Forming a Vision for Future Internet Research

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Abstract: This paper presents a vision for the Future Internet and its impact on individuals, businesses and society as a whole; the vision presented is based on an extended consultation carried out by the authors within the European Future Internet research community, as part of the work of the Future Internet Assembly (FIA). The core result of this paper is the identification of six research priorities for the future. We also present a scenario related to the London Olympic Games, which is intended to link together the research priorities and related findings.

1. Introduction

This paper presents a vision for the Future Internet and its impact on individuals, businesses and society as a whole; the vision presented is based on an extended consultation carried out by the authors within the European Future Internet research community, as part of the work of the Future Internet Assembly (FIA).

The purpose of the consultation was to identify key challenges and research priorities for the Future Internet, particularly from the standpoint of current European research projects (in Framework Programme 7). The output of the consultation is documented in the form of a visionary research roadmap [1]. The manner in which the consultation has been carried out will be set out in the Methodology section of this paper.

The vision we present is intended to inform future research funding programmes, including the European Commission's "Horizon 2020" framework programme. We have validated the results of our initial consultation, and the associated vision, with a significant number of researchers in the FI community, and in this paper we also present additional insights gained during this process of validation. Overall, we observe that there are several important areas of innovation for Future Internet research (which we have identified and categorised carefully) and that these need to be further developed and supported by researchers and policymakers both within and outside Europe.

2. Objectives

We will present here the methodology we used to carry out this consultation, the key findings of the FIA Research Roadmap that was subsequently produced, and the additional inputs we received during the process of validating these findings. The purpose is to paint a picture of the future based on the inputs received, to present the basic underlying model for our research, and to identify potential gaps and opportunities.

3. Methodology

In order to elicit inputs from members of the European Future Internet research community, we have had to actively participate in this community ourselves; the vehicle for doing so has been the EU Framework Programme 7 research project EFFECTS+ (see www.effectsplus.eu) , which carries out workshops and clustering activities for European projects, particularly in the area of ICT trust and security. As part of EFFECTS+ we have to actively participate in and run aspects of the Future Internet Assembly (FIA).

For the research roadmapping exercise documented here, we organised and ran a dedicated consultation event ("roadmapping workshop") at the European Commission in March 2011, attended by over 100 European researchers involved in Future Internet projects and related activities. Prior to the workshop, a call for contributions had been issued, and just under 25 of the submissions received were selected for presentation at the event. The first version of the FIA Research Roadmap was based on the ideas presented and the panel discussion that ensued.

The approach adopted in this work involves integrating contributions across the entire space of Future Internet research with the aim of bringing out the vision for how and where the Internet will make a significant difference in the future and identifying the broad challenges and gaps, and identifying the solutions and research needs in the future. To do this we asked for contributors to address the following:

- What **changes** will occur? Describe the broader social and other changes that research into the future Internet will need to take into account here. Indicate the timescale of these changes.

- What's the **vision**? What positive outcomes can be brought about by the use of technology? Discuss how you imagine the world will be as a result of the changes and advances that will have occurred; what impact will we be able to have? When will we have that impact?

- What are the difficult **challenges and gaps** (broader, technical …) that have to be addressed satisfactorily in order to handle the changes and realise the vision.

- What's the **solution**? Which new approaches/technologies/… will likely be most useful in addressing the gaps and challenges? What research needs will emerge as we try to build such solutions? What are the steps to developing the solutions?

We note here that the Research Roadmap that has been produced so far includes novel ideas and observations from numerous researchers – too many to name – and that the editing team that created the final document includes Markus Fiedler, Anastasius Gavras, Nick Papanikolaou, Hans Schaffers and Nick Wainwright. In the present paper we go beyond the roadmap and try to identify useful elements for a vision of the future, taking into account inputs and comments received after the roadmap document was produced and distributed.

4. Results: Description of Research Priorities for the Future

In our research priorities for the Future Internet we see three themes that are foundational and enabling and which support us in building the Future Internet. These are:

(i) going beyond converged infrastructure,

(ii) making use of networked data and

(iii)achieving real internet security.

Looking forward towards the research that will transform what we do and how we do it and which are fundamentally integrative, they exploit and use a wide range of networked technologies towards a diverse set of objectives, we see three priorities that support us in using the Future Internet. These are:

(iv)making full use of networked interaction, enabling people to interact better not just with each other, but also with information and the 'cyber-physical world',

(v) augmented worlds, and

(vi)networked innovation.

We discuss each of the above priorities in more detail, in order to justify their importance.

