Examination of the Potential for Using Dynamic L1 Connections Among Aggregates, For Possible Emphasis in Year-2

Joe Mambretti, iGENI

International Center for Advanced Internet Research, (icair.org)
Northwestern University < j-mambretti@northwestern.edu>

Introduction

New communications services will be based on distributed, programmable environments that will be designed and implemented as large-scale extended suites of resources that can be dynamically discovered. Integrated and utilized. These environments will be designed to be used as a foundation platform on which it will be possible to create many different types of communication services and networks. This approach will advance communication services from the monolithic models that are prevalent today to those that enable a much more diversified range of services and capabilities. The networking research community is currently contributing to the development of such environments through the GENI initiative, which is creating a distributed environment as an instrument for experimental network research.

The considerations for the design of GENI include those that relate to providing support for L1 research and innovation, for example, investigative topics such as dynamic L1 lightpath based services and implementing optical core network elements that can be addressed as individual components allowing them to be dynamically discovered and integrated with resource components at other layers. This report provides an overview of the potential for using static and dynamic L1 connections among GENI aggregates. This report was developed in the context of the iGENI project and iCAIR's experience in researching and developing new architecture and technology for dynamically provisioned L1 services and networks for over ten years, which has included the development of novel control plane technologies for dynamic lightpath services. Leveraging this experience, the iGENI initiative has been evaluating the potential for using dynamic L1 connections among aggregates for possible emphasis in the second year of the Spiral 2 project. Such considerations encompass four topical areas, static L1 paths that could be used as foundation support for the GENI environment, dynamic L1 paths that could be used as foundation support for the GENI environment, static L1 paths that could be addressed, integrated, and utilized by GENI researchers, and dynamic L1 paths that could be addressed, integrated, and utilized by GENI researchers. Each of these topical areas requires special sets of considerations related to architecture, facility design, and resources.

Opportunities Motivating New Architectural for L1 Services

The GENI environment should incorporate capabilities for exploring new opportunities in networking that are being made possible by advances in basic optical technologies and by new architecture enabled by those technologies. Traditionally, Dense Wave Division Multiplexing (DWDM) has been deployed by service providers only to support static optical channels. However, new low cost emerging systems, components, protocols, and software enable capabilities for dynamic provisioning including those using multifunctional optical cross connections (OXCs), addressable DWDM interfaces, controllable OADMs, tunable lasers, tunable amplifiers, flexible gatings, and other devices. These developments are motivating a major change from implementing optical components as static core resources to enabling a wide spectrum of capabilities for dynamic provisioning, including dynamic L1 services.

These developments provide opportunities not only for supporting L1 related research but also for supporting the emerging GENI environment. L1 services and technologies have significant potential for providing capacity, programmability, and capabilities for resource segmentation and partitioning. Capabilities for segmentation and partitioning are particularly important to assist in implementing mechanisms that allow GENI resources to be kept separate from general production networking environments. Even if segments of the GENI environment leverage production resources, it would be best if that environment as a whole was managed by the research community for the research community and not by production networking services organizations, which have alternative priorities. L1 services and foundation resources provide for opportunities to create separate environments, and they can assist with partitioning for all network layers. In addition, L1 services can assist with providing mechanisms for measurements that can be replicated through additional experimentation.

Any new L1 services should take place in the context of services oriented architecture, which provides standard mechanisms for defining and implementing functionality within programmable environments. In this context, L1 and underlying resources could be advertised as a "service." To develop new techniques for dynamic networking within a SOA context, iCAIR has been participating in the Open Grid Forum, the standards body for Grid technology, which has adopted the WS-RF architecture as a high level abstraction method. iCAIR is participating in working groups that are defining interface methods for dynamic path provisioning. In addition, iCAIR is following the efforts of the ITU ASN.1 committee (Telecommunication Standardization Sector of the International Telecommunication Union), which is creating a new standards that use the ASN.1 language as a new schema definition language for XML. ASN.1 specifies clear distinctions between content, for example, "abstract syntax," such as message descriptions that have no implied coding method and "transfer syntax," which provide for encoding methods. These techniques can be integrated with signaling used for general or core provisioning methods, including those defined by the ITU-T's ASTN (G.807) and ASON (Y.1304) architectural standards. A number of optical network research testbeds have been established to explore these and related architecture. These testbeds are described in a recent publication, a book on "Grid Networks."

Topical Areas Related to L1 Services

As indicated, considerations for L1 services encompass four topical areas. Two of these areas relate to a) static L1 paths that could used as foundation support for the GENI environment, and b) dynamic L1 paths used as foundation support for the GENI environment. Providing dedicated static L1 paths to support the GENI environment is a well known capability with proven techniques. The key issues related to providing the capabilities for static L1 paths primarily center on providing appropriate optically based resources. That is, providing such capabilities is not a technology issue, but a resource provisioning issue. These types of services, for example, static lightpaths, can be provided within existing production domains if organizational policies allow such provisioning.

