Future Internet: Challenges in Virtualization and Federation

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Abstract—*Future Internet is a clean-slate research activity in quest of new networking technologies to overcome the limits of the current Internet. In its experimental research, virtualization and federation are emerging as essential features, especially in the construction and operation of the testbeds. Moreover, they are believed to sustain as the fundamental functionalities of the Future Internet itself. Visions and experiences on virtualization and federation are given by leading experts from US, EU, and Asia.*

Keywords-future internet; virtualization; federation; testbed

I. INTRODUCTION

Future Internet is a clean-slate research activity in quest of new networking technologies to overcome the limits of the current Internet. Despite its tremendous success, the Internet has faced continuing challenges in providing advanced functionalities most of which not within its original design objectives. Numerous new functionalities have been patched to the original core Internet suite, yet only to leave zealous engineers even more desperately frustrated.

Bringing new networking technologies to reality is an overwhelmingly difficult endeavor. We've seen the fate of ATM and have yet to wait with painful impatience for the whole-scale operation of IPv6. Especially when the new technology in question is something of clean-slate approach as Future Internet is advocating, the task should be multiple times more difficult.

For this reason, setting right strategies for construction and operation of the Future Internet testbed is considered to be one of the vital steps to open a path toward its successful realization. One of such strategies gaining consensus of many researcher in the field is virtualization. By virtualizing the resources of networks, date storage, and computing, a plurality of new wild ideas can be concurrently tried out without intervening one another. Moreover, virtualization provides an attractive coexistence possibility of the current legacy Internet operation and new clean-slate technologies.

Virtualization by itself, however, does not suffice. Throughout the research and development of Future Internet, various different communities and entities will deploy and manage each one's own platforms. This is not at all negative. In fact, we have to ensure and even encourage maximal freedom of diverse research communities. Then, for the harmonious synergy of sometimes competing managerial authorities, a good federation scheme of the whole Future Internet testbed is of fundamental significance.

In this panel, some leading experts in the field are presenting and discussing their views and visions on the challenges in virtualization and federation of the Future Internet testbeds. Section II provides an academic background for the need of virtualization while Section III discusses challenging hurdles thereof. Section IV highlights the need and directions of federation, and Section V introduces a new initiative on federated management. Finally, an exemplary experience with an existing testbed is provided in Section VI and the paper concludes in Section VII.

II. PLATFORM FOR HIGH-PERFORMANCE NETWORK VIRTUALIZATION

A. Introduction: Need for Innovation

Despite relentless networking research over the past 20 years and the associated increase of knowledge, the rate of innovation in the Internet as it is being used today has been very disappointing. Indeed, the Internet as we use it today is still basically concerned with moving packets on a best-effort basis. The simplicity of the current Internet Architecture model is based on the ‘hourglass’ approach where the “waist”, the network layer, provides a minimal necessary level of generic network support, and self-configures (heals in response to failure) well enough to allow various data applications to operate reliably. It has been simple to link any new network to the Internet, providing instant benefits resulting from the interconnectivity with a huge range of communicating peers. This simplicity has provided for increasing network capacity by the rapid integration of faster link layer technologies. The transparency of the Internet has greatly steered innovation and the edges/hosts and facilitated the deployment of successively more complex network-agnostic applications and services and accounts for the second area of recent rapid innovations, namely the application layer (e.g. overlays, peer-to-peer, multimedia, content distribution networks, games, etc). However, innovation has often occurred at the application layer not by choice, but as a way to bypass the stumbling block to changes that the “ instrumental” TCP/IP network layer represents. Of course, while introducing new concepts at the application layer simplifies deployment, the solutions are often far from ideal and can exhibit some redundancy and sub-optimality resulting from competing objectives.

B. Resistance from ISPs

On the other hand, the lack of deployment of novel ideas at the very core of the Internet has been caused by the way Internet Service Providers (ISPs), who provide network services to their customers, have also traditionally done so while provisioning and managing their own network infrastructure. This, because of costs, fundamentally limits the global geographical reach of each ISP, who must then rely on other ISPs to allow their customers to communicate with others anywhere in the world. Consequently, ISPs very often do not control the overall end-to-end communication paths, which in turn seriously limits the competitive advantage that could be gained by deploying new services, as any benefit could be annihilated by another, non-compliant ISP further down the path. Adding to this the vested interest ISPs have in maximizing the return on investment made for their infrastructure, by protecting customer satisfaction and thus avoiding the deployment of any new technology that could potentially disrupt the service they offer, and it is little surprise that innovation is met by resistance.

