

Network Virtualization : A Way Forward for Accommodating Multiple, Heterogeneous Architectures in a Single Infrastructure

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Abstract – Future Internet researches revolve around the notion “Architecture”. Architecture can be defined as the set of principles and basic mechanisms that guide network engineering. Historically, informal architectural ideas guided design of the Internet protocols, but the architecture was formalized later. The today’s Internet architecture is under serious reconsideration and people started thinking about alternatives. It is necessary to support a variety of the new different architectures to accommodate the heterogeneity of Future Internet. In the paper, we discuss new challenges on network virtualization and discuss a new way forward for accommodating the multiple, heterogeneous architectures in a single infrastructure.

Keywords – Future Internet, Network Virtualization

1. INTRODUCTION

The Internet is a social trend that has changed, and continued to change how humans communicate for business work. Without question, almost all industrial sectors take advantage of the Internet, and all the networking services and technologies will be converged into all-IP networking technologies, according to these trends of emerging all-IP based global networking.

The today’s Internet technologies have significant deficiency that need to be solved before it can become a unified global communication infrastructure. Particularly, there are problems with a large number of hosts, such as sensors, the various wireless and mobile nodes, multiple interface and multi-homed nodes, the support of the fast mobile hosts, the safe e-transaction, the quality of service guarantee at a network, the business aspect complementary, etc., so various researches had been being in progress to solve these problems. Further, the concerns are drastically increasing now that shortcomings would not be resolved by the conventional incremental and backward-compatible style of current research efforts. That is the reason why “Clean-Slate Design for the New Internet’s Architecture” [1, 2] is required for the Future Internet research. Redefining Internet architecture requires many challenged works and a lot of new heterogeneous architectures suited to the future of the Internet would be considered. It is necessary to support a variety of the new different architectures to accommodate the heterogeneity of Future Internet. So, a common means should be provided to accommodate the new heterogeneous architectures.

2. PROBLEM STATEMENT FOR FUTURE INTERNET

This section elaborates on general problems with today’s Internet technology for Future Internet. The problems for the Future Internet could be classified into 1) basic problems and 2) problems with original design principles of Internet as follows [3, 4]: Some of

issues below are being also discussed in Internet Engineering Task Force (IETF) and Internet Research Task Force (IRTF), too [5, 6].

A. Basic Problems

(1) Routing Failures and scalability

The current Internet is facing challenges in scalability issues on routing and addressing architecture. The problems have been examined as being caused by mobility, multi-homing, renumbering, provider independence (PI) routing, IPv6 impact, etc. on the current Internet architecture. The problem is known to be caused by current Identifier-Locator integration architecture within IP address scheme.

It is envisioned that the telecommunication networks including internet will undergo several major transitions with respect to technologies, services, size, and so on during the next 10-15 years. For example, machine-to-machine communication might be pervasive in addition to the current way of communication that human-beings are involved.

Therefore, the challenges in providing a scalable and robust global routing system will also change over time as the Internet continues to evolve. Scalability consideration shall include following aspects:

- ✦ Routing and addressing architecture
- ✦ Multi-homing and provider independence (PI routing)

(2) Insecurity

One of the main problems on the current Internet is not to provide secure communication. As current communication is not trusted, problems are self-evident, such as the plague of security breaches, spread of worms, and denial of service attacks. Even without attacks, service is often not available due to failures in equipment of fragile IP routing protocols.

(3) Mobility

Current Internet technologies are designed for hosts in fixed locations, and ill-suited to support mobile hosts. Mobile IP was designed to support host mobility, but Mobile IP has problems on update latency, signaling overhead, and location privacy. Also the current Mobile IP architecture is facing challenges in fast and vertical handover.