Going Beyond Converged Infrastructure

Internet infrastructures – networks, virtualised computing, storage systems, undergoing a period of intense convergence, the boundaries between service platforms and the infrastructure services layer are becoming blurred, and at the same time at the edge of the networks smart mobile devices are becoming pervasive and more capable at the edges of networks.

Future research in this space must look beyond converged infrastructure to the addressing the challenges of meeting the vastly increased demand for bandwidth and services and connectivity and new and different applications and services:

- Polymorphic networks – combining different networks to meet the for capacity and needs of new media, applications, services, infrastructures and networked 'things'
- Expanding the cloud to the edges of the network and beyond, providing the execution environments for new FI applications and services. Real time capabilities will be vital for these new services, data and event processing, interaction processing all demand real time responses, and variability in demand will provide real challenges for the services providers
- Looking beyond 'smart devices' towards 'smart edge systems' as the execution environments at the edges of the network that link physical and the cyber world.

The Rise of Networked Data

We use the term 'networked data' to refer to Big Data (now an established term) that is connected across the network to applications and services that can make use of it, not locked in silos. The aim is to enable the exploitation of network externalities that can occur if data is connected to many potential users. The concept of networked data owes much to but also goes beyond the concept of open data, which is defined as "A piece of data is open if anyone is free to use, reuse, and redistribute it — subject only, at most, to the requirement to attribute and/or share-alike." (http://opendefinition.org/) By placing an emphasis on the network connectivity to data we aim to make data available to be used in supply chain for services but also taking account the need for revenues, licencing models, provenance and security and of course respecting confidentiality and privacy.

Networked data on a massive scale is the powerhouse of the Internet today and the growth trend looks set to continue as new services and applications are developed, a greater part of

the economy and public sector relies on the Internet, and citizens spend increasing parts of their lives online.

Security

A decade away we will be conducting much more of our lives and economy online than we do now. The scale of Internet use continues to increase relentlessly, and our reliance on the Internet continues to increase. As we do so the potential opportunity, rewards, and impact of cybercrime becomes even more significant. The scale of threats, potential for conflict between individuals, organisations, and states online should not be underestimated.

Reliance on Internet for operation of our critical infrastructures means that cyber-defence is even more vital aspect of state security. Securing the Internet as a socio-technical system is a high priority and continued separate attention is necessary. Internet security can become part of Europe's new defence businesses, and a secure Internet is necessary condition for economic competitive.

Networked Interaction

Through the Internet we interact with each other, with the physical world, and with the digital world, and indeed, in the future the distinctions my blur even further. Social networks are not the last word on social interaction, web-cams and video conferencing are not the last word on collaboration, games and IPTV are not the last word on entertainment. New interfaces and modalities will create opportunities for richer interaction and for addressing our work, life and emotional needs. New ways of interacting with complex data provide ways to understand complex situation. New interactions with the digital world will provide new media experiences that look beyond 3D. Future networked interaction will not be delivered through one device, in a sit-back, sit-up, or handheld interaction mode, but through collections of devices brought together as smart edge systems, and ideas of ownership, situatedness, virtualisation will create interaction experiences that are effective, engaging, and empowering.

The research theme of interaction, supported by rich interfaces, displays, haptics, and other yet to be developed approaches makes possible to address some of our real concrete needs too – for carbon reduction for example through remote collaboration which can take people off roads, support knowledge business networks, or create valuable social links. Some of the biggest barriers to delivering Internet benefits to excluded groups in Internet are the interfaces. This is just one example, and looking forward the future of networked interaction has real potential to create value given that we are reaching the point where demand and capability come together to make new and valuable networked interactions possible.

Augmented Worlds

As we look to the start of the next decade and beyond we can begin explore how we can harness the power of the Internet to 'augment' lives, work, business and spaces in ways that add value. By 'augmentation' we mean 'increasing in intensity' the activities we are doing or the things we need done for us, addressing what we do in our jobs and daily lives, addressing needs of groups and communities, of industry, construction, maintenance, engineering,

manufacturing, transport with information, decisions support, risk analysis, options, delivered through interactions and interfaces that are intuitive and unobtrusive. What is currently described as 'augmented reality' has potential to develop into what is fundamentally an integrative, systems, applied approach to addressing problems of industry, people, society and developing techniques and frameworks that harness the scale of the network and networked data onto individual actions, tasks, and activities, transforming what we do and how we do it.

Internet-Style Innovation

It is clear that the Internet has been an incredible force for innovation over the past three decades at least. To have created such a platform for innovation, value creation, and benefits to society must rank as one of the outstanding achievements since the industrial revolution. It is our aim that this innovation and value creation should continue, and that Europe should play a big part in it. Every one of the research communities consulted in this programme stressed innovation – both within their field of work and enabling innovative benefits as a consequence of it.

