Towards Management Requirements of Future Internet

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Abstract. The Internet is one of the most successful modern technologies; we cannot imagine what our lives would be without the Internet. Despite the huge success of the Internet, many problems such as shortage of IP addresses, insufficient security and performance have emerged because of the increasing worldwide Internet population. Furthermore, the technologies developed to incrementally solve the abovementioned problems are causing new problems. Therefore, a redesign of the Internet architecture must be considered. Many research groups around the world are conducting work on the next version of the Internet architecture, called the Future Internet architecture. In this paper, we propose the management requirements and operations of the Future Internet with regard to the key parameters that are being researched through initiatives of research groups, such as FIND, GENI, FIRE and JGN.

Keywords: Future Internet, Management operation, Future Internet architecture, Cross-layer, resource virtualization, overlay network

1 Introduction

The Internet is a social phenomenon that has changed and continues to change how humans communicate, work, conduct businesses, handle emergencies, process military operations, etc. It has redefined expectations on the possibilities of interactions between humans, between computers and humans, and between computers. Almost all the major industrial sectors have readily accepted and utilized the Internet for its advantages. This widespread use of the Internet reflects the extent to which it has been successfully implemented; however, it also hints at the complexity and diversity of a system that has grown from interconnecting merely a few supercomputers to interconnecting the world. Users of the Internet value the new and diverse set of applications on the basis of their interactivity, whereas developers of the applications value them according to the ease with which they can develop new functionalities and reach a large and diverse set of users [3].

The success of the current Internet system is highlighted by the manner in which it has influenced our society. However, it is evident that the current Internet architecture is facing several challenges, many of them related to scalability issues, for example, supporting an ever growing number of users, devices, service attributes, applications, contexts, environments, security, vulnerability and networking technologies [2, 3, 4].

The worldwide research community has been increasingly drawn to the drawbacks of the current Internet. Many proposals have been suggested to solve the perceived

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problems, ranging from new enhanced protocols to fix specific problems up to the most radical proposal to redesign and deploy a fully new Internet. Most of the problems with the current Internet have originated from the tremendous pace of the increase in its use. Consequently, there was insufficient time available to address the drawbacks of the current Internet architecture. Many networking researchers around the world have identified the emerging limitations of the current Internet architecture and they have agreed that research must be conducted into to the long-term applications of the Internet, and its basic architecture must be reconsidered. Furthermore, investigations must be performed to determine a better architecture, even if it does not appear backwards compatible.

New technological solutions may follow either an incremental approach or a "clean slate" approach to improving the Internet [1, 9]. The first approach involves the evolution of a system from one state to another by implementing incremental patches; the second approach demands a radical redesign of the Internet architecture to offer new abstractions and improved performance. The latter approach might prove to be disruptive with regard to technologies, services, and business models. We name this redesigned Internet architecture as the Future Internet architecture. In the past 30 years, the Internet architecture was successfully developed by using the incremental approach [9]. At present, we have reached a stage where people are unwilling or unable to experiment on the current architecture and want to apply the clean-slate approach.

To design the new Internet architecture, we must consider the manageability of Future Internet starting from scratch [1, 5, 7]. In this paper, we investigate the worldwide research conducted on the challenges, requirements, architectures, and management of Future Internet. On the basis of our investigations, we propose an integrated architecture for Future Internet and summarize the management requirements and operations of Future Internet. In Section 2, we summarize the research conducted on Future Internet in the U.S., EU, and Japan. In Section 3, we investigate the research studies conduced on the architectural aspects of Future Internet and we propose an integrated architecture for Future Internet. In Section 4, we illustrate the management requirements and operations of Future Internet. Finally, in Section 5, we provide the conclusion and discuss possible future studies.

2 Summary of Research on Future Internet

Research on Future Internet is performed worldwide, particularly in the U.S. [2, 13, 14], EU [3, 4, 15, 16], and Japan [17, 18]. Two types of research activities are conducted: design of a new network architecture and construction of an experimental facility to verify the proposed architecture.