Providing dynamic L1 paths to support the GENI environment requires special considerations. Few production domains allow (or will allow in the foreseeable future) dynamic L1 provisioning within their core facilities. Consequently, these types of L1 capabilities must be provided through equipment that is implemented external to (but integrated with) core production equipment, but that can be managed through GENI processes. In other words, the core facility would provide the basic wavelengths, but the dynamic capabilities would controlled through external equipment that would be integrated into the GENI environment.

Two additional considerations relate to a) providing static L1 services that can be addressed, integrated, and utilized directly by GENI researchers, and b) providing dynamic L1 paths that can be addressed, integrated, and utilized directly by GENI researchers. If static L1 paths are available within the GENI environment, it would be possible to provide them to GENI researchers fairly readily. As noted, the primary issue relates to the availability of optically based resources. The costs for such resources have been declining rapidly, and this trend will continue. Consequently, over time these types of resources should become increasingly available to networking research communities.

Providing capabilities for dynamically provisioned L1 paths requires the ability to partition the dynamic resources so that that they will not impact other network resources. Techniques for providing those capabilities to the GENI community exist today. However, at this time, few resources are available to the research community to implement them.

Currently, few core optical resources are directly available to the GENI community, either as controllable or static resources. In part this circumstance relates to the different agendas of research and production networking activities. Although the National Lambda Rail, which owns its own fiber, provides a wavelength service that could be made available as a controllable GENI resource, this approach would require more resources than exist in the current NLR support model. Nonetheless, this wavelength service could be useful as a means of interconnecting GENI distributed optical resources, which could be controllable at selected sites. A few regional optical networks provide wavelength services that could also be part of such an environment, and several university campuses support either dedicated fiber for wavelength services or campus based wavelengths.

Global Lambda Integrated Facility (GLIF)

Internationally, the Global Lambda Integrated Facility (GLIF) was established specifically to support both data intensive global science and international wavelength based testbeds. Multiple dynamically provisioned network research testbeds have been established on this global optical infrastructure, which provides resources that constitute a major opportunity for the GENI community, especially in the context of the recent NSF IRNC TransLight/StarLight initiative. An international consortium has designed, implemented, and continues to develop the GLIF as an international platform provides discoverable and addressable core resources which can be used to create multiple differentiated specialized networks and services. The GLIF is a closely integrated environment designed specifically to support capabilities based on dynamic configuration and reconfiguration of such resources. By design, GLIF is based on a fabric consisting, in part, of dynamically allocated lightpaths, including individually addressable wavelengths. These lightpaths globally are interconnected through key sites, GLIF Open Lambda Exchanges (GOLEs) around the world that provide advanced communication services based on an open optical exchange point architecture. This GOLE architecture is being designed to enable edge processes to discover, integrate, and manage a wide range of specialized services and resources, e.g., through middleware integrated with control and management planes, including L1 paths on a dynamic, reconfigurable optical infrastructure.

For example, the StarLight national and international communications exchange facility in Chicago was established to provide for next generation communication services based on new services and technologies incorporating high level abstraction architecture. Related facilities have been established in other cities, such as NetherLight in Amsterdam, UKLight in London, NorththenLight in Copenhagen, CzechLight in Prague, KRLight in Daejeon, and others. Today, there are more than twelve GOLEs around the world, and several more are planned.

These GOLEs have implemented different control frameworks for dynamic network provisioning. Recognizing this diversity, the GLIF network research community is developing a common interface to these control frameworks, Fenuis, which was first publically demonstrated at the annual GLIF workshop in 2009. A more comprehensive multi-GOLE demonstration is planned for the 2010 workshop at CERN (in October).

The GLIF has already provided support for multiple large scale lightpath provisioning research projects. Recently, several optical testbeds were established using GLIF, and resources provided by the StarLight international exchange facility. One of the largest and most active dynamic optically based testbed networks testbeds today based on the GLIF infrastructure is the international HPDMnet. For dynamic resource provisioning, HPDMnet uses Argia, which has been derived from the earlier "User Controlled Lightpath" architecture that was designed to establish an L1 service that not only allocates a segmented lightpath (or set of lightpaths) but also the complete management and control systems for those resources. Agria allows edge processes to discover, access, provision, and dynamically reconfigure optical (L1) lightpaths within a domain or across multiple domains, without having to rely on any central management authority. Argia is based on a highly distributed architectural model. The Argia design, process capabilities, and interface software provide mechanisms directly for allocating facility resources, e.g., lightpaths, and for the control, management, and engineering systems for those resources. Argia has demonstrated capabilities for supporting international dynamic optical “multicast” -- point to multiple L1 across multiple domains. During the last 12 months, iCAIR has used the GLIF and HPDMnet for multiple experiments related to dynamic L1 inter-domain provisioning nationally and internationally, and it has staged large scale demonstrations of these capabilities at major conferences, including at the annual GLIF meeting in Deajeon South Korea in October and at SC09 in Portland, Oregon in November.