For the Future Internet, it is expected to support mobility of devices, services, users and/or groups of those seamlessly. Following features can be considered under the context of mobility in the future network.

a. Context-awareness

Mobility in the Future Internet is expected to support context-awareness. (6) a describes details on context-awareness. Although location is a primary capability, location-awareness does not necessarily capture things of interest that are mobile or changing.

b. Multi-homing and Seamless Switching

Mobility in the Future Internet should support multi-homing, i.e., multiple access paths to heterogeneous /homogeneous networks. It is also expected to support seamless switching between those multiple access paths.

c. Heterogeneity

Mobility in the future network is expected to support heterogeneity. (5) describes details on heterogeneity.

(4) Quality of Service

Internet architecture is not enough to support quality of service from user or application perspective. It is still unclear how and where to integrate different levels of quality of service in the architecture. In addition, QoS in the Future Internet is expected to support context-awareness described in (6).

(5) Heterogeneity

Recently, IP architecture is known as a “narrow waist or thin waist” of Internet hourglass. Today’s IP enables a broad range of physical layers and applications. But, this physical layers and applications heterogeneity poses tremendous challenges for network architecture, resource allocation, reliable transport, context-awareness, re-configurability, and security.

a. Application/Service Heterogeneity

Original Internet was designed to support host-centric, which means users tell client to contact to another host (e.g., telnet, ftp). However, new emerging services are more likely data-centric. Users want to access particular data or service (e.g., P2P) and do not care where the data or service is located.

b. Device Heterogeneity

The Future Internet is expected to support new devices such as sensors, RFIDs, etc.

c. Physical Media Heterogeneity

The Future Internet will accommodate heterogeneous physical media, such as optical fiber, wireless access (e.g., IEEE 802.11/16/15.4 ...), etc. This physical media heterogeneity poses tremendous challenges to Future Internet architecture.

(6) Customizability

Original Internet is designed mainly for packet delivery. The Future Internet, however, is expected to be customizable along with increasing various user requirements. Customizability will accommodate following features:

a. Context-Awareness

Three important aspects of context are: where you are; with whom you are; and what resources you are nearby. For example, context-awareness is applied to mobility, it refers to a general class of mobile systems that can sense their physical environment, i.e., their context of use, and adapt their behavior accordingly.

b. Re-configurability and Service Discovery

With emerging new invented technologies, it is expected to import and configure those technologies into the Future Internet architecture. Therefore, programmable and/or re-configurable networking and computing methods need to be adopted. One of the good examples would be programmable and/or re-configurable routers/switches. The Future Internet is expected to discover a service based on service-specific overlay control.

c. Content-Centric Services

The Future Internet is expected to support content-centric services. For example, numbering can be supported in a content-centric manner.

(7) Network Management

The original Internet lacks in management plane. The Future Internet will become more and more complex with emerging services and architectural diversity. Therefore, Instant and easy management is desired in the future network. Future Internet is expected to be manageable with the manner of robustness, fault-tolerance, and availability as the wire-line telephone network provides today. . For example, the following autonomic management features can meet the demand for future mobile networks: self-protecting, self-healing, self-configuring, self-optimizing, etc.

(8) Economy and Policy

Original Internet does not consider the economic features of itself. It is expected to provide economic incentives to the components/participants that contribute to the networking. For example, network providers and/or ISPs contribute to construct the infrastructure of network. The users of GRID computing contribute to provide resources. Therefore it is desired that the future network provides with explicit economic primitives in a fair way.

B. Problems with Original Design Principles

(1) Packet Switching

Current Internet technologies use packet switching making it hard to take advantage of improvements in optical. Packet switching is also known to be inappropriate for the core of networks and high capacity switching techniques (e.g., Terabit). Instead, we need to re-design dynamic circuit switching or hybrid (packet –circuit) switching for the core of networks.

(2) Models of the End-to-End Principle

The models of the end-to-end principle has been progressively eroded, most notably by the use of NATs, which modify addresses, and firewalls and other middle boxes, which expect to understand the semantics behind any given port number (for instance to block or differentially handle a flow). As a result, end hosts are often not able to connect even when security policies would otherwise allow such connections. This problem will only be exacerbated with the emerging need for IPv4-IPv6 translation. Beyond this, other change in the way the Internet is used has stressed the original unique-address:port model of transport connections.

