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Preface

The Internet constitutes the most vital scientific, technical, economic and societal set of infrastructures in existence and in operation today, serving 2.5 billion users. Continuing its development will secure future innovation and prosperity and underpin the sustainable economic growth needed in the future. Future Internet infrastructure research is therefore a must.

The Future Internet Assembly (FIA) is a successful conference that brings together participants of over 150 research projects from several distinct yet interrelated areas in the European Union Framework Programme 7 (FP7). The research projects are grouped as follows:

- The network of the future as an infrastructure connecting and orchestrating the future Internet of people, computers, devices, content, clouds, and things.
- Cloud computing, Internet of Services, and advanced software engineering.
- The public-private partnership projects on Future Internet.
- Future Internet research and experimentation (FIRE).

Researchers and practitioners associated with the Future Internet gather at the FIAs every six months in order to exchange ideas and interact on topics within the above areas.

This publication constitutes the 2013 edition of the annual Future Internet Assembly book, which has been published since 2009. It contains selected program-level results from the European Union FP7 program on the Future Internet, complementing the FIA conferences. The aim is to disseminate the results as widely as possible. Therefore, as with the previous books, the content is freely available online as well as in print form.

There were 45 submissions (36 submissions from the open call for chapters and 9 invited submissions). Each open call submission was peer-reviewed by 3 editors, while each invited submission was peer-reviewed by 4 editors. The editorial board decided to accept 26 submissions (18 submissions from the open call and 8 invited submissions). Introductions to the sections of the book and cross topics are also provided.

Each chapter presents both FI enabling technologies and their application to at least one of the networked system and service areas. The chapters of this book have been organized in five sections:

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1 The previous FIA books can be found online at
   www.springer.com/computer/communication-networks/book/978-3-642-30240-4,
   www.springer.com/computer/communication-networks/book/978-3-642-20897-3,
   www.booksonline.iospress.nl/Content/View.aspx?piid=12006 and
   www.booksonline.iospress.nl/Content/View.aspx?piid=16465
• Software Driven Networks, Virtualisation, Programmability, and Autonomic Management
• Computing and Networking Clouds
• Internet of Things
• Enabling Technologies and Economic Incentives
• Book Sponsoring Projects Overview

We would like to acknowledge the hard and expert work of the editors of this book. We also would like to voice our appreciation of the European FP7 projects that financially supported this publication as open access: 3DLIFE, CONCORD, FLAMINGO, GEYSERS, iCORE, IoT6, MOBILECLOUD, SMARTENIT, SMARTSANTANDER, and UNIVERSELF.

May 2013

Alex Galis
Anastasius Gavras
Introductions
Introduction

In the mid of the 2000s, contemporary communication and data networks have become ossified [1]. This term denotes their inability to be changed and to adapted to new technologies. The standstill happened although the networks were aligned along well-defined layering concepts, which were aiming at extendibility and adaptivity. The ossification of the network was traced to large extends to the missing separation of the data plane and the control plane.

Moreover at the same time, novel software technologies for distributed systems have demonstrated that software-based control concepts for networks can be superior to control paradigms using conventional networking hardware and software. These impressive capabilities were evidenced, for example, by the efficiency of P2P-based file-sharing systems or the quality of HTTP-based video streaming using smart control from server or host side.

The paradigms of Software-defined or Software-driven Networks have emerged recently as results of the above outlined trends. They are aiming at architecting computer networks that separate and abstract network elements and network resources. These paradigms largely exploit virtualization technologies for sharing and aggregation of resources and for decoupling and isolating virtual networking elements. The abstraction of networking elements enables and simplifies the programmability of networks based on these concepts. The desired operational features hoped for these new networking architectures are: a) higher cost efficiency, b) increased networking capabilities and c) innovative service offerings.
Challenges

The implementation of these paradigms in real world networks, however, is rather difficult. Their materialization constitute various research and implementation challenges. Amongst others, the challenges comprise the following topics:

- What is the appropriate level of abstraction for network elements and network resources?
- Which functional areas should be described by the abstraction and how do they relate in an architecture to each other?
- How can security be achieved in virtualized networks?
- How can today’s network elements be abstracted as future virtual elements and how can these virtual elements be mapped to generic physical network hardware?
- How does the abstraction of virtual network elements relate to future network services and applications?
- How can international standardization organizations support the features of abstraction and programmability?
- How future Internet architecture could be deployed in a transition approach based on virtualization?

Contributions

Chapters contained in this book that address some of the aforementioned challenges include:

- The chapter “The NEBULA Future Internet Architecture: A Mid-Course Report” describes a high reliable and trustworthy network architecture which is based on concepts from Cloud Computing. The architecture interconnects abstracted network elements which are assumed to be ultra-reliable, such data centers or high performance routers, by programmable interconnections.
- The chapter “Towards a Secure Network Virtualization Architecture for the Future Internet” proposes a virtualization architecture where elements refer to each other rather to be just interconnected. The referencing concept enables improved security in virtualized networks.
- The chapter “Integrating OpenFlow in IMS Networks and Enabling for Future Internet Research and Experimentation” is on the mapping of real-world network functions onto a virtualized and programmable network architecture that uses OpenFlow. The mapping is constituted for the example of the functions of the IP Multimedia Subsystem (IMS), which is used as an essential concept in current public 3G/4G mobile networks.
- The chapter “Towards an architecture for Future Internet applications” discusses the relationship of future application and virtualized and programmable networks. It focuses on middleware support to interconnect applications and networks.
The chapter “ComVantage: Mobile Enterprise Collaboration Reference Framework and Enablers for Future Internet Information Interoperability” presents a framework how mobile applications in enterprise environments can reference data by collaboration. It exploit the concept of Linked Data.

- The chapter “Open the Way to Future Networks – a viewpoint framework from ITU-T” outlines how the ITU as an international standards organization aims to provide support for the implementation of future virtualized and programmable networks.

Reference

— Introduction —
Autonomic Management and Operations

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Introduction

During the recent years, new applications and services are offered through different networks and devices over the wider umbrella of Internet. The success of the Internet is verified by the over a billion users world-wide. Of course, the constant development of new applications and services has imposed the respective evolution of the networks, services and technologies. The main goal of the Future Internet (FI) is to establish powerful network infrastructures, so as to support numerous applications and services and the emergence of new business models. To this end, the infrastructure will be highly pervasive consisting of people, smart objects, machines and the surrounding space, and embedded devices (e.g., sensors, RFID tags) that will result in a highly decentralized environment of resources, interconnected by dynamic Networks of Networks. This additional complexity will have to be supported so as to handle the multiple, demanding and changing conditions for the requested QoE/QoS, the maximization of the efficiency of the infrastructures, and their overall management.

