ICT - Information and Communication Technologies

FP7-288021

Network of Excellence in Internet Science

D13.2.1 Internet Science – Going Forward: Internet Science Roadmap (Preliminary Version)

Due Date of Deliverable: Jan 31, 2014

Actual Submission Date: Jan 17, 2014

Revision: Final Version

Start date of project: December 1st 2011 **Duration:** 42 months

Organization of lead contractor for this deliverable: NKUA, ULANC

Editors: Ioannis Stavrakakis, David Hutchison

Contributors: CERTH (GR), CNR (IT), UNIBO (IT), UIO (NO), IMINDS (BE), UOP/ UNI PASSAU (DE), TUM (DE), ULANC (UK), OII (UK), TUDELFT (NL), UESSEX (UK), EPFL (CH), NKUA (GR), ETH (CH), UWAT (CA), LSE (UK), KNAW (NL), UL (SLO), SOTON (UK), CU (UK), AIT (AUS)

Project Information

PROJECT	
Project name:	Network of Excellence in Internet Science
Project acronym:	EINS
Project start date:	01/12/2011
Project duration:	42 months
Contract number:	288021
Project coordinator:	Leandros Tassiulas – CERTH
Instrument:	NoE
Activity:	THEME ICT-2011.1.1: Future Networks
DOCUMENT	
Document title:	Internet Science – Going Forward: Internet Science Roadmap
Document type:	Report
Deliverable number:	D13.2.1
Contractual date of delivery:	31/01/2014
Calendar date of delivery:	17/01/2014
Editor:	Ioannis Stavrakakis (NKUA), David Hutchison (ULANC)
Authors:	CERTH (GR), CNR (IT), UNIBO (IT), UIO (NO), IMINDS (BE), UOP/ UNI PASSAU (DE), TUM (DE), ULANC (UK), OII (UK), TUDELFT (NL), UESSEX (UK), EPFL (CH), NKUA (GR), ETH (CH), UWAT (CA), LSE (UK), KNAW (NL), UL (SLO), SOTON (UK), CU (UK), AIT (AUS)
Workpackage number:	13
Workpackage title:	Dissemination and Co-operation –Workshop and Conference organisation, Publications
Lead partner:	NKUA - ULANC
Dissemination level:	PU
Date created:	Sept 1, 2013
Updated:	Jan 17, 2014
Version:	Final
Total number of Pages:	116
Document status:	Final

TABLE OF CONTENTS

1 Executive Summary

This is a preliminary draft of the Internet Science Roadmap (Deliverable DS3.2.2 Internet Science – Going Forward: Internet Science Roadmap (M36)), containing initial input from the EINS partners on Challenges and Issues that have emerged due to the wide proliferation of the Internet through all facets of society.

This version is not intended to be a comprehensive report, but rather it is a record of the Network's starting point of its work toward the Internet Science Roadmap (M36). This report will be used by EINS partners in order to facilitate the upcoming extensive deliberations during Y-3, leading to the final report that will be addressed to the entire community (inside and outside EINS). To serve this goal, the report intentionally leaves the footprint of our process of opinion collection from the Network partners, as explained below.

The report contains initial and as yet non-deliberated input expressing the initial views of EINS partners. As such, it has not been refined, unified or otherwise processed, in order not to be biased by the editors' views. We did not want to lose any intriguing and possibly provocative elements that will be useful in the deliberations to follow in the next period. Consequently, some repetitions in the titles of the challenges or their content may be observed. Any such repetition may also prove to be useful at this preliminary stage as it can convey the relative importance of the challenge to some extent.

The material provided in the Annex is already contained in the main text. We replicate it in the Annex because it is grouped there per partner rather than per JRA (as in the main part of the report). This is important in facilitating the upcoming deliberations and revealing subtle context in the presented text; the challenge and text can be read in the context of other relevant challenges that the same partner has brought up, and knowing the expertise of the partner behind it. Also, any correlations and cross-JRA context is more easily revealed, which we feel is also extremely important. By allowing for the identification of the partner behind the listed challenges (through the-per partner grouping), EINS partners will also know whom to contact to discuss a specific listed challenge in which the partner is interested. Finally, the per-partner grouping in the Annex also gives credit to the contributors and shows the level of involvement of the partners in shaping the roadmap at this point.

Finally, this executive summary contains summarized material on the per JRA challenges, to provide quick access to the challenges for both the reviewers and the EINS partners. This material is partly repeated in the next section (the Introduction), where some more background on the broader EINS and JRA goals is also provided allowing the reader to better relate the listed or repeated challenges to those goals.

The initial set of challenges associated with each JRA is briefly described in Section 3 of this report. These initial challenges ***will be further deliberated, refined and augmented through actions to be planned in all EINS project meetings and workshops during 2014*** (Section 4). ***The eventual goal is to lay down a set of fundamental challenges*** that are largely new, have clearly emerged as a result of the Internet's nature and its immense penetration to almost all aspects and functions of the society, that have not been challenges to any of the relevant classical sciences, and whose successful resolution will further enhance the Internet (as well as our fundamental knowledge) and open up new opportunities for economic growth and quality of life.

Some of the main initial challenges that have been identified are outlined below. It should be noted that most of them stretch across multiple JRAs.

JRA1-Towards a Theory of Internet Science

This JRA aims to define a multidisciplinary research foundation to develop a theory of Internet that joins human behaviour related sciences (sociology, anthropology, economics, etc.), ICT-based tools such as computer systems and network protocols and 'hard' sciences (e.g. mathematics, physics and biology), to understand the evolution and the behaviour of networks. Initial questions / challenges include:

- Crowdsourced Provisioning of Internet Connectivity and Integration of a network of data sources
- User Engagement and Incentives in Crowdsourcing
- Understanding the complex network of human social relationships for the design of Future Internet services
- Integration of network knowledge/analytics into existing Internet routing infrastructure
- Collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers
- Node centrality heuristics and associated vulnerability of Internet graphs.
- Human behaviour in ICT-mediated communications
- Information theory, spectra theory and structural characteristics for large-scale networks
- Collaborative research methodologies for quantitative and qualitative Internet Science
- Nature-inspired networking

JRA2 - Emergence Theories and Design Methodologies

JRA2 focuses on gathering, analysing and delivering design methods and methodologies that address the emergence of Internet-scale communication from multiple disciplinary perspectives. Initial questions / challenges include:

- How to evaluate a telecom network's business model in a quantitative way?
- Tackling 'wicked' design problems

JRA3 Evidence and Experimentation

This JRA focuses on infrastructures to foster studies and experiments for Internet Science. Essentially, this is at the crossroads of what is a common practice in various fields (computer science, physics, sociology, anthropology, communication studies, and economics). The core activities of JRA3 are related to identifying, assessing and providing methodologies, datasets and tools for Internet Science research focuses on gathering, analysing and delivering design methods and methodologies that address the emergence. Initial questions / challenges include:

- Enable Internet Scale
- Collecting and analyzing large-scale datasets about human social behavior in the cyber and physical worlds
- Evidence and Experimentation Base

JRA4 Governance, Regulation and Standards

This JRA examines the regulation, governance and standard-setting of the Internet, measured against social and humanities standards (with input from the technical community). The methodology develops multi-disciplinary approaches based on advanced social scientific methodology. Its specific aim is to expose the regulatory and governance mechanisms that have enabled the development of Internet standards, and to draw lessons from social scientific analysis in order to ensure the continued relevance of the standards process as the Internet becomes a multilingual mass-market artefact. Initial questions / challenges include:

- Regulating Code – Governance and Internet Science
- The right to the hybrid city
- Corporate governance and standards setting
- Trust and governance after Snowden

JRA5 Internet Privacy and Identity, Trust and Reputation Mechanisms

Aiming to become a reference point for the coordination of studies in legislation and technology addressing privacy, identity, online trust and reputation, JRA5 draws together and further develop research on distributed social networks, partial identities, privacy-protective sensor networks, privacy beliefs and behaviours, online trust and reputation mechanisms. It seeks to integrate research efforts, scientific concepts and methodologies from computer science, psychology, anthropology, sociology, political science, statistics, graph theory, behavioural economics and law, and will investigate trade-offs between anonymity and accountability, and how decentralized privacy-enhanced systems can protect against spam, offensive content and criminal activities, while at the same time creating reliable and trusted mechanisms for online interaction based on reputation systems. Initial questions / challenges include:

- Balance the power between data owners and giants (e.g. Google, Facebook, etc.)
- Big Data Privacy Markets
- How do we measure users' everyday practices related to privacy with regard to third party use of personal information?
- Secure Server Identities in the Web - Secure User Identities on the Internet
- Trust in social recommendation
- Privacy in the Cloud
- Private information and privacy concerns in online collaborative applications
- Building a Science of Internet Privacy

JRA6 Virtual Communities

The objective of this JRA aims at developing the social design methodologies that underline development and experimentation within virtual communities. These methodologies take into explicit account socio-economic, security, privacy concerns. This workpackage also considers the developments of the initiative on Platforms for Collective Awareness and Action which is being launched by the European Commission. Initial questions / challenges include:

- Characterising the structure of social networks formed by humans in virtual environments
- What platform for what kind of e-participation? Is e-participation really perceived as new channel for participation?
- Towards ad-hoc virtual communities
- Measuring Virtual Communities' Interaction as a 'Living Lab'

- Socio-psychological incentives for cooperation in online collaborative applications
- Private information and privacy concerns in online collaborative applications
- Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers
- Non- excluding, open and sustainable collaborative applications managing common/public goods
- Human behaviour in ICT-mediated communications
- Using community practice to imagine internet alternatives

JRA7 Internet as a Critical Infrastructure; Security, Resilience and Dependability Aspects

The Internet and data communication networks in general, serve increasingly critical applications, ranging from financial transactions and business operations to support of specialized security operations, earlier undertaken by mission-specific networks. As a consequence, the impact of all types of failures in their operation, whether due to human mistakes or software/hardware faults, as well as political decisions and increasingly intelligent and orchestrated, malicious attacks can be dramatic for economies and societies as a whole. The experience and practices from the network survivability and service dependability communities need to evolve to address novel and highly complex types of attacks as well as the extra difficulties related to the increasing expansion of Internet into wireless settings. Initial questions / challenges include:

- From Internet of Things to Internet of Data, Information, and Control
- Understanding the relationship between redundancy and resilience in networks
- Internet as Critical Infrastructure: socio-technical issues
- Cybersecurity risk and protective social objects
- Node centrality heuristics and associated vulnerability of Internet graphs
- Security and Risk Management for Smart Grids
- Cloud Computing for high-assurance applications
- Efficiently securing large-scale service-oriented architectures in the e-Government domain

JRA8 Internet for Sustainability

This JRA addresses the investigation, from a multi-disciplinary angle, of how the Future Internet could help to relieve the main problems affecting sustainability at planetary scale, including Greenhouse gas (GHG) emissions, energy production, sustainable lifestyles, and the related problem of climate change. On one hand, the Internet is worldwide responsible for a considerable and quickly increasing energy footprint on its own. On the other hand, new ICT and Internet solutions can also lead to many energy-saving potential in many other sectors of society (so-called ‘ICT for Green’). Initial questions / challenges include:

- Prosumers’ cooperation in Smart Grid
- Water Awareness Campaign
- Enable sustainable living
- Incentives, gamification and participatory sensing
- Smart Grids and the Internet of Energy
- Energy Consumption awareness @ Home
- From Internet of Things to Internet of Data, Information, and Control
- How can we create a sustainable Future Internet?
- Behavioural demand response
- Using storage systems to firm solar power
- Pervasive computation, sensing and control for energy efficiency and carbon footprint reduction

Cross-JRA Aspects

It is evident that several of the challenges do not fall within a single JRA activity and span thematically, and naturally, over a number of those areas. In fact, it is this blending of the more traditional areas that the Internet has facilitated, generating new challenges that shape a potentially distinct and new (multi-disciplinary) scientific domain. It is expected that a large number of the challenges to be identified in the final report on the Roadmap will be across several of the JRAs.

2 Introduction

The overall goal of EINS is to coordinate and integrate European research aimed at achieving a *deeper multidisciplinary understanding of the development of the Internet as a societal and technological artefact*, whose evolution is increasingly intertwined with that of human societies. Its main objective is to allow an open and productive dialogue between all the disciplines which study Internet systems from a variety of technological or humanistic perspectives, and which in turn are being transformed by the continuous advances in Internet functionalities and applications.

EINS brings together research institutions focusing on network engineering, computation, complexity, security, trust, mathematics, physics, sociology, game theory, economics, political sciences, humanities, law, energy, transport, artistic expression, and any other relevant social and life sciences. This multidisciplinary bridging of the different disciplines may also be seen as the starting point for a *new Internet Science, the theoretical and empirical foundation for a holistic understanding of the complex techno-social interactions related to the Internet*. It is intended to inform the future technological, social, political choices concerning Internet technologies, infrastructures and policies made by various public and private stakeholders, for example for the possible future consequences of architectural choices on social, economic, environmental or political aspects, and ultimately on quality of life at large.

A number of individual disciplines are contributing toward this goal. These disciplines themselves can of course benefit from a more holistic understanding of the Internet principles and in particular of the "network effect". These multi- and inter-disciplinary investigations are expected to improve the design of elements of Future Internet, enhance the understanding of its evolving and emerging implications at societal level, and possibly identify universal principles for understanding the Internet-based world that will be fed back to the participating disciplines. More specifically, EINS has committed to pursuing the following broad activities:

a) Coordinate the investigation, from a multi-disciplinary perspective, of specific topics at the intersection between humanistic and technological sciences, such as privacy & identity, reputation, virtual communities, security & resilience, and network neutrality

b) Lay the foundations for an Internet Science, based on (i.a.) Network Science and Web Science, aiming at understanding the impact of the "network effect" on human societies and organisations, and also for technological, economic, social, and environmental aspects.

c) Provide concrete incentives for academic institutions and individual researchers to conduct studies across multiple disciplines, in the form of online journals, conferences, workshops, PhD courses, schools, contests, and open calls.

The Roadmap to Internet Science is a forward-reaching initiative in line with activity b), aiming at capitalizing on the initial understanding of the challenges and opportunities that the wide Internet's proliferation has created. The first two years of JRA meetings, workshops, partner exchanges and exposure to diverse perspectives across multiple disciplines has helped in developing some of this understanding that will be further deepened and deliberated during the next period.

In preparing this preliminary draft of the Internet Science Roadmap, each EINS partner was asked to contribute – in the light of their experiences both within this Network of Excellence and otherwise – their opinions on the main challenges we face in developing the Future Internet for the benefit of society as a whole. Inevitably, these opinions are influenced by the wide variety of backgrounds of the partners. This, of course, is a good thing: the more diversity of opinions, the more value we may place on the outcome of this study.

The initial challenges related to each activity that are presented in this report will be further deliberated, refined and augmented. The goal is to end up with a set of *fundamental challenges* that are largely new, have clearly emerged as a result of Internet's nature and its immense penetration to almost all aspects and functions of the society, have not been challenges to any of the relevant classical sciences, and whose successful resolution will further enhance the Internet (as well as our fundamental knowledge) and open up new opportunities for economic growth and quality of life.

Some of the main initial challenges identified are listed below. It should be noted that most of them stretch across multiple JRAs.

JRA1-Towards a Theory of Internet Science

This JRA aims to define a multidisciplinary research foundation to develop a theory of Internet that joins human behaviour related sciences (sociology, anthropology, economics, etc.), ICT-based tools such as computer systems and network protocols and 'hard' sciences (e.g. mathematics, physics and biology), to understand the evolution and the behaviour of networks. Specific focus of this activity is on: (a) an economics' theory for information networks; (b) Understanding the structure and the evolution of communication network topologies; (c) fundamental basis of large-scale autonomous and dynamic information networks; and (d) Collective network intelligence. Initial questions / challenges include:

- Crowdsourced Provisioning of Internet Connectivity
- User Engagement and Incentives in Crowdsourcing

- Understanding the complex network of human social relationships for the design of Future Internet services
- Integration of network knowledge/analytics into existing Internet routing infrastructure
- Integrating a network of data sources
- Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers
- Node centrality heuristics and associated vulnerability of Internet graphs.
- Human behaviour in ICT-mediated communications
- The right to the hybrid city
- Information theory for large-scale networks
- Structural characteristics of large-scale networks
- Spectra of large graphs
- Collaborative research methodologies for quantitative and qualitative Internet Science
- Nature-inspired networking
- Understanding the relationship between Internet Science and other interdisciplinary areas

JRA2 - Emergence Theories and Design Methodologies

JRA2 focuses on gathering, analysing and delivering design methods and methodologies that address the emergence of Internet-scale communication from multiple disciplinary perspectives. Thus far, such phenomena have been emergent rather than intentionally designed. Bringing together resources from a breadth of disciplines such as information theory, network economics, HCI and sociology better positions us to study and understand this area in order to design for emergence, rather than respond to it. It is important to note that JRA2 distinguishes between ‘methods’, specific approaches to achieve a certain goal, and ‘methodologies’, in which multiple methods are brought together for use in sequence or in some other interconnected way. Specific focus of this activity is on: (a) distilling design methodologies; (b) developing a set of design tools; (c) exemplifying use of design tools; (d) recommendations to standards bodies and funding agencies. Initial questions / challenges include:

- How to evaluate a telecom network’s business model in a quantitative way?
- Tackling ‘wicked’ design problems

JRA3 Evidence and Experimentation

This JRA focuses on infrastructures to foster studies and experiments for Internet Science. Essentially, this is at the crossroads of what is a common practice in various fields (computer science, physics, sociology, anthropology, communication studies, and economics). The core activities of JRA3 are related to identifying, assessing and providing methodologies, datasets and tools for Internet Science research focuses on gathering, analysing and delivering design methods and methodologies that address the emergence. Specific focus of this activity is on: (a) Experimental and Empirical Methodologies and Tools; (b) Online experimental and empirical evidence base; (c) Setting-up a multidisciplinary dialogue. Initial questions / challenges include:

- Enable Internet Scale
- Collecting and analyzing large-scale datasets about human social behavior in the cyber and physical worlds
- Evidence and Experimentation Base

JRA4 Governance, Regulation and Standards

This JRA examines the regulation, governance and standard-setting of the Internet, measured against social and humanities standards (with input from the technical community). The methodology develops multi-disciplinary approaches based on advanced social scientific methodology. Its specific aim is to expose the regulatory and governance mechanisms that have enabled the development of Internet standards, and to draw lessons from social scientific analysis in order to ensure the continued relevance of the standards process as the Internet becomes a multilingual mass-market artefact. Specific focus of this activity is on: (a) overview of regulatory and governance methodologies; (b) cataloguing governance tools for standards; (c) standards body case studies; (d) map new participants in standards making from civil society, wider participation; (e) cross-mapping governance methodologies, actors and operational layers. Initial questions / challenges include:

- Regulating Code – Governance and Internet Science
- The right to the hybrid city
- Corporate governance and standards setting
- Trust and governance after Snowden

JRA5 Internet Privacy and Identity, Trust and Reputation Mechanisms

The explosion of content and data in the forms of messages, photos, videos and links in social networking sites and cloud computing servers across the Internet has raised questions about user privacy and the security of his/her data, concepts that are little understood even by experienced users. Aiming to become a reference point for the coordination of studies in legislation and technology addressing privacy, identity, online trust and reputation, JRA5 will draw together and further develop research on distributed social networks (such as Diaspora and Footlights), partial identities (PrimeLife), privacy-protective sensor networks (FRESNEL), privacy beliefs and behaviours (PVNets), online trust and reputation mechanisms. It will integrate research efforts, scientific concepts and methodologies from computer science, psychology, anthropology, sociology, political science, statistics, graph theory, behavioural economics and law, and will investigate trade-offs between anonymity and accountability, and how decentralized privacy-enhanced systems can protect against spam, offensive content and criminal activities, while at the same time creating reliable and trusted mechanisms for online interaction based on reputation systems. The basic goal of Internet Science for privacy and identity should be to find the right combination of autonomy (solving security and privacy issues a user cannot resolve) and user control, in a way that is comprehensible and likely to be accepted. These activities will draw on and feed into JRA4 (governance and regulation, particularly the EU data protection framework), JRA8 (where users must be reassured that energy-saving technology is not invading their privacy), JRA6 (allowing users to participate in virtual communities without over-exposing their personal data), JRA2 (incorporating privacy by design). Specific focus of this activity is on: (a) data protection assessment framework; (b) Analysis of privacy, reputation and trust in social networks; (c) Developing a roadmap for privacy techniques for the Internet of Things, clouds and sensor networks. Initial questions / challenges include:

- Balance the power between data owners and giants (e.g. Google, Facebook, etc.)
- Big Data Privacy Markets
- How do we measure users' everyday practices related to privacy with regard to third party use of personal information?
- Secure Server Identities in the Web
- Secure User Identities on the Internet
- Trust in social recommendation
- Privacy in the Cloud
- Private information and privacy concerns in online collaborative applications
- Building a Science of Internet Privacy

- Privacy, trust and reputation management

JRA6 Virtual Communities

The objective of this JRA aims at developing the social design methodologies that underline development and experimentation within virtual communities – including user needs analysis and the impact on technological design choices affecting future Internets. These methodologies take into explicit account socio-economic, security, privacy concerns. More specifically, this JRA brings together the various communities involved in the design of virtual communities both within this NoE (JRAs 5, 1-3) and within the wider scientific and stakeholder community. It will also develop a set of tools that can be used to answer a variety of design questions, such as regarding the economic and overall societal impact of solutions, directly leading to a measure of desirability as well as viability of given design choices. Finally, it will conduct a series of representative use cases that allow for demonstrating the various approaches of the involved communities as well as benchmarking the developed set of tools. This workpackage will also consider the developments of the initiative on Platforms for Collective Awareness and Action which is being launched by the European Commission (http://ec.europa.eu/information_society/activities/collectiveawareness/events/index_en.htm). Specific focus of this activity is on: (a) Overview of user needs analysis; (b) Mutual impact between virtual Internet communities and human social communities; (c) Exploring virtual community e-democracy; (d) Consensus building and e-voting in virtual communities; (e) Dissemination and collection of user cases catalogue. Initial questions / challenges include:

- Characterising the structure of social networks formed by humans in virtual environments
- What platform for what kind of e-participation?
- Is e-participation really perceived as new channel for participation?
- Towards ad-hoc virtual communities
- Measuring Virtual Communities' Interaction as a 'Living Lab'
- Socio-psychological incentives for cooperation in online collaborative applications
- Private information and privacy concerns in online collaborative applications
- Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers
- Non- excluding, open and sustainable collaborative applications managing common/public goods
- Human behaviour in ICT-mediated communications
- Using community practice to imagine internet alternatives

JRA7 Internet as a Critical Infrastructure; Security, Resilience and Dependability

The Internet and data communication networks in general, serve increasingly critical applications, ranging from financial transactions and business operations to support of specialized security operations, earlier undertaken by mission-specific networks. As a consequence, the impact of all types of failures in their operation, whether due to human mistakes or software/hardware faults, as well as political decisions and increasingly intelligent and orchestrated, malicious attacks can be dramatic for economies and societies as a whole. A more systematic approach to the criticality of Internet infrastructure calls for and can benefit from expertise in different sectors, which we want to bring together to evaluate existing solutions and discuss further cross-sector research directions. The experience and practices from the network survivability and service dependability communities need to evolve to address novel and highly complex types of attacks as well as the extra difficulties related to the increasing expansion of Internet into wireless settings. Moreover, specialized technologies such as virtualization or ad-hoc networking could prove valuable as long as the security concerns they raise are answered. It is therefore important to analyze security requirements and security capabilities of the contributing resources to enable their use. The cyber stress tests, which have recently been carried out in Europe and USA clearly demonstrate the significance attributed to the security of the infrastructure and the concerns of various stakeholders about it, including governments and international governance institutions. On the other hand, for network operators and service providers any resilience and/or security measures have to be assessed with techno-economical studies and resolve efficiently the benefit-cost trade-off ('resilience economics'). Risk and resilience should also be studied at a broader socio-technical level: jointly investigating how threat arises, and how resilience is conferred, by the combination of social actors using and operating the Internet with the technological structure of the Internet itself. On a relevant note, and as the 'network infrastructure' term expands to more user-oriented and -driven networking paradigms, one should also study more systematically properties of human psychology that may result in manifestation of (anti)social behaviour and threaten the network functionality. Specific focus of this activity is on: (a) resilient and robust services; (b) planning and evaluation of critical resources; (c) impact of social behaviour; (d) dependability and perception of threats; (e) impact of intentional behaviour; (f) critical infrastructures in future Internets. Initial questions / challenges include:

- From Internet of Things to Internet of Data, Information, and Control
- Understanding the relationship between redundancy and resilience in networks
- Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers
- Non- excluding, open and sustainable collaborative applications managing common/public goods

- Internet as Critical Infrastructure: socio-technical issues
- Cybersecurity risk and protective social objects
- Node centrality heuristics and associated vulnerability of Internet graphs
- Security and Risk Management for Smart Grids
- Cloud Computing for high-assurance applications
- Efficiently securing large-scale service-oriented architectures in the e-Government domain

JRA8 Internet for Sustainability

This JRA addresses the investigation, from a multi-disciplinary angle, of how the Future Internet could help to relieve the main problems affecting sustainability at planetary scale, including Greenhouse gas (GHG) emissions, energy production, sustainable lifestyles, and the related problem of climate change. Based on the vast research efforts to model and estimate the climate change, managed by the Intergovernmental Panel on Climate Change (IPCC), it has become clear that GHG emissions need to be drastically diminished during the coming decades to avoid a climate change catastrophe. The public and societal interest is incontestable, and many initiatives and ambitious goals are arising, such as the European 20-20-20 objective: 20% increase of energy efficiency, 20% increase of renewable energy sources and 20% reduction of CO2 emissions by 2020. This emergency obviously also has fuelled research activities in various domains of society, trying to design new alternatives to reduce the GHG emissions. One of these sectors is Information and Communication Technology (ICT), including the network itself and a wide variety of network terminal devices such as desktop and laptop PCs, servers in data centres, TV screens, etc.