In the U.S., the National Science Foundation (NSF) [12] is actively conducting research studies on Future Internet with regard to two perspectives; design and test facility. Two representative programs—Future Internet Design (FIND) [13] and Global Environment for Networking Innovations (GENI) [14]—are being conducted. FIND is a major long-term initiative of the NSF NeTS research program, it was started in 2006. It is also a funded project aimed at designing a next-generation Internet called the "Future Internet." The research goal of FIND is to design an end-to-end network architecture as well as consider the implications of the emerging technologies on Future Internet.

GENI is an experimental facility/infrastructure set up to validate and demonstrate research studies, this facility was launched in August 2005. GENI consists of two components–GENI research program and GENI research facility. The GENI research facility is a state-of-the-art, global experimental facility that fosters the exploration and evaluation of new networking architectures (at scale) under realistic conditions.

Research on Future Internet was started in the European Union (EU) as the sixth Framework Program (FP6). In 2007, the seventh Framework Program (FP7) was started as a continuation of FP6. The current FP, FP7, will continue for seven years (2007–2013). Approximately € 600M has been earmarked for R&D in the field of networked systems, including technologies for Future Internet and Experimental Facilities [4].

Future Internet Research and Experimentation (FIRE) [15] is an initiative that is aimed at determining and consolidating research activities at design of Future Internet and various network testbeds in the European Union. The activities of FIRE are being launched in the 2nd ICT Call for proposals and projects are envisaged to start by early 2008, under the FP7-ICT Objective 1.6 "New Paradigms and Experimental Facilities" (budget: € 40M).

In Japan, research of Future Internet is divided into mainly two phases. The first phase is the Next Generation Network (NXGN) and the second phase is the New Generation Network (NWGN) [18]. In NXGN, the fundamental structure of IP networking is maintained and the Quadruple-play services must be provided. In NWGN, the network architectures and service conditions are different from those in IP networks; hence, it supports a new network paradigm. At present, NWGN is in the research phase. Network architectures should be studied on the basis of the requirements for ubiquitous networking and new networking technologies such as advanced optical networking technologies.

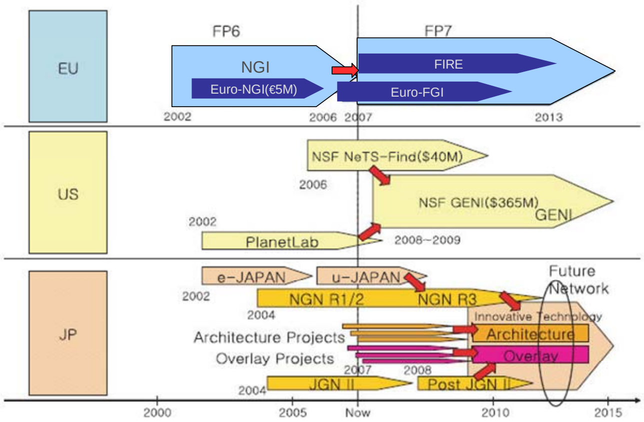

Fig. 1. Roadmaps of the Future Internet in the EU, U.S., and Japan

Fig. 1 shows the summary of the research conducted on the Future Internet system in the EU, U.S., and Japan. The EU will continue through FP7 up to 2013. The FIRE initiative by the EU is involved with the design of a network architecture and construction of a test facility. The US started the construction of a test facility called PlanetLab in 2002, and continued the design of the Future Internet system through

FIND; this will facilitate the upgradation of PlanetLab to GENI in order to build test environments on the basis of the design principles of FIND. Japan started the e-JAPAN and u-JAPAN projects in 2002 and 2006, respectively. Further, Japan started the projects to design an Internet architecture called New Generation Network (NWGN). Projects on overlay networks called JGN2 were started in 2004, and these projects will be continued by the name Post-JGN2 up to 2012.

3 Architecture of Future Internet

We have surveyed a large amount of research on the architecture of Future Internet, and we have extracted some key concepts such as cross-layer [10], resource virtualization [11], service-oriented architecture (SOA), and overlay network [17]. With regard to the challenges and requirements of Future Internet, we describe its architecture in this section.

Figure 2 shows our proposed architecture of Future Internet; it includes the key parameters of the Future Internet architecture, such as resource virtualization, cross-layered architecture, and service-oriented architecture, as investigated by other researchers [10, 11, 17].

