Management of the Future Internet — Dagstuhl Seminar No. 09052 —

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Abstract — From January 27 to January 30, 2009 the Dagstuhl Seminar No. 09052 on "Management of the Future Internet" was held in Schloß Dagstuhl, Leibniz Center for Informatics. During the seminar, several participants presented their current research and ongoing work, and open problems were discussed. Abstracts of these presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this report.

The first section describes the overall seminar goals and topics. The second section lists available abstracts. And the third section refers to a full paper in the appendix, which was directly written based on one of the discussions taking place.

I. Seminar Goals and Topics

The goal of this Dagstuhl Seminar on "Management of the Future Internet" was to discuss the development of the provisioning of high quality Future Internet services to everybody by means of modern Network Management methods. This was achieved in an effective manner, since the discussion and presentation of adequate management aspects capable of configuring, monitoring, and controlling the Future Internet services delivered was performed. Such a management plane has been the focus of research and development in the context of traditional data and voice networks. And it was shown that the development of tomorrow's Future Internet — providing integrated voice and data services over multiple access networks — puts new major challenges to this area in terms of scalability, dynamicity, security, and automation.

Within the "Management of the Future Internet" Dagstuhl Seminar, the functionality of existing work on management of the Internet technology, traditional management approaches, and economic management approaches, especially with respect to its capabilities to allow for an integrated approach of design and deployment of future networks that incorporate new services, have been considered.

More specifically, the following areas of interest have been partially addressed:

Management Mechanisms for the Future Internet: While a number of Future Internet architectures are being debated the set of relevant and highly related management principles have not been addressed so far.

Fault, Configuration, and Security Operation in the Future Internet: The design, modelling, and evaluation of algorithms in the three functional areas have to cope with large scale systems. Solutions for the Future Internet are to be discussed with respect to architectural and functional patterns for management frameworks in large scale analysis.

Intra and Inter-Domain Autonomic Management in the Future Internet: For fixed networks the degree of automated inter-domain QoS management, self-management of MPLS optical networks, the automated intra- and inter-domain fault-management i.e., service recovery, and resilience need to be determined.

Economic Network and Service Management in the Future Internet: In support of a technically feasible approach of operating a network for numerous commercial services in an efficient manner, technology-wise and economically, advanced network and service management functionality is required.

Commercial operator-oriented mechanisms (Traffic Management): The investigation of a suitable management architecture, to form a platform in support of the exploitation of economic traffic management schemes for overlay services in a world-wide networking environment is crucial due to the increasing overlay traffic amount. Thus, relevant commercial and operational view points have to be considered in combination.

The seminar did follow some of those classifications.

II. Presentation Abstracts

The set of abstracts below do cover the provided material by the presenter and in some case of their absence a short summary of the respective presentation, summarizes by the seminar organizers.

A. DYSWIS: Managing Unmanaged Networks, Henning Schulzrinne, Columbia University, U.S.A.

As home and small-business networks get larger and more complicated, hiring a system administrator for each family or barber shop remains infeasible. We propose a new distributed, peer-to-peer management system, DYSWIS (Do You See What I See), that allows non-technical end users to identify likely causes of network and software-related problems.

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http://drops.dagstuhl.de/opus/volltexte/2010/2530

B. *Architectural Considerations for the Management of the Future Internet: Management of Overlay Traffic and Virtualized Networks, Wolfgang Kellerer, DOCOMO Euro-Labs, München, Germany*

One problem of the Internet today is its slow innovation cycle. In fact, the innovation has shifted to the network edges and manifests in emerging overlay networks providing most of the popular services. This observation leads to several challenges with respect to network design. One issue is the management of the traffic emerging from overlay networks. In order to address the overlay traffic management, new capabilities for an interworking of overlay and underlay have to be developed and standardized. As a second issue, network virtualization is providing a means to allow several virtual networks to run in parallel on the same network substrate hosting specialized network solutions (e.g., from today's overlays). This supports speeding up the network innovation cycles and also poses new challenges to network management.