On one hand, the Internet (including the network itself and the network terminal devices) is worldwide responsible for a considerable and quickly increasing energy footprint on its own. A thorough and objective investigation in 2007 estimated that the complete life cycle of ICT equipment is responsible for about 4% of the worldwide primary energy consumption. This percentage is expected to double within a decade, if current Internet energy trends are not drastically deviated. Due to these forecasts, research activities on ICT and Internet energy reduction (so-called research on 'Green ICT') are steeply rising in the community.

On the other hand, new ICT and Internet solutions can also lead to many energy-saving potential in many other sectors of society (so-called 'ICT for Green'). Several key fields have been identified, for instance:

- Tele-'act' through high quality network: tele-working, video-conferencing, e-learning, e-shopping, e-newspaper, paperless office, etc.

- Improve energy consumption in buildings: reduce heating and lighting through intelligent building concept, e.g. based on sensors
- ICT to increase power grid efficiency: intelligent metering, adjusting demand vs. offer, taking into account renewable energy resources (smart grids & green energy)
- Improve transport efficiency: more efficient logistic processes, Internet-based solutions to improve access to green transport modes

This JRA will take stock of existing activities in the field of ICT and sustainability, promote coordination and stimulate synergies between them, and complement them with research in specific areas which are seen as key for influencing the definition of future Internet specifications at architectural, technological and infrastructural levels. Specific focus of this activity is on: (a) assessment and reduction strategies for ICT energy consumption; (b) Investigating 'ICT for Sustainability" tracks; (c) How to influence the user behaviour; (d) how to be influenced by the user behaviour: potential versus realistic benefit from 'ICT for Green' solutions. Initial questions / challenges include:

- Prosumers' cooperation in Smart Grid
- Water Awareness Campaign
- Enable sustainable living
- Incentives, gamification and participatory sensing
- Smart Grids and the Internet of Energy
- Energy Consumption awareness @ Home
- From Internet of Things to Internet of Data, Information, and Control
- How can we create a sustainable Future Internet?
- Behavioural demand response
- Using Storage Systems to Firm Solar Power
- Pervasive computation, sensing and control for energy efficiency and carbon footprint reduction

Cross-JRA Aspects

As is evident from the brief description of the preliminary challenges presented in Section 3, several of the challenges do not fall within a single JRA activity and span thematically, and naturally, over a number of those areas. In fact, it is this blending of the more traditional areas that the Internet has facilitated, generating new challenges that shape a potentially distinct and new (multi-disciplinary) scientific domain. It is expected that a large number of the challenges to be identified in the final report on the Roadmap will be across several of the JRAs.

3 Challenges

JRA1 Challenges

JRA1: Crowdsourced Provisioning of Internet Connectivity

Today we are witnessing two important socio-technological advances that herald the advent of a new era in communication networks: first, the ever increasing needs of users for ubiquitous and high-speed Internet connectivity which, in turn, has created an unprecedented volume of mobile data traffic; second, the technological advances that have resulted in sophisticated, yet low-cost, user-owned equipment such as small base stations (e.g., femtocells and WiFi access points), and smartphones with enhanced-capabilities. These devices not only satisfy the communication needs of their owners, but can also be used to offer communication services to other users. In a way, each user may act as a local *micro-operator*, e.g., operating as a mobile hotspot or offloading cellular traffic, These *user-provided connectivity* (UPC) services have substantial benefits both for the users (e.g., low energy consumption, improved quality of service, etc), and for the network operators (e.g., energy cost savings), and constitute a promising solution for addressing this traffic increase for the future Internet. Nevertheless, the successful implementation and adoption of such models presumes the design of proper pricing mechanisms that will allow the users-providers and users-clients to agree on the charged schemes/prices for serving each other. Clearly, the conventional pricing schemes employed by network operators are not suitable for these services. More interestingly, in many cases these services are network-assisted and as such, the operators should also be involved in determining the pricing of the services. Designing novel pricing schemes for crowdsourced Internet connectivity services will play a key role on the adoption of this new model which, in a way, *outsources the network functionalities* to the users, and brings performance and economic benefits to users and networks.

JRA1: User Engagement and Incentives in Crowdsourcing

Crowd sensing through mobile user devices, also known as Mobile Crowd Sensing (MCS), is an emerging paradigm for creating collective intelligence through end-user information contribution. More often than not, these contributions consist of measurement data, which are processed and refined, and offered accordingly as a service to interested users. The value of a crowd sensing service depends on the number of users contributing to this service through data they own, for which they have a cost for collecting it. It is therefore imperative for such a system to maintain end-user engagement. That is, the end-users should be given the appropriate motives so as to be part of the system and contribute their data to it. The theoretical foundations of such motives, also referred to as incentives, have been around in the economics literature for several years. However, their applicability in crowd sensing is still lagging primarily due to the existing gap between economics and engineering disciplines. It is therefore imperative to bring engineers and economists together so as to design and implement such incentive mechanisms for MCS platforms, by addressing the following questions (i) why should users share or exchange such information that is costly to them but important to others, (ii) what are the appropriate incentives to be employed and, (iii) how to realize a system that can encompass large growth in scale and user population, and make it sustainable by lowering costs and generating rewards for all involved players. The answers to these questions will largely determine the successful adoption and proliferation of such platforms for the future Internet.

JRA1: Understanding the complex network of human social relationships for the design of Future Internet services

In the perspective of such an integrated cyber-physical world, a key aspect to design efficient Future Internet solutions is the understanding of the properties of human social relationships. In a broad range of cases, devices in the cyber world are actually proxies of their users in the physical world, which follow them in their daily routines and behaviour (e.g., smartphones constantly carried by users). Therefore, the structures and properties of human social relationships can be naturally translated into relationships between the users' devices, around which networking solutions can be designed. Social Pervasive Networks are a possible longer-term evolution of the pervasive networking paradigm enabled by the tight integration of the cyber and physical worlds. Assuming that the diffusion of pervasive technologies will enable, in principle, communication between any two users anytime and anywhere, the resulting network might in fact be formed by edges that correspond to communication channels activated because of a social relationship between two users, and only when those users communicate due to their social relationship. In other words, the network and the communication events between the devices might closely map the corresponding human social network and the interaction patterns of the users. In this perspective, a key challenge is how to represent the complex networks describing social interactions between users, on which Future Internet services can be based. While descriptions and models of some of these networks exist in the literature, scalable models to generate synthetic networks of this kind are missing. This is a very important research topic, because having models to generate these kinds of networks is an enabler to correctly assess the performance of Future Internet services deployed on top of them. This topic is highly interdisciplinary. It is fundamental to have a clear understanding of the properties of human social networks, in order to embed them in these models. In addition, it is very challenging to guarantee that generated synthetic networks can scale up to the size of at least tens of thousands of nodes, without breaking key properties that fundamentally characterize human social networks. With respect to conventional models to generate synthetic networks using complex networking theories, the key novel aspect is to embed knowledge about the different types of social relationships behind a link that connects two nodes.

JRA1: Integration of network knowledge/analytics into existing Internet routing infrastructure

The Internet routing infrastructure suffers from design choices which have been made decades ago. Sequences of patches and extensions have been proposed to routing or signaling protocols in order to cope with required additional functionality, changed usage contexts, or to improve performance. Whereas these have solved immediate issues, in many cases they have introduced others. As a result, the routing system is more complex to operate and still lacks essential functionality such as enforcing routing profiles based on time patterns (e.g., day vs. night routing). While initiatives such as IETF I2RS are planning a first step to tackle these, an even more interesting set of patterns, such as network congestion patterns, traffic demand patterns or network attacks, would be equally or more valuable to integrate into them the routing system.

It remains an open challenge on how to improve the flexibility of existing routing systems. Although, elements seem to be available: i) radical, clean-slate (machine) learning-drive routing systems (e.g., AntNET, Cognitive Packet Networks), ii) capabilities to learn network patterns (e.g., anomaly detection systems), up to now, none of these methods are really integrated in current operational networks of ISPs. However, the ever-increasing network demands in terms of QoS, power consumption and security, stresses for novel methods which benefit from available network research. Network pattern analytics will enable to detect complex traffic behaviors as those induced by big content players like Google or Akamai, or learning from power consumption behaviors of networking systems. The capability of automatically translating data analytics into routing configurations to improve the overall performance of the network and reduce operational costs, is strongly missing in current routing systems.

JRA1: Integrating a network of data sources

With the exponential growth of the Internet, more and more online services enable users to upload and share structured data, including Google Fusion Tables[1,] Freebase[2], and Factual[3]. These services primarily offer easy visualization of uploaded data as well as tools to embed the visualization to blogs or Web pages. As the number of publicly available datasets grows rapidly and fragmentation of data in different sources is a common phenomenon, it is essential to create the inter-links between them. An example is the often quoted coffee consumption data found in Google Fusion Tables, which is distributed among different tables that represent a specific region. Extraction of information over all regions requires means to query and aggregate across multiple tables, thereby raising the challenge of

1 tables.googlelabs.com

2 freebase.com

3 factual.com

integrating a network of data sources, namely crowdsourced data integration. The goal of crowdsourcing data integration is establishing inter-connections between the data from multiple sources to achieve a unified view.

The tradition approach is defining a common standard and matching each data source against this standard. However, this approach is irrelevant for crowdsourced data integration because of two main reasons. The first reason is about heterogeneity. Since crowdsourced data are collected from a wide variety of sources, they have different formats and quality. Therefore, defining a common standard becomes an extremely difficult task. The second reason is about big data phenomenon. The common standard needs to be updated when a new data source is integrated. This is impractical since the data arrive frequently. Therefore, we model crowdsourced data integration as a *graph-based matching network*, in which data sources are directly matched against each other without going through a common standard.

The model of graph-based matching network is built on top of graph theory. We leverage theoretical advances in this field to deal with many challenges such as: network partitioning, network clustering, network evolution, and network evaluation. If these major obstacles are addressed effectively, users are benefited from Web-based collaboration in publishing and consuming data.

JRA1 – JRA6 – JRA7: Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers

The integration of sensing devices of various scopes and capabilities with mobile communication devices along with the wide proliferation of online social applications leverage the heterogeneity of users in terms of interests, preferences, and mobility, and enable the collection and dissemination of huge amounts of information with very different spatial and temporal context. This information can be intelligently controlled by platforms that collectively enrich people's awareness about their environment and its resources and enable new forms of participatory processes and approaches to managing them. Besides possibly generating information by themselves via the sensing devices they might be equipped with, the networked entities are also typically involved in disseminating this information widely, contributing to building collective awareness. Furthermore, these same entities may actually exploit this awareness of their environment to meet own needs or achieve certain individual objectives. That is, these entities are involved in the dissemination and consumption of the information.

If the disseminated information concerns the availability of some limited resource or service, then competition naturally emerges among entities desiring to use such resources. In such environments, it is important to understand how the presence of competition shapes decisions taken by these entities regarding (a) the way collective awareness is exploited if at all and (b) the way these entities participate in disseminating information and creating collective awareness. The first of these very general and fundamental questions amounts to deciding whether a networked entity will compete (and suffer excessive penalty if not successful) or not compete for the available resource, shaping this way the resulting congestion; key to such a decision is the available information regarding the level of available resources and competition. The second, amounts to deciding whether a networked entity will deviate from the expected behavior (misbehave) by hiding or falsifying resource/service availability information, aiming at reducing the competition to its advantage.

JRA1 - JRA7: Node centrality heuristics and associated vulnerability of Internet graphs.

Network graph characterization has received extensive attention in the past and has lately also considered real Internet graphs as revealed by experimental data. Not all network nodes are equally important in supporting network operations and for this reason a number of metrics have emerged assessing the importance or centrality of a node. In view of the fact that certain nodes are autonomic and their availability is not to be taken for granted, or that certain nodes may be attacked and become non-operational, a fundamental question is to assess the criticality of the various nodes – as inferred by the various centrality metrics available – in sustaining key network properties, such as connectivity, information carrying capacity, etc. As certain node centrality rankings are more easily detectable by an adversary than other rankings, an important question is to assess the correlations of the different rankings and ultimately assess the damage on the network if highly-ranked nodes are removed according to the various rankings.

JRA1/JRA6: Human behaviour in ICT-mediated communications

The role of technology on social life can be both positive and negative. On the one hand, it allows very efficient asynchronous information sharing and organization, the creation and maintenance of multiple overlapping networks, and a more flexible self-representation and engagement for individuals. But, on the other hand, it is exactly the same power that makes it easier to browse and filter our physical environment rendering invisible "the different others" , even if they may be standing next to us. It is indeed an irony that the increased physical mobility and accessibility to information of contemporary urbanites is complemented by an increased immobility within known habits, routines and patterns of behaviour that can easily lead to alienation. At the same time, the abstract space of modern cities does not always support social exchanges nor stimulate spatial appropriation, which may lead again to alienation.

But can we use the very same technology that may threaten our connection to the physical world and our immediate surroundings as a means to enhance the communication between strangers in the city?

Clearly, the answer cannot be definite nor generic. The outcome of different solutions will depend on the specific context and the combination of choices on numerous design details that can affect behaviour in complex and unpredictable ways. Moreover, it will be always very difficult to evaluate different outcomes since there are many conflicting objectives involved (e.g., the level of skills required for participation can improve the sophistication of the decisions but can also harm the level of representation due to various divides), dynamic processes (e.g., power relationships might appear over time), and possible unintended consequences (e.g., addiction).

What is important is to acknowledge the threat that ICTs pose on local communities and face-to-face communication and gather around the design process experts from various fields and disciplines from the computer science, and behavioural and social sciences to contribute the emerging interdisciplinary fields of urban and community informatics and support "real life experimentation" methodologies like the action research paradigm, living labs, and other co-creation models. The ultimate goal of this interdisciplinary scientific endeavour is to identify important causal relationships between design choices and outcomes in different contexts, which will allow informed choices based on local values and objectives.

JRA1/JRA4: The right to the hybrid city

Today the urban space becomes inherently *hybrid* since ICT technology acts very often as a mediator for exchanges and interactions between people in close physical proximity for short or long time periods, in public spaces or in urban neighbourhoods. The experience of this hybrid space is subject to different degrees of simultaneity and could range from synchronous interactions in which people experience the virtual and the physical in parallel, as in locative media, to asynchronous virtual and physical interactions as in the case of online neighbourhood web sites. These interactions could range from simple discussions and socialization to more sophisticated organization and resource sharing tasks (e.g., car pooling, face-to-face gatherings, alternative currencies, various types of service exchanges).

In addition, the hybrid realm may add novel types of communication between citizens and local authorities. First, it can support rich information flows from authorities to the citizens (e.g., open data), and from citizens to authorities such as in the crowdsourcing and citizen science paradigms. Second, it can provide a virtual spatial framework for e-participation and online deliberations around specific topics of interest. However, the simple existence of ICTs is not sufficient. It is the actual design of the evolving hybrid urban space that will determine whether their promises for increased civic engagement, participation, and community building will be materialized.

This means that for information and communication technologies (ICTs) to fulfil their promises for increased self-organization, civic engagement, and participation in planning, among others, the famous claim made by Henri Lefebvre for the "right to the city" (1996) needs today to be rephrased as the "right to the hybrid city". The original concept of the right to the city includes four different rights: 1) Access (digital divide), 2) Identity (freedom of expression, customisation), 3) Participation in design (decision-making, objectives), 4) Ownership (privacy, surveillance, control). It is easy to see that

Facebook and other commercial social networking platforms fail to provide all these four basic rights whose importance increases significantly, for example, when they are to be used for planning processes as it happens today with numerous facebook groups created by municipalities to facilitate the interactions between citizens and local authorities.

The ownership of an ICT framework could range from its social software, to the storage and management of all content and information produced, all the way to the underlying network infrastructure. For example, by choosing a customizable open source framework, a local community can define itself the rules that shape the communication among the inhabitants of the produced hybrid space at the city or neighbourhood level. If additionally there is the option to deploy user-owned wireless technology as in wireless community networks, one can further ensure the de facto physical proximity, grant easy access for everyone, allow the choice of the desired level of anonymity, and compete with global corporations such as Google and Facebook for the “right to the hybrid city”.

However, the design of the hybrid urban space is a very challenging interdisciplinary problem which in addition to the high intellectual complexity, it has to deal with significant costs for producing customized solutions and a range of important trade-offs whose resolution can have significant impact on everyday life and long-term effects on behaviour and social dynamics. This calls for a bottom-up design process consistent with ideas developed in social learning and action research methodologies, for which the role of the free and open source software (FOSS) development paradigm can be instrumental as already highlighted by related research in the areas of urban and community informatics. Finally, additional support is required from regulators and institutional frameworks which can provide the necessary tools and access to scarce resources (e.g., spectrum).

Finally, we note that the notion of hybrid design (ranging from internet protocols and user interfaces to physical interventions in the city), could be seen as a key element of the "system" that we can "control" to some extent and which affects decision making at different levels and thus the evolution of the system itself. In this sense it is important to devise ways to translate design choices to expected outcomes using an "interdisciplinary" language that will allow social scientists that are experts in understanding and dealing with complex, "wicked", problems to collaborate effectively with computer scientists in the design process.

JRA1: Information theory for large-scale networks

The size of the Internet requires us to develop a mathematical theory that can handle the “transfinite” dimensions of the Internet’s probability space.

JRA1: Structural characteristics of large-scale networks

When dealing with infinities or exceedingly large systems such as the Internet, mathematics can often be the only analytical approach that can yield useful results and new insights. More should be invested in developing an algebraic theory of large-scale networks.

JRA1: Spectra of large graphs

A graph can be represented as an NxN adjacency matrix, where N refers to the number of nodes and an element a_{ij} in the matrix is 1 if there is a link between nodes i and j, and 0 otherwise. One interesting corner stone in linear algebra is the spectral decomposition of a matrix, which enables us to write a matrix in terms of its eigenvectors and eigenvalues. The eigenstructure or spectrum, the ensemble of all eigenvectors with their corresponding eigenvalues, reflects the characteristic underlying properties of the matrix.

The theory of graph spectra refers to the application of spectral theory to matrices associated with graphs. Just as with Fourier or Laplace transforms, some network or graph problems are more easily and/or efficiently solved in the topology domain than in the spectral domain, and vice versa.

In the following, we list several challenges (or shortcomings) of spectral graph theory:

1. *Meaning*. What is the meaning of an eigenvalue and of the eigenvectors? The interpretation and "physical" meaning of the eigenstructure is a fundamental, open question in network science.
2. *Theory*. While most results concern the extreme eigenvalues (largest/smallest and second largest/smallest), little is known about the other individual eigenvalues, except for special graph types whose spectrum can be computed analytically.
3. *Directed graphs*. Most complex networks are directed, resulting in an asymmetric adjacency matrix. The power of spectral graph theory lies in symmetric matrices, whose spectrum is real. In general, the spectrum of a directed graph is complex. Moreover, some asymmetric matrices even cannot be diagonalized. These complications may question whether spectral graph theory is still the correct tool to extract network information or for which cases it is the correct tool.
4. *Weighted graphs*. Links and nodes are generally different and must be weighted differently. Given that the weights (delay, capacity, load, financial cost, …) on network links are known, spectral graph theory is, in most cases, valid, provided symmetry is not destroyed. The more challenging aspect is determining or measuring the weights of links in large graphs.
5. *Large graphs*. Most complex networks contain many nodes. Assuming that a complete description of the network is available, the computation of the spectrum is a challenge for numerical analysis.

JRA1: Collaborative research methodologies for quantitative and qualitative Internet Science

The situation today is that most Internet scientists from a qualitative research background do not understand the research methods used by scientists with a quantitative background. Most quantitative scientists don't even understand what the fuss is about, because they have difficulty imagining how one could conduct research without using quantitative methods. The few scientists who are familiar with both perspectives have a difficult time integrating them in their daily work. The Internet motivates us to do better at working together and communicating across this epistemological chasm, but this will take a lot of hard work and is definitely a major challenge.

JRA1 and JRA5: Do we need Internet Science as a new field?

Do we need Internet Science as a new field? What is the progress in the network so far?

Although the Internet as object of study penetrates all area of the sciences, the consortium's perspective – determined by the disciplinary background of most of the partners – is mainly computer science. We think it would serve us best to also be honest and state that while the big ambition of the project has a function of mobilization, it is a long way to go – and science-dynamics wise building a new community or theory is probably not what can be expected.

What has been archived is a raised awareness of communities, which have not been in touch so far. This was visible in the EINS conference. It is also an achievement to make a bridge from the science taking care of the back-bone of the Internet architecture to the regulations around its use which is much more a domain of expertise for social sciences, law and political sciences as well as economics. The work on privacy we have been involved in delivered interesting results. The same holds for work on more general reports.

But the questions below still breathe the grand ambition of the start, and it is uncertain whether we do ourselves a favor with this. We might maneuver ourselves in a situation we are bound to fail. Because, there will not be "one" or "an" Internet Science, but there might be a curricular with this label for engineering raising awareness to societal issues; and there might be a curricular in the social sciences/law/political science etc. raising awareness for the technical boundary box of operation, and if we would achieve this, this would be already great.

JRA1: Nature-inspired networking

A network consists of a topology specifying the nodes and their inter-connections (links) and a function for which it is designed, e.g. power transport. From a network design point of view one could ask the following research questions:

1. How should the power grid/Internet evolve in a self-adaptive way in order to maintain robustness against electrical blackout/malware?

2. How can individuals adapt their social contacts to prevent a wide spread of epidemics?

Nature-inspired networking, i.e. "how to design robust man-made networks inspired by nature", provides a promising direction for the following reasons:

- Man-made networks like the Internet and power grid have become complex and large in size. Although distributed solutions have been incorporated in e.g. traffic control, these infrastructures are often inflexible or centralized. Fully distributed design has been limited due to the lack of a deep understanding of a complex system with an amazingly large number of interacting components.
- Nature with its superior self-adaptivity and robustness enhances the design of man-made networks. In the brain, for example, the co-evolution where a synchronization process alters the neural connections is crucial for normal development, learning and repair of damage. Topological properties like small-world, scale-free degree distribution are widely observed in real-world networks and brain networks of various organisms. The brain's robust co-evolution and its similarities with other complex networks in topological properties is a motivation to explore how brain-inspired network co-evolution may lead to desirable network properties.
- With the development of measuring techniques and correspondingly the availability of big data, we could better understand how nature works.

The field of nature-inspired networking would benefit from a multidisciplinary approach combining network science, mathematics, and statistical physics, and could proof useful in diverse application domains ranging from communications networks, biological systems, social networks to economic systems. One key challenge is to determine the right abstraction level of viewing complex systems to find coherent and universal dynamic processes, which allow the knowledge transfer across systems.

JRA1: Understanding the relationship between Internet Science and other interdisciplinary areas

Understanding how Internet Science relates to areas such as Web Science or Network Science can help identify common research roadmaps where appropriate, build networks with additional research communities and share relevant research infrastructures. A major challenge will be to efficiently facilitate this dialogue on a semi-permanent basis (e.g. by organizing joint workshops or participating in relevant conferences) and, at the same time, to identify exactly how research infrastructures can be shared or co-developed as part of a collaboration roadmap with tangible outcomes.

JRA2 Challenges

JRA2: How to evaluate a telecom network's business model in a quantitative way?

This research challenge aims at developing a suitable methodology for quantitative evaluation of a telecom network or ICT service business model. The question to be answered is: is the network of service, which is technically feasible also economically viable? In the liberalized, fast evolving Internet market business models have become more difficult to grasp. Related business cases have become very difficult to estimate quantitatively. Considering the ever-increasing importance of the Internet market, both the relevance and the complexity is expected to grow even further.

The methodology to be developed will need to combine different disciplines: technology, economics and customer adoption. This includes estimation of costs and revenues based on either a top-down or a bottom-up approach. The techno-economic evaluation starts from an investment analysis study for all actors (based on estimated adoption and costs). Essential part of the new to be developed methodology is the multi-actor setting, where the actors have potentially different objectives. The Internet forms a very specific multi-actor setting, where technological as well as economic reasons lead to the existence of different platforms and where ownership is spread amongst public and private players, in a lot of cases subject to regulation or definitely strong policy impact.

JRA2: Tackling 'wicked' design problems online

'Wicked' problems were first discussed long before the emergence of the internet [1]. Such 'wicked' problems exhibit great complexity, often involving changing, incomplete or conflicting requirements, and frequently being entangled with other big issues. Examples of such problems include global warming, the financial crisis and dealing with terrorism.

In the context of Internet Science and design, such problems include: predicting the emergent behavior of interacting socio-technical systems; user trust, awareness and management of cyber security; online communications for people with mental health issues such as dementia or aphasia; facilitating appropriate levels of empathy online. As can be seen, computational and human issues translate into the digital world very easily. Indeed, such issues can be exacerbated by certain aspects of the internet, such as the speed with which emergent behaviors can develop, the internet's worldwide nature, and its limited communication modalities compared with face-to-face interaction.

There exist some methods that attempt to respond to 'wicked' problems in general: one example is Creative Problem Solving [2]. However, to our knowledge there are no methods to deal with wicked internet design problems. Any such method must not only encompass the properties of methods to deal with general 'wicked' problems, but also account for the unique features of the internet and design online.

The development and honing of such a method represents a rich opportunity to have a strong positive impact on online interactions in many contexts. Such an effort will rely on interdisciplinary inputs, and cannot be achieved without the combination of technological knowhow, sociological inputs and design expertise.

[1] C. West Churchman, Guest Editorial, Management Science, Vol. 14, No. 4 (December 1967)

[2] H2 Solve Wicked Problems, Paul Reali, published by lulu.com (2011)

JRA3 Challenges

JRA3: Enable Internet Scale Experimentation

The enormous Internet scale and its dynamics cannot be captured by simulations or local (even regional) testbeds. Therefore, experimentation with innovative protocols or services cannot produce reliable results. There are prior efforts to this direction (e.g. PlanetLab), but they are of rather primitive size and geographical distribution to claim Internet scale w.r.t. both number of nodes, traffic and topology. A huge gap is created between academia and industry, rendering academic research a second class citizen. It is important that the Internet continues to improve based on academic contributions that are also backed up by experiments. The challenge is to build efficient emulation environments that multiplex existing federated testbed infrastructure with large-scale virtual topologies that attempt to mimic the behavior of the Internet based on prior network measurements in the Internet. Another input parameter is the human-generated traffic by Internet activities, e.g. Web searches, participation in social networks, blogging, etc. This can be achieved by interdisciplinary effort in networks, machine learning, statistics and social networks.