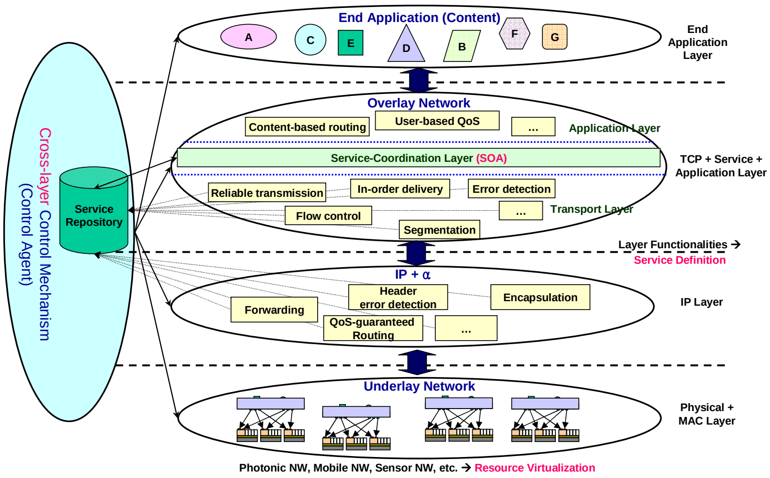

Fig. 2. Proposed Architecture of Future Internet

As shown in Figure 2, the proposed architecture is composed of four layers—underlay network, IP layer, overlay network, and applications. The key difference is in the overlay network. In the Japanese NWGN architecture [17], the overlay network will be focused on the extra functionalities, beyond what is supported by the basic internet. Similar to current internet, Future Internet will also need more functionalities. Overlay can provide, included mobility, customizing routing, QoS, novel addressing, enhanced security, multicast, and content distribution.

The functionalities of each layer are implemented as services, which are registered in the service repository. If a specific service is necessary, the service consumer requests the service repository by using a “find” operation, and the service repository sends the service provider information to the service consumer, then, the service consumer directly connects to the service provider and they interact with each other.

This is the mechanism of the service-oriented architecture (SOA); the proposed architecture follows the mechanism of the SOA. To implement the SOA among various service providers and consumers, a new scheme of naming and discovery must be provided. Moreover, the scalability problem of registering, searching, and receiving services must be solved.

The current layered architecture must be transformed into a cross-layered architecture [10]. If the overlay network does not require the IP layer services, it directly calls the underlay network services through a cross-layer control agent. The cross-layer control agent plays a role in connecting the cross-layer communications over the adjacent layers. To support cross-layer communications, the cross-layer agent must support an integrated cross-layer interface.

The underlay network can be of various types, for example, wired optical networks and wireless sensor networks. First, we must identify the network resources and virtualize the network resources in order to support various user-oriented services and share network resources among the many customers and services.

4 Management of Future Internet

In this section, we investigate the research conducted on the management of Future Internet and we propose the management requirements and operations of Future Internet.

4.1 Management Requirements of Future Internet

On the basis of the research conducted on the management of Future Internet, we present the requirements for managing it in order to operate and administer network resources and services [7]. We divide the management requirements in accordance with the following management models: information model, communication model, functional model and non-functional model.

The management requirements of the information model are as follows:

- *High-level, goal-directed specification of the network properties and policies*: Human network managers should describe the required configuration properties. Software network managers should be responsible for translating high-level properties (goals) into strategies for implementation at lower levels [19].
- *Definition of various management objects*: The management information model must specify the management objects ranging from hardware (HW) resources to business goals and management functionalities.
- *Extensibility*: The management information model must be extensible so that it can be applied to any type of new network resource and service.

The management requirements of the communication model are as follows:

- *Support for management operations*: The communication model must provide the basic management operations such as get, set, create, add, delete, act, and notify.
- *Operationally independent, self bootstrapping management plane*: The management plane should be operationally independent of the data plane and should be able to bootstrap without any pre-configuration [19].
- A *single, simple management interface for all data plane protocols*: The

operational complexity of protocols should be confined to their implementation, and they should express the information required for managing them through a simple management interface. This includes the responsibility on the protocol implementer for a detailed understanding of the protocol operation while reducing the burden on management applications.

