Technological Challenges for Assuring Business Benefits of Future Internet

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The current Internet is indubitably the sum and substance of today's global integrated communications infrastructure and service platform that has harnessed more than a billion users across the world. However, the tremendous impetus of internet-based infrastructures and services has resulted in the conception of a state of affaires that is completely different than what was envisioned when internet's architecture was designed in the 1970s. It is therefore become indispensable to develop the Future Internet that can cope with the emerging demands of in- formation society of tomorrow. An important factor for the successful deployment of Future Internet is to prepare a compelling case to convince the operators that Future Internet will assure business benefits for them. In this paper, we identify key technological challenges that need to be addressed to achieve this goal. This paper consolidates the activities of three research projects and provides valid and experienced design guidelines to model and evaluate new operation and maintenance solutions, and insert them into realistic business deployments that are the ultimate proof of their enhanced benefits.
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1 Introduction

Internet was designed to exchange data and information across the sites in a resilient manner. At the time of its inception, Internet (a network of networks) was seen as a logical evolution of packet-switching networks (X.25 networks) [1]. The internet kept a low profile and remained out of daily lives of general public till the World Wide Web (HTTP protocol) [2] was developed in 1990s at CERN. The web brought internet to the daily lives of common people resulting in new ways of using internet for personal, social, business, and governmental affairs. The highly broadened scope of internet in the 21st century has little to do with the primitive objectives of its design goals. It is now emerging as Critical Information Infrastructures (CII) [3] whose availability, reliability and resilience are essential to the functioning of a modern economy, security, and other essential social values. Markets depend on them, as much as governments, to function properly. It is therefore necessary to redesign the core of the internet so that it can cope with the future demands of networked society.

Many research activities are recently targeting the construction of a Future Internet. Operation and maintenance (OAM) is one of the key areas considered for re-design, in order to achieve new levels of reliability and efficiency. While the motivation for a new architecture is evident when looking at past network failures combined with predicted future network growth, little has been done to investigate and timely identify the benefits for key actors. For example, while the deployment of femtocells appears nowadays an inevitable technology for future access networks, this acknowledgement itself has not led to the identification of the key technical challenges in reduced or even self-management of large deployments of femtocells and especially their major expected benefits.

This paper is built on the experience of three major research projects in the area of management of the Future Internet to fill this gap. It identifies key technical areas, spanning traditional as well as emerging issues in network management (e.g. virtualization of resources). Each of them is then mapped to the potential benefits, evaluating both business impacts (operator's point of view) as well as usage and applications impacts (user's point of view). This analysis follows a top-down approach, derived from a reference scenario, and it is substantiated with examples.

This paper is organized as: Section 2 presents business benefits for the key actors with the help of a real life scenario. A set of technological challenges for the Future Internet arena are elaborated in the section 3. A set of frameworks for Future Internet management is briefed in the section 4. Finally some conclusions are drawn along with the perspectives of this work in the section 5.

2 Deriving Promising Business Opportunities

This section presents a set of those promising opportunities for the businesses that can be tapped from Future Internet based systems and services. We first present a real-life example scenario to depict how the Future Internet will facilitate virtual interactions of everyday lives of the people followed by a set of their associated business benefits for the key actors (operators).

2.1 An example of a Future Internet enabling scenario

An example scenario that illustrates the described challenges within the overall scope of the upcoming distributed, fixed-mobile converged world of femtocell deployments can be seen in a community application that involves several participants and multimedia streams. We named it "Ulla's gardening world". The described frameworks can be applied favorably to that environment, and also the benefits can be leveraged by the involved players. Figure 1 depicts the femtocell setting that will play the central role in Ulla's gardening world scenario.