JRA3: Collecting and analyzing large-scale datasets about human social behavior in the cyber and physical worlds

The worldwide proliferation of online social networks (hereinafter OSN) is rapidly introducing plenty of new means to create and maintain social relationships with others. Although these new ways to communicate are becoming part of our everyday life, we don’t have yet a complete view on how they are impacting on human behaviour in the actual society, both in the physical (real) and in the cyber (virtual) worlds. Human social behaviour is commonly studied using a model for the representation of personal social networks, called ego network - i.e., a social network formed of an individual (ego) and the people with whom ego is in contact (alters). While the properties of ego networks in the real world have been deeply studied in the anthropology and sociological literature, OSN ego networks are not yet completely understood. Specifically, there is a lack of knowledge regarding the structure and the dimension of ego networks in the virtual world. In addition, the fundamental differences between the properties of OSN ego networks and the well known results about social networks formed in the real world (referred to as human ego networks) are still under investigation.

To this end, it is important to design and develop novel tools to collect large scale datasets about the social behavior of people, both in virtual environments and in physical environments. In principle, such datasets should allow researchers to link both dimensions, and study the interplay, correlations and differences between them. As a concrete example we consider designing applications for Online Social Networks (and most notably Facebook), which could allow us to download large-scale datasets about the social behavior of the users, and correlate quantitative data about this behavior with subjective evaluation of the users about the perceived strength of their social ties. In the first part of EINS we have developed a first prototype of such an application. The challenge is to extend it to scale up to large population of users, and refine it to be more attractive such that users can be motivated to contribute the logs of their Facebook interactions through some reward. Inter-disciplinarity is crucial to design the application, understand which data should be logged, and how to correlate information provided by the users.

JRA3: Evidence and Experimentation Base

Internet Science research is increasingly relying on the availability of datasets, mixed methods, e-Infrastructures, and analytic and visualisation tools that can efficiently support interdisciplinary collaboration. However, those resources are currently spread across different repositories and often they are not readily available for use by Internet scientists. This lack of an evidence and experimentation base that can support Internet Science is a major obstacle to studying the socio-technical evolution of the Internet and its impact, and a barrier for new entrants to join relevant research activities.

Bootstrapping the creation of this base and ensuring its growth and sustainability is a major challenge that EINS will try to address. JRA3 activities to that end involve the cataloguing of datasets, tools, e-Infrastructures and methodologies for Internet Science, and the development of schemas to efficiently describe and search for them. They also involve the development of online repositories that can host datasets that project partners or other members of the community wish to make available. In addition, they envisage the development of the community engagement mechanisms that will enable this online evidence and experimentation base to grow, to support scientists from a range of disciplines and to be sustainable.

Beyond the bootstrapping phase that will be initiated by EINS, the major challenge will be to provide for the development of scalable and sustainable infrastructures for creating and sharing datasets, analytic tools, methodologies and e-Infrastructures with the wider Internet Science community. This effort will need to involve all major stakeholders including business, government and research institutions.

JRA3 will also focus on interacting with researchers and stakeholder collecting a large set of datasets, methodologies and tools related with the two following topics: network performances, with particular attention to network neutrality issues, and data quality, with particular attention to open data quality. Apart from providing a pilot for exploring the functionalities and potential of the e-Infrastructure provided by JRA3, these two topics represent by themselves two hot topics in Internet Science research and also two relevant policy issues which could be informed by a richer evidence base.

JRA4 Challenges

JRA4: Regulating Code – Governance and Internet Science

Internet regulation is a paradigmatic challenge for traditional governance processes, due to the unprecedented speed of technological change, market adoption of disruptive technologies, fundamental political and rights challenges to existing regulated technologies, and degree of 'prosumer' and stakeholder input into regulatory and governance design. During the period of the Internet science project alone, there have been extraordinary challenges to European citizens' trust and security online (notably revealed online by Wikileaks and Glenn Greenwald's reporting of Edward Snowden's revelations), the use of the Internet for political communication (notably via Twitter which has grown about 200% in the 2 years of EINS), and the proposed European Regulations on data protection and *ConnectedContinent*. Enhanced policy adoption of the academic insights offered by a holistic Internet science approach to inform law and policy has been widely recognized. JRA4 itself, as the most publicly 'mature' of the research communities inside EINS, moved from documenting and analyzing the key issues in Internet governance-regulation in 2012 to engaging very intensely with stakeholders in 2013, and this engagement will continue to intensify in 2014.

JRA4 was 'born' as an interdisciplinary collaboration, with the book 'Regulating Code' written in Year Zero of EINS in 2011-12, and published in March 2013. It was authored by JRA4 leader, lawyer Marsden, and JRA5 leader, computer scientist Brown. An article based on the book was published in the Proceedings of the 1st Internet Science conference. Publications from the book have continued throughout 2013, for instance at the IEEE SIIT conference. Marsden chaired a session on cloud/big data at the Society for Computers and Law 7th Annual Policy Forum at Herbert Smith LLP, before an audience of City law firm partners and others, and in 2014 the 8th Forum will be chaired by Brown (JRA5) supported by Marsden (JRA4).

In order to address public policy concerns about governance of trust and regulatory approaches to assuage public concerns about their Internet usage, the collaborations between JRA4 and JRA5 have continued throughout the project, with a joint workshop in Oslo hosted by Lee Bygrave of JRA4 in

September 2012, and joint co-chairing of the Internet Science-Web Science workshop in Paris in May 2013. The 2014 SCL Policy Forum will be a further such collaboration.

Many public concerns about Internet regulation (and trust) relate to their use of virtual communities. JRA4 has also closely collaborated with JRA6, a 'natural' outcome of their shared leadership by Sussex and shared research assistant in Ben Zevenbergen since September 2012. JRA4 hosted its official workshop in Indonesia at the UN Internet Governance Forum in October 2013, and a JRA6 speaker (David-Barrett) explained how analysis of Internet governance could be conducted using quantitative and qualitative metrics based on evolutionary interdisciplinary science (notably neuroscience and evolutionary economics).

Finally, standardization provides the underpinning for enabling more trustworthy and citizen protective regulation of users' behaviours on the Internet. Note the extremely close collaboration between JRA4 and SEA2, with Alison Powell bridging the two projects. Marsden (Sussex) met with Neidemeyer (TUM) and Powell in August 2013 to plan the 'Internet Governance' month series of 16 blog posts which had over 2,000 views. Marsden (Sussex) personally authored two of the entries. Marsden also posted 22 blog entries on the Internet Science blog itself, with Zevenbergen posting a 2000-word report on the United Nations workshop: http://internet-science.eu/blogs/24-10-2013/631

The challenge of the Internet for traditional regulatory and governance processes was also raised by JRA4 partners (notably Sussex) in keynotes at key stakeholder events in 2013 such as the Council of Europe (May); European Parliament (June); 9th International Conference on Internet, Law & Politics (June); United Nations Internet Governance Forum (October); United Nations Economic Commission for Latin America (October); 8th International Conference of Information Commissioners (September); DG CONNECT Co-regulatory Agora (December). There is confirmed extremely close interest in Internet Science from government and corporate stakeholders.

2014 is the year in which D4.2 is delivered (January) and D4.3, our final deliverable (December), but will also mark an intense year of mobility visits by partners, and collaboration with other JRAs and external stakeholders. Policy actors are becoming significantly more aware of the benefits of using holistic scientific advice to address their policy concerns, in order to provide proactive rather than reactive regulation and governance strategies for Internet users.

JRA1/JRA4: The right to the hybrid city

Today the urban space becomes inherently *hybrid* since ICT technology acts very often as a mediator for exchanges and interactions between people in close physical proximity for short or long time periods, in public spaces or in urban neighbourhoods. The experience of this hybrid space is subject to different degrees of simultaneity and could range from synchronous interactions in which people experience the virtual and the physical in parallel, as in locative media, to asynchronous virtual and physical interactions as in the case of online neighbourhood web sites. These interactions could range from simple discussions and socialization to more sophisticated organization and resource sharing tasks (e.g., car pooling, face-to-face gatherings, alternative currencies, various types of service exchanges).

In addition, the hybrid realm may add novel types of communication between citizens and local authorities. First, it can support rich information flows from authorities to the citizens (e.g., open data), and from citizens to authorities such as in the crowdsourcing and citizen science paradigms. Second, it can provide a virtual spatial framework for e-participation and online deliberations around specific topics of interest. However, the simple existence of ICTs is not sufficient. It is the actual design of the evolving hybrid urban space that will determine whether their promises for increased civic engagement, participation, and community building will be materialized.

This means that for information and communication technologies (ICTs) to fulfil their promises for increased self-organization, civic engagement, and participation in planning, among others, the famous claim made by Henri Lefebvre for the "right to the city" (1996) needs today to be rephrased as the "right to the hybrid city". The original concept of the right to the city includes four different rights: 1) Access (digital divide), 2) Identity (freedom of expression, customisation), 3) Participation in design (decision-making, objectives), 4) Ownership (privacy, surveillance, control). It is easy to see that Facebook and other commercial social networking platforms fail to provide all these four basic rights whose importance increases significantly, for example, when they are to be used for planning processes as it happens today with numerous facebook groups created by municipalities to facilitate the interactions between citizens and local authorities.

The ownership of an ICT framework could range from its social software, to the storage and management of all content and information produced, all the way to the underlying network infrastructure. For example, by choosing a customizable open source framework, a local community can define itself the rules that shape the communication among the inhabitants of the produced hybrid space at the city or neighbourhood level. If additionally there is the option to deploy user-owned wireless technology as in wireless community networks, one can further ensure the de facto physical proximity, grant easy access for everyone, allow the choice of the desired level of anonymity, and compete with global corporations such as Google and Facebook for the "right to the hybrid city".

However, the design of the hybrid urban space is a very challenging interdisciplinary problem which in addition to the high intellectual complexity, it has to deal with significant costs for producing customized solutions and a range of important trade-offs whose resolution can have significant impact on everyday life and long-term effects on behaviour and social dynamics. This calls for a bottom-up design process consistent with ideas developed in social learning and action research methodologies, for which the role of the free and open source software (FOSS) development paradigm can be instrumental as already highlighted by related research in the areas of urban and community informatics. Finally, additional support is required from regulators and institutional frameworks which can provide the necessary tools and access to scarce resources (e.g., spectrum).

Finally, note that the notion of hybrid design (ranging from internet protocols and user interfaces to physical interventions in the city), could be seen as a key element of the "system" that we can "control" to some extent and which affects decision making at different levels and thus the evolution of the system itself. In this sense it is important to devise ways to translate design choices to expected outcomes using an "interdisciplinary" language that will allow social scientists that are experts in understanding and dealing with complex, "wicked" problems to collaborate effectively with computer scientists in the design process.

JRA4: Corporate governance and standards setting

The experience of the internet is now not only configured by standards set by open standards bodies such as the IETF, but also by proprietary standards and business practices (related to data privacy, for example) of individual companies. Understanding these processes and determining how best to respond is a significant challenge.

JRA4: Trust and governance after Snowden

Even more broadly than the challenge mentioned previously, now that the world knows that the internet is an effective state surveillance machine, we have serious challenges related to trust, transparency and privacy. New multi-stakeholder processes are being invented by new global players (ie the government of Brazil) and existing powers such as the US government are arguing for little change to their mass surveillance projects. Our challenge is not only to understand how a future internet could be governed but also whether that governance appears legitimate (and to whom).

JRA5 Challenges

JRA5: Balance the power between data owners and giants (e.g. Google, Facebook, etc.)

Search-engine queries, sensor data (from mobile phones or other sensing infrastructure), user-published content on the Web (e.g. in Web pages, social networks, blogs, etc.) and data collected by “free” Web or mobile-phone applications is enthusiastically collected, archived and analyzed by service providers (and intelligence agencies). “If you are not paying for it, you are the product” says Jason Fitzpatrick on Lifehacker.com. Reducing privacy-losses, necessitating user consent for data exploitation, and rewarding users for the value that their data generates to others, involves increased awareness of privacy issues, privacy loss assessment, data value estimation, privacy-related contracts, etc. Therefore, facing this challenge involves interdisciplinary research in networks, ontologies and data semantics, data security, privacy and multidisciplinary research in sociology, economics and law sciences. Otherwise, the Internet runs the risk of being transformed into a crowd/mass manipulation and exploitation platform.

JRA5: Big Data Privacy Markets

The proliferation of online social networking platforms and, in general, the increasing penetration of online services has created a digital footprint for each user, i.e., an abundance of online information. In other words, social media and social networks are sources of Big Data. This huge volume of data can reveal crucial information about the user's habits, preferences and anticipated actions. Hence, under certain conditions, mining this big data has the potential to impact the privacy of the users. At the same time, this information can be monetized since, for example, it can serve as input for advanced user-profiling (consumer) methods. In this context, privacy and information are transformed to a commodity that can be traded in markets.

Users participating in such services may have concerns about their privacy and may be willing to pay for protecting their private information. On the other hand, they may be willing to partially sacrifice their privacy, by disclosing a portion of their private information under proper compensation. Allowing each user to determine this privacy tradeoff is a key issue in the future Internet and a prerequisite for the successful deployment of personalized online services. In this context, there is need to study and design appropriate market mechanisms related to such type of information. These markets can be broadly classified to *markets for personal information* and *markets for privacy.* The former type of markets refers to the case that various companies and information-brokers aim to collect user preference information. Therefore, one needs to design pricing schemes for determining how much each user should be compensated for disclosing his information.

Nevertheless, such information markets differ substantially from other commodity markets since information items exhibit strong externalities. For example, when a user discloses a certain item of information, the value of similar information previously disclosed by other users decreases. Similarly, markets for privacy, that offer privacy-enhancing services and products, need to take into account such dependencies. These particularities call for novel auction and pricing schemes tailored to the specifics of privacy markets.

JRA5: How do we measure users' everyday practices related to privacy with regard to third party use of personal information?

Surveys have been used to map users' attitudes and increasingly also their literacy towards privacy in social media. These results remain self-proclaimed and are therefore prone to involve an overestimation of the actual skills and practices of users with regard to privacy. One of the solutions to counter this issue is to conduct experiments where actual behaviour is measured and observed.

Although these experiments are based on observed behaviour, they also remain biased because they take place in a controlled environment away from users' everyday practices.

This could be solved through a combination of logging and qualitative research where participants are followed as they interact with third parties who request their personal information as an obligatory point of passage. This approach requires the cooperation of application developers because these would have to explain what data is demanded from users, but also when application adoption drops because of too much information queries (if we want to research everyday practices). On the other hand the qualitative research will have to be coupled to these results. This requires us to find particular respondents that are using the application and have shared certain information or chose not to use the app because of its perceived invasiveness. This last category will prove most difficult to interview, but also one of the most interesting.

JRA5: Secure Server Identities in the Web

Recent years have seen many cases of attacks on the certification process. Overall, the security model that any broken certificate authority (CA) can issue certificates for any site leads to a weakest link security situation, exploitable by hackers or rogue states. A variety of proposals try to mitigate the problem, most notably certificate pinning with TACK and certificate transparency to better control misbehaviour or faults of certificate authorities. It remains unclear if the browser taking control and refusing to continue communication in case of suspicious keys and certificates will be generally accepted. A fundamental problem analysis of the overall problem would need to include analysis from multiple disciplines ranging from security to economics.

JRA5: Secure User Identities on the Internet

The request of usernames and passwords for each site are still most common on the Internet, usually with a lot of reuse of one or few passwords on many sites. Identity Federation tries to resolve that problem, yet organizational and trust boundaries seem to limit its application. A federated identity in information technology is the means of linking a person's electronic identity and attributes, stored across multiple distinct identity management systems. Related to federated identity is single sign-on (SSO), in which a user's single authentication ticket, or token, is trusted across multiple IT systems or even organizations. SSO is a subset of federated identity management, as it relates only to authentication and is understood on the level of technical interoperability. Recent developments include reusing Facebook or Google accounts on other sites, which allows them to track users and reduce their privacy even further. Moreover, multiple social identities and lives of users also prohibit a more widespread usage of such forms of identity federation. Password safes, in particular in web browsers are another option, yet also limited in their security.

JRA5: Trust in social recommendation

The large amount of data generated everyday on the Web, on the one hand, provides rich information for users to consume, but on the other hand, also easily overloads users if no appropriate tools are provided to process such huge information for decision making. By suggesting information that is likely to interest users, recommender systems have become a promising tool to handle information overload in many application scenarios such as e-commerce, social media, Q&A systems, etc. Utilizing social network information to improve recommendation quality has recently become very popular, where the basic idea is to leverage opinions of users' friends who are assumed to share similar interest and taste (i.e., a friend's recommendation is more reliable than a stranger's). However, in reality, social relationships are complex and social networks are heterogeneous. For instance, users are connected in online social networks with different purpose, reflected by offline social networks, such as friendship, colleagueship, business partnership, etc.; different friends may have very different opinions on the same item (i.e., different recommendation), and the extent of such opinion diversity may be also subject to certain context; social relationships and users' preference may involve over time, where a friend's good recommendation a few weeks ago may not be suitable in the present situation.

These challenges of heterogeneous social information, if are carefully addressed, make the social recommendation approaches a useful tool to provide accurate recommendation in real world applications where social networks play an important role. On the other hand, trust modeling provides an alternative way to model the relationship between users at a finer granularity, thus is a promising method to cope with heterogeneous social relationships. Furthermore, the rich contextual information could also be utilized to improve the user similarity measure.

JRA5: Privacy in the Cloud

Cloud computing has become an essential part of people's electronic life. Services such as online file storage, collaborative document editing, music streaming, and photo browsing are just some examples of what users are utilizing in their everyday life for personal or professional purposes. With the increased dependency on the cloud as a medium for storing and managing the data a user shares, concerns have surfaced about the privacy of such data. So far, some cloud computing companies have addressed these concerns by providing users with the option of client-side encryption to protect their data on the cloud. Evidently, this encryption currently precludes the possibility of obtaining any services, other than storage and synchronization, based on user's data. Therefore, the user has to manually manage this tradeoff between maintaining privacy and utilizing services via specifying privacy settings for each group of data items.

Nevertheless, the majority of users are not experienced enough to select the adequate privacy settings, and even experienced users find it cumbersome to specify individual settings for each item they outsource to the cloud. Therefore, research is required on the problem of automated privacy risk management in personal cloud computing. This problem can be divided into two parts: risk estimation and risk mitigation. The former involves quantifying the risk of data sharing, in order to first inform the users about it and to also compare the risk of different privacy policies in the risk mitigation step. The latter can be accomplished by recommending optimized privacy policies to the user, thus relieving the user from the burden of thinking of the policy to match the privacy-utility tradeoff she envisions.

It should be kept in mind that the attitude towards privacy differs from one user to the other, ranging from introvert attitudes to extrovert ones. Hence, managing the privacy risk should be tailored to individual users' privacy attitudes. In fact, understanding and measuring such attitude is one important part of this challenge (of providing privacy to users). We cannot solely rely on users to declare their privacy preferences due to the well-known dichotomy between users' reported values of privacy and actual behavior, referred to as the *privacy paradox.*

JRA6 – JRA5: Private information and privacy concerns in online collaborative applications

In many collaborative networking applications, it is important to overcome the concerns of end users about the privacy of their data and locations. The intensity of these concerns varies broadly across the candidate contributors. In particular, the privacy concerns relate to how much personal information is (or needs to be) shared with third parties and how this information is treated. With mobile sensing devices, location accuracy also matters since the reported state/context information almost always is time/space-stamped.

One other standard factor that is related to user privacy is the processing requirements. For example, the information may be needed in raw form by the application, or some processing can be done locally and hence, a higher degree of privacy could be preserved. A further crucial dimension is the nature of the dependence of collaborative systems on information and, most importantly, the emerging reliability issues such as how graceful the degradation of utility is when the amount of information provided to these systems decreases.

JRA5: Building a Science of Internet Privacy

Privacy has become a heightened societal concern, fueled by the preponderance of digital data being recorded, shared, and collected about individuals (through the Internet, mobile networks, social networking websites, data aggregators and brokers). But privacy is by its nature a multidisciplinary concept with legal, business, psychological and technical (LBPT) aspects. In parallel, privacy – seen from a technical perspective – shares characteristics with security, which is notorious for its sensitivity to detail. Two challenges arise from these observations.

The first challenge is to understand and take into account all LBPT aspects when designing and evaluating a privacy mechanism. A technically sound mechanism is bound to fail if it is not also economically viable and cognitively feasible. For a very simple example from the security domain, using passwords for authentication works in theory, but people choose the same weak passwords across many systems in practice, because of the cognitive burden of remembering a multitude of complex ones. Email providers could easily provide encrypted email services, but it is economically undesirable to do so, as it is a nuisance for them to implement and maintain, while users do not actively ask for it. Tools and methodologies that cut across disciplines are needed, such as game theory and prospect theory for modeling business incentives as well as human cognitive biases, or tools inspired by mechanism design to study the effect of and to propose new regulations.

The second challenge, oriented more towards the ICT domain, is to distill and clearly articulate assumptions about the system, the attacker, and the privacy property that is to be safeguarded in a given real-world scenario. Cryptography has recently started to progress from an art to a science, exactly because such assumptions have started to be expressed formally. In security research, one has to specify the attacker's objectives and capabilities very precisely. It is only by finding an appropriate formalization of the real-world scenario that one can (a) properly evaluate the merits of a privacy mechanism, (b) compare the relative value of competing mechanisms, (c) identify any potential tradeoffs between privacy and data/service quality, and (d) hope to construct provably optimal privacy mechanisms that satisfy quality constraints.

JRA5: Privacy, trust and reputation management

The field of privacy, trust and reputation management is simultaneously pursued by a number of disciplines. This short summary lists a number of open questions from the computer science perspective:

1. How do you measure privacy, trust and reputation? A common measurement framework is needed to evaluate research contributions for privacy enhancement and trust-based transaction.
2. What is the value of privacy to the population in general? What people freely share on the Internet varies drastically between people - which elements are considered private, what is the driving factor between these differences?
3. To what extent does reputation and trust influence the conductivity of online marketplace and transactions? What are methods to capture and communicate the level of trust inside such systems?

JRA6 Challenges

JRA6: Charactersing the structure of social networks formed by humans in virtual environments

Online Social Networks (hereafter OSN) are one of the most important communication means that we use in our everyday life. They help us to maintain our social relationships with family and friends, as well as to enlarge our professional sphere and to acquire knowledge and new ideas from the network. OSN popularity is due to their ability to transform people into active producers of information, letting them create, access and share contents anywhere and anytime. These unique characteristics of OSN are producing strong effects on our society, but the extent to which they are impacting on human social behaviour is still unknown. Nevertheless, there is no doubt that their role will be of primary importance in our future. For this reason, studying people's behaviour in OSN is of great value to understand how the society is evolving and how we can contribute to the process, designing future OSN able to fulfill users' needs in terms of management of social relationships through digital communications. It is very challenging to acquire a deep understanding of the many properties of social relationships between users in OSN, and studying analogies and differences between online and offline social networks. One specific challenge to be addressed is to study the evolution over time of social relationships maintained in OSN by users. This can permit to carry out a sensitive analysis about the evolution of human social behaviour in OSN over time. This new approach to studying the dynamic properties of social relationships and networks can reveal many important aspects of OSN that should be considered to correctly understand their social properties. The analysis of the evolution of human social behavior in OSN has several practical implications. For example, it could be the basis of innovative applications that dynamically track the structure of the social networks of the users, helping people in the maintenance of their social relationships and suggesting possible actions to improve their social experience. Or, it could be used to classify users based on their dynamic behaviour, and use this classification as context information for customising other OSN applications. In general, it can be used for personalising the OSN applications experience to the specific dynamic social behaviour of the users.

JRA6: What platform for what kind of e-participation?

The Internet may enable a new and wide scale involvement of citizens by means of distributed applications, but this achievement is possible only following the establishment of a broad societal trust in e-voting platforms. Standard technical solutions are still lacking in the e-voting field. The first widely deployed systems did nothing to improve the public perception of their security and even usefulness. A more scientifically rigorous approach to the design, implementation and testing of these systems is needed.

A comprehensive review of the instruments currently available - with emphasis on those from grassroots activism or open software community - should be carried out, followed by an identification of the "characteristics" shared by different systems.

The first challenge is to pinpoint specific characteristics to the existing platforms for e-voting and e-consultation that will influence the degree of adoption in different contexts. Specific aspects, among many, that are of crucial importance are the role of anonymity and identification mechanisms at play in different social and political contexts: without a clear understanding of these, citizens would rather lose the potential benefits offered by Internet-based consultations than leave the safety of well-established procedures.

JRA6: Is e-participation really perceived as new channel for participation?

Besides purely technical strength, an important aspect to take into account is that effectiveness is very closely tied to the "citizens perception" and "level of acceptance". Once the critical technical specifications for trustable and credible e-voting systems are identified, their usability as perceived by the final users should be investigated to infer which are the most effective technologies. The goal is to report the main successful case studies of e-participation. A medium-term research activity can be foreseen, starting from existing literature in different areas, identifying subjects suitable for interdisciplinary efforts, to pursue innovative research directions. The challenge should be aimed at diagnosing what are the advantages that have to be channeled through a proper institutional communication to make citizens familiar with e-participation, informed and willing to participate. This gives Internet Science a chance to be acknowledged, disseminated, and communicated.