C. Virtualization to Resolve the Conflict of Interest

Nevertheless, the reliance on the Internet as a critical socio-economical infrastructure does fuel the constant need for improvement and innovation (e.g. increased mobility, increased security, increased connectivity, increased digital media usage, increased resilience, location-awareness, service composition, etc), while the Internet Architecture's capacity at meeting new communication requirements is reaching saturation point.

Until recently, development of the Internet was mostly technology-driven. But this changed with the advent of new services and applications, such as peer-to-peer, VoIP or IPTV, which trigger and drive new requirements on the underlying network and its architecture. Further, there is no doubt that the advent of future network applications will create yet unforeseen communication needs and requirements on the network. Surely, the new Internet Architecture must be sufficiently agile to accommodate seamlessly such future requirements.

To resolve the tensions between the need for innovation and resistance to change, as well as build an Internet general enough to meet future requirements, it is often proposed that the future Internet Architecture be polymorphic, that is, be capable of supporting several instances of different network architectures concurrently, on a same hardware infrastructure. With a polymorphic Internet, the current network architecture, new protocols, new services and new network architectures can all coexist safely.

In this context, we postulate that a polymorphic architectural principle will drive the Future Internet Architecture and virtualization will be one of the main mechanisms composing this architecture. Polymorphism is a fundamental architectural shift which, along with virtualization of network and system resources, introduces new actors and relationships in the Internet. Indeed, virtualization, for instance, allows the decoupling of the roles of service provider and infrastructure provider, relieving ISPs from the lack of end-to-end path control; while polymorphism of the network architecture allows safe and rapid deployment of new protocols.

D. Conclusion

We argue that modern commodity PC hardware architectures, with their multiple multi-core CPUs and high-speed interconnects, exhibit tremendous power and that coupled with the commoditization of high-speed, feature-rich L2/L3 switches capable of complex flow pre-processing, they can form the basis of a new high-speed, yet highly flexible and programmable, networking platform for virtualization. Because of the low cost of the proposed components, high scalability can then be achieved by high clustering density: at the time where "blue-sky" research is being called for, we essentially propose to put the new network in the cloud.

III. Virtualization and Future Internet

A. Position

Virtualization can be a valid tool for Future Internet research and become a technology widely used in the Internet of the future. Advanced virtualization capabilities in networking and in computing can help in creating versatile infrastructures for Future Internet research which are agnostic and present limited constraints to researchers. Virtualization is already part of the current Internet and it's increasing its role. It may become a key component in the Future Internet infrastructure.

B. Virtualization

Virtualization technologies have been used since the beginning of the computer era and they are available in networks, computers, storage and applications. In the last years, the use of virtualization has constantly increased, in particular in computing systems. Its success has been fostered by reduction in the total cost of ownership of large number of virtual systems when virtualized and by the advanced functionalities as to increase resiliency and redundancy. In addition, virtualization makes faster and simpler to duplicate and geographically move functions based on a specific software set-up. To improve performance, virtualization functionalities are lately being implemented in hardware.

In brief, virtualization is intended here as the capability to create a virtual version of resources. The virtual resources(a virtual circuit, a disk partition, a virtual computer) are usually created by segmenting a physical resource. Virtualization may create un-configured (clean) virtual resources, e.g. an image of the hardware of a computing element on which (almost) any operating system can be installed, point to point network circuits, a portion of disk space. Those resources can be then tailored to various needs and even moved from a virtualization-aware platform to another. The resource types of interest here are:

- connectivity in form of a point to point circuit with or without assured capacity guarantees and a with or without a data link protocol (a "bit pipe")

- a computing element, offering the equivalent of a computer hardware made of mass storage, RAM, CPU, network interface and so on. The computing element is capable of hosting various operating systems and functionalities (e.g. routing)

C. *The Virtualization Framework*

A framework based on virtualization may be usefully schematized in two distinct layers:

- the virtualization substrate. The physical infrastructure which contains all the hardware and software to instantiate the virtual resources
- the virtual infrastructures created, containing the virtual resources and an initial logical topology connecting them

The virtualization substrate is usually a single instance and a single administrative domain. The virtual infrastructures are in principle an unlimited, or very large number, restricted by the physical resources available and the requested characteristics.