(3) Layering

Layering was one of important characteristics of current Internet technologies, but at this phase, it has inevitable inefficiencies. One of challenging issues is how to support fast mobility in heterogeneous layered architecture. We should explore where interfaces belong, and what services each layer must provide.

3. CHALLENGES ON NETWORK VIRTUALIZATION

Network virtualization is the technology that enables the creation of logically isolated network partitions over shared physical network infrastructures so that multiple heterogeneous virtual networks can simultaneously coexist over the shared infrastructures. Also, network virtualization allows the aggregation of multiple resources and makes the aggregated resources appear as a single resource [7]. The purpose of network virtualization is to de-ossify the today's Internet. It could realize virtual networks with programmable network elements and support the architecture of multiple architectures. Different virtual networks can provide alternate end-to-end packet delivery systems and may use different protocols and packet formats. Network virtualization provides a common means to accommodate the new heterogeneous architectures and facilitate architecture revolution. Figure 1 illustrates disruptive technologies and architecture support using network virtualization.

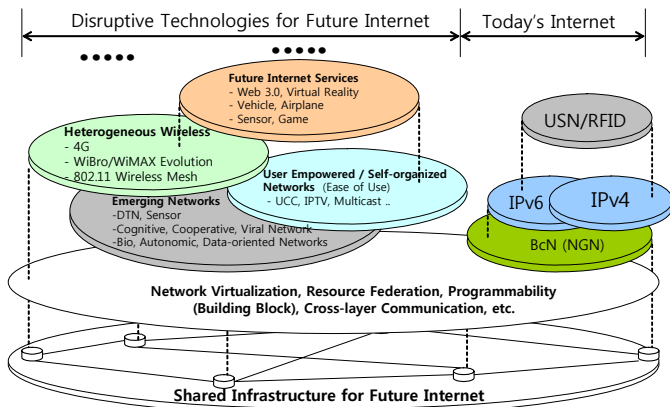


Figure 1. A Shared Infrastructure and Disruptive Technologies for Future Internet

However, there are a couple of challenges which should be resolved to realize; performance and programmability. In general, in order to get performance gain, hardware-based virtualization should be preferred rather than software-based virtualization. Figure 2 shows an example of comparisons between software-based virtualization and hardware-based virtualization. Hardware-based virtualization can support fast forwarding, and take more performance enhancement. Also, to ensure flexibility and manageability, programmability is one of indispensable requirements of network virtualization. Only through programmability, service providers can implement customized protocols and deploy diverse, disruptive architectures [8].

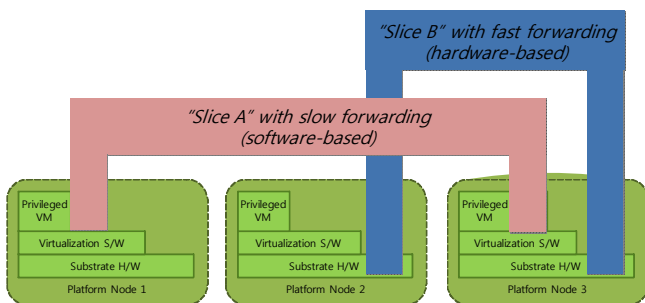


Figure 2 software-based virtualization vs. hardware-based virtualization

4. ETRI VIRTUALIZED PROGRAMMABLE PLATFORM

We propose a virtualized programmable platform to support a new way forward for accommodating the multiple, heterogeneous architectures in a single infrastructure. We have developed the high performance Future Internet virtualized programmable platform based on network processors (NPs). The ETRI platform has several blades comprising of up to 10 line cards, switch board, and processor board over the ATCA chassis compliant to PICMG 3.0 and 3.1. Each line card supports 10GbE and 1GbE interfaces and accommodates dual Octeon NPs of CN58xx in which each supports the maximum 16 MIPS cores. A processor board uses an Intel's Dual Xeon CPU. The platform could provide the advanced architecture with high performance and flexible data path configuration for prototyping and validating clean-slate ideas for Future Internet.