Challenges

Autonomic systems, having the ability to self-manage and adapt to given circumstances without external intervention, are seen as the most viable direction for realizing the FI era. Moreover, the autonomic systems also incorporate learning mechanisms, evolving knowledge and establishing a decision making process for handling future situations. More specifically, self-management is essential for fast adaptations to changing situations, while learning can increase the reliability of decisions through knowledge. This feature enables multiple heterogeneous management systems to act on top of a common managed infrastructure in both fixed and mobile Internet, leading to reductions in the OPEX and CAPEX. Autonomic systems call for the design, development and validation of functionality in the area of context acquisition and reasoning, the derivation and
evaluation of policies, distributed optimization techniques, and learning for acquiring and sharing knowledge and experience. In the latest years, work has been done with respect to governance, coordination, and support through knowledge of autonomic systems and application areas.

The chapters selected for this FIA book cover the areas of optimization and algorithms, protocols for the Future Internet, management platforms for the autonomic Future Internet, security issues and standardization initiatives for the autonomic management of the Future Internet.

Contributions

Chapters contained in this book that address some of the aforementioned challenges include:

- The chapter “High Availability in the Future Internet”, gives a comprehensive overview of Loop-Free Alternates (LFA) and survey the related LFA network optimization methods, pointing out that these optimization tools can turn LFA into an easy-to-deploy yet highly effective IP fast resilience scheme.
- In chapter “Towards a Minimal Core for Information-Centric Networking” the concept of information space as a potential solution is introduced, based on the sharing of information and late binding service composition of decoupled entities as the essence of information-centrism. The specified framework is an abstract model without dependencies to low-level implementation details and achieves minimality by leaving naming and content security outside the core. This approach makes the experimentation of new features above and their implementation below faster and provides a possible evolutionary kernel for information-centric networking (ICN).
- In chapter “Managing QoS for Future Internet Applications over Virtual Sensor Networks” the way the VITRO routing solution could be employed in various use cases including smart homes/buildings, smart cities, smart business environments and security-related applications is demonstrated. The achieved performance using computer simulation results is evaluated and guidelines for prospective users are provided.
- The chapter “Design and Implementation of Cooperative Network Connectivity Proxy using Universal Plug and Play” introduces a new approach to design and implement the cooperative Network Connectivity Proxy (NCP) for reducing energy waste in the ever-growing Future Internet. The NCP allows all registered network hosts to transition into the low power sleep modes and maintains the network connectivity on their behalf. It handles basic net-work presence and management protocols like ICMP, DHCP, ARP etc. on behalf of the sleeping network hosts and wakes them up only when their resources are required. Depending on the network hosts time usage model, the NCP can provide about 60–70% network energy savings.
- In chapter “Cooperative Strategies for Power Saving in Multi-standard Wireless Devices” the way cognitive radio and cooperative communication can be
integrated in 4G networks is presented, so as to conduct wireless devices to either perform vertical handover or execute relaying by exploiting their available short range interfaces (e.g., WiMedia, Bluetooth, etc.) to reduce their power consumption, while still enabling the required QoS. Simulation and experimental results validate that 4G wireless devices can double their battery lifetime by adopting the proposed strategies.

– The chapter “Towards a Socially-aware Management of New Overlay Application Traffic Combined with Energy Efficiency in the Internet (SmartenIT)” focuses on an incentive-compatible cross-layer network management for providers of over-lay-based application (e.g., cloud applications, content delivery, and social net-works), network providers, and end-users to ensure a QoE-awareness, by ad-dressing accordingly load and traffic patterns or special application requirements, and exploiting at the same time social awareness (in terms of user relations and interests). Moreover, energy efficiency with respect to both end user devices and underlying networking infrastructure is tackled to ensure an operationally efficient management. Incentive-compatible network management mechanisms for improving metrics on an inter-domain basis for ISPs serve as the major mechanism to deal with and investigate real-life scenarios.

– The chapter “The NEBULA Future Internet Architecture: A Mid-Course Report” focuses on a future network that enables the vision of cloud computing to be realized. With computation and storage moving to data-centres, networking to these data-centres must be several orders of magnitude more resilient for some applications to trust cloud computing and enable their move to the cloud.

– The chapter “SmartSantander: Internet of Things Research and Innovation through citizen participation” presents two novel services that have been implemented in order to bring the Smart City closer to the citizen. The Participatory Sensing service proposed exploits the advanced features of smartphones to make the user part of the ubiquitous sensing infrastructure over which the Smart City concept is built. The Augmented Reality service is connected to the smart city platform in order to create an advanced visualization tool where the plethora of available information is presented to citizens embedded in their natural surroundings.

– In chapter “Counting the Cost of FIRE – Overcoming Barriers to Sustainable Experimentation Facilities” the way cost modelling and usage accounting can be used to support operational and sustainability decisions for a federated cloud experimentation facility is demonstrated.

– The chapter “Towards a Secure Network Virtualization Architecture for the Future Internet” discusses the Global Virtualization Architecture (GVA) that enables communications between network entities according to the way they refer to each other rather than understanding the constraints of particular networks. The approach is to instantiate a virtual network that is based on identities of network entities and their demands on security and network capabilities.
– In chapter “Open the Way to Future Networks – a viewpoint framework from ITU-T” the background and the context of Future Networks’ standardization, the results and future plans originated from the initial standardization work performed by ITU-T are presented.
Introduction

Cloud computing has received tremendous attention the last years, both in academia as well as in industry, especially with the deployment of multiple commercially available solutions that foster the basis for a variety of value-added services. In the Future Internet era, the cloud will still have a considerable impact on the way the new infrastructures will be used by the Future Internet envisioned applications. However this attention is moving fast beyond from purely computing-oriented focus (although this will expand), towards covering networking and mobility.

The Future Internet Architecture will integrate the Cloud computing paradigm to a new level encompassing several aspects such as the Cloud of Things, Software Defined Networking, Fog Computing etc. Considerable research efforts are already devoted today to ensure that the amalgamation between new revolutionary network technologies and the Cloud computing is properly exploited in context like data deluge.

