To: Internet2 Community Design Workshop Attendees

From: Rick Summerhill

Re: Draft Technical Overview

This document includes a description of Internet2's new network, the next-generation hybrid optical network for US research and education that has resulted from community planning efforts over the past two years. This new network represents Internet2's continued commitment to its membership and the higher education community and provides a next-generation, advanced networking environment in which world-caliber research, science, education, and services can develop and flourish.

The following technical overview reflects the current thinking about the new network's design and implementation. Transition plans from the current Abilene are also included, and while the transition in IP services will evolve over the next year, many of the new network's capabilities will be available almost immediately. While the basic properties of the network have been determined by the carrier agreement, there are many options and capabilities that must be discussed and resolved by the community to ensure the most effective implementation of the advanced capabilities available through the agreement. It is essential that the community continue to be involved in determining the final design and implementation of the plans. The Community Design Workshop on 15-16 June 2006 will be a key forum for discussing topology, access points, services, and a variety of other issues. In addition, this document includes current thinking about the cost-recovery model and advisory group structure, which are still to be determined.

As input and advice comes forward, this document will be updated, and as such, should be considered a living document representing the evolving plans and ideas for the community's next generation network.

Rick Summerhill

Internet2's New Backbone Network

Technical Overview

Draft Version 0.9

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Executive Summary

Internet2 has entered into a partnership with a leading national telecommunications carrier[1] to provide the US research and education community with an innovative and cost-effective hybrid optical and packet network. For discussion purposes, this network has the working name of "NewNet." An extension of the Internet2 leading-edge tradition, NewNet is designed to provide production services as well as a platform for the development of new networking ideas and techniques. While the basics of this network are outlined here, substantial input is still needed from the community to complete the design. This document describes the new infrastructure and will evolve over time in accordance with input from the community.

A major driver for work on NewNet is the Abilene network replacement deadline of October 2007. In March 2006, Internet2 declined an option to extend the current agreement with Qwest past September of 2007. Therefore, the community has approximately 15 months to move to a new infrastructure. Internet2 will begin provisioning wave and sub-wave services in the next several months.

The strategic objectives for NewNet include:

- Establish community control of the underlying network infrastructure
- Leverage the capabilities of a global telecommunications leader
- Capitalize on the latest technological advancements in networking
- Create an asset that benefits the entire community – researchers, regional optical networks, universities, industry, government, K-12, and the international community.

Internet2 is also committed to ensuring community involvement in the development, implementation, and operations of the new network.

NewNet will be deployed nationally over 13,000 miles of dedicated fiber, providing complete control of the optical layer and highly granular lightpath services that can be provisioned dynamically. It will provide short-term and long-term waves, as well as on-demand or advanced reservation "lightpath" scheduling. The NewNet IP network, corresponding to the current Abilene network, will be built on the optical network. The basic connectivity package for direct connectors is expected to include two 10 Gbps waves, one for IP and one for point-to-point optical services.

NewNet's Optical (layer 1) network characteristics:

- Initial deployment – 10 x 10 Gbps wavelengths along network footprint
- Maximum capacity – 80 x 10 Gbps wavelengths
- Scalability – potential migration to 40 Gbps and 100 Gbps capabilities
- Reliability – carrier-class standard assurances for wavelengths

[1] Under the terms of this agreement and to comply with securities regulations, Internet2 has agreed not to disclose the name of the carrier until the option of building the new network is formally executed.

- Flexibility – support for sub-wavelength (e.g., 1 GigE) dynamic provisioning across every wave on the NewNet backbone.
- Community control – provisioning as well as switching wavelengths and sub-channels

The carrier will be responsible for meeting a Service Level Agreement (SLA). Internet2 engineering support will include: Control Plane aspects of dynamic provisioning; Application and Advanced Services Support; Engineering, Monitoring, and Management.

The transition to NewNet will not disrupt existing connectivity and services. Internet2 will use the optical capabilities to transition connections in the near term and provide support for evolution to the longer-term, 2 x 10 Gbps basic connectivity package while allowing connectors to upgrade at a slower pace.

The basic connectivity package will also include commodity services. Even with these additional services, the new network's connection fee is expected to be similar to today’s 10 Gbps Abilene connection.

NewNet will be guided by an advisory structure and by the partnership nature of the agreements with the carrier and other partners in order to provide the community with the most advanced capabilities available.