It has also ProtoGENI [9] compatible control framework and the functions of dynamic resource management, dynamic topology management and program download. Figure 3 and 4 illustrate ETRI virtualized programmable platform and hardware specification, respectively.

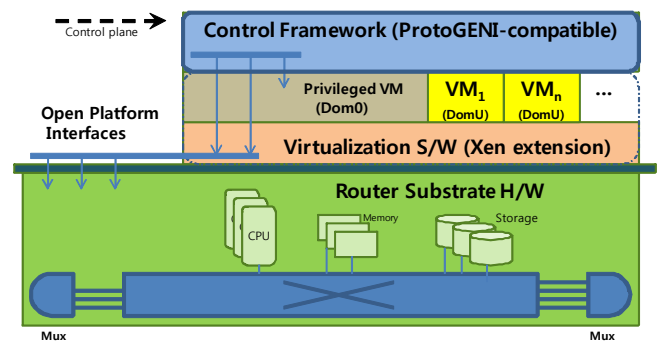


Figure 3. ETRI Virtualized Programmable Platform

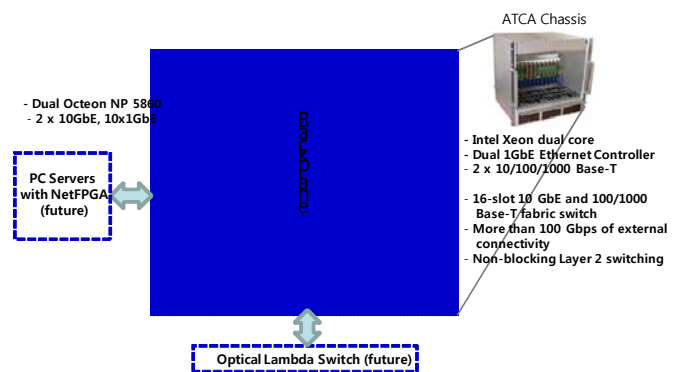


Figure 4. Hardware specification of ETRI Virtualized Programmable Platform

In our platform, we have designed two open platform interfaces – 1) programming APS for researchers and 2) component management APIs to enhance flexibility and programmability. As for 1), in order to support hardware-based packet processing, the following APIs are defined.

- ✦ `work_request_sync()` /* get_work */
- ✦ `send_packet_prepare()` /* packet building */
- ✦ `send_packet_finish()` /* packet sending */

Also the following APIs are proposed for component management. A component manager is the entity responsible for allocating resources at a component. It exports a standard interface. That interface is also exported by aggregates. Though it is intuitive to think of the component manager residing on the component it manages, this is not necessarily the case. This is a part of our platform APIs which have been defined at this moment.

- ✱ Create-Sliver
- ✱ Define-Sliver-Rspec
- ✱ Check-Sliver-Available-Rspec
- ✱ Allocate-Sliver-Rspec
- ✱ Delete-Sliver-Rspec
- ✱ Delete-Sliver
- ✱ Create-Interface
- ✱ Define-Interface-Rspec
- ✱ Check-Interface-Available-Rspec
- ✱ Allocate-Interface-Rspec
- ✱ Duplicate-Interface
- ✱ Delete-Interface-Rspec
- ✱ Delete-Interface
- ✱ Create-Link
- ✱ Define-Link-Rspec
- ✱ Check-Link-Available-Rspec
- ✱ Allocate-Link-Rspec
- ✱ Delete-Link-Rspec
- ✱ Delete-Link
- ✱ Start-Link-Flow
- ✱ Stop-Link-Flow
- ✱ Replace-Link
- ✱ Query-Processor-Utilization
- ✱ Query-Memory-Utilization
- ✱ Query-Link-Utilization
- ✱ Load-Program
- ✱ Unload-Program
- ✱ Start-Program-Execution
- ✱ Stop-Program-Execution

