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REPORT

Management of the Future Internet: Status and Challenges

A Report on the 4th IEEE/IFIP International Workshop on Management of the Future Internet (ManFI 2012)

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Abstract The 4th IEEE/IFIP International Workshop on Management of the Future Internet (ManFI 2012) was held on April 16, 2012 in Maui, USA. This report summarizes the keynotes, presentations and discussions in ManFI 2012 and provides a high-level view of ideas, challenges, strategies and the current state of the research activities in the field of the Future Internet management.

Keywords Future Internet · Network management · Future Internet management · Management architecture · Autonomic networking · OpenFlow-based Future Internet architectures

1 Introduction

The 4th IEEE/IFIP International Workshop on Management of the Future Internet (ManFI 2012) was organized as a forum to promote Future Internet research activities, to provide recent results and to discuss upcoming challenges related to management aspects of the Future Internet. The workshop took place on April 16,

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2012, in the Lahaina Westin Hotel, in conjunction with the 13th IEEE/IFIP International Network Operations and Management Symposium (NOMS 2012). ManFI 2012 was sponsored by the IEEE Communications Society, and POSTECH IT Convergence Engineering (ITCE), Ghent University—IBBT, and NEC. The workshop was endorsed by the IEEE Communication Society's Technical Committee on Network Operations and Management (CNOM).

The currently ongoing research in the area of management of the Future Internet can be classified in four main categories: (1) architecture design for management of the Future Internet and its validation through specific use cases, (2) design of advanced Future Internet management mechanisms, i.e. enablers to be integrated with the management architectures (3) software defined networking and OpenFlow-based Future Internet architectures and (4) traffic identification, trust and QoS in the Future Internet. In each of these categories, many researchers are currently active and making significant progress.

The accepted ManFI 2012 full papers were clustered in four sessions, each focusing in particular on one of the four above mentioned categories. During each session, the progress made and challenges ahead in each of these four categories were discussed amongst the presenters and all attendees.

Each year, there is a growth in the community that is dedicated to exploring how the Future Internet can be better governed and managed. The first edition of ManFI was held in 2009 with the IEEE/IFIP Integrated Management Symposium (IM) 2009 in New York, USA, the second was held in 2010 with NOMS 2010 in Osaka, Japan, the third was held in 2011 with IM 2011 in Dublin, Ireland. Typical for the four ManFI workshops is the high degree of interaction between the speakers and the audience. In this year's edition, the interaction and discussion between the attendees was further stimulated by introducing (1) two motivating keynote speeches, and (2) poster presentations on recent and emerging topics in this year's technical program. The first keynote speech took place in the morning and addressed in a provocative way the first two categories, mentioned above (Future Internet management architecture design and mechanism design). The second keynote took place right after the lunch break and focused on the status and challenges in the last two categories (software defined networking and OpenFlow-based Future Internet architectures and traffic identification, trust and QoS in the Future Internet). The ManFI 2012 posters were presented and discussed with the attendees during a dedicated timeslot in the agenda and also during the coffee breaks. This way, we further contributed to the ManFI vision of encouraging the development of new ideas and promising approaches during a one day single track workshop. We believe that this year's edition of ManFI will help stimulate researchers in considering how to manage the Future Internet.

The ManFI 2012 program featured 10 technical papers, 8 poster presentations, and two keynote addresses. Authors from 16 different countries submitted papers and all submitted papers were reviewed by at least three members of the technical program committee, consisting of international experts in the field management of the Future Internet. Based on the review comments, scores, quality of the presentation and answering of the questions, two best paper awards were given at the closing of the workshop.

2 Keynote Addresses

The opening keynote titled, ''Future Internet Management: Surfing a New Wave'' was given by Joel Fleck, who is a senior researcher with HP, USA.