1 Strategic Objectives

Internet2, conceived at a time when higher education had the foresight and resolve to partner with industry and government, formed a community that raised the level of access to and standards for advanced networking and the development of advanced applications. Internet2's challenge today is to sustain the strength of its membership involvement in driving the evolution of the next-generation optical network environment, with a multiplicity of capabilities reaching beyond the community's current networking requirements. By meeting this challenge, Internet2 will ensure that revolutionary research, advanced applications development, and global scholarship will be supported by a robust, flexible, and cost-effective advanced network environment, in keeping with the values of technical excellence and community participation that are its hallmarks.

Beginning in 2005, Internet2 focused on developing a plan to implement the community's shared vision of a networking infrastructure that provides a far richer suite of services than current high-performance, nationwide networks serving research and education communities. In order to successfully meet the needs of our community, four key objectives emerged:

1. Ensure community control of the underlying network infrastructure
2. Leverage the capabilities of a global telecommunications leader
3. Capitalize on the latest technological advancements in networking
4. Create an asset that benefits the entire community – researchers, regional optical networks, universities, industry, government, K-12, and the international community.

The resulting network achieves all of these objectives and will replace Abilene to greatly expand the nationwide networking capabilities available to the Internet2 community. Through an extraordinary partnership with a leading global telecommunications carrier, Internet2 will be able to cost-effectively deliver a new class of hybrid network that will form a foundation for efforts to further advance the community's leading-edge capabilities.

The carrier agreement provides the community with unprecedented control over the networking infrastructure without taking on the risks of equipment obsolescence and the burden of substantial operational responsibilities. This model allows Internet2's new network, with the temporary working name of NewNet, to be deployed across its own fiber pair, utilizing the latest optical and switching technologies. Unencumbered by the restrictions of being part of a shared system, NewNet will allow the community to benefit from the ability to provision and switch wavelengths at will while technology upgrades can be performed when the community requires them. No longer will researchers have to wait for industry-wide adoption of a standard or for the carrier to conduct a market study to convince management or share holders and justify a feature upgrade. This partnership also allows the community to have direct access to the entire system for management and research purposes while also

Objective One:
Community Control

allowing for the development and deployment of new dynamic services. With this level of control, the deployed network will become a natural extension of Internet2's Hybrid Optical Packet Infrastructure (HOPI) Project that has sought to make advances in customer-provisioned and application-driven networking. Under considerably relaxed use constraints in the carrier agreement, Internet2 members may use this infrastructure to carry essentially all traffic generated by the community and its broad set of affiliates and thus help establish a firm, long-term network neutrality position for the research and education community.

The second objective — leveraging the experience and superior operational capabilities of the carrier — presents a key advantage for NewNet. Providing carrier-class reliability and expanded breadth of services on a national scale requires significant upfront capital investments and the maintenance of a large, highly-skilled workforce. Combining the research and education community's relatively small size with its need for the latest cutting-edge technologies, requires partnering with a carrier that can provide these services at incremental costs to achieve long-term affordability. More importantly, Internet2 considers it an inefficient use of its members' funds to dedicate resources to the duplication of networking services that carriers already provide more cost-effectively with their significant economies of scale. Because the NewNet partner-carrier already has the organizational and procedural structure in place to ensure network reliability, it has no difficulty in offering production-level support (service level agreements) on its layer 1 wavelength services as part of this partnership. To enable the broadest possible connectivity, these wavelength services will reach beyond the footprint of the NewNet backbone to everywhere the carrier and its business relationships deliver networking services. Additionally, Internet2 has guaranteed access to strategic assets such as long-haul and metropolitan fiber for years to come, ensuring continued industry engagement with the community.

Objective Two:
Leverage Partner Capabilities

Internet2 decided to form this relationship with a carrier and not a particular equipment vendor to avoid any technology or vendor 'religion' and to provide the community the flexibility to deploy best-of-breed equipment over the life of the partnership. The carrier was chosen partly due to its decision to deploy Infinera's next-generation Digital Transport Node optronics. The low cost and fully flexible add/drop capabilities of Infinera's photonic integrated chip technology align perfectly with the service objectives for NewNet. The dynamic, on-demand network facility envisioned by the authors of the Group A Report (see section 3: *Requirements)* requires a pool of inexpensive, provisionable wavelengths from which to assign bandwidth as needed. Infinera's bandwidth increments and 80 channel capacity, combined with its sub-lambda configurability and end-to-end service management via Generalized Multi-Protocol Label Switching (GMPLS), are uniquely suited to the vision of such an on-demand network. An aggressive roadmap, which includes 40 Gbps and 100 Gbps as well as GMPLS optical user-to-network interface

Objective Three:
Latest Technology

(UNI) development, ensures this network's usefulness well into the foreseeable future. The carrier and Internet2 will therefore not be facing difficult end-of-life decisions.