Clouds in the Future Internet are expected to come in various forms depending on their stakeholders’ needs. Sophisticated capabilities will significantly expand what we today classify under “computing” and for instance real-time analytics on big data will empower a new generation of services and applications. To this direction networking and information exchange will be further enhanced and cross-layer interactions among the billions of interconnected devices, systems and services will be assisted by the Future Internet Cloud paradigm. In that era, mobility will be of key importance and will be supported both in terms of mobile users and their devices, as well as seamless transcoding of sessions among different systems of varying capabilities. The Future Internet Cloud is seen at the heart of the service offering and empowerment in the Future Internet vision.
Challenges

In the Future Internet Cloud, the main concerns raised today will still be a challenge, e.g., aspects related to security, trust, privacy, interoperability and portability. As the Future Internet will stretch the Cloud infrastructure, other aspects such as quality of service, high performance guarantees, dependability, value-added services, data management, analytics, etc. will still need to be addressed in order to assist industry embracement of the Future Internet solutions.

Of special importance is of course the support of the billions of mobile users and the respective apps running in the increasingly heterogeneous devices. Hence the integration with the Internet of Things (an amalgamation described as Cloud of Things) as well as offering value added services on huge amounts of data (Big Data), will foster key challenges that need to be addressed. All these will need to be done with new approaches that guarantee adherence to concerns on security and privacy as well as to industry requirements for lifecycle management of the data and the services.

Networking and efficient interaction with the cloud and its services, as well as cross-cloud interaction (federation of cloud infrastructures) and development of value added services on top will be of pivotal importance. Adding also the seamless provision of service to the mostly mobile devices and users, as well as support for mobility in emerging application areas e.g., smart cities needs to be tackled. Considering also the global sustainability goals, green cloud computing in the Future Internet needs also to be efficiently addressed in a cooperative holistic way.

Contributions

Chapters contained in this book that address some of the aforementioned challenges include:

- The chapter "Open the Way to Future Networks – a viewpoint framework from ITU-T" focuses on the Future Network objectives and design goals for further developing technologies and systems. The chapter points out the results and future plans stemming from the initial standardization work performed by ITU-T as well as recommendations for standardization bodies in order to support the Future Networks development.

- The chapter "The NEBULA Future Internet Architecture: A Mid-Course Report" is presenting an architecture intended to provide secure and resilient networking to support present and future applications of cloud computing. To this end, reliable routing, data-center interconnections, data plane with policy enforcements, and a control plane for network configuration are investigated.

- The chapter "Towards a Secure Network Virtualization Architecture for the Future Internet" analyses different architecture proposals for the Future Internet and subsequently presents an architecture design that fills those gaps
by means of virtualization techniques working together with the overlay network concept. The notion of Virtual Group Networks, which group physical and abstract mobile entities, and focus on the demands in terms of security and network capabilities is introduced.

- The chapter "Seeding the Cloud: An Innovative Approach to Grow Trust in Cloud Based Infrastructures" tackles the issues of security, trust and privacy in the cloud. It introduces a network of secure elements (software and hardware elements connected locally with or in pieces of equipment), defining a minimal trusted computing base and allowing an end-to-end virtual security chain from the user to the server where the services are executed or data is stored.

- In the chapter "Cloud-based Evaluation Framework for Big Data" a discussion on the challenges that arise when doing benchmarking on big data is depicted. The problem of bringing the algorithms to the data in the Cloud is analysed in conjunction with the particular use cases of segmentation and retrieval of three-dimensional medical images.

- The chapter "Resource Optimisation in IoT Cloud Systems by using Match-making and self-Management Principles" a proposal to annotate data of monitored cloud performance and user profiles and adapt the management systems to use shared infrastructures and resources to enable efficient deployment of Internet-of-Things services and applications is depicted.

- The chapter "Contrail: Distributed Application Deployment under SLA in Federated Heterogeneous Clouds" addresses the challenges of offering reliable Cloud services and how to ensure quality of service and of protection in a federation of Cloud providers. Moreover, a deployment service, for distributed applications, that allows interoperability among the Cloud sites participating to the federation is investigated.

- The experimental studies presented in chapter "Optimizing Service Ecosystems in the Cloud" are related to the optimization of service compositions. The service ecosystem is emulated in a multi-site federated Cloud and the study subjects are two optimization models.

Conclusions

In the Future Internet, the Cloud is playing a pivotal role. There are several open challenges, some of which are addressed in the chapters presented in this section. However, significant research is remaining in order to support effectively the Future Internet envisioned applications as well as their infrastructure requirements such as computation (including analytics), mobility and networking.
Introduction

Internet of Things is seen as a key part of the Future Internet vision which will enable real-time interaction with the physical environment. Billions of connected heterogeneous devices, sensing and actuating the physical environment in which they are embedded, and interacting among them or with remote users comprise the foundation of IoT.

More sophisticated approaches go beyond simple communication integration and target more complex interactions where collaboration of devices and systems is taking place. The cross-layer interaction and cooperation is pursued (i) at machine-to-machine (M2M) level where the machines cooperate with each other (machine focused interactions), as well as (ii) at machine-to-business (M2B) level where machines cooperate also with network-based services and business systems (business service focus).

As the Future Internet will be a very complex system of systems, the Internet of Things is expected to enable approaches that tame that complexity via real-time fine-grained monitoring, analytics-assisted decision making, and timely management. To do so, it will have to highly depend on the Future Internet infrastructure and envisioned capabilities in an open and collaborative way. This collaborative way of interactions is expected to lead to emergent behaviours in the Future Internet that, at the end, will better serve the end-users.

Challenges

Realizing the vision of Future Internet of Things requires tackling numerous challenges spanning a range of domains from the technical ones, to the social, design, economics etc. domain, or new area like smart cities. At the same time
the traditional issues such as security, trust, privacy, openness, user-friendliness and rapid development still have to be supported.

Connectivity will remain in Future Internet a key aspect. However, the major focus is shifted towards supporting interoperable interactions at multiple layers and among various Internet of Things empowered services, and at the same time support legacy systems. The latter includes also aspects of migration of the current partially networked infrastructure to a fully-connected open system in the Future Internet era. Additionally, complexity management, crowdsourcing, real-time analytics, knowledge capturing and communication, simulation are only some indicative aspects that will need to be investigated as they will impact the next generation of Future Internet enabled applications.

Designing software solutions for the Future Internet of Things, and analysing the impact (e.g. of malfunctions) at system-wide level can be assisted by big data analytics. A new generation of data explorative tools, as well as sophisticated algorithms considering context specific information at several levels on very large scale systems will need to be designed, developed and piloted. Extracting and understanding the business relevant information under temporal constraints and being able to effectively built in solutions that utilize the monitor-analyse-decide-manage approach for a multitude of domains is challenging.