C. *Towards a Service-aware Future Internet and its Management, George Pavlou, U.K.*

The Internet plays a central role in society, thus, work, business, education, and entertainment services arose. Being the victim of its own success, services impose new requirements, while, *e.g.*, last changes of routers by CIDR had happened in the 1990s, the TCP congestion control algorithms exist since 1986, and no changes are foreseen from GP in next 10 years. The solution space is large and the foible of today's Internet Management cover the fact that no technologies that are good enough for all management tasks, mostly non-automated approaches exist with human input, and no closed-loop management or automotive adaptive distributed management are in place. Thus, self-management in both, an evolutionary and a clean-slate approach are needed.

D. *Economic Traffic Management, Spiros Spirou, INTRACOM Telecom, Greece*

As users, applications, and traffic increase, networks inevitably grow in size and complexity. Such growth under a single authority, makes management increasingly expensive and error-prone. Also, as users and service providers try to work around network operator restrictions towards a flat service delivery model, management becomes adversarial and inefficient. Autonomy and cooperation could help in approaching these two challenges. Before any low level management mechanism is designed, the players, their goals, and related incentives should be identified in the network to be managed. Methods from Economics, such as Game Theory and even Mechanism Design, could the be applied to this triad of information to produce a set of rules for the players to follow. Careful economical modeling can produce rules that are mutually beneficial, so that players cooperate willingly. With such a set of compatible incentives, the managed network can achieve sustainable equilibrium autonomically. Only then should technical elements facilitating rule application should be designed and deployed. We call this method Economic Traffic Management. An application to the management of P2P traffic, identifies Overlay Providers, Network Operators, and Users as players, with QoS, profit, and QoE as their respective goals. The exchange of information about traffic flows and network status between Overlay Providers Network Operators creates an incentive for cooperation and autonomically fulfills all goals. In practice, the Network Operator should deploy a device facilitates the information exchange through related interfaces.

E. *Prediction of the Management of the Future Internet, Aiko Pras, University of Twente, The Netherlands*

Researchers focus to much on terms useful for getting funding. In Dagstuhl we'll do not need to sell our future project, but we can discuss fundamental concepts.

While popular statements include "Management should be included in the design" or "Autonomic/self-* management is the solution", it may not be the realistic approach at all. For sure, management is an essential evil! To cope with unexpected changes in requirements, to cope with unexpected problems, such as systems/networks failures, security attacks, is the key challenge all management systems needs to tackle. Thus, the Future Internet management approaches are in that respects very similar to existing ones.

F. *Future Internet – Challenges from Today's Perspective, Ivan Gojmerac, FTW, Austria*

The issue of identifying the most important Internet research topics represents one of the hardest challenges nowadays, as many technologies we use are perceived as "just working well". The only persistent wish by the users currently seems to be obtaining ever more bandwidth, while the concepts of QoS do not really seem purposeful in a world of abundant core transport capacities. (The shared nature mobile broadband access of course represents a notable exception form that paradigm.) In order to design a comprehensive Future Internet (FI) concept, it will be crucial to primarily identify the currently unfulfilled or latent needs of the users, instead of choosing a purely technology-driven approach.

G. *Future Internet: How Could it Work and Challenges to Management, Gabi Dreo Rodosek, Germany*

Future Internet: Is it just old stuff in new clothes? There are no news, very similar concepts, and new buzzwords. But the Future Internet is more: covering in an integrated manner mobility, QoS, security, situation-awareness, which does support new concepts of virtualization and self-management, just to name a few. The problem is: Do we request for contradictionary aims? Thus, the new management challenges need to be determined to outline new management approaches.

H. How Many Humans Should Manage the FI? How Each of Them Will "See" the Network? Lisandro Granville, Brazil

For the Future Internet the service and infrastructure providers are separated. Furthermore, virtualization includes P2P Overlays, virtual layer, and the physical network. Thus, the question is how to manage them, while covering existing routers, firewalls, and other devices? Following the discussion of the pros and cons of virtualization (flexible, cheaper, faster vs. more complex, slower, more expensive), the managing of the management sees the cost to be paid for virtualizuation. As an open issue it remains: the final balance may be positive, but who can save money in these scenarios?