Joel pointed out that new technologies (such as service oriented architectures, cloud computing) require a dynamic means to build and to maintain relationships between domains and "on-demand" or "as-needed" linking of services or applications requires a high degree of confidence that the desired services or applications will be available. Policy-based Management is essential to support the adaptive nature of the emerging environments, and there is a need to manage "the space between" domains and clouds.

A Model driven approach to managing Inter-Domain relationships provides a means to achieve all of these. As solutions become increasingly more distributed (both geographically and in terms of number of providers), semantics will become critical, context will be an important factor in the total solution, and the models must be adaptive. As a summary, the emerging highly adaptive and distributed network requires a new vision for management: one that is focused on an adaptive, policy-driven, model-based approach that is designed, developed and run in partnership with the network and applications.

The second keynote, titled "Software defined Networking and OpenFlow: Challenges and Opportunities", was given by Masayoshi Kobayashi, who is a researcher at NEC and visiting scholar at Stanford University, USA. The presenter is a strong contributor to the Open Networking Summit, which gathered in San Francisco in April 2012 and attracted 800 participants from industry and academia. Masayoshi first presented several use cases and scenarios (home network management, access and core network management and customization of cloud applications) and pointed out the current limitations in terms of configuration and related flexibility issues. Second, he proposed network virtualization as a solution to overcome the current limitations. For each of the above presented scenarios, the benefits in terms of configuration flexibility and gains for the involved stakeholders were highlighted. Next, a detailed overview was provided of the current state-of-the art in available research prototypes and software stacks for software defined networking and OpenFlow in particular. The main identified challenges were expressed in terms of security extensions and tool improvement for building applications on top of an Openflow platform.

3 Technical Paper Sessions

The technical paper sessions were structured in four sessions: two sessions related to the first keynote before noon and two sessions related to the second keynote in the afternoon. A total number of ten papers was selected for presentation at the workshop. Accepted papers were classified in four sessions: (1) Future Internet Management Architecture Design, (2) Design of Advanced Future Internet Management Mechanisms, (3) OpenFlow-based Future Internet Architectures, (4) Traffic Identification, Trust and QoS in the Future Internet.

In the following, we provide a brief overview of the contributions of the papers in each of the sessions.

3.1 Session on Future Internet Management Architecture Design

Saber Zrelli (Yokogawa Electric Corporation, Japan) presented "ENM: A Service Oriented Architecture for Ontology-Driven Network Management in Heterogeneous Network Infrastructures". The authors propose the ENM (Extended Network Management) framework, a scalable and extensible service oriented architecture for deploying ontology-driven network management services for large scale, multi-technology and multi-vendor heterogeneous network infrastructures. The ENM framework leverages two technologies, namely ontologies for data and knowledge representation and the Diameter protocol for multi-domain communication framework. The ENM Knowledge Base is responsible of storing data and semantics needed by ontology-driven network management applications. The Web Ontology Language (OWL) is used for storing ontologies in the ENM Knowledge Base and the SPARQL ontology query language for accessing the ontologies. To demonstrate the feasibility of the proposed framework, a proof of concept was implemented, deployed and evaluated on a test-bed for both intra-domain and inter-domain operations.

Sung-Su Kim (Pohang University of Science and Technology, Korea) presented "Autonomic Fault Management based on Cognitive Control Loops". This paper describes the design of an autonomic fault management architecture based on cognitive control loops which are part of the new FOCALE model. The cognitive control loop determines the priorities of network alarms, processes alarms with three different control loops, and then infers root causes of the problems based on learning and reasoning. The presented concepts are validated using synthetically generated alarm data sets. Missing and changing dependencies in the manually defined dependency model are automatically detected by a learning phase of the control loops. Ontologies and SWRL rules are used to represent the relationships among network resources, services, and alarm priorities. The evaluation results clearly show that the number of alarms is reduced, and that root causes are found easily by the association rules.