Whether we are discussing topics such future enterprise, cities, or experiences, ideas abound on the kinds of approaches that enable innovative value creation to take off. The network effect, scale, openness, experimentation, software, and pilots, and services, SME and start up participation, application, and real users. This is the 'Internet-style' innovation we aim for. Innovation that happens at the edges of the network, that is stimulated by linkages between sectors, that involves people, where people, communities, business, even public sector, are 'empowered' to take control of opportunities to innovate. Ideas such as making cities into experimental services environments, creating platforms, integrating across industries and sectors, releasing and exploiting data, are enabling factors – they set the conditions for unlocking value and if carried out 'Internet style' they set the conditions for innovation and provide an environment for new applications and services need to be instantiated, built, used, and grow.

4. Developments: Addressing gaps and extending our vision

The vision presented here builds strongly on the research we have carried out while developing the FIA Research Roadmap [1]. On 25th June 2012, we held a workshop in Brussels to present to the FIA research community and review the first version of the Research Roadmap contained in the preceding pages. Two kinds of inputs were solicited from the community in written form: (i) commentary papers and (ii) "new idea" papers. At the workshop there was a discussion of the content of the roadmap with a view to identifying gaps that the community felt needed to be addressed in future EU funding calls.

Topics that were brought out during this discussion included:
- **Sustainable or 'Green' ICT**
  Green ICT is both about developing products in an environmentally friendly way, and about optimizing energy usage of devices and networks. One issue that was brought out quite strongly was the impact on power consumption created by a widespread adoption of sensors that is foreseen as we move towards the Internet of

Things (IoT). Not only will such sensors generate huge quantities of data that need to be transferred and stored; simply operating the sensors will require a lot of power, and there needs to be much research in finding ways to reduce power consumption and operate these devices in an environmentally friendly manner. It was pointed out there a number of sessions related to these topics held at FIA Aalborg in May 2012.

- **Integration of existing technologies and project outputs**
  There was a detailed discussion centred around joining together outputs of current research projects that are closely related, and on finding ways of exploiting the architectures and platforms developed in these projects to address future research problems. Examples of exploitation routes mentioned included standardization activities.

- **Further emphasis on Big Data**
  The emergence of vast quantities of data that need to be processed, exchanged and stored (namely, Big Data), needs to be addressed in a 'big' way in future research programmes. This is a problem that cannot be ignored, and there is an opportunity for doing research that looks purely into scalability aspects of the Future Internet, and efficient ways to manipulate and exploit the data 'pile' that is accumulating.

- **Further emphasis on Cloud Interoperability**
  It was clear from discussions that there needs to be much research on bridging the cloud computing offerings of different service providers on a technical level.

- **Developing better risk analysis and security assurance mechanisms for the software development lifecycle**
  It was felt that certain aspects of security assurance are not sufficiently covered in the preceding pages; the undisputed importance of building security mechanisms into systems from the outset needs to be made more explicit.

- **Developing proactive security for the FI to thwart smart, adaptive attackers**
  Cyber threats and the security required for the Future Internet were discussed in some detail at the workshop, and it became clear that Future Internet security research needs to evolve to develop responses to ever smarter attackers. Rather than building traditional protection mechanisms, research is required on means of teaching systems to proactively defend and protect themselves. It was suggested this should be a topic for future FIA events.

New topics that were presented in detail at the workshop included:

- **Augmented Cognition**
  Are we moving towards a society where human cognition will be directly assisted by ICT through sensors and actuators attached to our bodies? There is much research to be considered here, and, at the workshop, topics including retinal chip implants, brain implants to control robots, and artificial limbs were presented. Research in this space should deal not only with the potential offered by such technology, but also with the deeper implications and consequences for the way we live our lives and the way we evolve as a society.

- **Smart Destinations**
  How can we enable a traveller to feel technologically 'at home' when visiting a new destination? What R&D is required to enable this? This was another of the topics identified at the workshop, with strong linkages to smart cities research.

- **Solving Domain-Specific Real-World Societal Issues**

How can we innovate if we don't understand the real-world problems we're trying to address? One of the key topics discussed at the workshop as a way of moving forward was how to bring technologists closer to social scientists and others who work with 'real people'?

