eu
- Prague- 11 May 2009
  www.fi -prague.eu
- Madrid, 9 December 2008
  www.fi -madrid.eu
- Bled, 20 March 2008
  www.fi -bled.eu

UPCOMING EVENTS

www.ict-mobilesummit.eu/2009
Santander – 10-12 June 2009

ICT-MobileSummit 2009 will address all the challenges of building the Future Internet, which will be based on mobile, wireless and fixed broadband communications infrastructures. The impact of such Future Networks on the underlying Internet infrastructure will continue to be emphasized in the 2009 Summit. Technology enabling services and applications for billions of users involving trillions of interconnected potentially mobile devices will be addressed at the event.

http://www.ict-fireworks.eu/events/fireweek-2009-in-lulea.html Luleå – 29 June – 3 July

The meeting will discuss ongoing matters in experimental test facilities and their contribution to the Future Internet activities, Living Labs, feature tutorials and workshops as well as project reviews.

http://www.nem-summit.eu/
Saint-Malo, 28-30 September 2009
Networked Media Summit 2009

The NEM Summit is the major conference and exhibition devoted to the field of networked and electronic media and ICT at large.

http://www.fi-stockholm.eu/
Stockholm - 23-24 November 2009

Biannual Future Internet Assembly Workshop (limited to the currently 95 FIA project and their participants)

FIA'10 Conference, Valencia, 14-16 April 2010

Annual Future Internet community conference to be followed by the bi-annual Future Internet Assembly (FIA) workshop. The conference will bring together high-level policy makers and stakeholders in the Future Internet Assembly to discuss the achieved and announce new initiatives.

Future Internet 2020

CALL FOR ACTION BY A HIGH LEVEL VISIONARY PANEL

INFORMATION ABOUT THE ACTIVITIES OF THE EUROPEAN COMMISSION ON THE FUTURE OF THE INTERNET.
http://ec.europa.eu/foi

INFORMATION ABOUT THE ICT PROGRAMME, ITS ACTIVITIES AND PEOPLE INVOLVED.

European Commission
Information Society and Media Directorate-General
http://europa.eu/information_society/
CORDIS
The European Union window to research and technological development
http://cordis.europa.eu/ict/ch1/
In addition, the ICT Programme maintains a network of national contact points throughout Europe and the world. It is available to you with information, advice, guidance and training.

Find your nearest contact point at:
http://cordis.europa.eu/fp7/ict/ncps_en.html

ICT Information Desk

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