I. Selected Management Challenges for the Future Internet — Working on a Dream! Olivier Festor, France

Assuming that the cores are all optical, that fixed access, wireless, mobile, and ad-hoc situations are available in private and overlay networks, the Internet of Things is going to be true, eventually about humans. Thus, networking is getting closer to physics and the Internet is out, and it can't be changed. Since 2000 networking research really got closer to physics: we have an object to study, we need models to understand how these objects work, but the network mutates and evolves in usage. Therefore, probabilistic and autonomic management are important and their scale is essential. The need for management benchmarks and common metrics to evaluate algorithms against attacks are the key. In conclusion, a management middleware needed, which will cover a management plane and knowledge plane.

J. Past, Current, Future Internet – Socio-economic Management Challenges and Perspectives, David Hausheer, Switzerland

It is necessary to put the user into the center of the view. Traffic in the past was measured, C/S-based traffic (such as E-mail and FTP) dominated, and TCP fairness worked, However, today the introduction of P2P traffic changed dramatically into dynamic overlays outside of the control of the ISP. Thus, TCP fairness fails to a certain extend, and ISPs deploy DPI boxes. Since more users are expected to come, different traffic volumes will result, and more capacity will become available (due to optics), the socio-economic management is crucial for a Future Internet success. This needs to cover in an integrated manner network, services, and content as well as self-interest and maliciousness. Solution approaches shall consider monetary vs. non-monetary incentives, trust and reputation, and identity and privacy; all of which needs regulation and governance.

K. Towards Self-destructive Networks, Jürgen Schönwälder, Germany

The inconvenient truth is: True innovations do not come from researchers, classic networking is reaching a dead-end, and network management as well. Of course, networking research is over-sized, the Future Internet research temporarily as well. While network generations, such as the phone network (focus on wires) and the Internet (focus on end-points) as well as dissemination networks (focus on content), exist, this means for network management to address privacy management, rights management, and conflict resolution, moderation with human resources. Within current content dissemination networks (example), the security work is flawed, spam identification and classification is in its infancy, and intrusion detection and beyond are not solved. Thus, there is the need for self-destructive networks, covering self-destructive e-mail and self-destructive MP3. Managing the privacy of users as a value-added service will become a lucrative business, which needs fully distributed self-management, economic-inspired control techniques, and learning techniques — and, may be, a self-destructive networks

L. Challenges Regarding P2P and QoS. Tobias Hoßfeld, Germany

P2P video streaming is an important application domain. And to avoid unnecessary costs and lower QoS, it is important to address the fact that QoE does not equal all QoS achieved. The dynamics of P2P shall be integrated into the management approach, such as with ETM (Economic Traffic Management) and its combination with a QoE management. These paths do act as an enabler for network virtualization.

M. How Does a Management for a Future Internet Looks Like? Filip De Turck, Belgium

The service layer covers a.o. a service workflow. The overlay layer on top handles the overlay path, node management, and topology construction. Finally, the network layer provides the communications facilities. Based on the assumptions on numerous services being available for a composition of new services, the need for a platform to support intelligent routing between nodes involved was derived. This is considered as a main aspect of the Future Internet functionality.

N. Application to Network Communication, Dirk Staehle, Germany

Applications can tell the network to open a TCP or UDP socket, not more. Thus, changes are required! In case of WiMAX (IEEE 802.16) — including a detailed MAC specification — a parametrization is provided. Since QoS cannot work or only with much more complexity without any cooperation of the application, especially mobile service providers offer different services: Voice, SMS, MMS, Video, Internet Access. But still: how to do the resource control for the "Internet Access Service"? While it is getting better for the iPhone or G1, such solutions are proprietary. Therefore, the role of the application is to tell the network what it requires, to give feedback to the network in a short- as well as long-term

manner, and the network could inform in turn applications on their choices available.