JRA6: Towards ad-hoc virtual communities

In the beginning of internet science virtual communities were seen as a reflection of offline communities acting in an online environment. Not only similar subdivisions were made (community of practice, community of interest…), the internet technology was in the first place an enabler to scale up – both from a geographical point of view (the globe was in reach) as from an entry point of view (the internet lowered the barriers to step in or to be part of a community were, due to the level of anonymity and distance). However, today communities are being challenged. Due to new mobile technologies, sensing devices and big data analysis, combined with an always mobile connectivity, communities are being formed on the spot. We already see with social location based services ((LBS) such as foursquare for example) that communities are being constructed based on the time, location and activity of the user. The user will constantly and seamlessly be hopping from one community into the other. It is therefore important to investigate how this has an impact on the users on the one hand and the concept of (virtual) communities on the other. The research of communities will therefore have to focus, more than ever, on the boundaries of communities, on how new future internet technologies as LBS impacts this concept (erode or enhance) as well as on the elements that bounds people into one or more communities. In order to investigate a longitudinal, multi-method approach, combining various qualitative methods with big-data (based on log-files), is required.

JRA6: Measuring Virtual Communities' Interaction as a 'Living Lab'

To understand virtual communities holistically requires intensely interdisciplinary examination that must be based on quantitative and qualitative criteria. This is the major methodological challenge for those studying virtual communities, and despite some recent research to the contrary, our strong working assumption is that virtual communities typically arise from, and respond to, offline communities. The history of Internet-based communication is also a history of the rise of virtual communities, tied into the geographic penetration of access to the Internet, and therefore creating a symbiosis between online and offline experiences.

Recognising that the Internet Science network is an artefact of virtual community, and that its membership is designed expressly to create interdisciplinary collaboration between computer scientists and social scientists, the aim of JRA6 is to explore that 'living lab'. The results of our research are delivered in three ways:

- in the collaborations already planned and undertaken to date, in which concentrations of quantitative and qualitative research clusters can be readily identified (see D6.3.1);
- in the increased collaborations between and across the range of disciplines, some of which can already be identified (see Brown/Marsden 2013, Dini/Sartori 2013, and the range of outputs of Passarella, Crowcroft and Dunbar) which will increase as further collaborative activity develops through EINS;
- in exploring through a specific case study the development of Internet Science as a community of researchers based on a developing methodology of integrating quantitative and qualitative indicators .
- It is this last exploration which is the Internet Science attempt to further develop the 'Holy Grail' of interdisciplinary research, to bridge successfully between disciplines in a manner which enriches both quantitative and qualitative method, while explicitly acknowledging the normative dimension of our work. In this, we expect to provide the foundations for Internet Science's original contribution to the wider arena of scientific endeavour, and our further work packages will take this work forward. This will require substantial input from, and collaboration with, other JRAs, notably JRA1/2/3/4/5, as well as partners funded through the 'Open Calls' in 2013, and other funded parties such as the CAPS programme.

An example of an area in which qualitative-quantitative interaction needs measuring is multistakeholder governance of the Internet itself. The proceedings of the JRA4 United Nations workshop in October 2013 made clear that measuring the impact of the multistakeholder approach to Internet governance is a challenging academic and urgent practical task. Although the exchange of ideas at the Internet Governance Forum, along with the social aspects and networking opportunities between stakeholders are important for mutual understanding in the complex process of Internet Governance, it remains important to find out to what extent the different variations on multistakeholder has an effect on real standard setting and policy making, which influences daily use of the internet. The discussion on metrics and methods to measure the impact of the multistakeholder approach in Internet governance has only commenced at the IGF2013 and will be continued in more depth in JRA4 working in partnership with JRA6 and other interested parties.

In D6.3.1 (June 2013), which Sussex led, JRA6 systematized the vast and heterogeneous body of knowledge produced by different disciplines thus proposing some overarching dimensions along which classification can be made across traditional disciplinary boundaries, summarising the literature in the field, notably that from sociology, media and communication, evolutionary neuroscience and economics, psychology and regulatory theory.

JRA6: Socio-psychological incentives for cooperation in online collaborative applications

Online collaborative systems, realized through social networking and enabled by the growing number of mobile sensing devices, are currently viewed as a promising vehicle for unlocking the tremendous potential that technology-enabled, highly-connected, distributed and participatory human beings can bring about for the benefit of the society and the environment. To render these highly distributed, user-centric, socio-technical systems efficient and survivable, we need to better understand a number of issues. The different instances of online collaborative systems largely rely on the collaboration and contribution of human beings with very different mixtures of personalities, attitudes, socio-psychological and cognitive biases attributes. Indeed, their behavior is exposed to social influence and their decisions are shaped by the real and virtual communities they participate in, being, also, subject to time constraints and human inherent computational and knowledge limitations.

Thus, in such emerging user-centric networking paradigms, collaboration of network members cannot be taken for granted. In fact, end-users may exhibit a rich set of behaviors, ranging from greedily selfish to fully altruistic. One key challenge is, on the one hand, to understand the cognitive task of the users that deal with this kind of collaborative systems and the processes that underlie the opinion dynamics of individuals within the emerging communities, and on the other hand, to perform observations of the role of the end-user community on user behavior/decisions. These socio-psychological aspects are difficult to capture in a model. Yet, gamification techniques allow for tracking group dynamics and community structures and relating them with user profiles, behaviors and strategies. Understanding these key aspects supports identifying those types of incentives (non-monetary, e.g., reputation or monetary, e.g., payment or virtual credit schemes in the case of sensing-enabled application), which engage humans into mechanisms of active contribution and sharing of knowledge. These incentives mechanisms should be flexible with reasonable levels of segregation or even personalization, and account for different levels of rationality in the way end-users decide to participate/collaborate or not. In parallel, the question of incentives has to be pursued for all participating players and entities that are directly (or indirectly) involved in the systems, either as system operators or as open data providers.

JRA6 – JRA5: Private information and privacy concerns in online collaborative applications

In many collaborative networking applications, it is important to overcome the concerns of end users about the privacy of their data and locations. The intensity of these concerns varies broadly across the candidate contributors. In particular, the privacy concerns relate to how much personal information is (or needs to be) shared with third-parties and how is this information treated. With mobile sensing devices, location accuracy also matters since the reported state/context information almost always is time/space-stamped. One other standard factor that is related to user privacy is the processing requirements. For example, the information may be needed in raw form by the application, or some processing can be done locally and hence, a higher degree of privacy could be preserved. A further crucial dimension is the nature of the dependence of collaborative systems on information and, most importantly, the emerging reliability issues such as how graceful the degradation of utility is when the amount of information provided to these systems decreases.

JRA1 – JRA6 – JRA7: Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers

The integration of sensing devices of various scopes and capabilities with mobile communication devices along with the wide proliferation of online social applications leverage the heterogeneity of users in terms of interests, preferences, and mobility, and enable the collection and dissemination of huge amounts of information with very different spatial and temporal context. This information can be intelligently controlled by platforms that collectively enrich people's awareness about their environment and its resources and enable new forms of participatory processes and approaches to managing them. Besides possibly generating information by themselves via the sensing devices they might be equipped with, the networked entities are also typically involved in disseminating this information widely, contributing to building collective awareness. Furthermore, these same entities may actually exploit this awareness of their environment to meet own needs or achieve certain individual objectives. That is, these entities are involved in the dissemination and consumption of the information.

If the disseminated information concerns the availability of some limited resource or service, then competition naturally emerges among entities desiring to use such resources. In such environments, it is important to understand how the presence of competition shapes decisions taken by these entities regarding (a) the way collective awareness is exploited if at all and (b) the way these entities participate in disseminating information and creating collective awareness. The first of these very general and fundamental questions amounts to deciding whether a networked entity will compete (and suffer excessive penalty if not successful) or not compete for the available resource, shaping this way the resulting congestion; key to such a decision is the available information regarding the level of available resources and competition. The second, amounts to deciding whether a networked entity will deviate from the expected behavior (misbehave) by hiding or falsifying resource/service availability information, aiming at reducing the competition to its advantage.

JRA6 – JRA7: Non- excluding, open and sustainable collaborative applications managing common/public goods

Collective Awareness and Collective resource-Access Platforms (CACAPs) are rapidly emerging aiming at facilitating the detection of the state of the environment and consequently the utilization of some desirable resource. While today's technology makes it easy to implement potentially interesting ideas, these ideas will not go far unless they do provide concrete benefits to the users of the platforms at realistic penetration levels. The question of the sustainability of such CACAPs is one that needs to be explored by understanding the cost-benefit tradeoff as assessed by human-driven participants. Furthermore - and possibly more important - it is important to ensure that such CACAPs do not in pretty much either exclude non-participants from joining or – even more – from accessing public goods. The enhanced service enjoyed by the CACAPs participants should be due to the wealth generated by the CACAPs (that is distributed to its participants) and not to reducing competition by excluding or prioritizing against non-participants.

JRA1/JRA6: Human behaviour in ICT-mediated communications

The role of technology on social life can be both positive and negative. On the one hand, it allows very efficient asynchronous information sharing and organization, the creation and maintenance of multiple overlapping networks, and a more flexible self-representation and engagement for individuals. But, on the other hand, it is exactly the same power that makes it easier to browse and filter our physical environment rendering invisible "the different others" , even if they may be standing next to us. It is indeed an irony that the increased physical mobility and accessibility to information of contemporary urbanites is complemented by an increased immobility within known habits, routines and patterns of behaviour that can easily lead to alienation. At the same time, the abstract space of modern cities does not always support social exchanges nor stimulate spatial appropriation, which may lead again to alienation.

But can we use the very same technology that may threaten our connection to the physical world and our immediate surroundings as a means to enhance the communication between strangers in the city?

Clearly, the answer cannot be definite nor generic. The outcome of different solutions will depend on the specific context and the combination of choices on numerous design details that can affect behaviour in complex and unpredictable ways. Moreover, it will be always very difficult to evaluate different outcomes since there are many conflicting objectives involved (e.g., the level of skills required for participation can improve the sophistication of the decisions but can also harm the level of representation due to various divides), dynamic processes (e.g., power relationships might appear over time), and possible unintended consequences (e.g., addiction).

What is important is to acknowledge the threat that ICTs pose on local communities and face-to-face communication and gather around the design process experts from various fields and disciplines from the computer science, and behavioural and social sciences to contribute the emerging interdisciplinary fields of urban and community informatics and support “real life experimentation” methodologies like the action research paradigm, living labs, and other co-creation models. The ultimate goal of this interdisciplinary scientific endeavour is to identify important causal relationships between design choices and outcomes in different contexts, which will allow informed choices based on local values and objectives.

JRA6: Using community practice to imagine internet alternatives

Can local, bottom-up networking projects provide alternative ways of thinking about a future internet? With the rising privacy concerns some activists are proposing ‘post-crisis’ networks such as distributed local mesh networks. In what ways do these experiments suggest possibilities for new or alternative internets based on bottom up rather than top down (state) governance processes? Or do they simply try to ‘reinvent the wheel’?

JRA7 Challenges

JRA7 & JRA8: From Internet of Things to Internet of Data, Information, and Control

In the recent years we have witnessed the introduction of many new kinds of sensors that can be connected to the Internet and used for many application domains, like Smart Grid, Environmental Monitoring, eHealth and Ambient Assisted living to name a few. Research related to sensor based systems has been and is performed under umbrellas like wireless sensor networks, Internet of Things and Cyber Physical Systems. So far the sensor device has been in the foreground, as many titles suggest, but in the long term it is actually not about the sensing devices, but about the data they produce and for what it can be used. It should also be noted that the number of networked actuators is constantly increasing. This will lead to a new era in computing. From the beginning of computing the interaction between the computing device and the real world has been through human mediation (except specialized control systems). The Internet of the Future will enable large scale direct interaction between computing, i.e., cyber world, and the real world.

If the sensing and actuation devices themselves are not important for applications, but instead the data they can collect and which aspect of the real world they can control, it is just a consequent step to also look at other data sources and control nobs in the Internet. These could be network monitoring probes of various kinds for example network management purposes, but also data stored in data bases and data published on the web in newspapers, social networks etc. From a data management point of view it does not matter whether the data comes from an A/D converter (i.e. physical sensor) or a monitoring probe (i.e., logical sensor). It should noted that this point of view that aims to address real world and cyber world through the same concepts has been also brought up by Norbert Wiener in Cybernetics [Wiener 1961].

There are several big challenges to be solved to move from the Internet of Things to the Internet of Data, Information, and Control, including

- The four V's of data [IBM 2013]: Volume respectively scale of data is very large, i.e., Zetabytes of data; Varity of data because it comes in many forms, structured and unstructured etc.; Velocity of data because sensors generates data streams, e.g., in a single car there are more than 100 sensors; and finally Veracity refers to uncertain data, e.g, sensor readings impacted by noise.
- Integration of networking and data processing: one common idea is to move all data into the cloud and process it in the cloud. However, privacy issues and also to reduce resource requirements demand also in-network processing of data to derive useful information from data within the network.
- Control: feedback control loops are often closed systems, this is not the case in the future Internet. Furthermore, to properly actuate a system domain knowledge from the application domain is needed. As such only interdisciplinary approaches can be successful to build and maintain smart self-controlling systems, like smart grid, smart houses, or elderly care in Ambient Assisted Living.

Any solution for these and other future issues related to an Internet of data, information and knowledge will contribute to the usefulness, robustness, and efficiency of systems and applications and finally contribute to sustainable solutions for humans that increase their safety and well being.

References

[Wiener 1961] Norbert Wiener: "*Cybernetics: Or Control and Communication in the Animal and the Machine*". Paris, (Hermann & Cie) & Camb. Mass. (MIT Press) ISBN 978-0-262-73009-9; 2nd revised ed. 1961

[IBM 2013] IBM Global Business Services, Business Analytics and Optimization, Executive Report: "*Analytics: The real-world use of big data: How innovative enterprises extract value from uncertain data*", Document Number: GBE03519USEN, 2013

JRA7: Understanding the relationship between redundancy and resilience in networks

In order to increase fault tolerance, redundancy is typically employed. In networks this may encompass the addition of redundant nodes and links to be able to tolerate single node and link failures. The Internet is a prime example of this approach in the sense that between any two nodes in the Internet there are typically a multitude of possible paths for communication such that failure of a single node or link will not inhibit communication. As such, the Internet is quite resilient to failures and it has been demonstrated in the past that failure of single links or nodes will have local effects at most. With communication becoming more and more important also for other kinds of networks (e.g., power grid, utility networks, …) there is one the one hand a need for a highly reliable communication network (and thus the question, whether the Internet can fulfill that role). On the other hand, it might be beneficial to retrofit the resilience concepts of the Internet to other critical networks and infrastructures.

There are, however, several important topics to be considered here. First, there is obviously a tradeoff between adding redundancy and minimizing cost (both OPEX and CAPEX). This also encompasses resource- or energy-efficiency, considering that additional equipment operating as a hot spare will consume resources and possibly energy. Second, the question remains, at which point redundancy (i.e., an additional node or link) should be added to maximize the gain in resilience. Third, it is known that in some cases redundancy can actually decrease performance (e.g., Braess's Paradox) and, thereby, possibly resilience. A better understanding of where and how redundancy can increase overall network resilience thus remains an important topic for further research.

JRA1 – JRA6 – JRA7: Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers

The integration of sensing devices of various scopes and capabilities with mobile communication devices along with the wide proliferation of online social applications leverage the heterogeneity of users in terms of interests, preferences, and mobility, and enable the collection and dissemination of huge amounts of information with very different spatial and temporal context. This information can be intelligently controlled by platforms that collectively enrich people's awareness about their environment and its resources and enable new forms of participatory processes and approaches to managing them. Besides possibly generating information by themselves via the sensing devices they might be equipped with, the networked entities are also typically involved in disseminating this information widely, contributing to building collective awareness. Furthermore, these same entities may actually exploit this awareness of their environment to meet own needs or achieve certain individual objectives. That is, these entities are involved in the dissemination and consumption of the information.

If the disseminated information concerns the availability of some limited resource or service, then competition naturally emerges among entities desiring to use such resources. In such environments, it is important to understand how the presence of competition shapes decisions taken by these entities regarding (a) the way collective awareness is exploited if at all and (b) the way these entities participate in disseminating information and creating collective awareness. The first of these very general and fundamental questions amounts to deciding whether a networked entity will compete (and suffer excessive penalty if not successful) or not compete for the available resource, shaping this way the resulting congestion; key to such a decision is the available information regarding the level of available resources and competition. The second, amounts to deciding whether a networked entity will deviate from the expected behavior (misbehave) by hiding or falsifying resource/service availability information, aiming at reducing the competition to its advantage.

JRA6 – JRA7: Non- excluding, open and sustainable collaborative applications managing common/public goods

Collective Awareness and Collective resource-Access Platforms (CACAPs) are rapidly emerging aiming at facilitating the detection of the state of the environment and consequently the utilization of some desirable resource. While today's technology makes it easy to implement potentially interesting ideas, these ideas will not go far unless they do provide concrete benefits to the users of the platforms at realistic penetration levels. The question of the sustainability of such CACAPs is one that needs to be explored by understanding the cost-benefit tradeoff as assessed by human-driven participants. Furthermore - and possibly more important - it is important to ensure that such CACAPs do not in pretty much either exclude non-participants from joining or – even more – from accessing public goods. The enhanced service enjoyed by the CACAPs participants should be due to the wealth generated by the CACAPs (that is distributed to its participants) and not to reducing competition by excluding or prioritizing against non-participants.

JRA7 The Internet as Critical Infrastructure: socio-technical issues.

As the Internet replaces specially deployed data networks to become the carrier for an increasing number of critical applications - such as financial data transactions or security operations - the impact of failures in its operation can become dramatic. Essentially, the Internet has become a critical infrastructure, though it was not designed for this purpose. It is therefore imperative that we integrate technical, economical, sociological, political and legal viewpoints and expertise in addressing the criticality of the Internet infrastructure and the challenges that may arise from usage patterns, technical faults, local political decisions or malicious attackers. But making critical infrastructure systems inherently reliable and safer is more than a simple, or even a complex technical problem. What a range of studies of critical infrastructure failure has illustrated is that such complex systems also have important organizational and human components that need to be understood and integrated into design. Rinaldi et al (2001) identify six dimensions - the technical, economic, business, social/political, legal/regulatory, public policy, health and safety, and security concerns - that impact on critical infrastructure operations and have the potential to influence social well-being and aspects of everyday social and organizational life. Accordingly we seek a mix and wide range of interdisciplinary, technical and social understandings the Internet as a critical infrastructure.

Ref: Rinaldi, S. M., Peerenboom, J. P., & Kelly, T. K. (2001). Identifying, understanding, and analyzing critical infrastructure interdependencies. *Control Systems, IEEE*, *21*(6), 11-25.

JRA7 Cybersecurity risk and protective social objects

An important area is cybersecurity risk and protective social objects, which aims to combine knowledge and insights in computer science (especially resilience and security in computer networks) and management science (especially organizational failure and risk analysis). It is concerned with risks to cybersecurity, but less with the strategies of attackers and more with the actions of benign agents that undermine the risk controls intended to forestall the attackers. In particular it is concerned with the use of social objects to protect systems. At some point all technical systems are dependent for their security on a social system. They rely on acceptable use policies, authorisation levels, user roles, passwords, rules about choosing, protecting and (not) sharing passwords, rules about non-disclosure, rules not to leave systems logged on and so on. These are all social objects, and only function - as rules for instance - because there is some collective intention that they function as such. And this collective intention sometimes fails, typically for reasons that are socially adaptive. A group of users may agree to leave a terminal logged on, for example, when their work requires urgent responses and logging back on is time consuming. The aim of this work is to investigate how we can reason systematically about the operation and vulnerability of the social objects that protect against cybersecurity risks. This will involve developing ways of representing the functioning of such objects, ways of measuring exposure and resilience, and ways of methodically designing systems to be more resilient. It will involve getting to grips with the background both in computer network security and in risk analysis, development work to produce a prototype formalism and supporting editor, and fieldwork to investigate likely areas of application such as industrial SCADA systems and telecommunications networks.

Ref: Busby, J.S. and Bennett S.A. (2007). Loss of defensive capacity in protective operations: the implications of the Überlingen and Linate disasters. *Journal of Risk Research*, 10, 3-27.

JRA1 - JRA7: Node centrality heuristics and associated vulnerability of Internet graphs.

Network graph characterization has received extensive attention in the past and has lately also considered real Internet graphs as revealed by experimental data. Not all network nodes are equally important in supporting network operations and for this reason a number of metrics have emerged assessing the importance or centrality of a node. In view of the fact that certain nodes are autonomic and their availability is not to be taken for granted, or that certain nodes may be attacked and become non-operational, a fundamental question is to assess the criticality of the various nodes – as inferred by the various centrality metrics available – in sustaining key network properties, such as connectivity, information carrying capacity, etc. As certain node centrality rankings are more easily detectable by an adversary than other rankings, an important question is to assess the correlations of the different rankings and ultimately assess the damage on the network if highly-ranked nodes are removed according to the various rankings.

JRA7: Internet as a Critical Infrastructure: Security, Resilience and Dependability Aspects

AIT will focus its activities within EINS on the positioning of next generation security concepts for the following critical application areas of the future Internet:

- **Security and Risk Management for Smart Grids**

Future energy grids (such as the *smart grid*) will make extensive use of the integration of ICT technologies, and in some cases will make use of the Internet to support user services. Thus, cyber security risks become a major threat for energy suppliers. New multi-disciplinary approaches are necessary to strengthen the resilience of smart grids against cyber-attacks. This includes specific risk management approaches for utility providers, processes and guidelines for implementing security in smart grid environments, and also security assessment and monitoring solutions.

Due to the extensive use of ICT for the future energy networks, the dependability on the availability of the energy infrastructure will dramatically increase. It is necessary to raise awareness within a whole industry and to define methodologies, architectures and tools to prepare the energy infrastructure for the challenges of the future. There is still missing a common harmonized and accepted view within Europe on security requirements, network architecture, role models (role of public authorities) and an economical useful migration methodology from today's networks to the future grid concerning the security requirements. To address these problems, clearly a multi-disciplinary approach is required, which draws on expertise, e.g., on engineering power grids, computer networks, economics and sociology, making this ideally suited to being considered as an Internet Science problem.

- **Cloud Computing for high-assurance applications**

Cloud computing adoption is taking place in different application areas, including those that have higher security requirements. Existing cloud offerings are not well placed to address these issues. Due to the opacity and elasticity of cloud environments, the risks of deploying critical services in the cloud are difficult to assess – specifically on the technical level, but also from legal or business perspectives. Furthermore, clouds are being coupled with large-scale machine-to-machine (M2M) communication infrastructures, e.g., supporting the processing and storage of data from large sensor and actuator networks. In many cases, these infrastructures will support the infrastructures that our society depends on. In a similar manner to a supporting cloud infrastructure, these M2M infrastructures are likely to be dynamic in nature. In order to understand the security and resilience characteristics of these highly dynamic infrastructures, new models and techniques are required. Furthermore, novel architectures are required that consider the end-to-end connectedness, dynamic and large-scale nature of these infrastructures. If these issues are not appropriately addressed, the services that such infrastructures support could be vulnerable to a wide variety of attacks and other challenges.

- **Efficiently securing large-scale service-oriented architectures in the eGovernment domain**

Large scale distributed service-oriented architectures are implemented across Europe by the various eGovernment initiatives for private and business users. They usually utilize a number of technologies like federated identity management, cryptography, etc. for ensuring confidentiality and integrity of the system. In many cases, these eGovernment services make use of the public Internet to provide connectivity, which increases the risk of being attacked and outages due to network failures. As in the other application domains that are considered by AIT, new architectures and security analysis approaches, such as risk assessment approaches, are required to build these infrastructures in a secure and resilient manner.

JRA8 Challenges

JRA8: Prosumers' cooperation in Smart Grid

Smart Grid is a promising new concept to efficiently use all available energy resources in order to accommodate energy demands in a reliable uninterrupted manner. Internet technologies hold a significant role to the operation of the smart grid enabling real time communication and management of energy through the development of web based platforms (meter data management) and internet of things (smart meters, advanced metering infrastructure). One of the key aspects of the smart grid is the participatory role of the users. Users can have both the role of producer and consumer of energy, given the general term "prosumer". One interesting challenge would be to motivate prosumer cooperation based on sophisticated algorithms. The main goal is to provide automatic clustering of prosumers that can yield to a virtual power plant (a production entity of the energy network) which can have active participation to the energy market. A collaborative community of prosumers can share their residual produced energy and also dynamically enter the energy market by selling it in the grid utility. In that way, prosumers using internet platforms and automation algorithms will benefit from their cooperation but they will also build eco behavior. Other challenges here would be to provide the appropriate mechanisms in order to efficiently coordinate such communities and determine the energy allocation mechanism in the community as well as the framework for efficient establishment of bilateral contracts in the future energy market between prosumers communities and the grid. This direction is highly interdisciplinary and is based on the convergence of ICT with the energy sector. More precisely, it is based on distributed management and control, optimization, game theory, renewable energy sources and power networks. Concepts from sociology and notions of “trust” and “reputation” will also play a crucial role in the incentives created for prosumers communities.

JRA8: Water Awareness Campaign

One of the problems with existing information is its fragmentation. Usually, it is only available as project documentation, offering general overviews of projects and focusing on various topics besides awareness raising. Systematic exchange of awareness raising ideas is difficult. Much can be learnt by exchanging and comparing the experiences of very different initiatives within a sector, such as the water sector. There is a growing recognition of the importance of social norms and attitudes in the management of water. Recent main policy documents recognize the importance of awareness raising to influence these norms and values towards a more sustainable use of water resources. For example, the Water Framework Directive has established the drivers for public participation in water resources management; however, guidance on the design, implementation and management of appropriate tools, particularly ICT-based tools and processes to support such participation remains sparse. Public participation is usually realized through meetings of key stakeholders or public group representatives that protect their own interests, without actually including the “public” itself. It is clear that representatives of "public interest" groups could present their views of the public interest in most regulatory forums. But with the corresponding proliferation of "public interest" groups, it became increasingly less clear what the "public interest" in a particular issue was and who appropriately spoke for that interest. By now, it is becoming increasingly apparent that the public has a multiplicity of interests and that no single spokesperson can represent them.