Finally, Internet2's NewNet creates an asset that serves the needs of the entire research and education community – from the regional optical networks to K-12 students. This new infrastructure accomplishes that objective by providing both experimental and production services within the same architecture through the most cost-effective means possible. Researchers will be able to perform experiments across their own on-demand wavelengths while universities will be able to obtain low cost commodity IP through their Internet connection.

Objective Four:

Benefit the Entire Community

Internet2 recognizes that this extremely ambitious effort to provide experimental dynamic capabilities on a network that is simultaneously delivering carrier-class commodity services has never before been attempted. For that reason, the initial focus will be on the balance between operational stability and innovation. The HOPI Project will continue to serve as the proving ground for the significant control plane development that must occur and will be the testbed for the roll out of these dynamic services. Eventually, both sub-lambdas (such as 1 Gbps circuits) and entire wavelengths will be provisioned on the order of seconds for periods ranging from hours to months on both an immediate and advanced reservation basis. In addition to these services, Internet2 will be able to offer to the community expanded services at aggregate pricing levels. Institutions will benefit from the advantages of Internet2's use of separate logical networks to carry their commodity IP, Voice over IP, production-quality video, and other services across its backbone where high performance is guaranteed via service level agreements.

For new services that aren't available today to the community or the marketplace, the carrier has offered to provide dedicated support from its networking services unit to provide guidance and resources to assist in customized capabilities designed to meet the specialized needs of the Internet2 community.

1.1 Community Involvement

The basic structure and ideas have been developed for NewNet, but there is substantial input needed from the community to complete the design. Some features are fixed, such as the fiber footprint, which is essentially determined by the carrier's own footprint. However, there are a large number of details yet to be determined, such as the locations for interconnection points. This document describes the basic properties of NewNet and the fundamental ideas behind its design; but in the near future, Internet2 will bring the research and education community together to refine thoughts about designs and services, and consider the necessary details. An initial **Community Design Workshop** will address basic questions, including:

- PoP Locations and Addresses?
- Tail circuit availability and capacity?
- Availability of dark fiber IRUs?
- Relocation issues?

NewNet is Community-Driven Design

- Collocation issues and availability?
- Cross-connects?
- Redundancy needs?

Many other questions need to be addressed at the workshop. A second version of this document will be created following the workshop to respond to questions and provide greater detail.

2 Background

When Internet2 was organized in October 1996, one defining goal was to support the U.S. research universities' need for scalable, sustainable, and high-performance networking. Community investment provided an infrastructure comprising campus, regional, and national components to support the research and education community. The Internet2 community initially relied upon the National Science Foundation-supported very high performance Backbone Network Service (vBNS) to interconnect member institutions.

The Abilene network must be replaced by October of 2007. The community will transition to NewNet over a period of 15 months.

In 1998, the Abilene backbone was created using 2.5 Gbps SONET circuits as part of a partnership with Qwest Communications. The five-year agreement with Qwest was later extended to October of 2007, and the Abilene backbone was upgraded to 10 Gbps from 2001 to 2003.

Hybrid Networks

The Abilene backbone, together with the regional and campus networks, forms a high-performance Internet Protocol (IP) network to support the research and education community in the United States. The basic infrastructure has succeeded in providing the performance needed to support the broad spectrum of learning and research activities, and yet the very fundamental properties of the network have remained the same as the original Internet Protocol (IP) NSFNet and its predecessors. While capacity has increased exponentially, and the network has significantly greater capabilities, Abilene is a network very similar to previous generations of IP networks.

With the availability of dedicated optical fiber at the national, regional, and campus geographic scales, and with the advent of Dense Wave Division Multiplexing (DWDM) optical equipment that enables multiple channels of light on a single fiber optic cable, network designers have begun looking at ways to operate networks using optical capabilities to supplement IP. Very rapid provisioning of circuits in optical networks is now possible, creating the opportunity to examine fundamentally different network architectures. The resulting networks are called hybrid networks.

