Next Generation Internet

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The Internet was conceived nearly 40 years ago, by a small number of creative and forward-looking people. It started with the simple idea to enable direct communication between computers via a simple network protocol – later dubbed the Internet Protocol (IP). It started with a simple configuration – only four nodes – and the subsequent success story is well-known. Driven by several factors – the immense advances in microelectronics, computer and software technology and innovative, disruptive business models – today the Internet consists of millions of interconnected subnetworks and more than a billion private and business users and devices all over the globe using a huge variety of services. The average traffic over the Internet adds up to some exabytes (10^{18} byte) per day. The growth with respect to users and traffic is continuing exponentially, especially since the mobile data communication is gaining momentum, but also because realtime applications like telephony and streaming services have been introduced and are becoming popular. Even more application areas are evolving, like Internet TV or sensor-based systems. So why are we talking now about a "Next Generation Internet" or "Future Internet"? Are there any deficits and problems which can hamper the further usage and expansion of the Internet? The answer is: yes.

From today's perspective, the IP technology is about to take over all traditional communication networks: the telephone, the data networks, the mobile/wireless and even the broadcast networks. It has evolved into a "critical infrastructure". This already poses severe problems today and entails big challenges for the future. The Internet and its protocol stack were definitely not built for

- high-quality realtime communication,
- support of network-wide mobility,
- wireless devices,
- extreme scalability (billions of devices),
- very high bit rates (Gbit/s and Tbit/s),
- high resilience and carrier-grade networks,
- provisioning security against professional attackers,
- community applications, file sharing, gaming and other mass applications,
- eCommerce including accounting and billing, and
- cost-effective network operation and service

to name only the most obvious issues.

The lack of security in the Internet is seen as the most important problem, but also perhaps the most difficult to solve. Similarly critical is the mobility aspect. Due to the exploding numbers of mobile users going online with a mobile device (especially in countries where the fixed line network access is not or not yet fully available) the need for a better "Mobile Internet" is obvious, allowing the long-promised online-access "everywhere and everytime". There are already billions of devices in the net, but the anticipated advent of myriads of microdevices like sensors and other "ambient" and more or less intelligent systems requires an enormous grade of scalability in the network architecture, the addressing scheme, in the network management and other areas. Rather straightforward seems to be the speed evolution. The upcoming wireless and wireline technologies like forth generation mobile networks, advanced DSL and optical transmission will bring extremely high bit rates to the edge and to the core of the network: Many Gbit/s to the users and many Tbit/s to the core. This will relax the performance bottlenecks of today's Internet, but also call for careful design and control of the network to guarantee the quality-of-service or quality-of-experience even if it cannot be predicted what the users really will use the vast bandwidth for. The Internet, from the beginning, was designed for being relatively robust against network outages. More or less automatically it changes routes when it detects network failures. However, in times where the Internet serves as the "central nervous system" of the society and most of the business world we have to pay attention to the requirement of "seamless service" which means a high availability of "five nines" or even better, like the classical telephone networks. The fact that most of the IP networks today are privately owned by ISPs or companies and the rather high investment and operating costs for the infrastructure bring the question of cost effectiveness more and more into the focus, also of the technical community. In the future, the preferred solutions will be the ones which are suited to lower the cost for running an IP network not only through lower equipment cost but also through innovative techniques for operation and management without sacrificing the system performance.

It should be stated that many of the drawbacks of the Internet are not new, and have been worked on for many years. Enhancements to the current protocol stack and techniques have been continuously proposed, discussed, implemented, tested, adopted by the IETF, and introduced into the market. And this innovation – or renovation – process is ongoing. The worldwide efforts, however, have led to – as critics say – a patchwork of new things. And, no wonder, a patchwork might create an even more complicated system, which is, in turn, harder to manage, understand, and improve. In recent years, the idea came up to re-think the Internet completely, to rather escape the current "internet repair shop" of evolutionary steps and risk a rather revolutionary "clean slate approach".

Several research initiatives have been started recently to tackle topics around the open issues of the Next Generation Internet with a time horizon of 10 to 20 years. At this point in time, the US lead the activities, with the programs GENI (Global Environment for Network Innovations) and Future Internet Design (FIND), both funded by the U.S. National Science Foundation NSF. In Japan research initiatives in the context of mainstream NXGN (NeXt Generation Network, next 15 years) and visionary NWGN (NeW Generation Network, beyond 2018) can be observed, with a large number of projects, e. g., in the Akari framework. In Korea the Korean Ministry of Information and Communication (MIC) and the Institute for IT Advancement (IITA) have started the platform uIT839 aiming at pragmatic developments towards NGI. In Europe a number of NGI projects in the FP7 Framework (EuroNF Network of Excellence, Eiffel, 4WARD, SmoothIT, …) and the FIRE framework (Future Internet Research and Experimentation) are already kick-started, accompanied by various nationally funded initiatives.