D. *Virtual or Real?*

A key issue of a virtual resource is how much its behavior differs from the physical resource it's mimicking. As an example, a virtual circuit may not be capable of offering a constant, fixed amount of bit per second, and a virtual computer image may not provide a constant CPU usage.

The quality of a virtual resource can then be defined as a function of the difference between the behavior of the virtual and the physical resource. The difference is due to two main independent causes:

- sharing of the physical resource with other virtual resources
- the virtualization technology itself, usually a layer placed between the physical resources and the virtual ones

Hardware assistance for virtualization has been introduced recently to reduce such a difference. Since 2005 the main CPU manufacturers have added virtualization-friendly extensions, in particular related to protection rings.

E. *Virtualization and Research on Future Internet*

An infrastructure substrate based on virtualization can provide an ideal environment for innovative research. It can create virtual infrastructures containing combination of the basic, "raw" fundamental virtual resources in arbitrary topologies and hosting any operating system and application type. Such virtual infrastructures

- are almost constraints free. None or a very limited set of technologies are embedded in the resources;
- may contain a copy of a part of current Internet to check the migration paths and it can be interconnected to Internet to study interoperability;
- may span all communication and computing layers;
- are fully controllable by the user.;
- can be reconfigured in a very short time.

It is assumed here that the digital representation of data (in form of bits and hence digital transmission) and digital computation will stay at the basis of the future Internet. The set of basic virtual resources can then be sufficient.

Examples of existing infrastructures at the computing system level are PlanetLab[1], Onelab[2,3]. Emulab[4] is partially using virtualization. The project FEDERICA[5] is relying heavily on virtualization to offer an infrastructure for Future Internet research. GENI[6] is developing the infrastructure and technologies, among which virtualization may be a key element.

These environments have to face at least three major challenges:

- the reproducibility and the stability of the behavior of the virtual resources, as fundamental requirements for quantitative evaluations of new ideas.
- the physical resources characteristics, their amount and configuration to ensure that the virtualization substrate is a highly-reliable fabric.
- the increasing complexity of the system, which may actually reduce the reliability and the quality of the system, increasing its operational cost.

The complexity is in particular a serious risks. Multiple parallel virtual networks on the same physical infrastructure may be recursively created as an example. Such advances require better ad-hoc support in the hardware and the development of new standards for virtual resource representations. In particular the need is for a more rich information system which tracks the relationships between entities (virtual or real).

The FEDERICA project is committed to leverage virtualization at all communication and system layers, to offer its users full control of the virtual resources with reproducible behavior.

F. *Virtualization and Future Internet*

Virtualization technologies are already used in computing elements and in networks in the present Internet. Virtualization decouples the complexity of physical resources from the services offered and allows a simpler interface to the user, independently of geographical location and access device. Virtual communities already share Internet with various applications.

Internet will continue to develop a grow according to two basic requirements: interconnect a constantly growing number of elements and offer ubiquitous, permanent connectivity to the majority of its users. The possibility for any user to connect to any other user is also considered fundamental to allow access to all types of information, also sensors and generic objects.

Virtualization may well facilitate this development, as well as the introduction of new technologies, compatibility and migration paths. It is therefore realistic to assume that virtualization will be a significative technology in the Future Internet, in particular because it can guarantee that applications and data developed in the past may be available on modern hardware.

Nonetheless not all needs to be based on virtualization technologies and most equipment and application will not be based on it, also to reduce the global complexity.

G. Conclusion

Virtualization is a tool which can be extremely useful in researching, building and enabling Future Internet at all communication and computing layers. The characterization of a virtual infrastructure behavior, its quality and its representation are mandatory results which are tackled now. The overall system complexity is a serious risks which suggests keep the system as simple as possible.