The management requirements of the functional model are as follows:

- *FCAPS*: The functional model must support the basic management functionalities such as Fault, Configuration, Accounting, Performance and Security (FCAPS).
- *Support service-oriented architecture (SOA):* As mentioned in Section 3, the architecture of Future Internet is based on the SOA. The management functionalities must be defined as services, registered in the service repository, and then discovered and implemented by using the SOA.
- *Intelligent and programmable network nodes*: Network nodes such as terminal, intermediate and core networks must be programmable in order to provide intelligent and autonomic management capabilities.
- *Identification and addressing*: The identities of users and objects (terminals, sensors, actuators, all types of electronic device), application identifiers, flows identifiers and network addresses (locations) may have to be defined independently by means of a global unified architectural approach. Such an address de-layering approach would support migration from multi-service networks to multi-network services, with services implemented by external facilities.
- *Discovery and Dissemination*: Each NMS periodically floods the network with beacons, which gather the IDs of the devices through which they propagate, thus they provide each device with a path to the NMS. This allows the devices to send source-routed frames to the NMS. In turn, the NMS can respond to these devices; this forms the NMSs *management channel*. Note that the management channel does not require any pre-configuration and is completely independent of the data plane paths in the network.
- *Data repository management*: Management of the Future Internet architecture will require data on the current state of the network, available in real time. The challenge is that the proposed instrumentation systems can potentially gather vast quantities of high-dimensional data. This implies the requirement of a repository unit that will organize the measurement data efficiently and enable management decisions over a wide range of time scales.
- *Guaranteed QoS*: Currently, most ISPs employ over-provisioning methods to guarantee QoS. Although the Future Internet architecture is supposed to provide higher bandwidth and more cost-effective channels as compared to its predecessor networks, the cost of bandwidth in Future Internet wireless networks will remain higher than that in wired networks. Thus, over-provisioning methods in Future Internet will not be feasible and QoS support mechanisms will definitely be required [6].
- *Support generalized mobility*: Currently, horizontal handoff, which involves a terminal device to change cells within the same type of network in order to maintain service continuity, is the only service provided. In the future,

mobility will be offered in a broader sense where users may have the ability to use technologies that are more accessible, thereby allowing movement between public wired access points and public wireless access points of various technologies. In Future Internet environments, in addition to horizontal handoff, vertical handoff must be supported. The greater challenge lies in facilitating vertical handoffs while satisfying a certain set of QoS requirements.

The non-functional management requirements of Future Internet are as follows:

- *Scalability*: The largest networks comprise thousands of routers/switches and tens of thousands of devices, and the default-free zone of the current Internet handles and routes hundreds of thousands of destination prefixes. Is it possible for conventional servers to manage a large number of devices and respond to events with sufficient speed in order to satisfy the network's goals? Will the amount of management information being transferred by the dissemination plane overwhelm the network's ability to carry data? Scalability is one of requirements of Future Internet. In addition, the management systems and operations of Future Internet must be scalable in order to support thousands and millions of different network devices and to provide services [5].
- *Interoperability*: We assume that there may exist different NMSs that play different roles such as security and performance. Also, interactions occur between NMSs in different domains, and the NMSs of different vendors compete for the same role in a given domain. Thus, interoperability needs to be provided.
- *Efficiency*: Along with the expansion of networking technologies and capabilities, there is an ever increasing need for streamlining and economizing network operations. Network management teams in Future Internet must be able to operate and maintain their infrastructures with the same amount or fewer human resources as compared to that required for the current networks [20].
- *Autonomic aspect*: Autonomic management has recently emerged as the evolution of automated management. In terms of management functionality, systems can be characterized as unmanaged, managed, predictive, adaptive, and autonomic [7]. Adaptive closed-loop automated management is the first form of autonomic behavior, and the ultimate target is a fully distributed adaptive automated management. The various and complex network resources and services of Future Internet must be managed automatically and must include self-management capabilities.