An interesting question that should be addressed is: “who is the public?” A potential list of stakeholders is the following: a) interested individuals, b) local public interest groups, c) national public interest groups, d) regulated industry and trade associations, e) affected labor groups and f) competitors of the regulated entity. While it maybe easy for categories (c) through (f) to have a voice in water resources management, interested individuals and local public interest groups, especially those that are not computer savvy are usually left out. Furthermore, advancements in technology drive a perceived need for spatially and temporally distributed measurements to quantify complex earth system processes. The expansion of mobile phone/internet technology provides many opportunities to engage citizens in all levels of decision-making, getting them involved in the stage of public consultation and beyond. Studies have shown that for the public to respect a regulation, they have to get involved in its planning. This is especially true for rules and regulations that involve behavioral changes in people, such as household water use. The challenge here is to get everybody involved (even the ones that are not prone to the use of technology) and make them aware that they take part in the decision-making process. A good example is reaching out to farmers in poor regions in the countryside that are major water stakeholders but usually appear to be totally left-out from the decision-making process. Internet is the ideal way to reach out to all those people and raise their awareness on issues related to water and open up the decision-making process to everybody. Once this level of communication and this platform is established, people can have a constant stream of data and communication with authorities and such platform can be extended to a number of issues, such as raising their awareness on water or electricity use, or several similar issues, thus achieving and promoting sustainable living with lower environmental footprints. The problem is indeed multi-disciplinary, involving water managers, environmentalists, agricultural engineers, ICT and WSN specialists, software designers, as well as legal experts and sociologists.

JRA8: Enable sustainable living

Internet evolution led to smooth, effortless and non-invasive monitoring of people's every-day life, measuring data such as energy consumption, temperature, CO_2 concentration etc., taking advantage of smart devices that can be connected to the Internet. Data streams on traffic, noise, house energy consumption, user mobility, food consumption, etc. reach the user and inform him on individual carbon impact and its relation to that of others, e.g. family, friends, neighborhood. This challenge necessitates efficient data collection and online data processing at ultra-high scales. It requires Demand-Response systems to be employed that provide the user feedback on daily schedule changes that would enable more sustainable living. It needs information on user surrounding possibly collected by other users. Ultimately, aggregated data from various sources should be fused and transformed to useful information to the user for sustainable living through persuasive user interfaces. This challenge necessitates interdisciplinary research in sensor networks, cloud computing, databases, HCI, and multidisciplinary research in sociology, economics, electrical engineering, urban planning and more.

JRA8: Incentives, gamification and participatory sensing

Internet technologies, smart phones and social media platforms can provide a link for incentives, gamification and participatory sensing in various domains that are directly related to the environmental protection and the energy efficiency. Incentives are usually derived by discounts or tokens and are displayed in the internet platforms of the users, used to fulfill specific targets. One can be the case of demand response. Gamification is the procedure that the internet platform is used to manipulate the behavior of the user towards one specific direction through the participation of users in a game. It usually includes comparisons and efficiency competitions games. Participatory sensing is referred to the case where the user (and usually smart phones with sophisticated applications or additional sensors) is called to capture parameters that are important for the protection of the environment. This may include actual sensor readings or multimedia data. The user, in that case, is modeled as a moving sensor that can cover large geographical areas.

A relative challenge is the development of efficient incentives, gamification algorithms and participatory sensing solutions to provide environmental monitoring and energy management. This is an interdisciplinary research area and covers the case of ICT, user behavior, environment and energy. The risks associated to this area involve the efficiency of the coupling of existing infrastructure with the development of the proposed algorithms and techniques. In general, this area of research is expected to hold an important role of the future internet since it combines the internet of things, social networks, user behavior and environmental protection.

JRA8: Smart Grids and the Internet of Energy

The term smart grid is commonly used to refer to a modernized electrical system which will permit new and more sustainable models of energy production, distribution and usage by: i) enabling the massive deployment and efficient use of distributed energy resources, ii) incorporating real-time distributed intelligence; iii) allowing demand-response and load shaping functionalities, and iv) fostering the electrification of transportation systems. In this revolutionary power system, energy will not flow anymore unidirectionally from power plants to the customers, but grid users will be both energy producers and energy consumers and the smart grid infrastructure must be capable of managing bidirectional energy flows. To some extent, there are fundamental similarities between the architectural model of the Future Internet and the reference model of the smart grid. To recognize those similarities is important because they motivate the adoption of Future Internet design principles when designing scalable, reliable and secure networking solutions for the smart grid. For instance, both the Internet and the power grid are witnessing a transition from a structure with a clear distinction between the core network and the access network (with almost all the system intelligence residing in the core) to a more federated system where the intelligence of the network (i.e., its ability to distribute, store, or modify information and energy, respectively) can be migrated to the periphery. Furthermore, both the Future Internet and the smart grid will by highly heterogeneous and wide-area complex systems, which must support various degrees of autonomous control at different time scales. In this vision, the smart grid will emerge as a true Internet of Energy (IoE) allowing units of energy to be dispatched when and where it is needed. Energy routers must be deployed in the smart grid to enable innovative paradigms for energy distribution and control, in which energy is logically packetized, buffered and forwarded over the physical energy network. We believe that flow-based congestion control algorithms, which have been commonly applied in large-scale information net- works will play a fundamental role in the design of autonomous control functionalities for the IoE. For instance, there are electric devices that can elastically adapt the amount of instantaneous power they need, such as many common household appliances. Then, those devices could intelligently increase/decrease their power demands depending on congestion feedback signals from the utilities. Furthermore, innovative ways of dispatching energy in a smart grid can be devised taking advantage of electric vehicles (EVs). For instance, we can use the batteries of EVs as a mean of physically moving electrical energy. Alternatively, EVs can supply back part of their stored electric power to stabilize the electricity produced by intermittent renewable energy sources. In this way EVs can support a delay-tolerant transfer of energy between grid endpoints. A new optimization is needed to solve the optimal energy delivery problem and to investigate the basic structure of the optimal energy delivery policy.

JRA8: Energy Consumption awareness @ Home

The availability of sensors and devices for environmental monitoring and energy consumption measurement connected to the Internet enabled recently a whole new set of possible actions to foster energy aware behaviors. The penetration of such devices and concepts has been to date mostly relegated to the industrial environment and is very limited in the residential environment yet.

Internet enabled energy consumption monitoring and control for residential user could exploit social media to share experience, promote virtual behavior, foster cooperative energy saving actions at the building, suburb, town level, especially if supported in some way by the local municipalities. Municipalities could play an important role by providing platforms to collect, merge and publish data in open format. On such data independent user groups and or energy providers could implement further processing and service design. In particular the results of cooperative actions by sensitive user groups could have a significant impact on the energy consumption habits of large user populations.

This is a field where IT technologies are well established already, while a very limited analysis of the user perception, interest and/or degree of acceptance is currently available, as well as limited analysis has been carried on about which kind of public policies could be implemented based on such concepts and which public value such policies could bring.

JRA7 & JRA8: From Internet of Things to Internet of Data, Information, and Control

In the recent years we have witnessed the introduction of many new kinds of sensors that can be connected to the Internet and used for many application domains, like Smart Grid, Environmental Monitoring, eHealth and Ambient Assisted living to name a few. Research related to sensor based systems has been and is performed under umbrellas like wireless sensor networks, Internet of Things and Cyber Physical Systems. So far the sensor device has been in the foreground, as many titles suggest, but in the long term it is actually not about the sensing devices, but about the data they produce and for what it can be used. It should also be noted that the number of networked actuators is constantly increasing. This will lead to a new era in computing. From the beginning of computing the interaction between the computing device and the real world has been through human mediation (except specialized control systems). The Internet of the Future will enable large scale direct interaction between computing, i.e., cyber world, and the real world.

If the sensing and actuation devices themselves are not important for applications, but instead the data they can collect and which aspect of the real world they can control, it is just a consequent step to also look at other data sources and control nobs in the Internet. These could be network monitoring probes of various kinds for example network management purposes, but also data stored in data bases and data published on the web in newspapers, social networks etc. From a data management point of view it does not matter whether the data comes from an A/D converter (i.e. physical sensor) or a monitoring probe (i.e., logical sensor). It should noted that this point of view that aims to address real world and cyber world through the same concepts has been also brought up by Norbert Wiener in Cybernetics [Wiener 1961].

There are several big challenges to be solved to move from the Internet of Things to the Internet of Data, Information, and Control, including

- The four V's of data [IBM 2013]: Volume respectively scale of data is very large, i.e., Zetabytes of data; Varity of data because it comes in many forms, structured and unstructured etc.; Velocity of data because sensors generates data streams, e.g., in a single car there are more than 100 sensors; and finally Veracity refers to uncertain data, e.g, sensor readings impacted by noise.
- Integration of networking and data processing: one common idea is to move all data into the cloud and process it in the cloud. However, privacy issues and also to reduce resource requirements demand also in-network processing of data to derive useful information from data within the network.
- Control: feedback control loops are often closed systems, this is not the case in the future Internet. Furthermore, to properly actuate a system domain knowledge from the application domain is needed. As such only interdisciplinary approaches can be successful to build and maintain smart self-controlling systems, like smart grid, smart houses, or elderly care in Ambient Assisted Living.

Any solution for these and other future issues related to an Internet of data, information and knowledge will contribute to the usefulness, robustness, and efficiency of systems and applications and finally contribute to sustainable solutions for humans that increase their safety and well being.

References

[Wiener 1961] Norbert Wiener: "*Cybernetics: Or Control and Communication in the Animal and the Machine"*. Paris, (Hermann & Cie) & Camb. Mass. (MIT Press) ISBN 978-0-262-73009-9; 2nd revised ed. 1961

[IBM 2013] IBM Global Business Services, Business Analytics and Optimization, Executive Report: "*Analytics: The real-world use of big data: How innovative enterprises extract value from uncertain data*", Document Number: GBE03519USEN, 2013

JRA8: How can we create a sustainable Future Internet?

We estimated that over the last five years, the yearly energy consumption growth of ICT in general and the Internet in particular is higher than the growth of the worldwide electricity consumption in the same time frame. The combined electricity consumption of three important ICT categories – i.e. communication networks, personal computers and data centers – is growing at a rate of nearly 7% per year (i.e. doubling every 10 years), with the strongest growth observed in communication networks, which is the basis infrastructure of the Future Internet. In 2012 each of the three ICT categories mentioned above, accounted for roughly 1.5% of the worldwide electricity consumption. Taken together, the relative share of this subset of ICT products and services in the total worldwide electricity consumption has increased from about 3.9% in 2007 to 4.6% (or 900 TWh) in 2012.

The above observations highlight the need for research – both technical and user oriented – on energy-efficient and sustainable technologies across all ICT domains. As ICT can also reduce the energy consumption in other sectors, an increased consumption of ICT can be justified as long as its grow rate is not increasing exponentially. A further intensification of measures and research towards sustainable technologies combined with the current shift to smaller/mobile devices could lead to a reduced growth rate of electricity consumption by ICT in the coming years. In the future, frequent estimates of the worldwide electricity use by ICT will be essential to provide timely feedback if indeed ICT electricity consumption remains relatively small, or instead continues to grow at an unsustainable rate.

JRA8: Behavioural demand response

Managing peak electricity usage and increasing the share of renewable energy in the electricity pool is crucial for fulfilling CO2 emissions reduction targets, while keeping the grid running with the necessary level of reliability. Demand response (DR) refers to a set of dynamic demand mechanisms that aim at managing consumption of electricity in response to supply-side signals. DR is often carried out through direct load control (DLC) by the DR service provider. Nevertheless, DR can also be based on indirect methods that aim at influencing the consumer to behave differently through incentives, real-time information, or dynamic prices. While with DLC the expected outcome of a DR signal is measurable and quantifiable, with indirect methods the outcome is less predictable, as it depends on the behavioural response of the consumer. Although the residential sector makes up 20% of total energy demand and 60% of peak load demand, it still remains an untapped resource. The financial incentives for residential facilities to participate in DR (e.g., savings on the monthly bills) are not very lucrative, which results in low engagement of residential consumers. Another reason that keeps residential consumers out of DR is privacy and security. The concerns about the possibility of a “Big Brother” control of appliances, with external entities, either legitimate or not, may take control of the energy consumption of the house, is a deterrent for widespread involvement of residential consumers in DR programmes. Finally, decreased responsiveness (i.e., “demand fatigue”) is another concern. Proof of that is the fact that most operational experiences of indirect DR are usually designed to call for load reductions over a low number of days or hours of the year, in order to minimise the likelihood of an exit from the DR programme.

To overcome all these barriers that limit a widespread adoption of residential DR, new innovative solution concepts are needed to drive energy consumers along new behavioural paths. Behavioural sciences and information technology must come together to find methods and technologies that are able to trigger the motivation and to support the ability for pursuing a behavioural change that is sustainable in the long run. Gamification (i.e., the use in non-game contexts of the engagement mechanisms common in popular games), social collaborative campaigns, user-centric information feedback supported by intelligent analytics can all be suitable means to provide personalised insights that motivate consumers towards the desired energy behaviour.

JRA8: Using Storage Systems to Firm Solar Power

Traditionally, energy generators are finely controlled to match the fluctuations in aggregate demand. Unfortunately, due to their intrinsic stochastic nature, solar energy generators cannot be controlled in this way, making it difficult to integrate them into the grid. Specifically, solar fluctuations can harm power quality, increase the need for regulation, and complicate load following and unit commitment. Hence, these fluctuations must be mitigated. One of the most promising ways to mitigate solar power fluctuations is to use energy storage systems (ESS).

Due to the high cost of storage, it is necessary to size the ESS parsimoniously, choosing the minimum size to meet a certain reliability guarantee. In practice, parsimonious ESS dimensioning is challenging due to the stochastic nature of generation and load and the diversity and high cost of storage technologies. We take an inter-disciplinary approach by using an isomorphism between ESS and network buffers. This allows us to size an ESS in a similar way that the teletraffic theories size a buffer. This, however, needs an accurate model for solar power fluctuations. The high variability of solar power due to intrinsic diurnal variability, as well as additional stochastic variations due to cloud cover, have made it difficult to model solar power. We provide an analytical solar power model which accounts for solar power variations both from diurnal effect and cloud's effect. Using real solar power data traces, we show that our analytical ESS dimensioning closely matches the simulation results.

JRA8: Pervasive computation, sensing and control for energy efficiency and carbon footprint reduction

The Internet has become the unifying communications backbone that allows gathering of data from pervasive sensors, the analysis of this data in centralized data centers, and the subsequent actuation of globally distributed control elements. This 'Internet of Things' will allow us to remove ineffeciences in energy usage as well as reduction in the carbon footprint in energy generation and consumption processes. This control paradigm is already being instantiated in approaches such as demand-response (reducing demand during load peaks), using electric vehicles for frequency regulation in the smart grid, and building control systems that rapidly respond to changes in occupancy state. In the future, we anticipate that, growing from these roots, many existing physical systems will evolve to highly-connected cyberphysical systems. The gains from this change, as well as the potential pitfalls are enormous. One the one hand, it may allow developing regions to improve their GDP without a concommitant increase in carbon emissions. On the other hand, it may lead to catastrophic failures due to crashes of transportation or power systems. To meet this challenge, what is needed is the design of a robust, scaleable, control plane that allows the decoupling of provably stable and safe control algorithms from theunderlying sensing infrastructure, allowing the development of higher-level 'applications' that are abstracted from the lower-level details. This architectural effort, which will require inputs from system analysts, network scientists, infrastructure managers as well as power engineers, will lie at the heart of future cyberphysical systems and is clearly a significant grand challenge for Internet Science.

JRA Cross-Challenges

As has already been evident from the earlier description of the initial challenges identified within JRA1-JRA8, several of these challenges do not fall within a single JRA area, but rather they span thematically, and naturally, over a number of those areas. In fact, it is this blending of the more traditional areas that the Internet has facilitated, generating new challenges that shape a potentially distinct and quite new (multi-disciplinary) scientific domain. It is expected that a large number of the challenges to be identified in the final report on the Roadmap will be across several of the JRAs.

In conclusion, this report brings together a diverse and multi-disciplinary set of views from the EINS partners about the challenges that lie ahead to develop the Future Internet.

4 Plan of Action

The goal of the final version of the deliverable on the Internet Science Roadmap (Deliverable DS3.2.2 Internet Science – Going Forward: Internet Science Roadmap (M36)), is to bring together and attempt to consolidate a diverse and multi-disciplinary set of views from the EINS partners about the challenges that lie ahead to develop the Future Internet.

To achieve this goal, this initial input will feed discussions that will be planned to take place in all of the EINS project JRA meetings, workshops, relevant panels/sessions, and other relevant activities during 2014. The organizer of the activity will be asked to provide ***"The Input of activity X to the Internet Science Roadmap".*** The size and nature of this input will depend on the activity. This input will be ***consolidated on a quarterly basis*** and be available for further consideration and deliberations in subsequent activities.

5 Conclusions

In conclusion, this report brings together a diverse and multi-disciplinary set of views from the EINS partners about the challenges that lie ahead to develop the Future Internet.

This is a preliminary draft of the Internet Science Roadmap (Deliverable DS3.2.2 Internet Science – Going Forward: Internet Science Roadmap (M36)), containing initial input from the EINS partners on challenges and issues that have emerged due to the wide proliferation of the Internet through all facets of society. This is not meant to be a comprehensive report, but rather a record of the starting point of our work towards the Internet Science Roadmap (M36).

These initial challenges will be further deliberated, refined and augmented through actions to be planned in all EINS project meetings and workshops during 2014 (Section 4). The eventual goal is to lay down ***a set of fundamental challenges*** that are largely new, have clearly emerged as a result of Internet's nature and its immense penetration to almost all aspects and functions of the society, have not been viewed as fundamental challenges to any of the relevant classical sciences, and whose successful resolution will further enhance the Internet (as well as our fundamental knowledge) and further and open up new opportunities for economic growth and quality of life.

6 Annex I

1-CERTH (GR)

JRA1: Crowdsourced Provisioning of Internet Connectivity

Today we are witnessing two important socio-technological advances that herald the advent of a new era in communication networks; first, the ever increasing needs of users for ubiquitous and high-speed Internet connectivity which, in turn, has created an unprecedented volume of mobile data traffic; second, the technological advances that have resulted in sophisticated, yet low-cost, user-owned equipment such as small base stations (e.g., femtocells and WiFi access points), and smartphones with enhanced-capabilities. These devices not only satisfy the communication needs of their owners, but can also be used to offer communication services to other users. In a way, each user may act as a local *micro-operator*, e.g., operating as a mobile hotspot or offloading cellular traffic, These *user-provided connectivity* (UPC) services have substantial benefits both for the users (e.g., low energy consumption, improved quality of service, etc), and for the network operators (e.g., energy cost savings), and constitute a promising solution for addressing this traffic increase for the future Internet. Nevertheless, the successful implementation and adoption of such models presumes the design of proper pricing mechanisms that will allow the users-providers and users-clients to agree on the charged schemes/prices for serving each other. Clearly, the conventional pricing schemes employed by network operators are not suitable for these services. More interestingly, in many cases these services are network-assisted and as such, the operators should also be involved in determining the pricing of the services. Designing novel pricing schemes for crowdsourced Internet connectivity services will play a key role on the adoption of this new model which, in a way, *outsources the network functionalities* to the users, and brings performance and economic benefits to users and networks.

JRA1: User Engagement and Incentives in Crowdsourcing

Crowd sensing through mobile user devices, also known as Mobile Crowd Sensing (MCS), is an emerging paradigm for creating collective intelligence through end-user information contribution. More often than not, these contributions consist of measurement data, which are processed and refined, and offered accordingly as a service to interested users. The value of a crowd sensing service depends on the number of users contributing to this service through data they own, for which they have a cost for collecting it. It is therefore imperative for such a system to maintain end-user engagement. That is, the end-users should be given the appropriate motives so as to be part of the system and contribute their data to it. The theoretical foundations of such motives, also referred to as incentives, have been around in the economics literature for several years. However, their applicability in crowd sensing is still lagging primarily due to the existing gap between economics and engineering disciplines. It is therefore imperative to bring engineers and economists together so as to design and implement such incentive mechanisms for MCS platforms, by addressing the following questions (i) why should users share or exchange such information that is costly to them but important to others, (ii) what are the appropriate incentives to be employed and, (iii) how to realize a system that can encompass large growth in scale and user population, and make it sustainable by lowering costs and generating rewards for all involved players. The answers to these questions will largely determine the successful adoption and proliferation of such platforms for the future Internet.

JRA3: Enable Internet Scale Experimentation

The enormous Internet scale and its dynamics cannot be captured by simulations or local (even regional) testbeds. Therefore, experimentation with innovative protocols or services cannot produce reliable results. There are prior efforts to this direction (e.g. PlanetLab), but they are of rather primitive size and geographical distribution to claim Internet scale w.r.t. both number of nodes, traffic and topology. A huge gap is created between academia and industry, rendering academic research a second class citizen. It is important that the Internet continues to improve based on academic contributions that are also backed up by experiments. The challenge is to build efficient emulation environments that multiplex existing federated testbed infrastructure with large-scale virtual topologies that attempt to mimic the behavior of the Internet based on prior network measurements in the Internet. Another input parameter is the human-generated traffic by Internet activities, e.g. Web searches, participation in social networks, blogging, etc. This can be achieved by interdisciplinary effort in networks, machine learning, statistics and social networks.

JRA5: Balance the power between data owners and giants (e.g. Google, Facebook, etc.)

The evolution of the Internet leads to the vast disempowerment of the individual towards protecting his privacy. Web search-engine data, sensor data (from mobile phones or other sensing infrastructure), user-published content in the Web (e.g. in Web pages, social networks, blogs, etc.) and data collected by "free" Web or mobile-phone applications is greedily collected, archived and analyzed. "If you are not paying for it, you are the product" says Jason Fitzpatrick on Lifehacker.com. Reducing privacy-losses, necessitating user-consent on data exploitation and rewarding the users for the value that their data generates to others, involves increased people's awareness on privacy issues, privacy loss assessment, data value estimation, privacy-related contracts, etc. Therefore, facing this challenge involves interdisciplinary research in networks, ontologies and data semantics, data security, privacy and multidisciplinary research in sociology, economics and law sciences. Otherwise, Internet runs the risk of being eventually transformed to a crowd/mass manipulation and exploitation platform.

JRA5: Big Data Privacy Markets

The proliferation of online social networking platforms and, in general, the increasing penetration of online services has created a digital footprint for each user, i.e., an abundance of online information. In other words, social media and social networks are sources of Big Data. This huge volume of data can reveal crucial information for the user habits, preferences and anticipated actions. Hence, under certain conditions, mining this big data has the potential to impact the privacy of the users. At the same time, this information can be monetized since, for example, it can serve as input for advanced user-profiling (consumer) methods. In this context, privacy and information are transformed to a commodity that can be traded in markets. On the one hand, users participating in such services may have concerns about their privacy and may be willing to pay for protecting their private information. On the other hand, the users may be willing to partially sacrifice their privacy, by disclosing a portion of their private information under proper compensation. Allowing each user to determine this privacy tradeoff is a key issue in the future Internet and a prerequisite for the successful deployment of personalized online services. In this context, there is need to study and design appropriate market mechanisms related to such type of information. These markets can be broadly classified to *markets for personal information* and *markets for privacy.* The former type of markets refers to the case that various companies and information-brokers aim to collect user preference information. Therefore, one needs to design pricing schemes for determining how much each user should be compensated for disclosing his information. Nevertheless, such information markets differ substantially from other commodity markets since information items exhibit strong externalities. For example, when a user discloses a certain item of information, the value of similar information previously disclosed by other users decreases. Similarly, markets for privacy, that offer privacy-enhancing services and products, need to take into account such dependencies. These particularities call for novel auction and pricing schemes tailored to the specifics of privacy markets.

JRA8: Prosumers' cooperation in Smart Grid

Smart Grid is a promising new concept to efficiently use all available energy resources in order to accommodate energy demands in a reliable uninterrupted manner. Internet technologies hold a significant role to the operation of the smart grid enabling real time communication and management of energy through the development of web based platforms (meter data management) and internet of things (smart meters, advanced metering infrastructure). One of the key aspects of the smart grid is the participatory role of the users. Users can have both the role of producer and consumer of energy, given the general term "prosumer". One interesting challenge would be to motivate prosumer cooperation based on sophisticated algorithms. The main goal is to provide automatic clustering of prosumers that can yield to a virtual power plant (a production entity of the energy network) which can have active participation to the energy market. A collaborative community of prosumers can share their residual produced energy and also dynamically enter the energy market by selling it in the grid utility. In that way, prosumers using internet platforms and automation algorithms will benefit from their cooperation but they will also build eco behavior. Other challenges here would be to provide the appropriate mechanisms in order to efficiently coordinate such communities and determine the energy allocation mechanism in the community as well as the framework for efficient establishment of bilateral contracts in the future energy market between prosumers communities and the grid. This direction is highly interdisciplinary and is based on the convergence of ICT with the energy sector. More precisely, it is based on distributed management and control, optimization, game theory, renewable energy sources and power networks. Concepts from sociology and notions of "trust" and "reputation" will also play a crucial role in the incentives created for prosumers communities.

JRA8: Water Awareness Campaign

One of the problems with existing information is its fragmentation. Usually, it is only available as project documentation, offering general overviews of projects and focusing on various topics besides awareness raising. Systematic exchange of awareness raising ideas is difficult. Much can be learnt by exchanging and comparing the experiences of very different initiatives within a sector, such as the water sector. There is a growing recognition of the importance of social norms and attitudes in the management of water. Recent main policy documents recognize the importance of awareness raising to influence these norms and values towards a more sustainable use of water resources. For example, the Water Framework Directive has established the drivers for public participation in water resources management; however, guidance on the design, implementation and management of appropriate tools, particularly ICT-based tools and processes to support such participation remains sparse. Public participation is usually realized through meetings of key stakeholders or public group representatives that protect their own interests, without actually including the "public" itself. It is clear that representatives of "public interest" groups could present their views of the public interest in most regulatory forums. But with the corresponding proliferation of "public interest" groups, it became increasingly less clear what the "public interest" in a particular issue was and who appropriately spoke for that interest. By now, it is becoming increasingly apparent that the public has a multiplicity of interests and that no single spokesperson can represent them.