O. Impact of Location Information on the Future Internet, Martin Waldburger, Switzerland

To determine characteristics and network management challenges of the Future Internet in advance appears to be difficult if not even impossible. Nevertheless, deriving the respective anticipated management requirements based on observed development in today's Internet is needed to identify those fundamental Future Internet characteristics to prepare for.

One fundamentally changed characteristic of the Future Internet to be anticipated is caused by the increased availability of location information of various types, such as a service user's current location. While today's Internet is essentially extra-territorial by design, the Future Internet can be expected to turn towards a territorial infrastructure. This is driven by the match between newly available location information and the inherent business need for marketing and market separation. For instance, content services and focused online advertisements may profit most directly from location information in order to implement market separation.

Similarly, territoriality may have an important impact on the requirements raised towards a legally compliant contract formation of international contracts. Compliance in this context would mean to respect those processes imposed by private international law. For instance, this would have a direct impact on the automated determination of jurisdiction and applicable law for a to be concluded contract between service provider and service user — a process of high complexity, thus, leading to a considerable management effort.

P. Management of the FI Needs to Consider the Requirements from User Perspectives, A. Fessi, Germany

Key starting points on this discussion include dependability, security, and privacy. The need to take into account user requirements is crucial, although, the provider wants to tunnel all into its core networks first. Thus, a cooperative management between providers and users/peers will solve the problem and does provide for an adequate solution.

Q. Challenges to Support Increased u2u Interaction, Iris Hochstatter, Germany

The Future Internet is about an easy access to content and services. Thus, services may be provided by everyone and show characteristics such as ubiquitiousness, high dynamics, mobile use and provisioning, and they do include context information from many sources. The challenge is to assemble those requirements into a single and unified management solution.

R. The Role of Policies in the Management of the Future Internet, Marinos Charalambides, U.K.

The expected growth of networked devices, a shift toward dynamic, and volatile environments requires a management of the Future Internet being different from today's solutions! The need for operational directives and respective policies for autonomic management are drawn on that ground. The intelligence is pushed to those devices and the human is out of the loop. Only the degree of freedom are defined by humans. However, some unresolved issues remain: policy refinements, dynamic policy conflict analysis, and the lacking support from industry in such systems.

S. Performance Monitoring of Managed Services, Peter Racz, Switzerland

Multiple services on top of IP require managed services in the operator's domain, such as minimum QoS, IPTV, VoD, and VoIP. How to support such quality assurance by network management mechanisms is the key question. While monitoring a single session may be doable, but relevant information may not be known beforehand. Thus, the question is: how to measure and collect these information. The monitoring of all sessions sees a complexity increase and too many information being collected. Therefore, an aggregation of this information collected has to be done in a scalable, reliable, and automated manner. The major open issue remaining addresses the problem of detecting of low quality sessions.

T. Managing Autonomic Processes, Antonio Liotta, The Netherlands

Since it is not clear what the Future Internet (FI) will look like, understanding the issues that will arise is a guess work. What seems to be the trend is an increasing degree of automation at various levels within the management and control chains. It is possible that extreme automation will generate more control problems than those it tries to tackle. So an interesting proposition is to study the fundamental problem of managing autonomic processes (such as stability, convergence, resilience, or accountability).

Future systems might try to continuously adapt to a relentlessly dynamic context, through self-controlling and self-reconfiguration mechanisms. How can we ensure that independent, autonomic behavior of different entities does not create interference and instability? Bio-inspired approaches have potential but could further exacerbate this issue.

Another interesting problem is that of trying to simultaneously load-balance computing and network resources. Will it be possible to address these two conflicting goals? The FI will probably not be fully autonomic but it will most probably be more automated than it is today. So the above issues will call for creative solutions and, possibly, a paradigm shift

U. Future of Internet: Challenges and Opportunities for Network Management, Prosper Chemouil, France

This presentation suggests some challenges regarding the evolution of current Internet regarding the management of Networks and Services.