5. Scenario / Applications: Future Internet for the Olympic Games

In this final section we imagine how the capabilities we have described can come together to achieve the objectives for the Horizon 2020 framework for research and innovation. At the time of writing, the London 2012 Olympics are about to begin, and in September 2012 the host city for the 2020 Olympics will be chosen from the short list of three – Madrid, Tokyo, and Istanbul. Imagining how Future Internet technologies can turn the 2020 Olympic city into a truly 'smart destination' for millions of physical visitors and more than a billion virtual visitors, address the logistical needs of delivering such a huge event and at the same time continue to meet the needs of those living and working there can illustrate, if only in a brief sketch possible in the space available in this paper, how future internet technologies can transform our world.

For a billion virtual visitors the ability to immerse themselves in the Olympic experience without travelling to the Olympic city means greater than ever opportunities for participation, with 'immersive' experiences in high definition 3D being made available almost certainly from the viewpoint of competitors but also possibly synthesised from the viewpoint of millions of visitors. For those attending – participating with friends both there and at home can be taken to a new level through innovative networked interaction from everything from sophisticated handheld devices to 'digital street furniture' that could include interactive display surfaces in buildings and public spaces. Imagining all those visitors – virtual and in person – being comfortable wearing digital glasses for an augmented reality experience seemed farfetched but a generation used to the pace of change in smart phones can find such features entirely plausible.

Creating a city that could adapt to the huge demands of such an event is a challenge of scale – able to manage traffic, transport, people, security, logistics and to respond to unforeseen events in real time – security events being perhaps the most obvious and challenging but at the same time managing and responding to myriad incidents and issues that present as much of a challenge. Data and content – from sensors, services, applications, utilities, environment and every possible source including that which might be acquired from the numerous digital devices carried by citizens and those deployed for a whole range of other purposes – could be available to innovative applications and services that might for example make possible new cultural experiences by interacting with interactive street displays in real time. The combination of networked data as described earlier, augmented systems in our cities, and internet-style innovation provides a potent mix for new applications and service.

Creating a truly "smart destination" requires of course a digital infrastructure that goes beyond what we have today even for London 2012. Capacity required to for support content and data traffic to for events will be incredibly concentrated, at the same time those running the events and the city as a whole must continue to operate and 'hotspots' must not become 'deadspots' for either. Wireless capacity and the ability to actively cache and serve content and applications from edges of the network will be vital. Capacity to capture, analyse and

serve networked "big data applications" in real time become critical. Alternative infrastructures such as peer-peer and delay-tolerant networks may play a part in in new interactive applications and services. With such dependence on digital infrastructures security of course is paramount both of the infrastructure and applications.

The internet featured little in the Olympic Games eight years ago in 2004 in Athens. Today the internet is a big part of individual and collective experience of the games and of the city. Looking forward the eight years to 2020, the internet will play an even more central role to the event and to the destination, whichever of the three cities shortlisted are chosen. Imagining and sketching out the conditions for innovative applications and services is as far as we can go in this paper, however if the conditions are right, the potential for innovation that will transform the experience of visitors and citizens alike is vast.

6. Conclusions

We believe that the six areas identified in this abstract, namely, (i) going beyond converged infrastructure, (ii) making use of networked data, (iii) achieving real internet security,
(iv) making full use of networked interaction, enabling people to interact better not just with each other, but also with information and the 'cyber-physical world,' (v) augmented worlds, and (vi) networked innovation, are the key research priorities for Future Internet research in Europe.

References

[1] FIA Research Roadmap. Available from http://fisa.future-internet.eu/index.php/FIA_Research_Roadmap.
[2] ITU (2009): The Future Internet. ITU-T Technology Watch Report 10.
[3] Oxford Internet Institute (2011): Towards a Future Internet. Interrelation between Technological, Social and Economic Trends. Final Report for DG INFSO and Media.
[4] Tselentis, G. et al. (2010): Towards the Future Internet. Emerging Trends from European Research. IOS Press (2010).
[5] European Commission (2009): Future Internet 2020. Call for Action by a High-Level Visionary Panel.
[6] FIRE Roadmap. Available from http://www.ict-fire.eu/home/fire-roadmap.html
[7] 'Internet of Things in 2020: Roadmap for the Future' v1.1. Available from http://www.iot-visitthefuture.eu/fileadmin/documents/researchforeurope/270808_IoT_in_2020_Workshop_Report_V1-1.pdf
[8] NeSSoS Project. Engineering Secure Future Internet Services: A Research Manifesto and Agenda from the NESSoS Community. Available from http://www.nessos-project.eu/media/deliverables/y1/NESSoS-D4.1-PartII-Roadmap.pdf
[9] SysSec Project. System Security Research in Europe: A Research Roadmap. Available from http://www.syssec-project.eu/media/page-media/3/system-security-research-roadmap-whitepaper.pdf