An interesting question that should be addressed is: "who is the public?" A potential list of stakeholders is the following: a) interested individuals, b) local public interest groups, c) national public interest groups, d) regulated industry and trade associations, e) affected labor groups and f) competitors of the regulated entity. While it maybe easy for categories (c) through (f) to have a voice in water resources management, interested individuals and local public interest groups, especially those that are not computer savvy are usually left out. Furthermore, advancements in technology drive a perceived need for spatially and temporally distributed measurements to quantify complex earth system processes. The expansion of mobile phone/internet technology provides many opportunities to engage citizens in all levels of decision-making, getting them involved in the stage of public consultation and beyond. Studies have shown that for the public to respect a regulation, they have to get involved in its planning. This is especially true for rules and regulations that involve behavioral changes in people, such as household water use. The challenge here is to get everybody involved (even the ones that are not prone to the use of technology) and make them aware that they take part in the decision-making process. A good example is reaching out to farmers in poor regions in the countryside that are major water stakeholders but usually appear to be totally left-out from the decision-making process. Internet is the ideal way to reach out to all those people and raise their awareness on issues related to water and open up the decision-making process to everybody. Once this level of communication and this platform is established, people can have a constant stream of data and communication with authorities and such platform can be extended to a number of issues, such as raising their awareness on water or electricity use, or several similar issues, thus achieving and promoting sustainable living with lower environmental footprints. The problem is indeed multi-disciplinary, involving water managers, environmentalists, agricultural engineers, ICT and WSN specialists, software designers, as well as legal experts and sociologists.

JRA8: Enable sustainable living

Internet evolution led to smooth, effortless and non-invasive monitoring of people's every-day life, measuring data such as energy consumption, temperature, CO_2 concentration etc., taking advantage of smart devices that can be connected to the Internet. Data streams on traffic, noise, house energy consumption, user mobility, food consumption, etc. reach the user and inform him on individual carbon impact and its relation to that of others, e.g. family, friends, neighborhood. This challenge necessitates efficient data collection and online data processing at ultra-high scales. It requires Demand-Response systems to be employed that provide the user feedback on daily schedule changes that would enable more sustainable living. It needs information on user surrounding possibly collected by other users. Ultimately, aggregated data from various sources should be fused and transformed to useful information to the user for sustainable living through persuasive user interfaces. This challenge necessitates interdisciplinary research in sensor networks, cloud computing, databases, HCI, and multidisciplinary research in sociology, economics, electrical engineering, urban planning and more.

JRA8: Incentives, gamification and participatory sensing

Internet technologies, smart phones and social media platforms can provide a link for incentives, gamification and participatory sensing in various domains that are directly related to the environmental protection and the energy efficiency. Incentives are usually derived by discounts or tokens and are displayed in the internet platforms of the users, used to fulfill specific targets. One can be the case of demand response. Gamification is the procedure that the internet platform is used to manipulate the behavior of the user towards one specific direction through the participation of users in a game. It usually includes comparisons and efficiency competitions games. Participatory sensing is referred to the case where the user (and usually smart phones with sophisticated applications or additional sensors) is called to capture parameters that are important for the protection of the environment. This may include actual sensor readings or multimedia data. The user, in that case, is modeled as a moving sensor that can cover large geographical areas.

A relative challenge is the development of efficient incentives, gamification algorithms and participatory sensing solutions to provide environmental monitoring and energy management. This is an interdisciplinary research area and covers the case of ICT, user behavior, environment and energy. The risks associated to this area involve the efficiency of the coupling of existing infrastructure with the development of the proposed algorithms and techniques. In general, this area of research is expected to hold an important role of the future internet since it combines the internet of things, social networks, user behavior and environmental protection.

2-CNR (IT)

JRA1: Understanding the complex network of human social relationships for the design of Future Internet services

In the perspective of such an integrated cyber-physical world, a key aspect to design efficient Future Internet solutions is understanding the properties of human social relationships. In a broad range of cases, devices in the cyber world are actually proxies of their users in the physical world, which follow them in their daily routines and behaviour (e.g., smartphones constantly carried by users). Therefore, the structures and properties of human social relationships can be naturally translated into relationships between the users' devices, around which networking solutions can be designed. Social Pervasive Networks are a possible longer-term evolution of the pervasive networking paradigm enabled by the tight integration of the cyber and physical worlds. Assuming that the diffusion of pervasive technologies will enable, in principle, communication between any two users anytime and anywhere, the resulting network might in fact be formed by edges that correspond to communication channels activated because of a social relationship between two users, and only when those users communicate due to their social relationship. In other words, the network and the communication events between the devices might closely map the corresponding human social network and the interaction patterns of the users. In this perspective, a key challenge is how to represent the complex networks describing social interactions between users, on which Future Internet services can be based. While descriptions and models of some of these networks exist in the literature, scalable models to generate synthetic networks of this kind are missing. This is a very important research topic, because having models to generate these kinds of networks is an enabler to correctly assess the performance of Future Internet services deployed on top of them. This topic is highly interdisciplinary. It is fundamental to have a clear understanding of the properties of human social networks, in order to embed them in these models. In addition, it is very challenging to guarantee that generated synthetic networks can scale up to the size of at least tens of thousands of nodes, without breaking key properties that fundamentally characterize human social networks. With respect to conventional models to generate synthetic networks using complex networking theories, the key novel aspect is to embed knowledge about the different types of social relationships behind a link that connects two nodes.

JRA3: Collecting and analyzing large-scale datasets about human social behavior in the cyber and physical worlds

The worldwide proliferation of online social networks (hereinafter OSN) is rapidly introducing plenty of new means to create and maintain social relationships with others. Although these new ways to communicate are becoming part of our everyday life, we don't have yet a complete view on how they are impacting on human behaviour in the actual society, both in the physical (real) and in the cyber (virtual) worlds. Human social behaviour is commonly studied using a model for the representation of personal social networks, called ego network - i.e., a social network formed of an individual (ego) and the people with whom ego is in contact (alters). While the properties of ego networks in the real world have been deeply studied in the anthropology and sociological literature, OSN ego networks are not yet completely understood. Specifically, there is a lack of knowledge regarding the structure and the dimension of ego networks in the virtual world. In addition, the fundamental differences between the properties of OSN ego networks and the well known results about social networks formed in the real world (referred to as human ego networks) are still under investigation.

To this end, it is important to design and develop novel tools to collect large scale datasets about the social behavior of people, both in virtual environments and in physical environments. In principle, such datasets should allow researchers to link both dimensions, and study the interplay, correlations and differences between them. As a concrete example we consider designing applications for Online Social Networks (and most notably Facebook), which could allow us to download large-scale datasets about the social behavior of the users, and correlate quantitative data about this behavior with subjective evaluation of the users about the perceived strength of their social ties. In the first part of EINS we have developed a first prototype of such an application. The challenge is to extend it to scale up to large population of users, and refine it to be more attractive such that users can be motivated to contribute the logs of their Facebook interactions through some reward. Inter-disciplinarity is crucial to design the application, understand which data should be logged, and how to correlate information provided by the users.

JRA6: Charactersing the structure of social networks formed by humans in virtual environments

Online Social Networks (hereafter OSN) are one of the most important communication means that we use in our everyday life. They help us to maintain our social relationships with family and friends, as well as to enlarge our professional sphere and to acquire knowledge and new ideas from the network. OSN popularity is due to their ability to transform people into active producers of information, letting them create, access and share contents anywhere and anytime. These unique characteristics of OSN are producing strong effects on our society, but the extent to which they are impacting on human social behaviour is still unknown. Nevertheless, there is no doubt that their role will be of primary importance in our future. For this reason, studying people's behaviour in OSN is of great value to understand how the society is evolving and how we can contribute to the process, designing future OSN able to fulfill users' needs in terms of management of social relationships through digital communications. It is very challenging to acquire a deep understanding of the many properties of social relationships between users in OSN, and studying analogies and differences between online and offline social networks. One specific challenge to be addressed is to study the evolution over time of social relationships maintained in OSN by users. This can permit to carry out a sensitive analysis about the evolution of human social behaviour in OSN over time. This new approach to studying the dynamic properties of social relationships and networks can reveal many important aspects of OSN that should be considered to correctly understand their social properties. The analysis of the evolution of human social behavior in OSN has several practical implications. For example, it could be the basis of innovative applications that dynamically track the structure of the social networks of the users, helping people in the maintenance of their social relationships and suggesting possible actions to improve their social experience. Or, it could be used to classify users based on their dynamic behaviour, and use this classification as context information for customising other OSN applications. In general, it can be used for personalising the OSN applications experience to the specific dynamic social behaviour of the users.

JRA8: Smart Grids and the Internet of Energy

The term smart grid is commonly used to refer to a modernized electrical system which will permit new and more sustainable models of energy production, distribution and usage by: i) enabling the massive deployment and efficient use of distributed energy resources, ii) incorporating real-time distributed intelligence; iii) allowing demand-response and load shaping functionalities, and iv) fostering the electrification of transportation systems. In this revolutionary power system, energy will not flow anymore unidirectionally from power plants to the customers, but grid users will be both energy producers and energy consumers and the smart grid infrastructure must be capable of managing bidirectional energy flows. To some extent, there are fundamental similarities between the architectural model of the Future Internet and the reference model of the smart grid. To recognize those similarities is important because they motivate the adoption of Future Internet design principles when designing scalable, reliable and secure networking solutions for the smart grid. For instance, both the Internet and the power grid are witnessing a transition from a structure with a clear distinction between the core network and the access network (with almost all the system intelligence residing in the core) to a more federated system where the intelligence of the network (i.e., its ability to distribute, store, or modify information and energy, respectively) can be migrated to the periphery. Furthermore, both the Future Internet and the smart grid will by highly heterogeneous and wide-area complex systems, which must support various degrees of autonomous control at different time scales. In this vision, the smart grid will emerge as a true Internet of Energy (IoE) allowing units of energy to be dispatched when and where it is needed. Energy routers must be deployed in the smart grid to enable innovative paradigms for energy distribution and control, in which energy is logically packetized, buffered and forwarded over the physical energy network. We believe that flow-based congestion control algorithms, which have been commonly applied in large-scale information net- works will play a fundamental role in the design of autonomous control functionalities for the IoE. For instance, there are electric devices that can elastically adapt the amount of instantaneous power they need, such as many common household appliances. Then, those devices could intelligently increase/decrease their power demands depending on congestion feedback signals from the utilities. Furthermore, innovative ways of dispatching energy in a smart grid can be devised taking advantage of electric vehicles (EVs). For instance, we can use the batteries of EVs as a mean of physically moving electrical energy. Alternatively, EVs can supply back part of their stored electric power to stabilize the electricity produced by intermittent renewable energy sources. In this way EVs can support a delay-tolerant transfer of energy between grid endpoints. A new optimization is needed to solve the optimal energy delivery problem and to investigate the basic structure of the optimal energy delivery policy.

3-UNIBO (IT)

JRA8: Energy Consumption awareness @ Home

The availability of sensors and devices for environmental monitoring and energy consumption measurement connected to the Internet enabled recently a whole new set of possible actions to foster energy aware behaviors. The penetration of such devices and concepts has been to date mostly relegated to the industrial environment and is very limited in the residential environment yet.

Internet enabled energy consumption monitoring and control for residential user could exploit social media to share experience, promote virtual behavior, foster cooperative energy saving actions at the building, suburb, town level, especially if supported in some way by the local municipalities. Municipalities could play an important role by providing platforms to collect, merge and publish data in open format. On such data independent user groups and or energy providers could implement further processing and service design. In particular the results of cooperative actions by sensitive user groups could have a significant impact on the energy consumption habits of large user populations.

This is a field where IT technologies are well established already, while a very limited analysis of the user perception, interest and/or degree of acceptance is currently available, as well as limited analysis has been carried on about which kind of public policies could be implemented based on such concepts and which public value such policies could bring.

JRA6: What platform for what kind of e-participation?

The Internet may enable a new and wide scale involvement of citizens by means of distributed applications, but this achievement is possible only following the establishment of a broad societal trust in e-voting platforms. Standard technical solutions are still lacking in the e-voting field. The first widely deployed systems did nothing to improve the public perception of their security and even usefulness. A more scientifically rigorous approach to the design, implementation and testing of these systems is needed.

A comprehensive review of the instruments currently available - with emphasis on those from grassroots activism or open software community - should be carried out, followed by an identification of the “characteristics” shared by different systems.

The first challenge is to pinpoint specific characteristics to the existing platforms for e-voting and e-consultation that will influence the degree of adoption in different contexts. Specific aspects, among many, that are of crucial importance are the role of anonymity and identification mechanisms at play in different social and political contexts: without a clear understanding of these, citizens would rather lose the potential benefits offered by Internet-based consultations than leave the safety of well-established procedures.

JRA6: Is e-participation really perceived as new channel for participation?

Besides purely technical strength, an important aspect to take into account is that effectiveness is very closely tied to the "citizens perception" and "level of acceptance". Once the critical technical specifications for trustable and credible e-voting systems are identified, their usability as perceived by the final users should be investigated to infer which are the most effective technologies. The goal is to report the main successful case studies of e-participation. A medium-term research activity can be foreseen, starting from existing literature in different areas, identifying subjects suitable for interdisciplinary efforts, to pursue innovative research directions. The challenge should be aimed at diagnosing what are the advantages that have to be channeled through a proper institutional communication to make citizens familiar with e-participation, informed and willing to participate. This gives Internet Science a chance to be acknowledged, disseminated, and communicated.

4-UiO (NO)

JRA7 & JRA8: From Internet of Things to Internet of Data, Information, and Control

In the recent years we have witnessed the introduction of many new kinds of sensors that can be connected to the Internet and used for many application domains, like Smart Grid, Environmental Monitoring, eHealth and Ambient Assisted living to name a few. Research related to sensor based systems has been and is performed under umbrellas like wireless sensor networks, Internet of Things and Cyber Physical Systems. So far the sensor device has been in the foreground, as many titles suggest, but in the long term it is actually not about the sensing devices, but about the data they produce and for what it can be used. It should also be noted that the number of networked actuators is constantly increasing. This will lead to a new era in computing. From the beginning of computing the interaction between the computing device and the real world has been through human mediation (except specialized control systems). The Internet of the Future will enable large scale direct interaction between computing, i.e., cyber world, and the real world.

If the sensing and actuation devices themselves are not important for applications, but instead the data they can collect and which aspect of the real world they can control, it is just a consequent step to also look at other data sources and control nobs in the Internet. These could be network monitoring probes of various kinds for example network management purposes, but also data stored in data bases and data published on the web in newspapers, social networks etc. From a data management point of view it does not matter whether the data comes from an A/D converter (i.e. physical sensor) or a monitoring probe (i.e., logical sensor). It should noted that this point of view that aims to address real world and cyber world through the same concepts has been also brought up by Norbert Wiener in Cybernetics [Wiener 1961].

There are several big challenges to be solved to move from the Internet of Things to the Internet of Data, Information, and Control, including

- The four V's of data [IBM 2013]: Volume respectively scale of data is very large, i.e., Zetabytes of data; Varity of data because it comes in many forms, structured and unstructured etc.; Velocity of data because sensors generates data streams, e.g., in a single car there are more than 100 sensors; and finally Veracity refers to uncertain data, e.g, sensor readings impacted by noise.
- Integration of networking and data processing: one common idea is to move all data into the cloud and process it in the cloud. However, privacy issues and also to reduce resource requirements demand also in-network processing of data to derive useful information from data within the network.
- Control: feedback control loops are often closed systems, this is not the case in the future Internet. Furthermore, to properly actuate a system domain knowledge from the application domain is

needed. As such only interdisciplinary approaches can be successful to build and maintain smart self-controlling systems, like smart grid, smart houses, or elderly care in Ambient Assisted Living.

Any solution for these and other future issues related to an Internet of data, information and knowledge will contribute to the usefulness, robustness, and efficiency of systems and applications and finally contribute to sustainable solutions for humans that increase their safety and well being.

References

[Wiener 1961] Norbert Wiener: "*Cybernetics: Or Control and Communication in the Animal and the Machine"*. Paris, (Hermann & Cie) & Camb. Mass. (MIT Press) ISBN 978-0-262-73009-9; 2nd revised ed. 1961

[IBM 2013] IBM Global Business Services, Business Analytics and Optimization, Executive Report: "*Analytics: The real-world use of big data: How innovative enterprises extract value from uncertain data*", Document Number: GBE03519USEN, 2013

6-iMinds (BE)

JRA1: Integration of network knowledge/analytics into existing Internet routing infrastructure

The Internet routing infrastructure suffers from design choices, which have been made decades ago. Sequences of patches and extensions have been proposed to routing or signaling protocols in order to cope with required additional functionality, changed usage contexts, or to improve performance. Whereas these have solved immediate issues, in many cases they have introduced others. As a result, the routing system is more complex to operate and still lacks essential functionality such as enforcing routing profiles based on time patterns (e.g., day vs. night routing). While initiatives such as IETF I2RS are planning a first step to tackle these, an even more interesting set of patterns, such as network congestion patterns, traffic demand patterns or network attacks, would be equally or more valuable to integrate into them the routing system.

It remains an open challenge on how to improve the flexibility of existing routing systems. Although, elements seem to be available: i) radical, clean-slate (machine) learning-drive routing systems (e.g., AntNET, Cognitive Packet Networks), ii) capabilities to learn network patterns (e.g., anomaly detection systems), up to now, none of these methods are really integrated in current operational networks of ISPs. However, the ever-increasing network demands in terms of QoS, power consumption and security, stresses for novel methods which benefit from available network research. Network pattern analytics will enable to detect complex traffic behaviors as those induced by big content players like Google or Akamai, or learning from power consumption behaviors of networking systems. The capability of automatically translating data analytics into routing configurations to improve the overall performance of the network and reduce operational costs, is strongly missing in current routing systems.

JRA2: How to evaluate a telecom network's business model in a quantitative way?

This research challenge aims at developing a suitable methodology for quantitative evaluation of a telecom network or ICT service business model. The question to be answered is: is the network of service, which is technically feasible also economically viable? In the liberalized, fast evolving Internet market business models have become more difficult to grasp. Related business cases have become very difficult to estimate quantitatively. Considering the ever-increasing importance of the Internet market, both the relevance and the complexity is expected to grow even further.

The methodology to be developed will need to combine different disciplines: technology, economics and customer adoption. This includes estimation of costs and revenues based on either a top-down or a bottom-up approach. The techno-economic evaluation starts from an investment analysis study for all actors (based on estimated adoption and costs). Essential part of the new to be developed methodology is the multi-actor setting, where the actors have potentially different objectives. The Internet forms a very specific multi-actor setting, where technological as well as economic reasons lead to the existence of different platforms and where ownership is spread amongst public and private players, in a lot of cases subject to regulation or definitely strong policy impact.

JRA5: How do we measure users' everyday practices related to privacy with regard to third party use of personal information?

Surveys have been used to map users' attitudes and increasingly also their literacy towards privacy in social media. These results remain self-proclaimed and are therefore prone to involve an overestimation of the actual skills and practices of users with regard to privacy. One of the solutions to counter this issue is to conduct experiments where actual behaviour is measured and observed. Although these experiments are based on observed behaviour, they also remain biased because they take place in a controlled environment away from users' everyday practices.

This could be solved through a combination of logging and qualitative research where users are being followed as they interact with third parties who request their personal information as an obligatory point of passage. This approach requires the cooperation of application developers because these would have to explain what data is demanded from users, but also when application adoption drops because of too much information queries (if we want to research everyday practices). On the other hand the qualitative research will have to be coupled to these results. This requires us to find particular respondents that are using the application and have shared certain information or chose not to use the app because of its perceived invasiveness. This last category will prove most difficult to interview, but also one of the most interesting.

JRA6: Towards ad-hoc virtual communities

In the beginning of Internet science virtual communities were seen as a reflection of offline communities acting in an online environment. Not only similar subdivisions were made (community of practice, community of interest…), the Internet technology was in the first place an enabler to scale up – both from a geographical point of view (the globe was in reach) as from an entry point of view (the internet lowered the barriers to step in or to be part of a community were, due to the level of anonymity and distance). However, today communities are being challenged. Due to new mobile technologies, sensing devices and big data analysis, combined with an always mobile connectivity, communities are being formed on the spot. We already see with social location based services ((LBS) such as foursquare for example) that communities are being constructed based on the time, location and activity of the user. The user will constantly and seamlessly be hopping from one community into the other. It is therefore important to investigate how this has an impact on the users on the one hand and the concept of (virtual) communities on the other. The research of communities will therefore have to focus, more than ever, on the boundaries of communities, on how new future internet technologies as LBS impacts this concept (erode or enhance) as well as on the elements that bounds people into one or more communities. In order to investigate a longitudinal, multi-method approach, combining various qualitative methods with big-data (based on log-files), is required.

JRA8: How can we create a sustainable Future Internet?

We estimated that over the last five years, the yearly energy consumption growth of ICT in general and the Internet in particular is higher than the growth of the worldwide electricity consumption in the same time frame. The combined electricity consumption of three important ICT categories – i.e. communication networks, personal computers and data centers – is growing at a rate of nearly 7% per year (i.e. doubling every 10 years), with the strongest growth observed in communication networks, which is the basis infrastructure of the Future Internet. In 2012 each of the three ICT categories mentioned above, accounted for roughly 1.5% of the worldwide electricity consumption. Taken together, the relative share of this subset of ICT products and services in the total worldwide electricity consumption has increased from about 3.9% in 2007 to 4.6% (or 900 TWh) in 2012.

The above observations highlight the need for research – both technical and user oriented – on energy-efficient and sustainable technologies across all ICT domains. As ICT can also reduce the energy consumption in other sectors, an increased consumption of ICT can be justified as long as its grow rate is not increasing exponentially. A further intensification of measures and research towards sustainable technologies combined with the current shift to smaller/mobile devices could lead to a reduced growth rate of electricity consumption by ICT in the coming years. In the future, frequent estimates of the worldwide electricity use by ICT will be essential to provide timely feedback if indeed ICT electricity consumption remains relatively small, or instead continues to grow at an unsustainable rate.

7-UoP/ UNI PASSAU – University of Passau (DE)

JRA7: Understanding the relationship between redundancy and resilience in networks

In order to increase fault tolerance, redundancy is typically employed. In networks this may encompass the addition of redundant nodes and links to be able to tolerate single node and link failures. The Internet is a prime example of this approach in the sense that between any two nodes in the Internet there are typically a multitude of possible paths for communication such that failure of a single node or link will not inhibit communication. As such, the Internet is quite resilient to failures and it has been demonstrated in the past that failure of single links or nodes will have local effects at most. With communication becoming more and more important also for other kinds of networks (e.g., power grid, utility networks, etc.) there is one the one hand a need for a highly reliable communication network (and thus the question, whether the Internet can fulfill that role). On the other hand, it might be beneficial to retrofit the resilience concepts of the Internet to other critical networks and infrastructures.

There are, however, several important topics to be considered here. First, there is obviously a tradeoff between adding redundancy and minimizing cost (both OPEX and CAPEX). This also encompasses resource- or energy-efficiency, considering that additional equipment operating as a hot spare will consume resources and possibly energy. Second, the question remains, at which point redundancy (i.e., an additional node or link) should be added to maximize the gain in resilience. Third, it is known that in some cases redundancy can actually decrease performance (e.g., Braess's Paradox) and, thereby, possibly resilience. A better understanding of where and how redundancy can increase overall network resilience thus remains an important topic for further research.

8-TUM (DE)

JRA5: Secure Server Identities in the Web

Recent years have seen many cases of attacks on the certification process. Overall, the security model that any broken certificate authority (CA) can issue certificates for any site leads to a weakest link security situation, exploitable by hackers or rogue states. A variety of proposals try to mitigate the problem, most notably certificate pinning with TACK and certificate transparency to better control misbehaviour or faults of certificate authorities. It remains unclear if the browser taking control and refusing to continue communication in case of suspicious keys and certificates will be generally accepted. A fundamental problem analysis of the overall problem would need to include analysis from multiple disciplines ranging from security to economics.

JRA5: Secure User Identities on the Internet

The request of usernames and passwords for each site are still most common on the Internet, usually with a lot of reuse of one or few passwords on many sites. Identity Federation tries to resolve that problem, yet organizational and trust boundaries seem to limit its application. A federated identity in information technology is the means of linking a person's electronic identity and attributes, stored across multiple distinct identity management systems. Related to federated identity is single sign-on (SSO), in which a user's single authentication ticket, or token, is trusted across multiple IT systems or even organizations. SSO is a subset of federated identity management, as it relates only to authentication and is understood on the level of technical interoperability. Recent developments include reusing Facebook or Google accounts on other sites, which allows them to track users and reduce their privacy even further. Moreover, multiple social identities and lives of users also prohibit a more widespread usage of such forms of identity federation. Password safes, in particular in web browsers are another option, yet also limited in their security.

10-ULANC (UK)

JRA7 The Internet as Critical Infrastructure: socio-technical issues.

As the Internet replaces specially deployed data networks to become the carrier for an increasing number of critical applications - such as financial data transactions or security operations - the impact of failures in its operation can become dramatic. Essentially, the Internet has become a critical infrastructure, though it was not designed for this purpose. It is therefore imperative that we integrate technical, economical, sociological, political and legal viewpoints and expertise in addressing the criticality of the Internet infrastructure and the challenges that may arise from usage patterns, technical faults, local political decisions or malicious attackers. But making critical infrastructure systems inherently reliable and safer is more than a simple, or even a complex technical problem. What a range of studies of critical infrastructure failure has illustrated is that such complex systems also have important organizational and human components that need to be understood and integrated into design. Rinaldi et al (2001) identify six dimensions - the technical, economic, business, social/political, legal/regulatory, public policy, health and safety, and security concerns - that impact on critical infrastructure operations and have the potential to influence social well-being and aspects of everyday social and organizational life. Accordingly we seek a mix and wide range of interdisciplinary, technical and social understandings the Internet as a critical infrastructure.