The high heterogeneity of systems, models, quality of data and associated information, uncertainties as well as complex system-wide interactions, will need to be investigated to identify business opportunities and realize a business benefit. Supporting effectively all stakeholders in the Future Internet Era is a key challenge that we will have to deal with. This implies new business models, information exchange and business collaborations that create added value for all participating stakeholders and that will open new business opportunities.

Contributions

Chapters contained in this book that address some of the aforementioned challenges include:

- The chapter ”Test-Enabled Architecture for IoT Service Creation and Provisioning” targets the service creation and testing in the Future Internet of Things environment. An architecture design is investigated that extends the existing IoT reference architecture and enables a test-driven, semantics-oriented management of the entire service lifecycle. Future Internet of things challenges addressed include integration, service creating and semantic-enabled interaction.

- The chapter ”A Cognitive Management Framework for Empowering the Internet of Things” presents a framework that has the ability to dynamically adapt its behaviour, through self-management functionality, taking into account information and knowledge (obtained through machine learning) on the situation (e.g., internal status and status of environment), as well as policies (designating objectives, constraints, rules, etc.). Several Future Internet
of Things challenges such as integration, collaboration, self-X, reliability and efficiency are addressed.

– The chapter “SmartSantander: Internet of Things Research and Innovation through citizen participation” shows the applicability of the Future Internet of Things in urban environments. The two examined services i.e., participatory sensing and augmented reality, address challenges towards the added-value and business effect of the Future Internet of Things.

– The chapter ”IoT6 – Moving to an IPv6-based future IoT” investigates the design and development of a highly scalable IPv6-based Service-Oriented Architecture to achieve interoperability, mobility, cloud computing integration and intelligence distribution among heterogeneous smart things components, applications and services, taking advantage of the IPv6 features. The domain of building automation is chosen to show the feasibility of the approach. The challenges addressed include integration, service-driven interaction, openness and empowerment of applications and services in IPv6 Future Internet of Things era.

– The chapter ”Building modular middlewares for the Internet of Things with OSGi” investigated how to develop intelligent infrastructures combining various devices through the network by fully utilizing the capabilities of OSGi for development of modular, fine-grained and loosely coupled Java applications. Challenges of the Future Internet of Things addressed include scalability, integration, lifecycle management etc.

Conclusions

The Internet of Things is an integral part of the Future Internet vision. There are numerous challenges that need to be tackled that spawn several domains. Some of the chapters presented in this book go towards depicting how a subset of these challenges can be addressed. It is clear however, that we are still at the dawn of an the Future Internet of Things era and significant research efforts need to be investigated in a well balanced way in order to make sure that the benefits expected can be harvested.
Introduction

This section describes the enabling technologies and infrastructures and experimentation endeavours for the Future Internet. These topics are covered by chapters devoted to (i) network and information-centric network architectures; (ii) cloud-related solutions; and (iii) IoT-related research, the Internet of Things. These three domains are addressed by a multitude of chapters describing currently ongoing projects and results of past projects.

Challenges

The challenges in enabling technologies are diverse. It is clear that the Internet has become omnipresent and the Internet of Things will increase this permanent presence. Many different applications and techniques exist and are currently being tested in various settings. Network and access questions are another challenge discussed by several of the chapters. Energy efficiency of networks and systems is increasingly getting important with big data centres for cloud infrastructures consuming massive amounts of energy. The data centers are necessary for cloud computing, another approach that is currently being used in many applications and in many different ways. Trust and security in clouds are getting important as critical or confidential data are increasingly being stored in clouds.

Contributions

Chapters contained in this book that address some of the aforementioned challenges include:
The chapter “An Internet–based Architecture Supporting Ubiquitous Model–driven User Interfaces” describes how Web technology and the Internet infrastructure make ubiquitous applications a reality. The authors present webinos, a multi–device application platform founded on the Future Internet infrastructure and describe webinos’ model–based user interface framework as a means to support context–aware adaptiveness for applications that are executed in such ubiquitous computing environments.

The invited chapter “Sustainable Wireless Broadband Access to the Future Internet – The EARTH Project” gives an overview of the FP7 project EARTH contributions to a sustainable wireless broadband access to the Future Internet. The chapter explains the wide range of areas in which EARTH has and will have significant impact ranging from reinforced leadership of European industry in the field of Future Internet technology, over increase economic efficiency of access infrastructures, global standards, interoperability and European IPRs reflecting federated and coherent roadmaps to accelerated uptake of next generation of network and service infrastructure. Project EARTH was awarded best FIA project at the last Future Internet Assembly that was held in Aalborg, in spring 2012.

The chapter “High Availability in the Future Internet” presents a comprehensive overview of Loop–Free Alternates (LFA) and survey the related LFA network optimization methods, pointing out that these optimization tools can turn LFA into an easy–to–deploy yet highly effective IP fast resilience scheme.

The chapter “Design and Implementation of Cooperative Network Connectivity Proxy using Universal Plug and Play” describes a new approach to design and implement the cooperative Network Connectivity Proxy (NCP) for reducing energy waste. The NCP allows all registered network hosts to transition into the low power sleep modes and maintains the network connectivity on their behalf. Depending on the network hosts time usage model, the NCP can provide about 60–70% network energy savings.

The chapter “Towards a Minimal Core for Information-Centric Networking” proposes an abstract model for information–centric networking (ICN), that allows the bulk of features of current ICN architectures to be expressed as independent extensions to this model. It presents a possible evolutionary kernel for ICN allowing experimentation of new features above and implementation below faster.

The chapter “Cooperative Strategies for Power Saving in Multi–standard Wireless Devices” demonstrates how cognitive radio and cooperative communication can be integrated in 4G networks to reduce their power consumption while still enabling the required QoS. Simulation results validate that 4G wireless devices can double their battery lifetime by adopting the proposed power saving strategies.

On the second point, the chapter “Seeding the Cloud: An Innovative Approach to Grow Trust in Cloud Based Infrastructures” proposes a way to build a secure and trustable Cloud. The idea is to spread and embed Secure Elements on each level of the Cloud in order to build a trusted infrastructure.
complying with access control and isolation policies. This chapter presents a trusted Cloud infrastructure based on a Network of Secure Elements (NoSE), and illustrates it through different use cases.