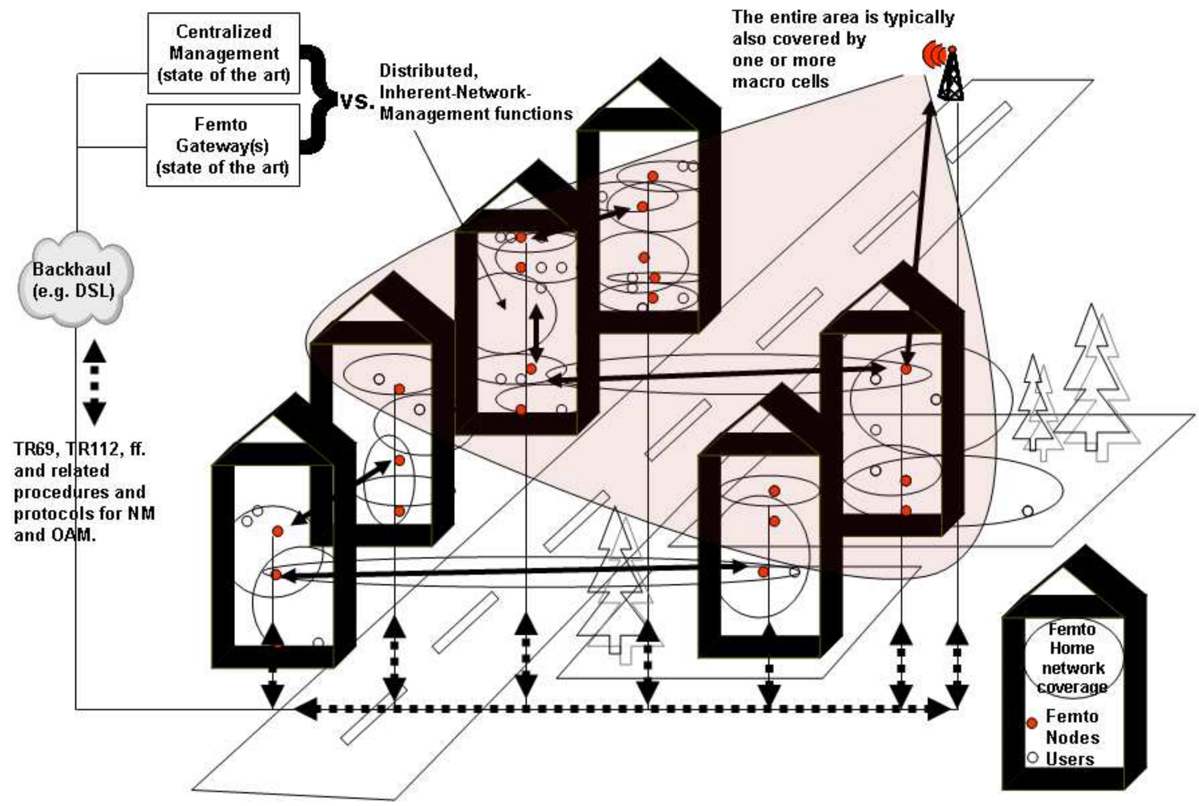

Fig. 1. The femtocell setting

The starting point is Ulla's assumed interest in gardening. She is interested in sharing her hobby with others. Therefore, she asks for a convenient service to create a virtual community with her remote friends. Such a virtual community service is assumed to be offered as all-in- one package to Ulla and her community. The presence of an underlying infrastructure provider and different services bundled together is transparent to Ulla and the other community members who exchange multimedia contents about their gardening topics such as comparing live views from their gardens with cameras. The gardening community service involves a number of participants in a conference-type setting with full multimedia support. The participants need not to be static: they can move around inside their gardens, and they do not need any special equipment. They enjoy the seamless access to their virtual session wherever they go. All the community members are connected via fixed or mobile access systems and corresponding user devices. Community members often show each other their gardens' specific areas such as rare flower bloom or cherry-tree's leafs damaged by a certain parasite. This can be imagined as one big multimedia conference, performed by ordinary, non-technical consumers who have not much of a technical background. Still they are tapping the full benefits of the virtual community service. The setting is comparable to the public or group conferences that can be instantiated with Skype clients on desktop computers. The difference with this technology is the optimization and integration with femtocell networking and mobile operators, leading to a more seamless service of higher quality and integration with mobile and home devices.