3.2 Session on Design of Advanced Future Internet Management Mechanisms

Sylvain Hallé (Université du Quebec à Chicoutimi, Canada) presented "ValidMaker: A Tool for Managing Device Configurations Using Logical Constraints". The authors introduce a formal language, referred to as Configuration Logic (CL), to enable a network management engineer to express constraints in terms of the actual parameters found in the configuration of network devices. An algorithm is highlighted (1) to check a pool of devices automatically for conformance to a set of CL constraints and (2) to determine the part of the configuration, which is responsible for the error when a constraint is violated. The authors integrated a CL validation engine into a network management tool, referred to as ValidMaker. During the ManFI 2012 presentation a live demo was shown for efficient VLAN

configuration based on formal constraints. Moreover, results from a validation time performance analysis were presented.

Andreas Louca (Lancaster University, UK) presented "Efficient Message passing and Autonomic Management Architecture for NGNs". In this paper, the authors build further on the Network Architecture Project (ANA) and some of the essential concepts such as Functional Blocks and Information Dispatch Points. ANA proposed a clean-slate design, whereas in this paper, the authors present a holistic approach to Network Management, which re-uses the existing management protocols and techniques used to manage modern networks but within a novel autonomic management architecture. Management functions and monitoring/analysis algorithms are de-composed into functional blocks. Function blocks then self-organize into Autonomic Services, which in turn manage a part of a network. The key element behind the architecture is a novel message-passing framework, which facilitates loose coupling, self-organization and self-configuration. The Message Passing framework is detailed in the paper, and detailed performance results based on a proof-of-concept implementation are reported upon.

Xiongqi Wu (University of Kentucky, USA) presented "Network Path Advising Service for the Future Internet". The authors motivate the need for a new service that assists applications in selecting network paths in the Future Internet. The design of such a network path advising service (NPAS) is detailed in the paper. Given a set of possible paths, the NPAS service selects appropriate paths based on both recent path measurements and end-to-end feedback collected from other applications. The authors detail the NPAS service abstraction, API calls, and present a distributed implementation that achieves scalability by determining the most important metrics to monitor based on actual usage. Furthermore, a prototype implementation of the NPAS service is presented.

3.3 Session on OpenFlow-Based Future Internet Architectures

Eiji Kawai (National Institute of Information and Communications Technology, Japan) presented "Deployment and Operation of Wide-area Hybrid OpenFlow Network". In this paper, the authors point out that deploying hybrid, wide-area, OpenFlow networks is currently unavoidable because it is impractical to replace such wide-area networks with OpenFlow-enabled ones at once. They state that the design, deployment, and operation of such hybrid OpenFlow networks are often conducted intuitively without in-depth technical considerations. For this reason, they present a systematic overview of the technical aspects of the hybrid architecture for OpenFlow networks based on their experiences so far in the development of wide-area hybrid OpenFlow networks in Japan (i.e. JGN2plus and JGN-X). Furthermore, they also describe in detail the design and operation of RISE (research infrastructure for large-scale network experiments). Their planned future work includes: (1) introduction of MPLS tunneling technology, (2) improved management of user slices, and (3) interconnection of RISE to other international OpenFlow testbeds.

Edmundo Madeira (University of Campinas, Brazil) presented "A Proposal Management of The Legacy Network Environment using OpenFlow Control Plane". The authors tackle the challenge of how to enable and to evaluate

experimentally new Future Internet services in realistic experimental settings without sacrificing the current production infrastructure. The authors point out that when using the OpenFlow protocol, there is a practical problem that arises with Legacy networks that do not support OpenFlow and need to be replaced/upgraded or refined by means of costly network re-engineering. The paper proposes a new OpenFlow architecture with components, capable of managing Legacy-non-OpenFlow elements by offering a new solution that facilitates the management of Legacy technologies and allows them to be employed in Future Internet experimentation environments. The LegacyFlow approach is described in detail and presented by means of illustrative scenarios.