- The chapter “Optimizing Service Ecosystems in the Cloud” presents experimental results of the performance of two optimization models in service ecosystems by (i) testing the maturity of existing technology and its suitability for use in Future Internet scenarios, and (ii) investigating the existing infrastructure capabilities.

- The chapter “Cloud-based Research Infrastructure for Evaluation on Big Data” describes a cloud-based research infrastructure for evaluating machine learning and information retrieval algorithms on large amounts of data. Instead of downloading data and running evaluations locally, the data are centrally available in the cloud and the algorithms are executed in the cloud, effectively bringing the algorithms to the data.

- The chapter “Contrail: Distributed Application Deployment under SLA in Federated Heterogeneous Clouds” presents the challenges of interoperability, performance guarantee, and dependability. It then presents three components: Contrail federation; SLA manager; and Virtual Execution Platform. These components provide interoperability guarantees in a cloud federation and enable deployment of distributed applications over a federation of heterogeneous cloud providers.

- On the third point, the chapter “Test-Enabled Architecture for IoT Service Creation and Provisioning” presents the efforts of the IoT.est project to develop a framework for service creation and testing in an IoT environment. The architecture extends the IoT reference architecture and enables a test-driven, semantics-based management of the service lifecycle. Its validation is illustrated through a dynamic test case generation and execution scenario.

- The chapter “A Cognitive Management Framework for Empowering the Internet of Things” presents a Cognitive Management framework for the Internet of Things (IoT). The framework dynamically adapts its behaviour, through self-management functionality, based on knowledge of status and policies. It presents a first indicative implementation of the proposed framework, comprising real sensors and actuators. The preliminary results demonstrate high potential towards self-reconfigurable IoT.

- The chapter “Resource Optimisation in IoT Cloud Systems by using Matchmaking and self-Management Principles” focuses on integrated IoT cloud service data management based on annotated data of monitored cloud performance and user profiles. It illustrates a cloud service management approach based on matchmaking operations and self-management principles that enable faster distributed service analysis and use the results as mechanisms to control applications and services deployment in cloud systems.
Conclusions

The enabling technologies for the future Internet are manifold. The articles described in this section show several future directions towards innovative uses of computing clouds and an extension of the Internet towards an Internet of things that can have many faces and potential application areas.
Introduction

Previous sections of the FIA 2013 book with respect to the Future Internet area focused on architectures, foundations, and enabling technologies; this part III addresses the highly relevant dimensions of trust and security, combined with economic incentives, and open solutions. These three dimensions determine key enabling aspects in operationally feasible and sensible approaches, which the Future Internet needs to be supported with rather sooner than later.

While the inter-operation between providers and users (determining the two very distinct groups of stakeholders in place today and tomorrow) is required to be either run on a trusted basis, which has to be established by respective technical means, such as algorithms and system components, the security itself opens up a large umbrella of aspects, such as authentication, authorization, integrity, privacy, confidentiality, non-repudiation, and trust. Enabling user-driven policy enforcements and configurations requires a well-balanced selection of such mechanisms. However, in all cases a system-specific view on any vulnerabilities and attacks need to be established to understand the full risks of operation, which involves a trusted or untrusted human.

Only the optimal combination of those aspects, which are application-dependent at least, and the ease-of-use type of solution will determine a successful deployment of large scale in the Future Internet. However, since only the right set of incentives will make a pure technology-driven solution operational, typically, in a commercialized world of services and interactions, economic incentives will enable a viable solution under combined technological and commercial views. Therefore, the examination and further development as well as implementation of economic incentives for those two groups of stakeholders are a key condition for a viable Future Internet functionality.

The user plays a crucial role. His and her requirements shall be taken into consideration closely and respective user interfaces are deemed highly ubiquitous.
Last but not least, the openness of such approaches, solutions, mechanisms, and implementations will help accelerate the implementation of technological solutions into a user-acceptable system, which forms the very basic for an advantageous, productive, and finally prosperous Future Internet, since all parameters and settings are openly visible, they may be configured to application needs and per-use specific demands. In that sense the ITU-T’s standardization work is considered a valuable path to follow.

Challenges

The recently published FIA 2020 Roadmap [1] presents an interesting analysis of the ongoing importance of trust and security, based on the view of the Future Internet as a complex technical-socio-economic system. As the scale of threats and potential for conflicts and the society's reliance on Internet-based networks for operation of critical infrastructures continues to increase, the management of securities and the development of adequate and also "user-friendly" technologies and solutions remains a challenge over the next decades. A holistic, systems approach to security will be necessary. This will be based on not only intelligent and differentiated measures and robust systems architectures, but also on making the user part of the system secure. This will involve security considerations being automatically taken into account during the software development, with justifiable assurance that the software is secure. It will be possible to dynamically compose and personalize services in a secure way, and customization does not come at a cost to security. Services that are available on the open market will have well defined security properties. Inter-organizational security analysis and management will be possible. There will be good tools and other support for end users to understand security (and privacy) implications of those services they use. The crucial point is that it will be possible for users to make informed choices based on a sound understanding of security and risk; in parallel, users will need to be more empowered with appropriate control over the level of risk, notably through standard, transparent interaction with systems and networks.

Incentives define an economic mechanism to enable an interplay of stakeholders to act in a manner, which gives at best all of them a viable reason to contribute resources into a system and to discourage free-riders at the same time, thus, avoiding the use of resources only without commensurate contribution. Incentive mechanisms, such as BarterCast, tit-for-tat, Give-to-Get, or Private Shared History (PSH) in multiple variants, can be divided into two groups – trust-based and trade-based incentive mechanisms: (a) for trust-based incentive mechanisms, all peers are encouraged to act in a way to gain as much trust as possible. While a positive peer’s behaviour increases such a trust value, a negative behaviour decreases this value. (b) for trade-based incentive mechanism, resources are exchanged and peers are encouraged to provide in order to consume, thus, a misconduct results immediately in a penalty. With respect to the economic incentives a number of challenges are known today, which include the
search for transitive incentive mechanisms in application-independent networking systems, suitable approaches for mapping incentive mechanisms into viable monetary or non-monetized schemes, and especially general and integrated incentive mechanisms for streaming and video-on-demand systems. There are many application level incentive schemes, which are dependent on the business model. Whilst a majority is directly transposed from the bricks-and-mortar world, others leverage the viral effect of the Internet to deliver non-monetary values such as reputation and recommendations.