Ref: Rinaldi, S. M., Peerenboom, J. P., & Kelly, T. K. (2001). Identifying, understanding and analyzing critical infrastructure interdependencies. *Control Systems, IEEE*, *21*(6), 11-25.

JRA7 Cybersecurity risk and protective social objects

An important area is cybersecurity risk and protective social objects, which aims to combine knowledge and insights in computer science (especially resilience and security in computer networks) and management science (especially organizational failure and risk analysis). It is concerned with risks to cybersecurity, but less with the strategies of attackers and more with the actions of benign agents that undermine the risk controls intended to forestall the attackers. In particular it is concerned with the use of social objects to protect systems. At some point all technical systems are dependent for their security on a social system. They rely on acceptable use policies, authorisation levels, user roles, passwords, rules about choosing, protecting and (not) sharing passwords, rules about non-disclosure, rules not to leave systems logged on and so on. These are all social objects, and only function - as rules for instance - because there is some collective intention that they function as such. And this collective intention sometimes fails, typically for reasons that are socially adaptive. A group of users may agree to leave a terminal logged on, for example, when their work requires urgent responses and logging back on is time consuming. The aim of this work is to investigate how we can reason systematically about the operation and vulnerability of the social objects that protect against cybersecurity risks. This will involve developing ways of representing the functioning of such objects, ways of measuring exposure and resilience, and ways of methodically designing systems to be more resilient. It will involve getting to grips with the background both in computer network security and in risk analysis, development work to produce a prototype formalism and supporting editor, and fieldwork to investigate likely areas of application such as industrial SCADA systems and telecommunications networks.

Ref: Busby, J.S. and Bennett S.A. (2007). Loss of defensive capacity in protective operations: the implications of the Überlingen and Linate disasters. *Journal of Risk Research*, 10, 3-27.

12-OII (UK)

JRA5: Secure Server Identities in the Web

The recent years saw many cases of attacks on the certification process. Overall, the security model that any broken certificate authority (CA) can issue certificates for any site leads to a weakest link security situation, exploitable by hackers or rogue states. A variety of proposals try to mitigate the problem, most notably certificate pinning with TACK and certificate transparency to better control misbehaviour or faults of certificate authorities. It remains unclear if the browser taking control and refusing to continue communication in case of suspicious keys and certificates will be generally accepted. A fundamental problem analysis of the overall problem would need to include analysis from multiple disciplines ranging from security to economics.

JRA5: Secure User Identities on the Internet

The request of usernames and passwords for each site are still most common on the Internet, usually with a lot of reuse of one or few passwords on many sites. Identity Federation tries to resolve that problem, yet organizational and trust boundaries seem to limit its application. A federated identity in information technology is the means of linking a person's electronic identity and attributes, stored across multiple distinct identity management systems. Related to federated identity is single sign-on (SSO), in which a user's single authentication ticket, or token, is trusted across multiple IT systems or even organizations. SSO is a subset of federated identity management, as it relates only to authentication and is understood on the level of technical interoperability. Recent developments include reusing Facebook or Google accounts on other sites, which allows them to track users and reduce their privacy even further. Moreover, multiple social identities and lives of users also prohibit a more widespread usage of such forms of identity federation. Password safes, in particular in web browsers are another option, yet also limited in their security.

13-TUDelft (NL)

JRA1: Spectra of large graphs

A graph can be represented as an *N*x*N* adjacency matrix, where *N* refers to the number of nodes and an element a_{ij} in the matrix is 1 if there is a link between nodes *i* and *j*, and 0 otherwise. One interesting corner stone in linear algebra is the spectral decomposition of a matrix, which enables us to write a matrix in terms of its eigenvectors and eigenvalues. The eigenstructure or spectrum, the ensemble of all eigenvectors with their corresponding eigenvalues, reflects the characteristic underlying properties of the matrix.

The theory of graph spectra refers to the application of spectral theory to matrices associated with graphs. Just as with Fourier or Laplace transforms, some network or graph problems are more easily and/or efficiently solved in the topology domain than in the spectral domain, and vice versa.

In the following, we list several challenges (or shortcomings) of spectral graph theory:

- *Meaning*. What is the meaning of an eigenvalue and of the eigenvectors? The interpretation and "physical" meaning of the eigenstructure is a fundamental, open question in network science.
- *Theory*. While most results concern the extreme eigenvalues (largest/smallest and second
- largest/smallest), little is known about the other individual eigenvalues, except for special graph types whose spectrum can be computed analytically.
- *Directed graphs*. Most complex networks are directed, resulting in an asymmetric adjacency matrix. The power of spectral graph theory lies in symmetric matrices, whose spectrum is real. In general, the spectrum of a directed graph is complex. Moreover, some asymmetric matrices even cannot be diagonalized. These complications may question whether spectral graph theory is still the correct tool to extract network information or for which cases it is the correct tool.
- *Weighted graphs*. Links and nodes are generally different and must be weighted differently. Given that the weights (delay, capacity, load, financial cost, …) on network links are known, spectral graph theory is, in most cases, valid, provided symmetry is not destroyed. The more challenging aspect is determining or measuring the weights of links in large graphs.
- *Large graphs*. Most complex networks contain many nodes. Assuming that a complete description of the network is available, the computation of the spectrum is a challenge for numerical analysis.

JRA1: Nature-inspired networking

A network consists of a topology specifying the nodes and their inter-connections (links) and a function for which it is designed, e.g. power transport. From a network design point of view one could ask the following research questions:

- How should the power grid/Internet evolve in a self-adaptive way in order to maintain robustness against electrical blackout/malware?
- How can individuals adapt their social contacts to prevent a wide spread of epidemics?

Nature-inspired networking, i.e. "how to design robust man-made networks inspired by nature", provides a promising direction for the following reasons:

- Man-made networks like the Internet and power grid have become complex and large in size. Although distributed solutions have been incorporated in e.g. traffic control, these infrastructures are often inflexible or centralized. Fully distributed design has been limited due to the lack of a deep understanding of a complex system with an amazingly large number of interacting components.
- Nature with its superior self-adaptivity and robustness enhances the design of man-made networks. In the brain, for example, the co-evolution where a synchronization process alters the neural connections is crucial for normal development, learning and repair of damage. Topological properties like small-world, scale-free degree distribution are widely observed in real-world networks and brain networks of various organisms. The brain's robust co-evolution and its similarities with other complex networks in topological properties is a motivation to explore how brain-inspired network co-evolution may lead to desirable network properties.
- With the development of measuring techniques and correspondingly the availability of big data, we could better understand how nature works.

The field of nature-inspired networking would benefit from a multidisciplinary approach combining network science, mathematics, and statistical physics, and could proof useful in diverse application domains ranging from communications networks, biological systems, social networks to economic systems. One key challenge is to determine the right abstraction level of viewing complex systems to find coherent and universal dynamic processes, which allow the knowledge transfer across systems.

JRA5: Privacy, trust and reputation management

The field of privacy, trust and reputation management is simultaneously pursued by a number of disciplines. This short summary lists a number of open questions from the computer science perspective:

- How do you measure privacy, trust and reputation? A common measurement framework is needed to evaluate research contributions for privacy enhancement and trust-based transaction.
- What is the value of privacy to the population in general? What people freely share on the Internet varies drastically between people - which elements are considered private, what is the driving factor between these differences?

- To what extent does reputation and trust influence the conductivity of online marketplace and transactions? What are methods to capture and communicate the level of trust inside such systems?

JRA7: Network robustness metrics

- Metrics are by definition always a reduction of information; there is no single metric that can assess the state of the entire network. The question hence becomes how to pick metrics that capture a particular behavior best, in other words that are suited as a basis for resilience optimization. This in turn however raises two important concerns: a) how do we choose metrics so that they give a representative picture of a complex layered system and do not fall prone to observation bias and b) how confident can we be that if one does not measure something, it also means that it is not there?
- When choosing metrics, it should be possible to have a small reference set: First, because while a large number of metrics will certainly encode more information, it will also be more difficult to spot the relevant information. Second, it would be beneficial to obtain a reference against which network planning and mitigation approaches could be benchmarked.
- As a more specific problem of metric selection, more study is needed to investigate the orthogonality of metrics, i.e., making sure that each metric captures a different aspect of the underlying system. If such an orthogonality is not given, certain operating states will naturally be under- or overrepresented in a robustness analysis.
- While cross-layer optimization (specifically in wireless networks) has received a large amount of attention over the past decades, there is still (too) little insight in the interactions of different layers from a resilience perspective. Specifically, would a particular mitigation strategy in one component of the system strengthen or weaken the features or resilience schemes in another?
- Finally, how should we evaluate robustness in general and what should be seen as sufficient? This is a difficult question per se (similar as in the field of security); does it make sense to quantify a hard value, given that the entire challenge space is not known?

JRA8: Energy-efficient routing

Much effort is being devoted to becoming more energy efficient and sustainable. Since energy is of key importance, there is a dichotomy between robustness and security on one side and privacy and efficiency on the other. This becomes even more pronounced when one has to deal with multi-domain networks, where (ICT, energy, …) network providers are reluctant to share information on (the energy use of) their devices. Often a fine-grained energy profile for their network is not known and if it would be, then the question of what information and how to distribute it needs to be addressed. Hence, tools and models are needed to exchange energy information in a multi-domain network environment.

Within the realm of communications networks, recently two new (and complementary) technologies have drawn significant interest, namely Software Defined Networking (SDN) and Network Functions Virtualization (NFV), where the networks move towards more programmability and the network services are becoming more virtualized. This enables a more flexible form of networking in which potentially energy objectives could be translated into network configuration policies. How network programmability and virtualization can help to become more energy efficient needs to be studied.

The present lack of (multi-domain) real-time knowledge makes it impossible to manage the network and its traffic in an energy-efficient manner and to define (SDN/NFV) algorithms/protocols that could leverage this information. Clearly, the development of suitable energy-efficient algorithms and protocols is also a challenge.

14-SUSSEX (UK)

JRA4: Regulating Code – Governance and Internet Science

Internet regulation is a paradigmatic challenge for traditional governance processes, due to the unprecedented speed of technological change, market adoption of disruptive technologies, fundamental political and rights challenges to existing regulated technologies, and degree of 'prosumer' and stakeholder input into regulatory and governance design. During the period of the Internet science project alone, there have been extraordinary challenges to European citizens' trust and security online (notably revealed online by Wikileaks and Glenn Greenwald's reporting of Edward Snowden's revelations), the use of the Internet for political communication (notably via Twitter which has grown about 200% in the 2 years of EINS), and the proposed European Regulations on data protection and *ConnectedContinent*. Enhanced policy adoption of the academic insights offered by a holistic Internet science approach to inform law and policy has been widely recognized. JRA4 itself, as the most publicly 'mature' of the research communities inside EINS, moved from documenting and analyzing the key issues in Internet governance-regulation in 2012 to engaging very intensely with stakeholders in 2013, and this engagement will continue to intensify in 2014.

JRA4 was 'born' as an interdisciplinary collaboration, with the book 'Regulating Code' written in Year Zero of EINS in 2011-12, and published in March 2013. It was authored by JRA4 leader, lawyer Marsden, and JRA5 leader, computer scientist Brown. An article based on the book was published in the Proceedings of the 1st Internet Science conference. Publications from the book have continued throughout 2013, for instance at the IEEE SIIT conference. Marsden chaired a session on cloud/big data at the Society for Computers and Law 7th Annual Policy Forum at Herbert Smith LLP, before an audience of City law firm partners and others, and in 2014 the 8th Forum will be chaired by Brown (JRA5) supported by Marsden (JRA4).

In order to address public policy concerns about governance of trust and regulatory approaches to assuage public concerns about their Internet usage, the collaborations between JRA4 and JRA5 have continued throughout the project, with a joint workshop in Oslo hosted by Lee Bygrave of JRA4 in September 2012, and joint co-chairing of the Internet Science-Web Science workshop in Paris in May 2013. The 2014 SCL Policy Forum will be a further such collaboration.

Many public concerns about Internet regulation (and trust) relate to their use of virtual communities. JRA4 has also closely collaborated with JRA6, a 'natural' outcome of their shared leadership by Sussex and shared research assistant in Ben Zevenbergen since September 2012. JRA4 hosted its official workshop in Indonesia at the UN Internet Governance Forum in October 2013, and a JRA6 speaker (David-Barrett) explained how analysis of Internet governance could be conducted using quantitative and qualitative metrics based on evolutionary interdisciplinary science (notably neuroscience and evolutionary economics).

Finally, standardization provides the underpinning for enabling more trustworthy and citizen protective regulation of users' behaviours on the Internet. Note the extremely close collaboration between JRA4 and SEA2, with Alison Powell bridging the two projects. Marsden (Sussex) met with Neidemeyer (TUM) and Powell in August 2013 to plan the 'Internet Governance' month series of 16 blog posts which had over 2,000 views. Marsden (Sussex) personally authored two of the entries. Marsden also posted 22 blog entries on the Internet Science blog itself, with Zevenbergen posting a 2000-word report on the United Nations workshop: http://internet-science.eu/blogs/24-10-2013/631

The challenge of the Internet for traditional regulatory and governance processes was also raised by JRA4 partners (notably Sussex) in keynotes at key stakeholder events in 2013 such as the Council of Europe (May); European Parliament (June); 9th International Conference on Internet, Law & Politics (June); United Nations Internet Governance Forum (October); United Nations Economic Commission for Latin America (October); 8th International Conference of Information Commissioners (September); DG CONNECT Co-regulatory Agora (December). There is confirmed extremely close interest in Internet Science from government and corporate stakeholders.

2014 is the year in which D4.2 is delivered (January) and D4.3, our final deliverable (December), but will also mark an intense year of mobility visits by partners, and collaboration with other JRAs and external stakeholders. Policy actors are becoming significantly more aware of the benefits of using holistic scientific advice to address their policy concerns, in order to provide proactive rather than reactive regulation and governance strategies for Internet users.

JRA6: Measuring Virtual Communities' Interaction as a 'Living Lab'

To understand virtual communities holistically requires intensely interdisciplinary examination that must be based on quantitative and qualitative criteria. This is the major methodological challenge for those studying virtual communities, and despite some recent research to the contrary, our strong working assumption is that virtual communities typically arise from, and respond to, offline communities. The history of Internet-based communication is also a history of the rise of virtual communities, tied into the geographic penetration of access to the Internet, and therefore creating a symbiosis between online and offline experiences.

Recognising that the Internet Science network is an artefact of virtual community, and that its membership is designed expressly to create interdisciplinary collaboration between computer scientists and social scientists, the aim of JRA6 is to explore that 'living lab'. The results of our research are delivered in three ways:

- in the collaborations already planned and undertaken to date, in which concentrations of quantitative and qualitative research clusters can be readily identified (see D6.3.1);
- in the increased collaborations between and across the range of disciplines, some of which can already be identified (see Brown/Marsden 2013, Dini/Sartori 2013, and the range of outputs of Passarella, Crowcroft and Dunbar) which will increase as further collaborative activity develops through EINS;
- in exploring through a specific case study the development of Internet Science as a community of researchers based on a developing methodology of integrating quantitative and qualitative indicators .

It is this last exploration which is the Internet Science attempt to further develop the 'Holy Grail' of interdisciplinary research, to bridge successfully between disciplines in a manner which enriches both quantitative and qualitative method, while explicitly acknowledging the normative dimension of our work. In this, we expect to provide the foundations for Internet Science's original contribution to the wider arena of scientific endeavour, and our further work packages will take this work forward. This will require substantial input from, and collaboration with, other JRAs, notably JRA1/2/3/4/5, as well as partners funded through the 'Open Calls' in 2013, and other funded parties such as the CAPS programme.

An example of an area in which qualitative-quantitative interaction needs measuring is multistakeholder governance of the Internet itself. The proceedings of the JRA4 United Nations workshop in October 2013 made clear that measuring the impact of the multistakeholder approach to Internet governance is a challenging academic and urgent practical task. Although the exchange of ideas at the Internet Governance Forum, along with the social aspects and networking opportunities between stakeholders are important for mutual understanding in the complex process of Internet Governance, it remains important to find out to what extent the different variations on multistakeholder has an effect on real standard setting and policy making, which influences daily use of the internet. The discussion on metrics and methods to measure the impact of the multistakeholder approach in Internet governance has only commenced at the IGF2013 and will be continued in more depth in JRA4 working in partnership with JRA6 and other interested parties.

In D6.3.1 (June 2013), which Sussex led, JRA6 systematized the vast and heterogeneous body of knowledge produced by different disciplines thus proposing some overarching dimensions along, which classification can be made across traditional disciplinary boundaries, summarising the literature in the field, notably that from sociology, media and communication, evolutionary neuroscience and economics, psychology and regulatory theory.

17-EPFL – École Polytechnique Fédérale De Lausanne (CH)

JRA1: Integrating a network of data sources

With the exponential growth of the Internet, more and more online services enable users to upload and share structured data, including Google Fusion Tables[4], Freebase[5], and Factual[6]. These services primarily offer easy visualization of uploaded data as well as tools to embed the visualization to blogs or Web pages. As the number of publicly available datasets grows rapidly and fragmentation of data in different sources is a common phenomenon, it is essential to create the inter-links between them. An example is the often quoted coffee consumption data found in Google Fusion Tables, which is distributed among different tables that represent a specific region. Extraction of information over all regions requires means to query and aggregate across multiple tables, thereby raising the challenge of integrating a network of data sources, namely crowdsourced data integration. The goal of crowdsourcing data integration is establishing inter-connections between the data from multiple sources to achieve a unified view.

The tradition approach is defining a common standard and matching each data source against this standard. However, this approach is irrelevant for crowdsourced data integration because of two main reasons. The first reason is about heterogeneity. Since crowdsourced data are collected from a wide variety of sources, they have different formats and quality. Therefore, defining a common standard becomes an extremely difficult task. The second reason is about big data phenomenon. The common standard needs to be updated when a new data source is integrated. This is impractical since the data arrive frequently. Therefore, we model crowdsourced data integration as a *graph-based matching network*, in which data sources are directly matched against each other without going through a common standard.

The model of graph-based matching network is built on top of graph theory. We leverage theoretical advances in this field to deal with many challenges such as: network partitioning, network clustering, network evolution, and network evaluation. If these major obstacles are addressed effectively, users are benefited from Web-based collaboration in publishing and consuming data.

JRA5: Trust in social recommendation

The large amount of data generated everyday on the Web, on the one hand, provides rich information for users to consume, but on the other hand, also easily overloads users if no appropriate tools are provided to process such huge information for decision making. By suggesting information that is

4 tables.googlelabs.com

5 freebase.com

6 factual.com

likely to interest users, recommender systems have become a promising tool to handle information overload in many application scenarios such as e-commerce, social media, Q&A systems, etc. Utilizing social network information to improve recommendation quality has recently become very popular, where the basic idea is to leverage opinions of users' friends who are assumed to share similar interest and taste (i.e., a friend's recommendation is reliable than a stranger). However, in reality, social relationships are complex and social networks are heterogeneous. For instance, users are connected in online social networks with different purpose, reflected by offline social networks, such as friendship, colleagueship, business partnership, etc.; different friends may have very different opinions on the same item (i.e., different recommendation), and the extent of such opinion diversity may be also subject to certain context; social relationships and users' preference may involve overtime, where a friend's good recommendation in a few weeks ago may not be suitable in present situation.

These challenges of heterogeneous social information, if are carefully addressed, make the social recommendation approaches a useful tool to provide accurate recommendation in real world applications where social networks play an important role. On the other hand, trust modeling provides an alternative way to model the relationship between users at a finer granularity, thus is a promising method to cope with heterogeneous social relationships. Furthermore, the rich contextual information could also be utilized to improve the user similarity measure.

JRA5: Privacy in the Cloud

Cloud computing has become an essential part of people's electronic life. Services such as online file storage, collaborative document editing, music streaming, and photo browsing are just some examples of what the traditional users are utilizing in their everyday life for personal or professional purposes. With the increased dependency on the cloud as a medium for storing and managing the data a user shares, concerns have surfaced about the privacy of such data. So far, some cloud computing companies have addressed these concerns by providing users with the option of client-side encryption to protect their data on the cloud. Evidently, this encryption currently precludes the possibility of obtaining any services, other than storage and synchronization, based on user's data. Therefore, the user has to manually manage this tradeoff between maintaining privacy and utilizing services via specifying privacy settings for each group of data items.

Nevertheless, the majority of users are not experienced enough to select the adequate privacy settings, and even experienced users find it cumbersome to specify individual settings for each item they outsource to the cloud. Therefore, research is required on the problem of automated privacy risk management in personal cloud computing. This problem can be divided into two parts: risk estimation and risk mitigation. The former involves quantifying the risk of data sharing, in order to first inform the users about it and to also compare the risk of different privacy policies in the risk mitigation step.

The latter can be accomplished by recommending optimized privacy policies to the user, thus relieving the user from the burden of thinking of the policy to match the privacy-utility tradeoff she envisions.

It should be kept in mind that the attitude towards privacy differs from one user to the other, ranging from introvert attitudes to extrovert ones. Hence, managing the privacy risk should be tailored to individual users' privacy attitudes. In fact, understanding and measuring such attitude is one important part of this challenge (of providing privacy to users). We cannot solely rely on users to declare their privacy preferences due to the well-known dichotomy between users' reported values of privacy and actual behavior, referred to as the *privacy paradox.*

JRA8: Behavioural demand response

Managing peak electricity usage and increasing the share of renewable energy in the electricity pool is crucial for fulfilling CO2 emissions reduction targets, while keeping the grid running with the necessary level of reliability. Demand response (DR) refers to a set of dynamic demand mechanisms that aim at managing consumption of electricity in response to supply-side signals. DR is often carried out through direct load control (DLC) by the DR service provider. Nevertheless, DR can also be based on indirect methods that aim at influencing the consumer to behave differently through incentives, real-time information, or dynamic prices. While with DLC the expected outcome of a DR signal is measurable and quantifiable, with indirect methods the outcome is less predictable, as it depends on the behavioural response of the consumer. Although the residential sector makes up 20% of total energy demand and 60% of peak load demand, it still remains an untapped resource. The financial incentives for residential facilities to participate in DR (e.g., savings on the monthly bills) are not very lucrative, which results in low engagement of residential consumers. Another reason that keeps residential consumers out of DR is privacy and security. The concerns about the possibility of a “Big Brother” control of appliances, with external entities, either legitimate or not, may take control of the energy consumption of the house, is a deterrent for widespread involvement of residential consumers in DR programmes. Finally, decreased responsiveness (i.e., “demand fatigue”) is another concern. Proof of that is the fact that most operational experiences of indirect DR are usually designed to call for load reductions over a low number of days or hours of the year, in order to minimise the likelihood of an exit from the DR programme.

To overcome all these barriers that limit a widespread adoption of residential DR, new innovative solution concepts are needed to drive energy consumers along new behavioural paths. Behavioural sciences and information technology must come together to find methods and technologies that are able to trigger the motivation and to support the ability for pursuing a behavioural change that is sustainable in the long run. Gamification (i.e., the use in non-game contexts of the engagement mechanisms common in popular games), social collaborative campaigns, user-centric information feedback supported by intelligent analytics can all be suitable means to provide personalised insights that motivate consumers towards the desired energy behaviour.

19-NKUA (GR)

JRA6: Socio-psychological incentives for cooperation in online collaborative applications

Online collaborative systems, realized through social networking and enabled by the growing number of mobile sensing devices, are currently viewed as a promising vehicle for unlocking the tremendous potential that technology-enabled, highly-connected, distributed and participatory human beings can bring about for the benefit of the society and the environment. To render these highly distributed, user-centric, socio-technical systems efficient and survivable, we need to better understand a number of issues. The different instances of online collaborative systems largely rely on the collaboration and contribution of human beings with very different mixtures of personalities, attitudes, socio-psychological and cognitive biases attributes. Indeed, their behavior is exposed to social influence and their decisions are shaped by the real and virtual communities they participate in, being, also, subject to time constraints and human inherent computational and knowledge limitations.

Thus, in such emerging user-centric networking paradigms, collaboration of network members cannot be taken for granted. In fact, end-users may exhibit a rich set of behaviors, ranging from greedily selfish to fully altruistic. One key challenge is, on the one hand, to understand the cognitive task of the users that deal with this kind of collaborative systems and the processes that underlie the opinion dynamics of individuals within the emerging communities, and on the other hand, to perform observations of the role of the end-user community on user behavior/decisions. These socio-psychological aspects are difficult to capture in a model. Yet, gamification techniques allow for tracking group dynamics and community structures and relating them with user profiles, behaviors and strategies. Understanding these key aspects supports identifying those types of incentives (non-monetary, e.g., reputation or monetary, e.g., payment or virtual credit schemes in the case of sensing-enabled application), which engage humans into mechanisms of active contribution and sharing of knowledge. These incentives mechanisms should be flexible with reasonable levels of segregation or even personalization, and account for different levels of rationality in the way end-users decide to participate/collaborate or not. In parallel, the question of incentives has to be pursued for all participating players and entities that are directly (or indirectly) involved in the systems, either as system operators or as open data providers.

JRA6 – JRA5: Private information and privacy concerns in online collaborative applications

In many collaborative networking applications, it is important to overcome the concerns of end users about the privacy of their data and locations. The intensity of these concerns varies broadly across the candidate contributors. In particular, the privacy concerns relate to how much personal information is (or needs to be) shared with third-parties and how is this information treated. With mobile sensing devices, location accuracy also matters since the reported state/context information almost always is time/space-stamped. One other standard factor that is related to user privacy is the processing requirements. For example, the information may be needed in raw form by the application, or some processing can be done locally and hence, a higher degree of privacy could be preserved. A further crucial dimension is the nature of the dependence of collaborative systems on information and, most importantly, the emerging reliability issues such as how graceful the degradation of utility is when the amount of information provided to these systems decreases.