3.4 Session on Traffic Identification, Trust and QoS in the Future Internet

Sung-Ho Yoon (Korea University, Korea) presented "Signature Maintenance for Internet Application Traffic Identification using Header Signatures". The authors stress the importance of application traffic identification for the Future Internet and point out that the main problem of a header-based identification method is the extremely large number of signatures. For this reason, they designed a signature maintenance method using the properties of identified traffic and usage history of signatures. Based on a large experimental set up on a campus network, they present detailed results on the feasibility and applicability of the proposed method. In particular, the designed method is compared to two existing methods in the literature in terms of completeness and accuracy (both expressed in flow/byte) on one hand and number of signatures to maintain on the other hand. The results show that the proposed method can significantly reduce the number of signatures for identification (1.58 %) without sacrificing the performance in terms of completeness and accuracy.

Young-Tak Kim (Yeungnam University, Korea) presented "QoS-aware Network Operating System for Software Defined Networking with Generalized OpenFlows". In this paper, the authors build further on the Network Operating System (NOX), which was proposed to provide the control plane functions for OpenFlow. As an extension, a QoS-aware Network Operating System (QNOX) for Software Defined Networking with Generalized OpenFlow is presented. The functional modules and operations for QoS-aware SDN service provisioning are detailed in the paper. The current status of the prototype implementation and performance evaluation are reported upon. By means of a topology, consisting of 114 Generalized OpenFlow Forwarding Elements controlled by 1 Generalized OpenFlow Control element, the scalability of the QNOX is analyzed. The results confirm that the proposed framework can be applied for carrier grade large scale transport networks.

Shingo Ata (Osaka City University, Japan) presented "SeRViTR: A Framework for Trust and Policy Management for A Secure Internet and Its Proof-of-Concept Implementation". In this paper, the authors argue that in the Future Internet, it is desirable to provide user-centric or service-centric routing capabilities to achieve service-oriented traffic controls as well as trust and policy management. Based on these potential demands, a flexible, scalable, and robust routing framework which enables fine-grained flow control under given or dynamic policies called Virtual Trusted Routing and Provisioning Domain (VTRouPD) has been recently proposed by the

authors. In this paper a framework is outlined, referred to as the Secure and Resilient Virtual Trust Routing (SeRViTR) framework, which is a proof-of-concept model of VTRouPD at the implementation level. Moreover, the authors present a validation of the functional implementation of several SeRViTR components to illustrate how to create virtual domains and change of trust levels between virtual domains.

4 Ongoing Discussions and Ideas

The main areas of discussion following the keynote addresses and paper presentation were related to (1) the applicability of the prototypes, frameworks and results for other use cases than originally planned by the authors, (2) security aspects: can it be added as an afterthought in the presented platforms? (3) the business model assumptions and whether they will prove valid in Future Internet scenarios, (4) the public availability of tools, (5) the openness of management and configuration interfaces in the Future Internet, (6) the status and viewpoints of the standardization bodies, such as IETF, on Future Internet related topics and (7) the scalability aspects and potential optimizations for large scale service deployments in the Future Internet. Security is a very important requirement for Future Internet management platforms; however, the discussed that when developing prototype platforms and building up a first user base, security concerns might in some cases be addressed afterwards (i.e. when the prototype is turned into a commercial product). In terms of business models, there was a discussion about the feasibility of opening up network devices or cloud datacenter configurations and whether network and service providers are really willing to allow this; based on the illustrative scenarios by the keynote speaker, Masayoshi Kobayashi, the workshop participants were convinced that software defined networking is indeed a promising path for Future Internet management and new interesting business models can be developed based on this paradigm.