Finally, the open solutions point of view is associated with a list of challenges linked to the understanding and interpretation of openness from the perspectives of technology, economics/business models, as well as the overall “system” as an ecosystem. At the technology level, developments have focused on increasing interoperability in networks, applications and services, often coupled with considerations for standardization. At the business level, open business models have generated a large volume of scholarship, which is increasingly linked to the notion of open innovation as well as re-appraisal of business values. At the systemic level, the discussion on ecosystems has involved: (a) the development of a wide variety of applications based on a generic technology platform; (b) the development of business partnerships based around a provider’s core offering, typically for expanding and/or customizing the functionality of the offering for broadening market reach; and (c) the development of a system of relationships and the supporting infrastructures (technical and business) involving suppliers and customers, potential or actual, that are tightly aligned with those activities, characteristics, objectives, and value proposition of a company. Open solutions viewed through the lenses of an ecosystem are linked to the role of generic technologies in creating markets (as in a); the need to collaborate with a wider range of partners including third party developers, consultants, and channels (as in b), and the emergence of a new type of market and even mode of exchange brought about by Internet and especially Web native companies (as in c). Each of these involves a large set of issues with deep intersections between technology, business, and policy. Research in such areas will need to be intensified and deepened in the coming years.

Contributions

Chapters contained in this book that address some of the aforementioned challenges include:

– The “The NEBULA Future Internet Architecture” chapter discusses the future network enabling the vision of cloud computing. In particular, the NEBULA approach presented is organized into three major architectural thrust areas: (a) reliable routing system and data center interconnect, (b) a data plane enabling policy enforcement, and (c) a novel approach to a control plane architecture allowing users to control the network configuration from the edge.
– The chapter “User Involvement in Future Internet Projects” addresses user involvement in the Future Internet community. The authors were interested to find out, whether current Future Internet projects support user-led innovation and in this way empower ordinary people, citizens, and non-commercial entities. Thus, to determine actual attitudes and practices of those working in the Future Internet industry toward user-centricity, the approach presented follows a focus group approach.

– The chapter “An Internet-based Architecture Supporting Ubiquitous Application User Interfaces” presents the multi-device application platform “webinos” founded on the Future Internet infrastructure and in particular discusses this platform’s ability to dynamically adapt application user interfaces to the current delivery context.

– The chapter “Open the Way to Future Networks – A Viewpoint Framework from ITU-T” presents major background and the context of Future Networks’ standardization by the ITU-T, current results, and future plans originating from the initial standardization work performed, which has resulted by now in initial Recommendations laying out essential directions for subsequent detailed work including further standardization of Future Networks.

Reference

Introduction

This is the fifth book capturing the results of the Future Internet Assemblies – the first was published in 2009. In that time we can see that the prominence of applications has increased of that time – there were no application chapters in the first book. This increase is due to two main factors. Firstly, the technologies are maturing over time and are now at a stage where serious industrial deployment is feasible. Secondly, within the early Future Internet Assemblies (FIAs) there was a realization that a wide range of stakeholders needed to be engaged to ensure that we continue to move in a direction which meets Europe’s economic and societal needs. Moreover, it is essential that our stakeholder group includes representatives from the important vertical niches such as transport, energy and the public sector. The fact that we now combine Smart Applications and Services into one section highlights the strong connection between these two strands.

The Future Internet can be thought of in many ways. A simple service-centric view is the Internet has three main components: (i) a network to provide connectivity (wired or wireless), (ii) a service layer to expose resources and (iii) an application layer which provides added value for end-users. Within the service layer two main classes of services can be found. Infrastructure services expose core capabilities required for the service layer to function. Typically, these may be related to networking, to managing resource repositories and core SOA function such as service invocation. Higher level services support the creation of business services supplying value to customers typically for a fee. Thus, the service layer acts as a bridge between the low-level network infrastructure and companies enacting a variety of business models to serve the related communities.

Smart applications was a concept which was adopted early on in the FIA series. The notion captured here was that Future Internet technologies enable a new type of application to be constructed. Ubiquitous and high bandwidth connectivity means that in principle applications have access to all required data and resources in real-time as required with geographic distance no longer a barrier. Applications based upon ecosystems of online data and computational
resources, developers and users are now emerging where boundaries between both real-world and computational entities and roles are blurred.

The complexity in the Future Internet will increase, as billions of devices, users and service will coexist and interact. In such a sophisticated infrastructure which can be seen as a very complex system of systems, the applications will be the entry point for many users to interact and enjoy its offerings. Future Internet application developers will have to tame the heterogeneity of sources and target end-user devices, in addition to dealing with the utilization of the Future Internet infrastructure offerings such as Cloud Computing, and the Internet of Things. Collaborative approaches may give rise to a new generation of applications and sophisticated services that are user-centric and provide added-value at a fraction of time and cost. However for the latter to happen, several grand challenges still need to be tackled.

Challenges

A world where on the one hand users demand 24/7 access to cheap (or free), easy-to-use, secure, mobile, personalized and context aware applications and on the other where services and applications are provisioned within dynamic, fluid frameworks with no central control, provides many challenges for the Future Internet community. Within this scenario, the components of applications and services are spread over highly inter-connected infrastructures which may be hosted on heterogeneous hardware and software platforms within distinct organisations. In order to fulfil user demands service and application Future Internet technologies need to support a range of non-trivial requirements including:

- On-the-fly discovery – instantaneously finding resources which match new or changing user requirements, within a setting where no uniform description language or vocabulary exists.
- On-the-fly aggregation – automatically or semi-automatically composing components to create a running application requires a number of research problems to be solved.
- Transitivity – passing information related to payments and faults, for example, between just-aggregated systems across institutions and platforms is a significant challenge.
- Interoperability – systems run on a mixture of software and hardware platforms where data and services will differ in syntax, semantics and interaction characteristics. Mediating between these heterogeneities requires more research.
- Seamless substitution – if a service or resource becomes unavailable finding and accommodating a new one, which meets the needs in a seamless fashion, is an important pre-requisite to fulfilling end-user expectations today.