IV. Challenges in Federating Network Research Resources

A. Introduction

This paper considers some of the challenges to federation from the point of view of supporting infrastructure. Internet2, as an organization, participates in the GENI project in the United States primarily by providing infrastructure, although many Internet2 members participate in GENI academic network research.

The membership of Internet2 consists of research universities, regional networks, and corporations interested in network development. Many of these members provide intellectual capital, network infrastructure, or communications equipment to support the GENI project. Internet2 as an organization has contributed, as part of its national wave infrastructure, a 10 Gbps wave across the backbone that is dedicated to the GENI project office in the United States. The wave consists of 13,500 miles of dedicated capacity at 10 Gbps and provides the capability of connecting virtually every research university in the United States.

The Internet2 community also supports a project called InCommon that provides federated identity services to the vast majority of research institutions in the US, including the National Science Foundation and computational facilities like the TeraGrid.

B. Federation

From the GENI perspective, federation allows use of a variety of different types of capabilities. As defined in the GENI System Overview [1] as follows:

"Resource federation permits the interconnection of independently owned and autonomously administered facilities in a way that permits owners to declare resource allocation and usage policies for substrate facilities under their control, operators to manage the network substrate, and researchers to create and populate slices, allocate resources to them, and run experiment-specific software in them."

The concept of slices is especially important; allowing a researcher to obtain pieces of infrastructure that can be combined into a coherent experiment is a powerful and essential capability. While GENI is envisioned to be an NSF-supported facility for network research in the United States, with the capability of federating with other similar facilities across the world, there will also be local aspects to federation. There are likely to be local infrastructures under administrative domains that have either special policy requirements, or dedicated technical capabilities that require interesting interconnections. They include national, regional, or campus facilities that provide network, computational, or storage facilities, and all of these may have individual and challenging policies.

Federation will be required between different types of architectures, for example those that are primarily packet switched and those that might be circuit switched. Moreover, there may be multiple control environments that need to be federated in some way. Understanding performance issues across different infrastructures will also need federation. For example, different domains will have different techniques for setting up circuits, or allocating memory systems, or providing computation elements. Certainly, different administrative domains might have vastly different policy requirements for dissemination of performance and measurement data. Different domains will have different techniques and strategies for middleware and security, where federation is likely to play a major role. In addition, different administrative domains often use different types of management systems, or have different policies with respect to management of the various facilities. Internet2 has been dealing with many of these issues for a period of ten years. For Internet2, federation is world-wide, working with major global networks in Europe, Asia, South America, and several newly forming networks in Africa. The federation ideas are typically related to supporting services for discipline researchers, but the concepts and challenges are often similar to GENI, especially related to architecture, performance, middleware, security, and management, and associated policies.

C. Internet2 and GENI

An example of the challenges of federation is the wave provided by Internet2 to the GENI infrastructure. That wave will support two GENI prototypes initially: The ProtoGENI project from the University of Utah, and the Supercharged Planet Lab project out of Washington University in Saint Louis. The challenges related to supporting those two projects involve all of the topic areas described above. For example, the wave itself is provisioned on standard wave equipment providing standard Ethernet LANPHY 10 Gbps interfaces, but that means additional interconnecting equipment, with some form of control, is required to allow federated control by researchers using one or more of the projects. It also requires some form of coordination between control planes so that experiments on one project do not interfere with experiments on the other project. There are also issues related to performance, measurement, and documentation. For example, what data is available to the various research projects, and what data should be collected and made available via the standard Internet2 approach? Management is also an issue; who manages the facility, or the two projects? What structures are necessary to create the appropriate management structure to allow slices to be created?

Another question is whether or not some standardized federated identity approach like InCommon should be used across the GENI facility, and how does it relate to other identity approaches across the world?

Finally, an interesting question persists about GENI, and indeed about any global testbed: How do various functions developed for the testbed relate to research related to those functions? For example, security will be an issue for the testbeds, so how do the developments related to security on the testbed relate to security as a research topic?