GENI Control Frameworks and Distributed Infrastructure

All of the GENI control frameworks have the potential to incorporate capabilities for managing optically based resources, including L1 services. However, to date, of the existing control frameworks, the one that has been used most to demonstrate L1 services control is the Open Resource Control Architecture (ORCA). For example, ORCA has been used to directly manage the component resources of optical switches. ORCA supports multi-layered network provisioning in networks where it has access to individual network elements. For example, in BEN (Breakable Experimental Network, ORCA has access to Polatis fiber switches, Infinera DTN (DWDM equipment) and various switches and routers. When establishing VLANs between sites ORCA, whenever necessary also establishes need lower layer paths, like DWDM circuits and fiber paths by directly manipulating Infinera DTN and Polatis switches and establishing the necessary cross connections. The provisioning logic is supported by NDL-OWL semantic resource descriptions operated on using SPARQL queries and inferences.

L1 Services Signaling

Multiple iCAIR research projects have focused on enhancing capabilities for abstracting communication services from specific infrastructure implementations and configurations, including techniques that reduce hierarchical layers and provide for enhanced abstraction opportunities by transitioning both in-band and out-of band signaling architecture from legacy systems to IP based methods. One research initiative developed the Optical Dynamic Intelligent Network (ODIN) services architecture, which was designed, programmed, tested, and then implemented on a metro area optical testbed to demonstrate the potential for providing L1 services that could broker resource requests by edge processes without requiring centralized management functions. A series of investigative experiments showed that these signaling techniques can effectively provision lightpaths dynamically through specialized APIs invoked by edge processes. In these experiments, ODIN served as an intermediary service layer between the the edge signaling process and lower-level network components. ODIN provides a method of extending control plane functionality through the service layer directly to an edge process, including functions for provisioning core resources, for example, lightpath addressing, dynamic path computation, resource discovery and lightpath reachability, etc. ODIN can establish dynamically using a signaling protocol based on the experimental Lightweight Path Control Protocol (LPC), which was developed by iCAIR and which has been described in an IETF draft.

This protocol provides for a standard mechanism to enable edge processes to communicate requirements for specific network paths. Such paths can be any type of connection oriented paths, including those that are point to multipoint, multipoint to multipoint, and multipoint to point. Such paths can be based on any type of technology , not only lightpaths, but also L2 paths, MPLS paths, L3 tunnels, QinQ based paths, PBB, etc. The protocol relies on a server based process that directly implements such paths using network UNIs. Signaled requested are interpreted by a server and fulfillment is based on network state to which that server has direct access For optical level provisioning ODIN uses a tool, GMPLS(Generalized Multiprotocol Label Switching), which is an Internet Engineering Task Force (IETF) standard. ODIN was used for many years on advanced optical testbeds, including a wide area metro photonic testbed in the Chicago metro area, that supported 24 individually addressable wavelength based 10 GE optical channels among four core node sites interconnected with dedicated fiber. These nodes were comprised of a Dense Wave Division Multiplex (DWDM) photonic switch (2D-MEMs-based), an Optical Fiber Amplifier (OFA, to compensate for link and switch dB loss), optical transponders/receivers (OTRs), and high-performance L2/L3 router/switches.

These types of dynamic L1 services and addressable core optical capabilities would be useful resources to implement within the GENI environment. As noted, basic costs for these types of resources continue to decline, and opportunities exist to provide for integration into the basic emerging GENI infrastructure.

Future Directions

This report provides a brief overview of the potential for using dynamic L1 connections among GENI aggregates. Such capabilities should be part of the GENI environment to allow for network research on topics that relate to L1 based services, including optical layer design, high performance transport, and addressable optical core network elements. Some of the resources to provide this capability exist today. Others are emerging. For example, the advent of 100 Gbps and higher channels provides more than large capacity. These large volume capabilities provide additional opportunities to explore new services and capabilities based on the dynamic provisioning of lightpaths within these channels. During the next year, a framework of processes could be developed to enable progress on providing a prototype GENI environment that would enable network research related to on L1 services. However, these developments not only provide opportunities for supporting L1 related research but also important opportunities for enabling other capabilities within the emerging GENI environment. As noted, L1 services and technologies can provide significant network capacity, programmability, and resource segmentation and partitioning. These capabilities for segmentation and partitioning can be used to separate GENI resources from general production networking environments, enabling those resources to be managed by the research community for the research community.