JRA1 – JRA6 – JRA7: Competition-awareness: shaping collective awareness and congestion / crowd management, in the presence of autonomous, human-biased decision makers

The integration of sensing devices of various scopes and capabilities with mobile communication devices along with the wide proliferation of online social applications leverage the heterogeneity of users in terms of interests, preferences, and mobility, and enable the collection and dissemination of huge amounts of information with very different spatial and temporal context. This information can be intelligently controlled by platforms that collectively enrich people's awareness about their environment and its resources and enable new forms of participatory processes and approaches to managing them. Besides possibly generating information by themselves via the sensing devices they might be equipped with, the networked entities are also typically involved in disseminating this information widely, contributing to building collective awareness. Furthermore, these same entities may actually exploit this awareness of their environment to meet own needs or achieve certain individual objectives. That is, these entities are involved in the dissemination and consumption of the information.

If the disseminated information concerns the availability of some limited resource or service, then competition naturally emerges among entities desiring to use such resources. In such environments, it is important to understand how the presence of competition shapes decisions taken by these entities regarding (a) the way collective awareness is exploited if at all and (b) the way these entities participate in disseminating information and creating collective awareness. The first of these very general and fundamental questions amounts to deciding whether a networked entity will compete (and suffer excessive penalty if not successful) or not compete for the available resource, shaping this way the resulting congestion; key to such a decision is the available information regarding the level of available resources and competition. The second, amounts to deciding whether a networked entity will deviate from the expected behavior (misbehave) by hiding or falsifying resource/service availability information, aiming at reducing the competition to its advantage.

JRA6 – JRA7: Non- excluding, open and sustainable collaborative applications managing common/public goods

Collective Awareness and Collective resource-Access Platforms (CACAPs) are rapidly emerging aiming at facilitating the detection of the state of the environment and consequently the utilization of some desirable resource. While today's technology makes it easy to implement potentially interesting ideas, these ideas will not go far unless they do provide concrete benefits to the users of the platforms at realistic penetration levels. The question of the sustainability of such CACAPs is one that needs to be explored by understanding the cost-benefit tradeoff as assessed by human-driven participants. Furthermore - and possibly more important - it is important to ensure that such CACAPs do not in pretty much either exclude non-participants from joining or – even more – from accessing public goods. The enhanced service enjoyed by the CACAPs participants should be due to the wealth generated by the CACAPs (that is distributed to its participants) and not to reducing competition by excluding or prioritizing against non-participants.

JRA1 - JRA7: Node centrality heuristics and associated vulnerability of Internet graphs.

Network graph characterization has received extensive attention in the past and has lately also considered real Internet graphs as revealed by experimental data. Not all network nodes are equally important in supporting network operations and for this reason a number of metrics have emerged assessing the importance or centrality of a node. In view of the fact that certain nodes are autonomic and their availability is not to be taken for granted, or that certain nodes may be attacked and become non-operational, a fundamental question is to assess the criticality of the various nodes – as inferred by the various centrality metrics available – in sustaining key network properties, such as connectivity, information carrying capacity, etc. As certain node centrality rankings are more easily detectable by an adversary than other rankings, an important question is to assess the correlations of the different rankings and ultimately assess the damage on the network if highly-ranked nodes are removed according to the various rankings.

20-ETH (CH)

JRA1/JRA6: Human behaviour in ICT-mediated communications

The role of technology on social life can be both positive and negative. On the one hand, it allows very efficient asynchronous information sharing and organization, the creation and maintenance of multiple overlapping networks, and a more flexible self-representation and engagement for individuals. But, on the other hand, it is exactly the same power that makes it easier to browse and filter our physical environment rendering invisible "the different others" , even if they may be standing next to us. It is indeed an irony that the increased physical mobility and accessibility to information of contemporary urbanites is complemented by an increased immobility within known habits, routines and patterns of behaviour that can easily lead to alienation. At the same time, the abstract space of modern cities does not always support social exchanges nor stimulate spatial appropriation, which may lead again to alienation.

But can we use the very same technology that may threaten our connection to the physical world and our immediate surroundings as a means to enhance the communication between strangers in the city?

Clearly, the answer cannot be definite nor generic. The outcome of different solutions will depend on the specific context and the combination of choices on numerous design details that can affect behaviour in complex and unpredictable ways. Moreover, it will be always very difficult to evaluate different outcomes since there are many conflicting objectives involved (e.g., the level of skills required for participation can improve the sophistication of the decisions but can also harm the level of representation due to various divides), dynamic processes (e.g., power relationships might appear over time), and possible unintended consequences (e.g., addiction).

What is important is to acknowledge the threat that ICTs pose on local communities and face-to-face communication and gather around the design process experts from various fields and disciplines from the computer science, and behavioural and social sciences to contribute the emerging interdisciplinary fields of urban and community informatics and support "real life experimentation" methodologies like the action research paradigm, living labs, and other co-creation models. The ultimate goal of this interdisciplinary scientific endeavour is to identify important causal relationships between design choices and outcomes in different contexts, which will allow informed choices based on local values and objectives.

JRA1/JRA4: The right to the hybrid city

Today the urban space becomes inherently *hybrid* since ICT technology acts very often as a mediator for exchanges and interactions between people in close physical proximity for short or long time periods, in public spaces or in urban neighbourhoods. The experience of this hybrid space is subject to different degrees of simultaneity and could range from synchronous interactions in which people experience the virtual and the physical in parallel, as in locative media, to asynchronous virtual and physical interactions as in the case of online neighbourhood web sites. These interactions could range from simple discussions and socialization to more sophisticated organization and resource sharing tasks (e.g., car pooling, face-to-face gatherings, alternative currencies, various types of service exchanges).

In addition, the hybrid realm may add novel types of communication between citizens and local authorities. First, it can support rich information flows from authorities to the citizens (e.g., open data), and from citizens to authorities such as in the crowdsourcing and citizen science paradigms. Second, it can provide a virtual spatial framework for e-participation and online deliberations around specific topics of interest. However, the simple existence of ICTs is not sufficient. It is the actual design of the evolving hybrid urban space that will determine whether their promises for increased civic engagement, participation, and community building will be materialized.

This means that for information and communication technologies (ICTs) to fulfil their promises for increased self-organization, civic engagement, and participation in planning, among others, the famous claim made by Henri Lefebvre for the "right to the city" (1996) needs today to be rephrased as the "right to the hybrid city". The original concept of the right to the city includes four different rights: 1) Access (digital divide), 2) Identity (freedom of expression, customisation), 3) Participation in design (decision-making, objectives), 4) Ownership (privacy, surveillance, control). It is easy to see that Facebook and other commercial social networking platforms fail to provide all these four basic rights whose importance increases significantly, for example, when they are to be used for planning processes as it happens today with numerous facebook groups created by municipalities to facilitate the interactions between citizens and local authorities.

The ownership of an ICT framework could range from its social software, to the storage and management of all content and information produced, all the way to the underlying network infrastructure. For example, by choosing a customizable open source framework, a local community can define itself the rules that shape the communication among the inhabitants of the produced hybrid space at the city or neighbourhood level. If additionally there is the option to deploy user-owned wireless technology as in wireless community networks, one can further ensure the de facto physical proximity, grant easy access for everyone, allow the choice of the desired level of anonymity, and compete with global corporations such as Google and Facebook for the "right to the hybrid city".

However, the design of the hybrid urban space is a very challenging interdisciplinary problem, which in addition to the high intellectual complexity, it has to deal with significant costs for producing customized solutions and a range of important trade-offs whose resolution can have significant impact on everyday life and long-term effects on behaviour and social dynamics. This calls for a bottom-up design process consistent with ideas developed in social learning and action research methodologies, for which the role of the free and open source software (FOSS) development paradigm can be instrumental as already highlighted by related research in the areas of urban and community informatics. Finally, additional support is required from regulators and institutional frameworks which can provide the necessary tools and access to scarce resources (e.g., spectrum).

Finally, note that the notion of hybrid design (ranging from internet protocols and user interfaces to physical interventions in the city), could be seen as a key element of the "system" that we can "control" to some extent and which affects decision making at different levels and thus the evolution of the system itself. In this sense it is important to devise ways to translate design choices to expected outcomes using an "interdisciplinary" language that will allow social scientists that are experts in understanding and dealing with complex, "wicked", problems to collaborate effectively with computer scientists in the design process.

23-UWAT (CA)

JRA8: Using Storage Systems to Firm Solar Power

Traditionally, energy generators are finely controlled to match the fluctuations in aggregate demand. Unfortunately, due to their intrinsic stochastic nature, solar energy generators cannot be controlled in this way, making it difficult to integrate them into the grid. Specifically, solar fluctuations can harm power quality, increase the need for regulation, and complicate load following and unit commitment. Hence, these fluctuations must be mitigated. One of the most promising ways to mitigate solar power fluctuations is to use energy storage systems (ESS).

Due to the high cost of storage, it is necessary to size the ESS parsimoniously, choosing the minimum size to meet a certain reliability guarantee. In practice, parsimonious ESS dimensioning is challenging due to the stochastic nature of generation and load and the diversity and high cost of storage technologies. We take an inter-disciplinary approach by using an isomorphism between ESS and network buffers. This allows us to size an ESS in a similar way that the teletraffic theories size a buffer. This, however, needs an accurate model for solar power fluctuations. The high variability of solar power due to intrinsic diurnal variability, as well as additional stochastic variations due to cloud cover, have made it difficult to model solar power. We provide an analytical solar power model which accounts for solar power variations both from diurnal effect and cloud's effect. Using real solar power data traces, we show that our analytical ESS dimensioning closely matches the simulation results.

JRA8: Pervasive computation, sensing and control for energy efficiency and carbon footprint reduction

The Internet has become the unifying communications backbone that allows gathering of data from pervasive sensors, the analysis of this data in centralized data centers, and the subsequent actuation of globally distributed control elements. This 'Internet of Things' will allow us to remove ineffeciences in energy usage as well as reduction in the carbon footprint in energy generation and consumption processes. This control paradigm is already being instantiated in approaches such as demand-response (reducing demand during load peaks), using electric vehicles for frequency regulation in the smart grid, and building control systems that rapidly respond to changes in occupancy state. In the future, we anticipate that, growing from these roots, many existing physical systems will evolve to highly-connected *cyberphysical* systems. The gains from this change, as well as the potential pitfalls are enormous. One the one hand, it may allow developing regions to improve their GDP without a concommitant increase in carbon emissions. On the other hand, it may lead to catastrophic failures due to crashes of transportation or power systems. To meet this challenge, what is needed is the design of a robust, scaleable, *control plane* that allows the decoupling of provably stable and safe control algorithms from theunderlying sensing infrastructure, allowing the development of higher-level 'applications' that are abstracted from the lower-level details. This architectural effort, which will require inputs from system analysts, network scientists, infrastructure managers as well as power engineers, will lie at the heart of future cyberphysical systems and is clearly a significant grand challenge for Internet Science.

29-LSE (UK) – London School of Economics and Political Science

JRA1:

Information theory for large-scale networks:

The size of the Internet requires us to develop a mathematical theory that can handle the "transfinite" dimensions of the Internet's probability space.

Structural characteristics of large-scale networks: When dealing with infinities or exceedingly large systems such as the Internet mathematics can often be the only analytical approach that can yield useful results and new insights. More should be invested in developing an algebraic theory of large-scale networks.

Collaborative research methodologies for quantitative and qualitative Internet Science: The situation today is that most Internet scientists from a qualitative research background do not understand the research methods used by scientists with a quantitative background. Most quantitative scientists don't even understand what the fuss is about, because they have difficulty imagining how one could conduct research without using quantitative methods. The few scientists who are familiar with both perspectives have a difficult time integrating them in their daily work. The Internet motivates us to do better at working together and communicating across this epistemological chasm, but this will take a lot of hard work and is definitely a major challenge.

JRA4:

Corporate governance and standards setting: The experience of the internet is now not only configured by standards set by open standards bodies such as the IETF, but also by proprietary standards and business practices (related to data privacy, for example) of individual companies. Understanding these processes and determining how best to respond is a significant challenge.

Trust and governance after Snowden: Even more broadly than the challenge mentioned previously, now that the world knows that the internet is an effective state surveillance machine, we have serious challenges related to trust, transparency and privacy. New multi-stakeholder processes are being invented by new global players (ie the government of Brazil) and existing powers such as the US government are arguing for little change to their mass surveillance projects. Our challenge is not only to understand how a future internet could be governed but also whether that governance appears legitimate (and to whom).

JRA6:

Using community practice to imagine internet alternatives: Can local, bottom-up networking projects provide alternative ways of thinking about a future internet? With the rising privacy concerns some activists are proposing 'post-crisis' networks such as distributed local mesh networks. In what ways do these experiments suggest possibilities for new or alternative internets based on bottom up rather than top down (state) governance processes? Or do they simply try to 'reinvent the wheel'?

30-KNAW (NL)

Participate mainly in JRA1 (General theory of the internet) and JRA5 Privacy and internet

Instead of answering the questions below, we take a step back and look at the whole enterprise. Do we need Internet Science as a new field? What is the progress in the network so far?

What our group showed with the EINS mapping exercise is that, although the Internet as object of study penetrates all area of the sciences, the consortium's perspective – determined by the disciplinary background of most of the partners – is mainly computer science.

We think it would serve us best to also be honest and state that while the big ambition of the project has a function of mobilization, it is a long way to go – and science-dynamics wise building a new community or theory is probably not what can be expected.

What has been archived, in our view, is a raised awareness of communities, which have not been in touch so far. This was visible in the EINS conference. It is also an achievement to make a bridge from the science taking care of the back-bone of the Internet architecture to the regulations around its use which is much more a domain of expertise for social sciences, law and political sciences as well as economics. The work on privacy we have been involved in delivered interesting results. The same holds for work on more general reports.

But the questions below still breathe the grand ambition of the start, and I'm not sure we do ourselves a favor with this. We might maneuver ourselves in a situation we are bound to fail. Because, there will not be "one" or "an" Internet Science, but there might be a curricular with this label for engineering raising awareness to societal issues; and there might be a curricular in the social sciences/law/political science etc. raising awareness for the technical boundary box of operation, and if we would achieve this, this would be already great.

32-UL (SLO)

General

If it is a roadmap, its essence should be captured on a drawing.

Conceptual Modelling of the Regulation Processes (JRA 4 effectively)

Approaching the Internet Governance in particular and ICT regulation in general through a conceptual modelling lens reveals a multitude of combinations of how the various actors are involved, how they are grouped, in what parts of the processes they take part and what elements of the ICT products, services, conducts etc. are regulated. The number of possible combinations is richer than those discovered in the taxonomies that were created using a legal theory approach. In particular it reveals a much broader matrix of possible stakeholder participation in the various stages of regulation specification, creation, use and enforcement.

Related to the hybrid city

The hybrid city approach vastly increases the opportunities for public participation in the spatial-planning procedures. In the PhD dissertation (Bizjak, 2014) argues that it is possible to include public in spatial-planning more actively, create better response, better coverage, to get an effective public participation in spatial-planning, and to harvest the tacit knowledge "of the crowds" and learning from the local community. This enables that the people who live in an area not only "participate" in the urban planning but that their "feeling" about the space is captured and used by the experts. It is only such hybrid, digital city that allows for a full implementation of a the levels that the theory of public participation in policy-making recognizes and even pushes the envelope of this participation.

Related to strategic thinking

The rapid development of information and communication technology (ICT) is perhaps the most influential driver that is fundamentally changing the world and the societies we live in. ICT is (a) changing the communication fabric that is linking the elements of societies together and is (b) automating human routine work. The latter is enabling automation and creating an abundance of food, industrial products and information. This abundance is pushing the value creation towards the creation of new knowledge and meaningful (rather than only functional) products and services. Information, knowledge and meaning are the three key commodities of the modern economy. Innovation and creativity are key processes creating these commodities. The two activities are very significantly supported by information and communication technologies.

Therefore, the ICTs are politically acknowledged on several levels of future planning: in R&D programs, development strategies, strategic future studies and visions. However, a scientific base for all this is lacking. Most of the strategic forecasting is extrapolating current trends into the future and not seeing the ICT as a disruptive event causing a discontinuity (not necessarily a singularity). The reason is, in part, because scientific base for a different understanding of the impact of ICT on society is missing.

Definition of Internet Science

Any mature field of science is actually defined with:

- Axiology that defines a value system in the field.
- Ontology that defines "what exists", what is the area of discourse of a field.
- Epistemology that specifies what constitutes appropriate knowledge in the field, where it is and how it can be represented and transferred.
- Methodology that specifies the appropriate rules of inquiry and research.

For Internet Science to be recognised these four pivots need to be defined. Sometimes, internet science is attempted to be defined as a union of many disciplines, either from computer science or social science. Others are defining it as a cross-section of these disciplines – what they have in common. The true Internet Science, in my view is the area which is neither social not computer science but is panning the area between those two.

The change that IT is causing in the society will be profound and will result in reinvention of all institutions of society. The process already started where citizens are free and where businesses must adapt in order to be competitive. The process is stalled where powerful institutions and legal frameworks are blocking change and leading to rigidities in society. In the next years and decades, much will depend on how change will happen in these areas – in highly governed and regulated areas of society that include public services, rule of law, education etc.

Knowledge about this is needed on all levels of future thinking – from planning and strategies to forecasting and visions. A science that combines technologists with a clear understanding of where technology push and technology opportunity will be coming form, social scientists with an understanding of societal mechanisms, and humanities with a deeper understanding of the human being. Internet science should fill-in this gap – if it becomes to computer science what urban planning and logistics are to civil engineering. It is not about developing the underlying technology on how to build the infrastructure but taking technological infrastructure for granted and studying how it can be used to improve the lives of people, create new businesses and interesting new work opportunities.

33-SOTON (UK) The IT Innovation Centre, University of Southampton

JRA1: Understanding the relationship between Internet Science and other interdisciplinary areas

Understanding how Internet Science relates to areas such as Web Science or Network Science can help identify common research roadmaps where appropriate, build networks with additional research communities and share relevant research infrastructures. A major challenge will be to efficiently facilitate this dialogue on a semi-permanent basis (e.g. by organizing joint workshops or participating in relevant conferences) and, at the same time, to identify exactly how research infrastructures can be shared or co-developed as part of a collaboration roadmap with tangible outcomes.

JRA2: Tackling 'wicked' design problems online

'Wicked' problems were first discussed long before the emergence of the Internet [1]. Such 'wicked' problems exhibit great complexity, often involving changing, incomplete or conflicting requirements, and frequently being entangled with other big issues. Examples of such problems include global warming, the financial crisis and dealing with terrorism.

In the context of Internet Science and design, such problems include: predicting the emergent behavior of interacting socio-technical systems; user trust, awareness and management of cyber security; online communications for people with mental health issues such as dementia or aphasia; facilitating appropriate levels of empathy online. As can be seen, computational and human issues translate into the digital world very easily. Indeed, such issues can be exacerbated by certain aspects of the internet, such as the speed with which emergent behaviors can develop, the internet's worldwide nature, and its limited communication modalities compared with face-to-face interaction.

There exist some methods that attempt to respond to 'wicked' problems in general: one example is Creative Problem Solving [2]. However, to our knowledge there are no methods to deal with wicked internet design problems. Any such method must not only encompass the properties of methods to deal with general 'wicked' problems, but also account for the unique features of the internet and design online.

The development and honing of such a method represents a rich opportunity to have a strong positive impact on online interactions in many contexts. Such an effort will rely on interdisciplinary inputs, and cannot be achieved without the combination of technological knowhow, sociological inputs and design expertise.

[1] C. West Churchman, Guest Editorial, Management Science, Vol. 14, No. 4 (December 1967)

[2] H2 Solve Wicked Problems, Paul Reali, published by lulu.com (2011)

JRA3: Evidence and Experimentation Base

Internet Science research is increasingly relying on the availability of datasets, mixed methods, e-Infrastructures, and analytic and visualisation tools that can efficiently support interdisciplinary collaboration. However, those resources are currently spread across different repositories and often they are not readily available for use by Internet scientists. This lack of an evidence and experimentation base that can support Internet Science is a major obstacle to studying the socio-technical evolution of the Internet and its impact, and a barrier for new entrants to join relevant research activities.

Bootstrapping the creation of this base and ensuring its growth and sustainability is a major challenge that EINS will try to address. JRA3 activities to that end involve the cataloguing of datasets, tools, e-Infrastructures and methodologies for Internet Science, and the development of schemas to efficiently describe and search for them. They also involve the development of online repositories that can host datasets that project partners or other members of the community wish to make available. In addition, they envisage the development of the community engagement mechanisms that will enable this online evidence and experimentation base to grow, to support scientists from a range of disciplines and to be sustainable.

Beyond the bootstrapping phase that will be initiated by EINS, the major challenge will be to provide for the development of scalable and sustainable infrastructures for creating and sharing datasets, analytic tools, methodologies and e-Infrastructures with the wider Internet Science community. This effort will need to involve all major stakeholders including business, government and research institutions.

JRA3 will also focus on interacting with researchers and stakeholder collecting a large set of datasets, methodologies and tools related with the two following topics: network performances, with particular attention to network neutrality issues, and data quality, with particular attention to open data quality. Apart from providing a pilot for exploring the functionalities and potential of the e-Infrastructure provided by JRA3, these two topics represent by themselves two hot topics in Internet Science research and also two relevant policy issues, which could be informed by a richer evidence base.

CU – Cardiff University (UK)

JRA5: Building a Science of Internet Privacy

Privacy has recently become an important societal concern, fueled by the preponderance of digital data being recorded, shared, and collected about individuals (through the Internet, mobile networks, social networking websites, data aggregators and brokers). But privacy is by its nature a multidisciplinary concept with legal, business, psychological and technical (LBPT) aspects. In parallel, privacy – seen from a technical perspective – shares characteristics with security, which is notorious for its sensitivity to detail. Two challenges arise from these observations.

The first challenge is to understand and take into account all LBPT aspects when designing and evaluating a privacy mechanism. A technically sound mechanism is bound to fail if it is not also economically viable and psychologically-cognitively feasible. For a very simple example from the security domain, using passwords for authentication works in theory, but people choose the same weak passwords across many systems in practice, because of the cognitive burden of remembering a multitude of complex ones. Email providers could easily provide encrypted email services, but it is economically undesirable to do so, as it is a nuisance for them to implement and maintain, while users do not actively ask for it. Tools and methodologies that cut across disciplines are needed, such as game theory and prospect theory for modeling business incentives as well as human cognitive biases, or tools inspired by mechanism design to study the effect of and to propose new regulations.

The second challenge, oriented more towards the ICT domain, is to distill and clearly articulate assumptions about the system, the attacker, and the privacy property that is to be safeguarded in a given real-world scenario. Cryptography has recently started to progress from an art to a science, exactly because such assumptions have started to be expressed formally. In security research, one has to specify the attacker's objectives and capabilities very precisely. It is only by finding an appropriate formalization of the real-world scenario that one can (a) properly evaluate the merits of a privacy mechanism, (b) compare the relative value of competing mechanisms, (c) identify any potential tradeoffs between privacy and data/service quality, and (d) hope to construct provably optimal privacy mechanisms that satisfy quality constraints.

AIT – Austrian Institute of Technology

JRA7: Internet as a Critical Infrastructure: Security, Resilience and Dependability Aspects

AIT will focus its activities within EINS on the positioning of next generation security concepts for the following critical application areas of the Future Internet:

- **Security and Risk Management for Smart Grids**

Future energy grids (such as the *smart grid*) will make extensive use of the integration of ICT technologies, and in some cases will make use of the Internet to support user services. Thus, cyber security risks become a major threat for energy suppliers. New multi-disciplinary approaches are necessary to strengthen the resilience of smart grids against cyber-attacks. This includes specific risk management approaches for utility providers, processes and guidelines for implementing security in smart grid environments, and also security assessment and monitoring solutions.

Due to the extensive use of ICT for the future energy networks, the dependability on the availability of the energy infrastructure will dramatically increase. It is necessary to raise awareness within a whole industry and to define methodologies, architectures and tools to prepare the energy infrastructure for the challenges of the future. There is still missing a common harmonized and accepted view within Europe on security requirements, network architecture, role models (role of public authorities) and an economical useful migration methodology from today's networks to the future grid concerning the security requirements. To address these problems, clearly a multi-disciplinary approach is required, which draws on expertise, e.g., on engineering power grids, computer networks, economics and sociology, making this ideally suited to being considered as an Internet Science problem.

- **Cloud Computing for high-assurance applications**

Cloud computing adoption is taking place in different application areas, including those that have higher security requirements. Existing cloud offerings are not well placed to address these issues. Due to the opacity and elasticity of cloud environments, the risks of deploying critical services in the cloud are difficult to assess – specifically on the technical level, but also from legal or business perspectives. Furthermore, clouds are being coupled with large-scale machine-to-machine (M2M) communication infrastructures, e.g., supporting the processing and storage of data from large sensor and actuator networks. In many cases, these infrastructures will support the infrastructures that our society depends on. In a similar manner to a supporting cloud infrastructure, these M2M infrastructures are likely to be dynamic in nature. In order to understand the security and resilience characteristics of these highly dynamic infrastructures, new models and techniques are required. Furthermore, novel architectures are required that consider the end-to-end connectedness, dynamic and large-scale nature of these infrastructures. If these issues are not appropriately addressed, the services that such infrastructures support could be vulnerable to a wide variety of attacks and other challenges.

- **Efficiently securing large-scale service-oriented architectures in the eGovernment domain**

Large scale distributed service-oriented architectures are implemented across Europe by the various eGovernment initiatives for private and business users. They usually utilize a number of technologies like federated identity management, cryptography, etc. for ensuring confidentiality and integrity of the system. In many cases, these e-Government services make use of the public Internet to provide connectivity, which increases the risk of being attacked and outages due to network failures. As in the other application domains that are considered by AIT, new architectures and security analysis approaches, such as risk assessment approaches, are required to build these infrastructures in a secure and resilient manner.