D. Conclusion

The challenges associated with federation, at all levels, are daunting, and will take a concerted effort from the network and computational sciences community, but they are all solvable and indeed will lead to new ideas in the field. It will take a concerted effort on the part of all participants, including infrastructure providers, to help solve the problems and create the essential network research facility.

V. GENI Federated Management Infrastructure and Implications beyond GENI

A. Introduction

A question asked by the GENI Project Office in describing the GENI Operations, Management and Security Working Group is…"How will operators provision, operate, manage and trouble-shoot GENI?"

This presentation outlines Indiana University's funded GENI proposal for development of a preliminary infrastructure to address this question for the GENI facility. The presentation also proposes that this preliminary infrastructure may have more general uses beyond the GENI project.

B. GENI Related Concerns

In the GENI facility a key question is: "How can experiments communicate with network operators regarding the status of the network and its components?" For GENI this is a complex question because there will be an emphasis on multiple simultaneous experiments taking place across multiple networks operated (controlled by) multiple different organizations. Another serious issue related to GENI is that since it is an experimental network, experiments will, at times, run out of control. The experimenter needs information about the "out of control nature" of his/her experiment. The GENI federation needs to be protected from an out of control experiment. And, finally, the problematic experiment needs to be halted. Even this is complicated, as the virtualized devices that are part of one experiment may (in fact will likely) be part of others and simply "rebooting" may not be the best option.

Indiana University has proposed a communication mechanism to begin to address these questions. That mechanism, the GENI Meta-Operations Center (GMOC), will be explained in this talk.

C. Broader Applications

But, a mechanism that applies only to the GENI experimental network is of limited interest. We believe that the question of communication between network and experiment can be generalized to network-network and multi-network communication, which will become critical for future global cyberinfrastructure experiments. This global network communication capability must be a standard aspect of network operations, not some heroic add-on put in place at the last minute to patch-up a broken global network connection and enable a critical e-Science experiment.

D. The GENI Global Meta Operations Center (GMOC)

Within in GENI it is critically important to facilitate the sharing of operational and experimental information among GENI experimental components. Even though each component or prototype may have its own internal structure and its own internal operational support model, it is vital that GENI provide a unified method for these prototypes to share information about the important details of the state of the prototype and the data passing into and out of each prototype.

The GENI Meta Operations Center (GMOC) will provide this functionality. The GENI Meta Operations Center will take the disparate and dissimilar prototypes and components of the GENI experimental facility and provide a common collection point and protocol for the operational data sharing needed to operate the GENI testbed.

Technically, the GMOC will develop a well-defined protocol to help generalize the operational details of GENI prototypes and for the providers of prototypes to send those details to an operational data repository. It will largely be up to the GENI prototype participants to decide what data to share and how to collect this data from their prototype infrastructure. The GMOC will provide the standardized format for this data and the systems required to share, monitor, display, and act on this data. In addition, the GMOC will be used to help provide a repository for data collections passing into and out of GENI prototypes for the purpose of discovering and isolating prototypes that have caused problems. This will require additional instrumentation at the connection points between prototypes. This will be accomplished with the help of other prototypes which have agreed to partner with the GMOC to help define and coordinate this information.

In addition to addressing these important technical issues, it is important to develop the organizational structures needed to provide successful operations of the GENI facility. We will investigate how a Meta Operations Center might interact with the prototype participants. There are several possible models, and it will be important to take the time early in the development of GENI to evaluate these.

The success of the GMOC will depend on two things. First, it will depend on the ability to produce the Dataset schema, protocols, and processes required to provide a picture of the GENI federation. Second, it will depend on the ability to provide useful services to our initial partner projects and later to attract more projects to refine and expand GMOC services.

E. Extending the GMOC Concept

As science becomes more global, involving distributed databases, computing resources, scientific instruments and "built-to-order" network connections the ability of network operators (and experimenters) to understand the "health" of an experiment across a number of networks becomes critical. For a variety of reasons, including control, language and simple time differences, the idea that a single NOC, no matter how professional and well-staffed can control the global R/E internet is not reasonable. Network operators must interoperate. They must find a mechanism to simultaneously maintain appropriate control and security of their network and to provide a to-be-defined set of operational data to other network operators, allowing others a view into their network.