Meeting the above challenges has been a goal for the research carried out in the FIA projects since the begin of FIA.
Contributions

Chapters contained in this book that address some of the aforementioned challenges include:

– The chapter "Towards an architecture for Future Internet applications" deals with the needs of applications in the Future Internet Era where multiple devices should be addressed and context information provided by ubiquitous sensors need to be integrated. Here challenges addressed include integration and device-agnostic application development.
– The chapter "User Involvement in Future Internet Projects" addresses in a survey the aspect of user-centred development. User involvement is highly valued and expected to maximise the societal benefits of Future Internet applications.
– In chapter "An Internet-based Architecture Supporting Ubiquitous Application User Interfaces", a multi-device application platform founded on the Future Internet infrastructure is presented; the focus is on the model-based user interface framework as a mean to support context-aware adaptiveness for applications that are executed in ubiquitous computing environments such as those envisioned in Future Internet.
– The chapter "ComVantage: Mobile Enterprise Collaboration Reference Framework and Enablers for Future Internet Information Interoperability" presents a reference architecture for mobile enterprise collaboration based on linked-data interoperability. Additionally, security, semantic data lifting, business process modelling interoperability and mobile app orchestration enablers are presented with the goal of facilitating trustful and effective inter-organisational collaboration.
– The chapter "SmartSantander: Internet of Things Research and Innovation through Citizen Participation" depicts the development of smart city services and applications in the Future Internet era that benefit all stakeholders.

Conclusions

Smart applications and services lie at the heart of the Future Internet. Value added services and innovative applications that will empower their users is one of the key goals for the new global communications platform. The challenges that lie ahead in order to support multi-domain scenarios over an increasingly complex infrastructure should not be underestimated and need to be addressed in a cross-disciplinary manner.
# Table of Contents

**Software Driven Networks, Virtualisation, Programmability and Autonomic Management**

Towards a Socially-Aware Management of New Overlay Application Traffic Combined with Energy Efficiency in the Internet (SmartenIT) ... 3

*Burkhard Stiller, David Hausheer, and Tobias Hoßfeld*

The NEBULA Future Internet Architecture .................. 16

*Tom Anderson, Ken Birman, Robert Broberg, Matthew Caesar, Douglas Comer, Chase Cotton, Michael J. Freedman, Andreas Haeberlen, Zachary G. Ives, Arvind Krishnamurthy, William Lehr, Boon Thau Loo, David Mazières, Antonio Nicolosi, Jonathan M. Smith, Ion Stoica, Robbert van Renesse, Michael Walfish, Hakim Weatherspoon, and Christopher S. Yoo*

Open the Way to Future Networks – A Viewpoint Framework from ITU-T .......................................................... 27

*Daisuke Matsubara, Takashi Egawa, Nozomu Nishinaga, Myung-Ki Shin, Ved P. Kafle, and Alex Galis*

Towards a Minimal Core for Information-Centric Networking ........ 39

*Kari Visala, Dmitrij Lagutin, and Sasu Tarkoma*

Managing QoS for Future Internet Applications over Virtual Sensor Networks .......................................................... 52

*Panagiotis Trakadas, Helen Lelgou, Theodore Zahariadis, Panagiotis Karkazis, and Lambros Sarakis*

High Availability in the Future Internet .......................... 64

*Levente Csikor, Gábor Rétvári, and János Tapolcai*

Integrating OpenFlow in IMS Networks and Enabling for Future Internet Research and Experimentation .................... 77

*Christos Tranoris, Spyros Denazis, Nikos Mouratidis, Phelim Dowling, and Joe Tynan*

## Computing and Networking Clouds

Contrail: Distributed Application Deployment under SLA in Federated Heterogeneous Clouds ..................................... 91