Furthermore, the presented poster presentations also steered and added interesting contributions to the discussions. In particular, Shahnaza Tursunova (ETRI, Korea) explained the need for graph clustering based cloud provisioning algorithms and showed the benefits of a novel algorithm over traditional provisioning algorithms based on the minimum cut algorithm from graph theory. Muhammad Shoaib Siddiqui (Kyung Hee University, Korea) showed that applying autonomics in Policy-based Network Management has substantial benefits; he proposed two autonomic control loops for optimal configuration and policy optimizations in Policy-based Autonomic Network Management. Edmundo R. M. Madeira (University of Campinas, Brazil) argued the need for a multi-agent architecture for autonomic management of virtual networks and showed results based on simulation experiments. Yatao Yang (University of Zurich, Switzerland) mentioned the non-repudiation issue when users access the Internet via wireless mesh networks and introduced a novel non-repudiation scheme based on the user's Behavior Authentication Code (BAC). Mohit Chamania (Technische Universität Carolo-Wilhelmina zu Braunschweig, Germany) explained that BPEL-based workflow processing is beneficial for multi-layer management of IP-over-Optical networks and showed a multi-layer management architecture and measured configuration

times. Tim De Pauw (Ghent University, Belgium) stressed that in the future co-existing wireless, wireline and sensor networks have a strong potential to cooperate and to optimize dependability, connectivity, and energy efficiency dynamically. Such networks are referred to as symbiotic networks and he introduced a management architecture and service composition algorithm for symbiotic networks. Susana Sargento (Universidade de Aveiro/Instituto de Telecomunicacoes, Portugal) explained that in future autonomic network management platforms periodic exchange of information will not scale and the usage of social based metrics (neighbourhood friendship, associated nodes friendship and community nodes friendship) is an efficient means to improve information dissemination in large scale future networks. Matthias Strobbe (Ghent University—IBBT, Belgium) argued that in the future smart grid services will become part of our daily lives and service providers will need service management platforms for efficient provisioning and management of these services; he introduced a smart grid service management platform and showed the results obtained by an ongoing field trial.

In summary, many useful ideas were generated and interesting discussions took place amongst the attendees. We were happy to observe that the workshop inspired the participants and they could take home lots of ideas for consideration in their ongoing research projects or start new research projects to address the challenging topics.

5 Best Paper Awards

During the closing of the workshop, two best paper awards were given in recognition to the authors. The best papers were selected based on the review scores by the expert reviewers, the presentation during the workshop and the answering of the questions. The first best paper award went to a paper from academia, presented by Sylvain Hallé (Université du Quebec à Chicoutimi, Canada) with paper title "ValidMaker: A Tool for Managing Device Configurations Using Logical Constraints"; the paper is co-authored by Eric Lunaud Ngoupe, Gaetan Nijdam (Universite du Quebec a Chicoutimi, Canada), and Omar Cherkaoui, Petko Valtchev, Roger Villemaire (Universite du Quebec a Montreal, Canada). The other best paper award certificate was given to a paper from industry, presented by Eiji Kawai (National Institute of Information and Communications Technology, Japan), who presented the paper "Deployment and Operation of Wide-area Hybrid OpenFlow Network"; this paper was co-authored by Yoshihiko Kanaumi, Shu-ichi Saito (NEC Corporation, Japan), Shuji Ishii (National Institute of Information and Communications Technology, Japan), Kazumasa Kobayashi (Kurashiki University of Science and the Arts, Japan), and Shinji Shimojo (Osaka University, Japan).

6 Concluding Remarks

All ManFI 2012 full papers and short papers were also published in IEEE Xplore. Furthermore, all the program information of the workshop is available online at: http://www.manfi.org.

In summary, the workshop was very successful. All presentations were given as we planned and there were many fruitful discussions during and between sessions. We would like to thank the two keynote speakers for their excellent talks, the NOMS 2012 workshop chairs for their organizational support as well as all the authors for submitting and presenting their work and actively participating to the discussions. Finally, we thank all ManFI 2012 participants for their attendance and contributions to the discussions. The next ManFI workshop is planned to be organized again in collocation with IFIP/IEEE IM 2013 in Ghent, Belgium. If anyone is interested in getting involved in the organization and planning of ManFI 2013, please contact Prof. James Hong (jwkhong@postech.ac.kr).

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