In the broader context, this is the activity that the GMOC will facilitate. The GMOC project will construct in a small experimental context, a prototype to answer a number of difficult operational questions. What is the set of data that is required to be exchanged among network operators to facilitate global e-Science activities? How can that data be collected, stored and exchanged in a secure and reliable manner? How can security incidents and experimental malfunctions be handled in the least impactful manner.

F. Future Research Activities – a Call for Participation

The GMOC activities within the GENI project have begun. The GMOC is working with other GENI experiments to develop the GMOC concept. The GMOC is actively soliciting partners, particularly international partners, to participate in the development of data structures, software and process to answer these important questions posed above and to facilitate global e-Science.

VI. Towards a Service Platform for Virtualization and Federation: the Case of JGN2Plus

A. Introduction

New generation network R&D by clean slate approach is started world wide such as GENI in US, Future Internet activities in FP7 and AKARI in Japan. Following these trends, JGN2plus, a new testbed for an advaned networking and application R&D, has been started from April 2008 by NICT. Fundamental requirement for testbed is that it should be built for a proof of concept of newly developed technokogy while supporting development of new applications. Therefore, testbed should be consistant with API although we want to keep introducing new technology. A service platform based on a servie oriented architecture seems to be one of the candidate for flexible architecture. A service platform provides various advanced services to the applications in the help of network functionality. Most importantly, to support multiple experiments on new network functions, virtualization of network functionalities should be supported in a service platform. Finally, a service platform should be federated to support international experiments. In this paper, we propose a new service platform architecture for an advanced testbed for new generation networking research and development.

B. JGN2plus and New Generation Network

In Japan, the first testbed for network R&D started in 1999 as JGN (Japan Gigabit Network), followed by JGN2 in 2004 and JGN2plus in 2008. However, the purpose and its role of the testbed is slightly changed. In the first two phases, that is, JGN and JGN2, the high speed network is very precious resources and its connectivity is mostly important. Therefore, just a connection to various sites is mostly important to encourage R&D effort and application development. Through the use of the high speed testbed, various applications such as telemedicine, remote observation of, for example, the ultra high voltage microscope, remote education became possible by the range of quality such as DV (Digital Video), HD or even 4K digital cinema. Also other applications require to exchange a large volume of data such as eVLBI, LHC, etc. However, after ten years, although the connectivity to the high speed network is still highly appreciated, new requirements for testbed are rising:

- More dynamic and shared use of high speed network is required because of the limited budget and growth of its application.
- Security becomes very important even in the R&D network.
- New stype of ubiquitous applications with a large number of terminal or sensors are coming.
- Testbed is a field for global open innovation.

New generation network R&D by clean slate approach started world wide such as GENI[1] in US, Future Internet activities in FP7[2] and AKARI[3] in Japan which aim to attack these issues. Therefore, a new role is expected for testbed of new generation network R&D as follows:

- Testbed should be built for the proof of concept in more realistic environment.
- While appreciating existing applications in cyberinfrastructure, we are expecting more applications which utilize advanced functionality from the network.
- Testbed should be built on existing and operational technology while supporting evolution of technology.
- Virtualization and federation is a key concept for supporting multiple international experiments.

Therefore, the effort to build testbed network for new generation network is necessary but challenging. Among all above requirements, programmability for all layers is mostly important. To build flexible network testbed, our proposal is to introduce a layer of service platform between network layer and application layer. To support multiple experiments, concept of virtualization should be introduced in multiple layers. Virtualization helps to separate multiple experiments safely and securely. Currently, development of virtualization mechanisms are on going in different layers and projects.