This special issue aims to give an overview of recent accomplishments and activities in Germany towards the Future Internet, both from an industry and from an academic perspective. We deliberately avoid classifying the contributions into more evolutionary or more revolutionary ones but rather leave the papers theme-oriented. The collection of papers cover a broad spectrum of research projects and many interesting results which will, in one way or the other, have some impact on the ongoing debate about NGI and on future R&D efforts.

The first contribution by *Kellerer, Widmer and Berndt* focuses on mobility aspects discussing approaches addressing (wireless) access network heterogeneity, mobility management, and new roles of mobile devices, as well as service platforms for a Next Generation Mobile Internet. After discussing the requirements the authors outline new approaches in three fields: In the core network, where peer-to-peer overlays and virtualization of resources can increase the flexibility; in the wireless access network, where crosslayer optimization is recommended to provide the necessary QoS by a proper information exchange between the upper (application) and the lower layers (layer 1 and 2 protocols); and in the service platform architecture where it is crucial to allow for the "orchestration" of a multitude of providers in a future open service platform.

Flinck et al. are focusing on the new approach of creating a homogeneous and agile Ethernet-based packet transport infrastructure (the protocols below the IP layer). The introduction of "carrier-grade" Ethernet packet technologies – in contrast to the conventional TDM/SDH – for transport is expected to provide the desired cost advantages for the carriers, but also a higher degree of flexibility, resilience, scalability and manageability. IP will, of course, not disappear in this Ethernet-based world. Moreover it will keep its key role as the platform for applications and services, whereas Ethernet will become the "convergence" platform for transport of any kind of data across the global Internet.

Going up in the stack, *Menth et al.* present in their contribution an overview on the shortcomings of today's IP routing mechanisms. The key problem is that it does not scale since the routing tables become larger and larger. The article describes current approaches (worldwide) to solve these problems. It is focussing on the concept of splitting the (physical) locator and the identity function and discusses interworking issues and design options for this approach.

One of the basic properties of the IP technology is the "end-to-end principle". Thus, end-to-end applications should get support from the underlying layers also in a heterogeneous network environment which we will today and even more in the future. *Waldhorst et al.* present a novel type of overlay networks called Spontaneous Virtual Networks (SpoVNets) that enable flexible, adaptive, and spontaneous provisioning of application-oriented and network-oriented services to support QoS, group communication and mobile usage on top of heterogeneous networks. Beyond being a flexible architectural approach which can be introduced incrementally, it also allows the incremental replacement of SpoVNet services when “native” future Internet services become available. The applicability is demonstrated for two services (group communication and event handling) and two applications (online gaming and video streaming).

Overlay networking as a promising architectural concept is also the topic of the next contribution by *Kunzmann, Binzenhöfer and Stäber*. First created for allowing global file sharing, one type of such overlay networks, the self-organizing peer-to-peer (P2P) networks, have evolved in different forms – structured and unstructured architectures – and for a variety of applications beyond file sharing, like e. g. Internet telephony. The authors discuss in their paper the basics of structured P2P networks and investigate how they can be used to build reliable distributed telecommunication services. The system which was also realized in prototypical form, builds on a Distributed Hash Table (DHT) based Chord ring topology. The critical aspects described are methods to ensure the stability of the overlay despite joining and leaving of nodes and efficient methods for the maintenance of the structure. This is done by estimating and adjusting key system parameter in a self-organized way. The DHT-based solution is able to support telephony service for more than 500 k users.

The infrastructure is clearly only the “substrate” on which new services can be built. The key question here is how to design flexibility right into the basic architecture to create a versatile service architecture making use of advanced software and service engineering techniques. *Müller and Reuther* describe an approach based on the service oriented architecture (SoA) paradigm to enable applications built out of loosely coupled services. This can simplify the service development, deployment and replacement and hopefully reduces the complexity of the processes. Since the current available SoA techniques are not suitable on the level of networks, a novel generic message protocol to interconnect the services and new concepts for describing workflows and accessing services need to be defined. Here the key features are (again) flexibility and speeding up the development of new services.

As mentioned above, security is the most critical issue in the Internet. Early detection of anomalies in the network and the preparation of countermeasures against attacks are success factors in this field. *Zseby, Kleis and Hirsch* are describing methods for incorporating attack detection and defense strategies into communication networks. They build on the concept of autonomic communication thus enhancing the security management capabilities through cooperation techniques, learning strategies and in-network decision making. They argue that cooperation techniques are very well suited for the protection of large scale networks in a decentralized way.

As outlined above, we are witnessing an intense phase of NGI research. It is impossible to predict, which evolution path and according activities will be the most successful. It will be rather a “survival of the most accepted”. More than ever we need the competitive and concurrent investigation of different approaches which are also to be tested and compared in generic test beds and experimental platforms. Industry and academia will have to cooperate tightly to design, evaluate and hopeful market innovative solutions for the Internet of the Future.

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