2.2 Promising Business Benefits for Key Actors

Ulla's gardening world depicts a range of business perspectives for the key actors of the Future Internet (notably operators) due to new and improved services with fast time-to-market for service delivery. These benefits include:

- A distributed, network-inherent management and control framework integrates control loops for different functional components and supports a non-centralized approach, off- loading the operator's OAM/NM (Operation and Maintenance / Network Management) system;
- New signaling, monitoring and optimization algorithms work exclusively between nodes and enable a new level of autonomy while still operating on behalf of the operator;
- Virtual infrastructures' promising feature of computing as a commodity enhances the competitiveness of businesses; besides cost-effectiveness, they also assure optimized use of system and network resources, reduced carbon footprints, and simplified management of their underlying resources;
- The integration of services and their interfacing with related management procedures provides simplifications of service administration;
- The generic nature of the service interfaces will enable the businesses to enlarge their product (service) range with less supplementary efforts.
- The seasonal services can be easily offered at less substantial costs;
- The OPEX reduction, flexibility in service or behavior composition, provisioning and maintenance will assure fast time-to-market for service delivery and guaranteed performance and robustness of the network;
- Acceptable and realistic expenditure on CAPEX for both manufacturers and network providers/operators;
- Stronger basis for the cost estimations of the evolving network models and protocols.

3 Future Internet's Technological Challenges

It is necessary to identify the technical challenges in the way of achieving the

Future Internet realm so that they can be properly addressed and needful strategy can be formulated to tap the full potential of the vision of Future Internet. In this section, we present a set of these techno- logical challenges that provide some food for thought to the researchers working in this domain:

- Self-organized wireless femtocell administration and management. Quality of Service guarantees for the bundled services. Management of complex services;
- Service complexity: There is not just one end-to-end data path; instead it is like a live compartment with several sources and destinations of quite sophisticated multimedia traffic. The multimedia session may consist of multiple separate flows (video, audio, session control). This means that there are quite a number of nodes involved, ranging from user devices, femtocell access nodes, aggregation network(s), and backbone(s). It is unlikely that a centralized, classical network management system can cope with these services requirements. A virtualization layer on top of these services is useful to assure the needful abstraction of underlying infrastructures;
- Internal registration of the community, along with many others, their provisioning (several processes ranging from access control to final billing) and establishing a link with OAM/NM;
- Real time control loops for maintaining QoS even across layers. Any changes on the wireless channel may impact the transmission quality. This in turn requires very quick reactions and counter-measures for these very short-timed control loops. In the aggregation part of the network, this may lead to a reconfiguration at the MPLS level. Development of interfaces to translate business goals into network-level objectives focusing on features from self-management to self-learning for the improved delivery of services over the networks;
- Definition and Development of generic design principles required for an evolvable Generic Autonomic Network Architecture (GANA), such as the autonomic context-aware Decision-Making-Elements (DMEs), self-manageability aspects, the necessary abstractions, required distinctions between autonomic elements and their Managed-Entities (MEs) and management interfaces, control-loops, hierarchical, peering and sibling relations among autonomic elements (DMEs) within individual nodes/device architectures and the network architecture.

4 Frameworks for Future Internet Management

This section presents an overview of the three major research projects in the area of management of the Future Internet. The frameworks being developed under the auspices of these projects are explained with their positioning with the evolution of Future Internet.

4.1 The 4WARD Framework

In one of 4WARD's work packages, the focus is on the future of network management. The overall purpose and target of the INM (In-network Management) framework [4] that is developed in this work package is to describe a node architecture that enables a set of nodes to per- form management tasks in a co-operative way, and to maximize the level of autonomy, inherence and distributedness. INM does not rely on separate, or centralized or dedicated (specialized) nodes to execute the requirement management functions [5]. We make a logical distinction between the Self- managing Entity (SE) that represent the main purpose of a node, e.g. a routing function, and one or more processes that exercise control of any kind over the FC. For this purpose, we presume that the SE exposes two defined interfaces: the collaboration and organizational inter- faces.

This allows the exchange of a set of parameters that allow certain parameterized con- figuration and control, in short: management.