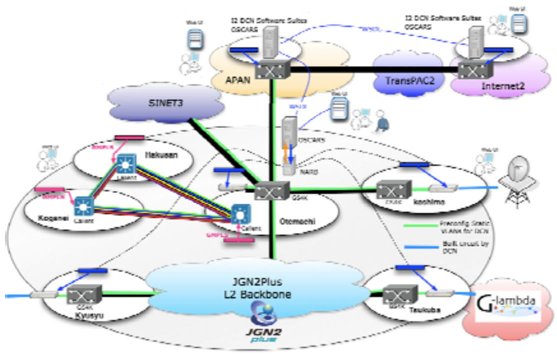

Figure 1. DCN deployment on JGN2plus

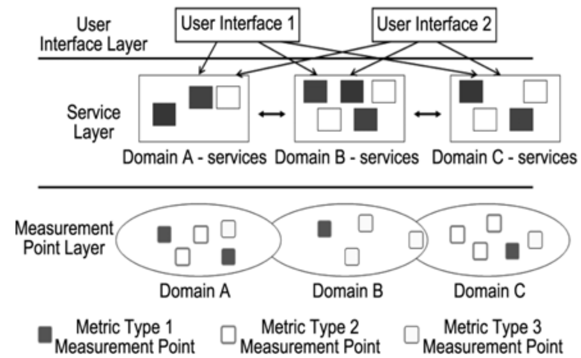

Figure 2. perfSONAR Framework

Therefore, virtualization mechanisms should be federated to support international experiments.

Currently we are developing virtualization mechanisms in our service platform in three layers. The Network Layer consists of an optical network and wireless network. On top of the optical network, many separated logical networks exist. Some of them are packet switched and some of them are circuit switched. For circuit switched networks, we are relying on VLAN. We also introduced virtually managed routers based on the state of art technology. In conjunction with high performance storage and CPUs, it could provide IaaS (Infrastructure as a Service) environment to support dynamic allocation of network, storage, and computing resources.

The Middleware Layer consists of control plane for this hybrid network, service elements for advanced networking. In the current implementation, control plane for JGN is DCN[4] and a service platform for performance metrics is a mechanism called perfFSONAR[5].

On top of these network layers, we are providing overlay layers based on P2P ubiquitous service platform, PIAX[6] and Planetlab[7]. Among these mechanisms, some of them are already internationally federated. As examples of internationally federated mechanisms, in this paper, we introduce our trial for DCN and perfSONAR.

C. *DCN Deployment on JGN2Plus*

DCN is a switching service that creates short-term circuits between end-users that require dedicated path separately from IP network. The DCN enables users to create a point-to-point circuit across multiple domains using control plane software. Now, DCN is partly deployed on the Internet2, ESnet, GEANT, and JGN2plus. Currently, DCN provides a way to set up separate logical network on JGN2plus.

Fig. 1 shows the planned DCN network in JGN2plus testbed. We installed Inter Domain Controller (IDC), appearing as OSCARS in this figure, in Otemachi, and IDC controls blue boxes in several sites such as Kashima, Tsukuba, and Kyusyu. These locations depend on applications' locations, so locations will be moved by experiment by environment. An E-VLBI application was demonstrated in SC08, as our first multi-domain interoperability trial between Kashima and SC08 booth via APAN, TransPAC2 and Internet2. By using these DCN networks, application users were able to use VLAN paths on demand, among JGN2plus, APAN, Internet2 and more DCN sites besides on Internet2. On the other hand, we are trying to install this technology into our optical testbed. The Interoperability working group (IWG) in Kei-han-na info-communication open laboratory develops a prototype node of GMPLS E-NNI which is interoperable with IETF and ASON model[8]. By using this GMPLS stack (red boxes) which can control optical layer switchs, not only VLANs but also optical paths can be served by DCN. This will enable users to establish dedicated optical paths when users need.

D. *perfSONAR Deployment on JGN2Plus*

The other important element of network service is measurement. The most frustration of current users in the R&E network is that they don't know what'a going on inside the network. If users will have some function to control the network, they should have some feedback from their control. That is, they should have some information about what's going on inside the network. Measurement information gives part of the information inside the network. The performance service oriented network monitoring architecture (perfSONAR) is the framework that enables users or operators to easily refer, collect, and evaluate the monitoring data in a multiple-domain network environment. perfSONAR has been developed by GÉANT2, ESnet, Internet2, and RNP as one of their core services. perfSONAR is based on the idea of the the three layer multiple-domain monitoring system shown in Fig. 2.