4.2 Management Operations of Future Internet

Management of Future Internet involves providing management functions for the Future Internet resources and services and facilitating communication between the management planes and the network resources or services and other management planes. The FCAPS management functionalities must also be supported for the management of Future Internet [21]. These categories are sufficient to cover most, if not all, of the issues related to the operations and management of the wired networks in Future Internet. With the introduction of wireless and cross-layered networks, a few additional categories, which could not be easily covered by FCAPS, had to be added. The additional categories include mobility management, virtual resource management, cross-layer management, and terminal management. FCAPS covers the basic functions in conventional network management and we think these functional management operations are also necessary in the management of Future Internet. Thus, we do not mention FCAPS again but focus on the additional management operations in this paper.

4.2.1 Mobility Management

Mobility management facilitates horizontal and vertical handoffs and roaming. Both horizontal and vertical handoff functionalities must be provided and a mobility management system is required to support them. A key challenge will be facilitating the handoff functionalities when changing a network for a session with certain QoS requirements. The QoS requirements must be satisfied in the new network in order to avoid problems. The question remains whether we should terminate the session or continue it with lower quality. Although the probability of selection of the latter option is high for most users, such decisions can be preset by the user in his or her personal profile.

4.2.2 Virtual Resource Management

To provide resource virtualization, we must explore the implications of virtualization of a central architectural component of the Future Internet architecture, with the explicit objective of encouraging diversity of end-to-end networks [18]. We must consider how virtualization can be integrated into the Future Internet architecture and how it can be delivered by using multiple cooperating organizations on a large scale and with sufficiently high performance in order to make it economically compelling. The virtualization management includes the development of a complete architecture for a diversified Internet system and an experimental demonstration of the major components of the developed architecture; further, it includes the development of the underlying protocols and mechanisms for enabling multiple end-to-end networks to co-exist within a shared infrastructure that is owned and operated by multiple organizations.

4.2.3 Cross-Layered Service Management

To provide cross-layered services, we need to support cross-layer interactions. The cross-layer control mechanism is responsible for appropriately adjusting all the service- and method-specific interfaces and facilitating cross-layer services [8, 10]. Composing a cross-layer service refers to determining the subset of services it contains, their order in the stack, and the method for implementing each service. The objective is to dynamically build a cross-layer service for each new connection. A cross-layer control system takes into account the QoS requirements of the application, current network resource availability, the precedence constraints among services, and any policy in effect at the time of application. Specifically, the control system should be possible to construct abstract representations of services in order to determine their properties and interactions.

4.2.4 Terminal Management

Terminal management corresponds to two subareas, namely terminal location management and terminal trace management. The terminal location information can be used to make QoS-related decisions by the operations and management system when a user wishes to use a particular service and when a certain set of QoS has been requested. Terminal trace management is important for detecting and tracing stolen terminals or frauds, which are currently one of the biggest challenges experienced by the service providers at present. Traced information can also play a key role in activities such as determining the root cause of a malfunctioning terminal, advanced trouble shooting, optimization of resource usage and quality, RF coverage control and capacity improvement, and dropped call analysis.

5 Concluding Remarks

The current Internet will continue to evolve as a support mechanism for many applications in our society, economy, and daily life [5]. The current Internet principles were not designed to address the future challenges posed by mobility, security, manageability, and scalability. It is the right time to start exploring new research ideas to enable the design of the Future Internet infrastructure. Many research activities are currently being performed to design the Future Internet and build test facilities. These R&D activities are largely opened to international cooperation and partnerships. Their first batch of proposals are being prepared for submissions; interested parties from all regions of the developed and developing world have an opportunity to join and participate towards the development of a common platform for networking the future global economy.

We believe there are huge opportunities for the research community to pursue a more revolutionary clean-slate approach to the problem of network control and management. If successful, this line of research could create an entire landscape of possibilities for networking researchers to deploy their ideas on real networks. Ultimately, data networks, equipped with new control and management protocols and software, could be simpler, more robust, more evolvable, and less prone to security breaches.

In this paper, we extracted management requirements and operations for manageability of the Future Internet. But we cannot directly apply them to real Future Internet infrastructures, because the details of suggested operations in this paper are general and conceptual in natural. For future work, we need to transform these conceptual operations into more concrete operations and evaluate these operations in order to manage the Future Internet.

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