In addition, one of important requirements of our platform is to support US GENI compatibility. GENI (Global Environment for Network Innovations), a project sponsored by the National Science Foundation, is open and broadly inclusive, providing collaborative and exploratory environments for academia, industry and the public to catalyze groundbreaking discoveries and innovation in these emerging global networks [10]. In order support GENI compatibility, we are collaborating with ProtoGENI team. The ProtoGENI is an NSF-funded implementation and deployment of GENI, led by the Flux research group at the University of Utah. Since ETRI platform is an entirely different hardware platform from the one Emulab normally manages, ETRI plans to implement a ProtoGENI compatible Component Manager interface for their platform. Thus, ETRI and Korean researchers will be able to use common APIs to create slices and allocate resources on any of protoGENI-based federated testbeds (Cluster C team) across national boundaries. Figure 5 show an idea on how to integrate ProtoGENI and ETRI platform through mapper and wrapper. Also, Figure 6 show a plan on how to establish K-GENI networks between Korean testbeds and US GENI.

5. CONCLUSION AND FURTHER WORKS

In this paper, we discuss new challenges on network virtualization and discuss a new way forward for accommodating the multiple, heterogeneous architectures in a single infrastructure. The ETRI platform is planned to be deployed nationwide such as

universities, laboratories for experimental infrastructure for the Future Internet research through the Korean research networks such as KREONET, KOREN, etc. Future work will continue more specific requirements for the Future Internet and details on how to build up and integrate new research works with regard to heterogeneous networks and architectures through our virtualized programmable platform. At the same time, we have started to discuss standardization efforts on network virtualization for Future Internet in ITU-T SG13 and ISO/IEC JTC1/SC6. The deliverables are expected to be published from the end of 2010.

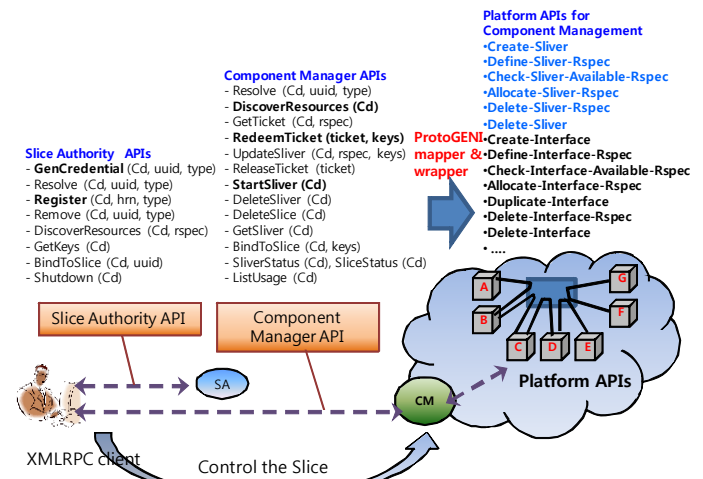


Figure 5 ProtoGENI Controls Integration

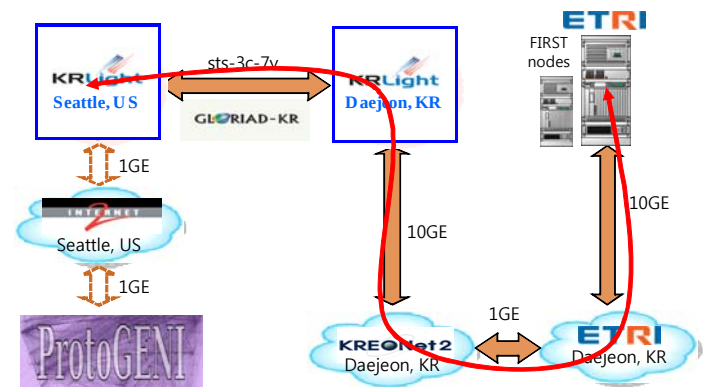


Figure 6 K-GENI Network Establishment

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