During the SC'08, perfSONAR infrastructure was deployed as a trial. It was the first time to deploy perfSONAR from the Asian region, and this facility could show the network performance parameters between the SC'08 and the counter part sites of the demonstrations. Fig. 3 is the snap shot of the network weather map based the perfSONAR data of several networks.

E. *Conclusion*

JGN2Plus is built as a national and international testbed network for advanced networking R&D. To support advanced international experiments, virtualization mechanism should be supported. And international federation of these mechanism is required. This is very critical exiting moment because these technologies are

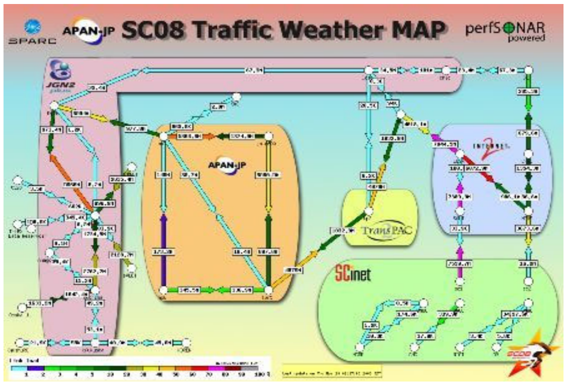

Figure 3. Traffic Weather Map based on perfSONAR

developing in parallel. Therefore, exchanging ideas in related project are mostly welcome.

VII. Conclusion

This panel discussed virtualization and federation of Future Internet testbeds. Although these strategic concepts are thought to form the basis of critical importance, the involved technologies are at most in its early stage and a whole lot still awaits ahead our imagination and challenges. We anticipate that it will be our very young engineers who will be the creator and the owner of the Future Internet success.

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Biography

Dae Young Kim is Professor in InfoCom Engineering, Chungnam University. He is vice chair of APAN and Future Internet Forum Corea, and has over 15 years of experience in network testbeds including ATM and NGI. He is also chair of ISO/IEC JTC1/SC6 which recently launched a project on Future Network.

Mathy Laurent is a Senior Lecturer at Lancaster University. He's got his degree in computer science from University of Liege and Lancaster University. He also worked with the Center for Integrated Computer Research at University of British Columbia and with the Distributed Multimedia Research Group at Lancaster University. He is an active member of ACM SigCOMM, now especially focusing on Future Internet.

Mauro Campanella is graduated in physics in 1985. He is at present working for the Italian National Research and Education Network (GARR) as responsible of research activities. He is one of the creator of the Premium IP QoS service of the European NREN network backbone GÉANT and created the architecture of the Bandwidth on Demand service of GEANT2 (AutoBAHN). He acts as coordinator of the FEDERICA project.

Rick Summerhill received the doctoral degree in mathematics from the University of Iowa in 1969. He is the Chief Technology Officer at Internet2, responsible for the research and development activities at Internet2, concentrating on network research and innovation for the higher education community in the United States. He has been closely associated with the the GENI project in the United States, and in particular federation with international partners. He is also concentrating on the integration of circuit and packet capabilities, including performance monitoring and authentication and authorization issues, especially across multiple administrative domains.

James Williams is the Director of International Networking and the Director of the GlobalNOC at Indiana University. He is the Chair of the Internet2 South Asia sub-group of the Emerging NREN SIG and Principal Investigator on the NSF funded IRNC-TransPAC2 award which provides network connectivity between the US and Asia/South Asia. He has detailed knowledge of network operations and is very experienced in international networking activities.

Shinji Shimojo received the M.E. and Ph.D. degrees from Osaka University in 1983 and 1986, respectively. He was an Assistant Professor with the Department of Information and Computer Sciences, and an Associate Professor with Computation Center each at Osaka University. During this period, he also worked for a year as a Visiting Researcher at the University of California, Irvine. He has been a Professor with the Cybermedia Center at Osaka University since 1998, and served as its director from 2005 to 2008. He is now working for NICT. His current research work is focusing on a wide variety of multimedia applications, peer-to-peer communication networks, ubiquitous network systems, and Grid technologies. He was awarded the Osaka Science Prize in 2005. He is a member of IEEE, IPSJ, and IEICE.