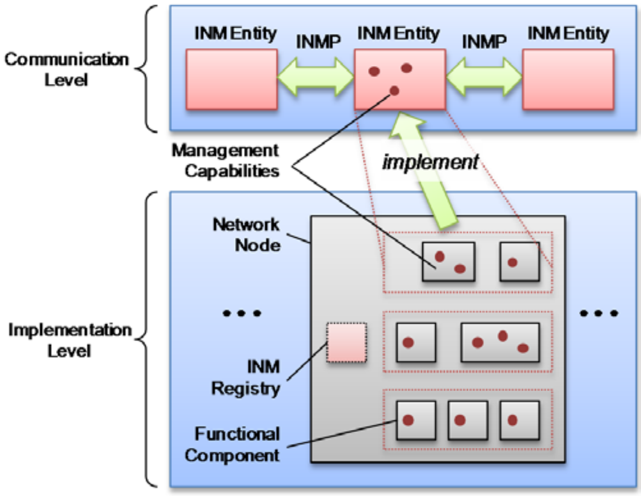

Fig. 2. Node Architecture and INM communication interface types

The classical FCAPS definition is still valid and applicable; however it seems that we would sometimes need more direct control of the FC. This leads to an overlap with the tasks of a classical control plane, which we prefer not to exclude from our research on management functions. In this sense we go slightly beyond FCAPS, while the focus is rather how we implement management in the way described above.

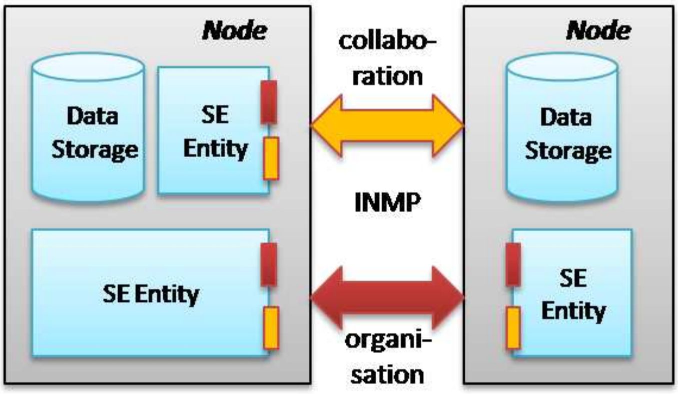

Fig. 3. Relation between functional components and management capabilities

The overlap of management with control plane also leads to one of our core principles: The co-design of management functionality and control plane functions. While typically, management functions are added after the functional components have been created, we encourage integrating management into the overall design and engineering process. The INM framework is the facilitator for this approach

4.2 The RESERVOIR Infrastructure

European FP7 project RESERVOIR (Resources and Services Virtualization without Barriers) project is developing breakthrough system and service technologies that will serve as the infrastructure for Cloud Computing and Future Internet of Services by creative coupling of ser- vice virtualization, grid computing, networking, and service management techniques [6].

The high-level objective of the RESERVOIR project is to significantly increase the competitiveness of the European ICT industry through the introduction of a next-generation infrastructure for the deployment of complex services on a compute cloud that spans infrastructure providers and even geographies, while ensuring QoS and security guarantees. In doing so, RESERVOIR will provide a foundation for a service-based online economy where resources and services are transparently and flexibly provisioned and managed like utilities. The vision of RESERVOIR is to enable the delivery of services on an on-demand basis, at competitive costs, and without requiring a large capital investment in infrastructure.