*Roberto G. Cascella, Lorenzo Blasi, Yvon Jegou, Massimo Coppola, and Christine Morin*
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud-Based Evaluation Framework for Big Data</td>
<td>104</td>
</tr>
<tr>
<td>Allan Hanbury, Henning Müller, Georg Langs, and Bjoern H. Menze</td>
<td></td>
</tr>
<tr>
<td>Optimizing Service Ecosystems in the Cloud</td>
<td>115</td>
</tr>
<tr>
<td>Usman Wajid, César A. Martín, and Nikolay Mehandjiev</td>
<td></td>
</tr>
<tr>
<td>Resource Optimisation in IoT Cloud Systems by Using Matchmaking and Self-management Principles</td>
<td>127</td>
</tr>
<tr>
<td>Martin Serrano, Danh Le-Phuoc, Maciej Zaremba, Alex Galis, Sami Bhiri, and Manfred Hauswirth</td>
<td></td>
</tr>
<tr>
<td>Towards a Secure Network Virtualization Architecture for the Future Internet</td>
<td>141</td>
</tr>
<tr>
<td>Pedro Martínez-Julía, Antonio F. Skarmeta, and Alex Galis</td>
<td></td>
</tr>
<tr>
<td>Seeding the Cloud: An Innovative Approach to Grow Trust in Cloud Based Infrastructures</td>
<td>153</td>
</tr>
<tr>
<td>Stéphane Betgé-Brezetz, Aline Bousquet, Jérémy Briffaut, Eddy Caron, Laurent Clevy, Marie-Pascale Dupont, Guy-Bertrand Kamga, Jean-Marc Lambert, Arnaud Lefray, Bertrand Marquet, Jonathan Rouzaud-Cornabas, Lamiel Toch, Christian Toinard, and Benjamin Venelle</td>
<td></td>
</tr>
<tr>
<td>Internet of Things</td>
<td></td>
</tr>
<tr>
<td>IoT6 – Moving to an IPv6-Based Future IoT</td>
<td>161</td>
</tr>
<tr>
<td>Sébastien Ziegler, Cedric Crettaz, Latif Ladid, Srdjan Krco, Boris Pokric, Antonio F. Skarmeta, Antonio Jara, Wolfgang Kastner, and Markus Jung</td>
<td></td>
</tr>
<tr>
<td>SmartSantander: Internet of Things Research and Innovation through Citizen Participation</td>
<td>173</td>
</tr>
<tr>
<td>Verónica Gutiérrez, Jose A. Galache, Luis Sánchez, Luis Muñoz, José M. Hernández-Muñoz, João Fernandes, and Mirko Presser</td>
<td></td>
</tr>
<tr>
<td>A Cognitive Management Framework for Empowering the Internet of Things</td>
<td>187</td>
</tr>
<tr>
<td>Vassilis Foteinos, Dimitris Kelaidonis, George Poulis, Vera Stavroulaki, Panagiotis Vlacheas, Panagiotis Demestichas, Raffaele Giaffreda, Abdur Rahim Biswas, Stephane Menoret, Gerard Nguyenbang, Matti Etelapera, Necifor Septimiu-Cosmin, Marc Roelands, Filippo Visintainer, and Klaus Moessner</td>
<td></td>
</tr>
<tr>
<td>Building Modular Middlewares for the Internet with OSGi</td>
<td>200</td>
</tr>
<tr>
<td>Jakub Flotyński, Kamil Krysztowiak, and Daniel Wilusz</td>
<td></td>
</tr>
<tr>
<td>Towards an Architecture for Future Internet Applications</td>
<td>214</td>
</tr>
<tr>
<td>Jacek Chmielewski</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>ComVantage: Mobile Enterprise Collaboration Reference Framework</td>
<td>220</td>
</tr>
<tr>
<td>and Enablers for Future Internet Information Interoperability</td>
<td></td>
</tr>
<tr>
<td>Angelika Salmen, Tobias Münch, Steffen Buzin, Jan Hladik,</td>
<td></td>
</tr>
<tr>
<td>Werner Altmann, Conny Weber, Dimitris Karagiannis, Robert Buchmann,</td>
<td></td>
</tr>
<tr>
<td>Jens Ziegler, Johannes Pfeffer, Markus Graube, Manuel Carnerero,</td>
<td></td>
</tr>
<tr>
<td>Oscar López, Mikel Uriarte, Patricia Órtiz, and Oscar Lázaro</td>
<td></td>
</tr>
<tr>
<td>Test-Enabled Architecture for IoT Service Creation and Provisioning</td>
<td>233</td>
</tr>
<tr>
<td>Suparna De, Francois Carrez, Eike Reetz, Ralf Tönjes, and Wei Wang</td>
<td></td>
</tr>
<tr>
<td>Enabling Technologies and Economic Incentives</td>
<td></td>
</tr>
<tr>
<td>Sustainable Wireless Broadband Access to the Future Internet -</td>
<td>249</td>
</tr>
<tr>
<td>The EARTH Project</td>
<td></td>
</tr>
<tr>
<td>Dietrich Zeller, Magnus Olsson, Oliver Blume, Albrecht Fehske,</td>
<td></td>
</tr>
<tr>
<td>Dieter Ferling, William Tomaselli, and István Gódor</td>
<td></td>
</tr>
<tr>
<td>An Internet-Based Architecture Supporting Ubiquitous Application</td>
<td>272</td>
</tr>
<tr>
<td>User Interfaces</td>
<td></td>
</tr>
<tr>
<td>Heiko Desruelle, Simon Isenberg, Dieter Blomme, Krishna Bangalore,</td>
<td></td>
</tr>
<tr>
<td>and Frank Gielen</td>
<td></td>
</tr>
<tr>
<td>Cooperative Strategies for Power Saving in Multi-standard Wireless</td>
<td>284</td>
</tr>
<tr>
<td>Devices</td>
<td></td>
</tr>
<tr>
<td>Firooz B. Saghezchi, Muhammad Alam, Ayman Radwan, and Jonathan</td>
<td></td>
</tr>
<tr>
<td>Rodriguez</td>
<td></td>
</tr>
<tr>
<td>Counting the Cost of FIRE: Overcoming Barriers to Sustainable</td>
<td>297</td>
</tr>
<tr>
<td>Experimentation Facilities</td>
<td></td>
</tr>
<tr>
<td>Michael Boniface, Philip Inglesant, and Juri Papay</td>
<td></td>
</tr>
<tr>
<td>User Involvement in Future Internet Projects</td>
<td>310</td>
</tr>
<tr>
<td>Anne-Marie Oostveen, Eric T. Meyer, and Brian Pickering</td>
<td></td>
</tr>
<tr>
<td>Design and Implementation of Cooperative Network Connectivity</td>
<td>323</td>
</tr>
<tr>
<td>Proxy Using Universal Plug and Play</td>
<td></td>
</tr>
<tr>
<td>Raffaele Bolla, Maurizio Giribaldi, Rafiullah Khan, and Matteo</td>
<td></td>
</tr>
<tr>
<td>Repetto</td>
<td></td>
</tr>
<tr>
<td>Book Sponsoring Projects Overview</td>
<td></td>
</tr>
<tr>
<td>3DLife - Bringing the Media Internet to Life</td>
<td>339</td>
</tr>
<tr>
<td>Qianni Zhang, Noel E. O’Connor, and Ebroul Izquierdo</td>
<td></td>
</tr>
<tr>
<td>CONCORD Project Management of the Future Internet</td>
<td>342</td>
</tr>
<tr>
<td>Ilkka Lakaniemi</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>FLAMINGO NoE Project Management of the Future Internet</td>
<td>344</td>
</tr>
<tr>
<td>Sebastian Seeber</td>
<td></td>
</tr>
<tr>
<td>The GEYSERS Concept and Major Outcomes</td>
<td>346</td>
</tr>
<tr>
<td>Anna Tzanakaki, Sergi Figuerola, Joan A. García-Espín, Dimitra Simeonidou, Nicola Ciulli, Philip Robinson, Juan Rodríguez, Giada Landi, Bartosz Belter, Pascale Vicat-Blanc, Matteo Biancani, Cees de Laat, Eduard Escalona, and Artur Binczewski</td>
<td></td>
</tr>
<tr>
<td>iCore: A Cognitive Management Framework for the Internet of Things</td>
<td>350</td>
</tr>
<tr>
<td>Raffaele Giaffreda</td>
<td></td>
</tr>
<tr>
<td>IoT6 Project in a Nutshell</td>
<td>353</td>
</tr>
<tr>
<td>Sébastien Ziegler and Cedric Crettaz</td>
<td></td>
</tr>
<tr>
<td>Mobile Cloud Networking: Mobile Network, Compute, and Storage as One Service On-Demand</td>
<td>356</td>
</tr>
<tr>
<td>Almerima Jamakovic, Thomas Michael Bohnert, and Georgios Karagiannis</td>
<td></td>
</tr>
<tr>
<td>The SmartenIT STREP Project: Socially-Aware Management of New Overlay Application Traffic Combined with Energy Efficiency in the Internet</td>
<td>359</td>
</tr>
<tr>
<td>Burkhard Stiller</td>
<td></td>
</tr>
<tr>
<td>The SmartSantander Project</td>
<td>361</td>
</tr>
<tr>
<td>José M. Hernández-Muñoz and Luis Muñoz</td>
<td></td>
</tr>
<tr>
<td>UniverSelf, Realizing Autonomics for Future Networks</td>
<td>363</td>
</tr>
<tr>
<td>Laurent Ciavaglia and Alcatel-Lucent</td>
<td></td>
</tr>
<tr>
<td>Author Index</td>
<td>367</td>
</tr>
</tbody>
</table>