Current reflections allow for re-visiting some concepts of Network Management thanks to technological and methodological advances. New paradigms for Network operations offer opportunities to solve some shortcomings of present network management. However some technical and regulation issues could be raised and should result in further research activities.

V. Management for the Future Internet — Questions for the Management Research Community, Rolf Stadler, Sweden

The revolution in network management will happen, since TMN management dimensions date 20 years back. The separation of management and managed systems is enforced by design, but do not manage IN my box! And the FCAPS approach is done on a per-device basis. Thus, the key questions to ask are: Which management functionality is generic? Applied across technologies? Replacement of management functionality by service functionality? What is the interface between management and the managed system? To which extend is network management an independent research discipline with unique challenges?

W. Challenges of Management of Content Delivery, Gerhard Haßlinger, Germany

Most data delivery happens today by CDN and P2P systems. The problem of suboptimal transport paths is not solved, however. Solution approaches for such traffic management may be seen on the application layer, in the network layer, or in a cooperative location information systems approach (ALTO). Thus, the question to answer is: how can systems optimize a global distribution os such information?

X. Future Internets — System Functions, Capabilities and Challenges, Alex Galis, U.K.

This position presentation identifies the research orientation together with the key challenges for the capabilities and the systems in the Management and Service-aware Networking Architectures (MANA) part of the Future Internet.

MANA covers the management, the service-aware networking and service platforms technologies and systems, which form the infrastructure for Future Internets. In this paper we also envisage capabilities spanning a range of technologies, including: Mobile, wireless and high function network core, edges and service nodes. Service-aware scalable and robust networking architectures, including: 1. Connectivity-to-network, network-to-network services, network service-to-service computing clouds and other service-oriented infrastructures; 2. Cross-domain interoperability and deployment; 3. Optimal orchestration of available resources and systems. Management systems covering FCAPS functionality, including self-awareness and self-management (i.e. all self-X functions).

Y. Management of the Future Internet —No Real News to be Expected?! Burkhard Stiller, Switzerland

We “do know” about handling separate networking principles separately (partly incomplete) and we “do know” about dealing with management “algorithms” (again, partly incomplete), but there is an observation: All of these aspects are conceptionally independent of the Internet or the Future Internet (FI) architecture. Furthermore, we “apply” research/engineering methodologies correctly:

Key necessities of management aspects not met today include: (a) Determination of risk of service failure, unavailability – insurance, (b) Clear distinction of time and control loop generalities for short-/mid-/long-term actions – proven separation of automated/human-based management tasks, (c) Incentive-compatible, operationally-efficient, economically-viable, and application-independent traffic management (multi-player game), and (d) non-voice QoE “measurements”. Plus, a number of key management gaps seen today for the FI.

Finally, the major observation is: Evolutionary or revolutionary approach of managing any FI architecture is not a problem, if and only if the right management algorithms are researched and engineered.

III. Discussion Groups

The Future Internet Architecture Discussion revealed that the set of management mechanisms needed range from known principles as of today to modern and emerging approaches to be researched. This detailed set of aspects, however, can only be finalized once the Future Internet Architecture as such will be stable.

The Future Internet Architecture Security discussion showed that in principle all relevant security mechanisms as well as approaches seem to be known today, which may be needed for the multi-service delivery platform of the future. Thus, only a selected set of adaptations will be needed, mainly according to service-specific requirements, provider needs, and user privacy aspects.

Finally, the Socio-economics and incentives discussion concluded that the involvement of the user as well as their crucial aspects of service quality, QoE, and service observations does have an effect on the overall Future Internet management approach. Details on this detailed discussion can be found in [1], a paper resulting directly from the Dagstuhl seminar’s discussion group.

References

[1] B. Stiller, D. Hausheer, T. Hoßfeld, A. Liotta, S. Spirou, M. Waldburger: *A Discussion of Socio-economic Management and Incentives for the Future Internet.* 2009 IEEE Globecom Workshops, 2nd IEEE Workshop on the Network of the Future, Honolulu, Hawai'i, U.S.A., December 2009, pp 33-38.