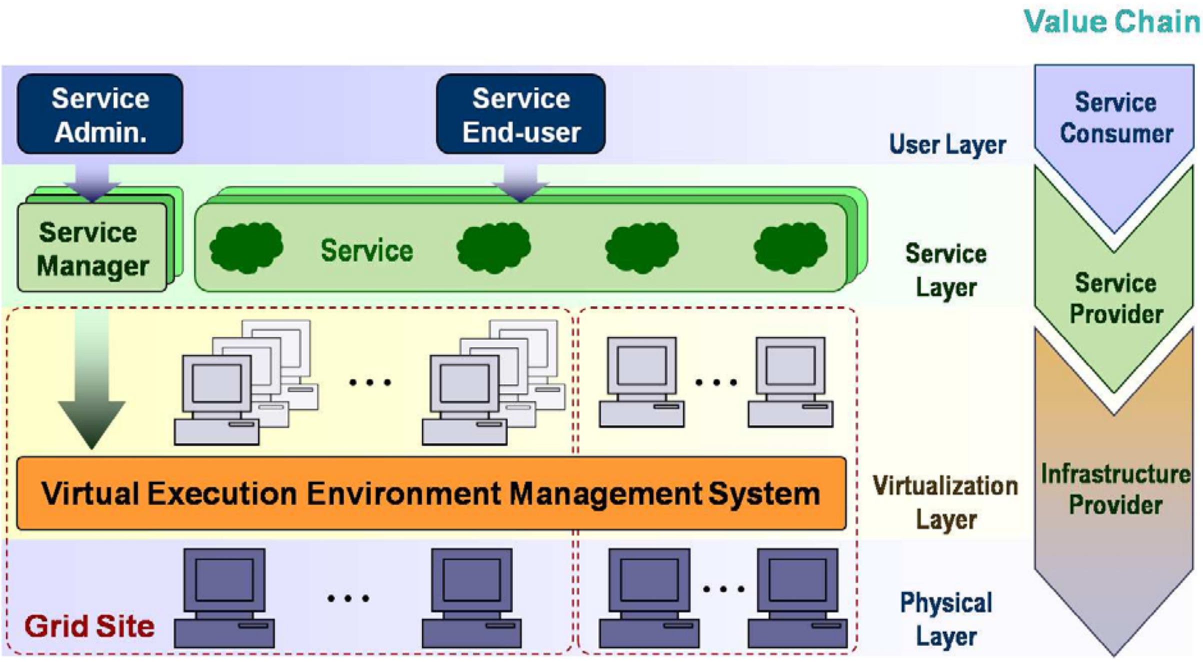

Fig. 4. RESERVOIR Architecture

RESERVOIR research on virtualization and management of services enables and unifies some of the emerging trends identified in the Future Internet initiative of the European Commission. The RESERVOIR project has analyzed several use-cases to skim the set of functions that are important for Future Internet Service provision. The value chain of these functions provides cutting-edge contribution of RESERVOIR project to the Future Internet. These functions are described in [7].

4.3 The EFIPSANS Architecture

The FP7 EFIPSANS project aims to create a viable ***Evolution Path*** towards Self-Managing Future Internet via a Standardizable Reference Model for Autonomic Network Engineering [8, 9]. A viable Evolution Path starts with today's network models, architectures, protocols such as IPv6 (in particular) and paradigms and defines the incremental changes and concepts necessitated and guided by a protocol-neutral generic architectural Reference Model for Autonomic/Self-Managing Network Engineering. This evolution of today's network models, architectures, protocols such as IPv6 (towards IPv6++) and networking paradigms must be guided and necessitated by the protocol-neutral architectural Reference Model.

The GANA must provide the definition of the generic design principles required for an evolvable autonomic network architecture, such as: the autonomic context-aware Decision-Making- Elements (DMEs), self-manageability aspects, the necessary abstractions, required distinctions between autonomic elements and their Managed-Entities (MEs) and management inter- faces, control-loops, hierarchical, peering and sibling relations among autonomic elements

(DMEs) within individual nodes/device architectures and the network architecture as a whole. DMEs within node/device and network architectures need not only take autonomic decisions that drive their associated control-loops but, also, all the management related functions such as (re)-configuration, set-up and management of virtualized resources, network slices and on-demand networks, etc. In order to develop the GANA for the benefits of interoperable Future Internet devices, a Work Item has been defined by the recently established ETSI Industry Specification Group called Autonomic network engineering for the self-managing Future Internet (AFI) [10], to which multiple stakeholders (including research projects) can contribute to the further Specifications of GANA.

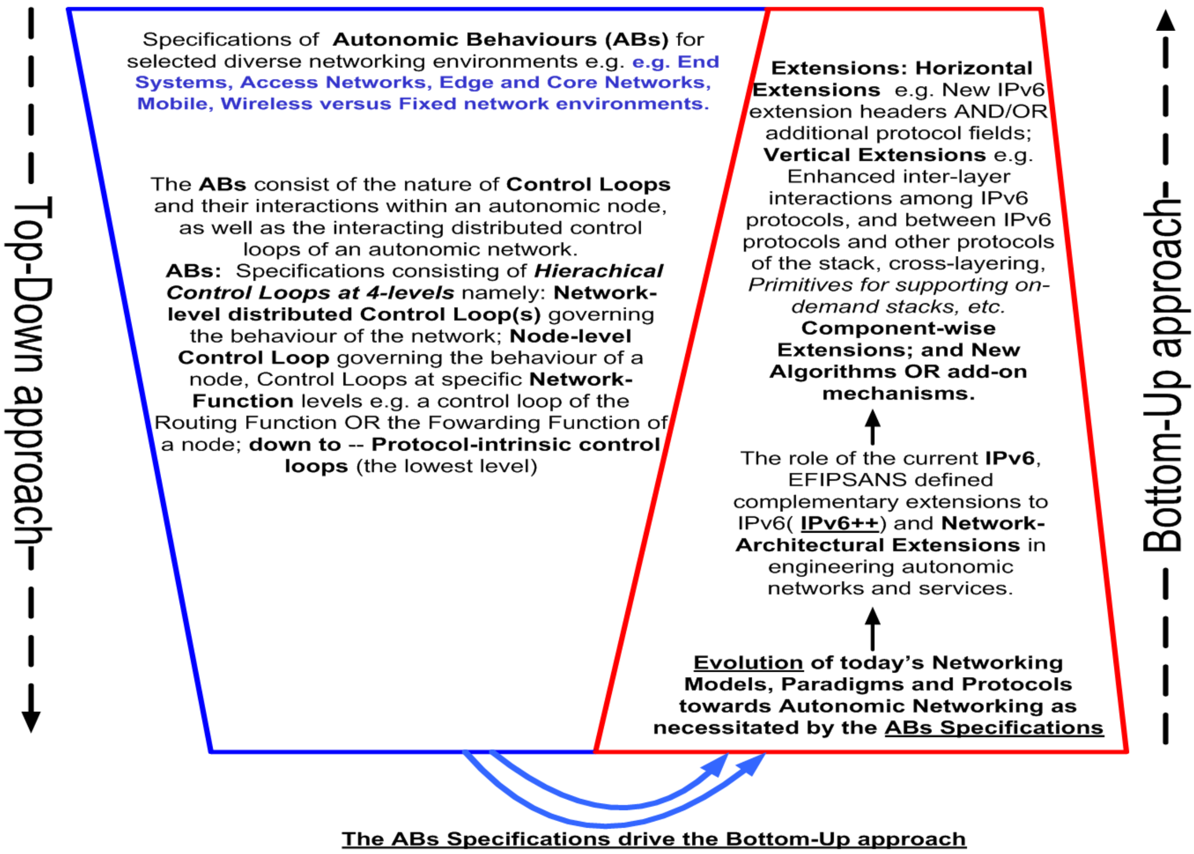

Fig. 5. GANA as a drive for requirements for extensions to IPv6 towards IPv6++

In EFIPSANS, some ideas on Extensions to IPv6 are now emerging as early draft IPv6 Extension Headers (new IPv6 protocols that complement existing IPv6 protocols), newly added protocol Options in the Extension Headers that support the notion of Options, extensions to the management interfaces of some protocols to ensure enriched autonomic control of the protocols by associated Decision-Making-Elements (DMEs), and network architectural extensions such as cross-layering, etc. Examples of IPv6 protocol extensions for self-managing networks being proposed by EFIPSANS include ICMPv6++ for advanced control information exchange, ND++ for advanced Auto-Discovery, DHCPv6++ for advanced Auto-Discovery, some recommendations for Extensions to proto- cols like OSPFv3, and some newly proposed IPv6 Extension Headers, etc. The guide/driver to the requirements for network architectural extensions, not just protocol extensions, but also architectural extensions is the GANA Reference Model, as illustrated by the two triangles on figure 5.

5 Conclusions

The Future Internet is envisaged to cope with the emerging demands of networked society. It is therefore very important for its designers to convince the key actors that Future Internet will assure business benefits for them. It is evident that business perspectives of the Future Inter- net technologies circle around operators and service providers. These technologies can enable businesses to enhance their customer base by providing them with a cost effective and broad range of services. We have identified key technological challenges that need to be addressed to achieve this goal. We focused on the definition of the expected behavior of the network; self-management features within the network for a distributed architecture; dedicated functions for resilience and quick reconfiguration inside the network; and automated re-allocation of resources according to varying conditions.

This paper is a joint venture of three major research projects in the area of management of the Future Internet. We plan to pursue this collaboration under the umbrella of European Com- mission's Future Internet Assembly (FIA) initiative to integrate each project's results to pro- vide valid and experienced design guidelines to model and evaluate new operation and maintenance solutions, and insert them into realistic business deployments to guarantee their enhanced benefits.

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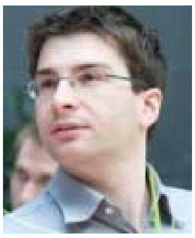

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