The Internet2 community has been experimenting with hybrid optical networks over the past two years through the HOPI project (see http://hopi.internet2.edu). This project has explored and tested a variety of different

NewNet is designed to provide a platform for both developing and delivering the resulting new capabilities.

techniques, including the setup of circuits across different domains, support of applications requiring specific network topologies, and new ways of providing data transfers by fast provisioning of circuits. There is much work to be done, and a new network design is needed to provide a platform for both developing and delivering the resulting new capabilities.

Process of Forming NewNet

In the spring of 2005, reports from community advisory groups, Group A and the Abilene TAC (see the "Requirements" section immediately following), set the vision of Internet2's future network requirements.

With the impending deadline of March 31, 2006 to either continue the existing Abilene network through 2008 or develop a completely new network, Internet2 began a process in January of 2006 to examine the possibilities for a new network. The goal was to "think outside of the box" to create a network that would continue to provide the capabilities of the existing Abilene IP network and also provide a vehicle for delivering new network capabilities.

Internet2 discussed the possibilities with a variety of different national carriers and equipment vendors. Internet2 initially planned to carry out these explorations collaboratively with National LambdaRail (NLR), but these discussions were not possible due to restrictions imposed by NLR's legal counsel. Even so, Internet2's resulting carrier contract for NewNet contains provisions for the consolidation of NLR resources into a common infrastructure.

Over the period of several months, many different options were considered. Several viable alternatives were developed, but as the discussions took place one was clearly superior. That option is described in this document and forms the basis for Internet2's new network. Because of this option's substantial capabilities, Internet2 declined to extend the Qwest agreement under which the Abilene backbone was implemented. The new network will replace Abilene and will greatly expand the capabilities available to the Internet2 community.

Today, Internet2 is actively pursuing the ability to provide wave and sub-wave services well in advance of the final deployment of the NewNet system.

3 Requirements

Over the past year, the research and education community has produced two important requirements documents. One is known as the Group A report and the other is known as the Abilene Technical Advisory Committee Report.

The Group A Report

In the spring of 2005, a small group of network designers from Internet2 and NLR met to discuss the requirements for the next generation network. That group, known as Group A, produced a final report, which discusses services, properties, and capabilities expected of the next-generation network. The attributes of the next network are described in detail, including capacity, duration, layer, availability, cost modeling, reach, collaboration, support, security, organization, and several others.

All of these attributes are built into the NewNet architecture. For example, dedicated circuits of variable bandwidth, even circuits that are variable on a real time basis, are possible with NewNet. Dedicated circuits with variable durations are also a possible standard service on NewNet. Circuits (e.g., 1 GigE) across the full backbone-regional-campus hierarchy will be capable of being provisioned on the order of seconds for durations as short as hours.

The Abilene TAC Report

The NewNet design follows the broad recommendations set forth in the Group A and Abilene Technical Advisory Committee Reports.

In March of 2005, the Abilene Technical Advisory Committee (TAC) produced a requirements document describing the essential features for the next generation network. It discusses the IP network and its general requirements, measurement and monitoring, performance and availability, peering capabilities, security, and transport services. The report's discussion includes the ability to provide new experimental services along side production capabilities.

Internet2's NewNet is designed to provide those seemingly disparate capabilities on a single platform. Indeed, NewNet provides precisely the kind of services outlined in the TAC report.

Other Collaborations

Internet2 continues to participate in a wide variety of collaborations with other national and international networks. It meets regularly as a group with CANARIE (Canada), GEANT (Europe), and ESnet (United States) to examine new networking ideas and techniques. CANARIE was the first networking organization to deeply consider the implication of having dedicated "lightpath" circuits available on a networking infrastructure. Internet2 also participates in the Global Lambda Integration Facility (GLIF), an informal international group that facilitates circuit types of services for advanced applications on a world-wide basis. NewNet is specifically designed to support optically-based, dedicated circuit services for the research community in the United States.

The MorphNet Document

In 1997, Robert J. Aiken, Richard A. Carlson, Ian T. Foster, Timothy C. Kuhfuss, Rick L. Stevens, and Linda Winkler, all from Argonne National Laboratory, articulated their vision of a network architecture capable of supporting both production and experimental network services. They coined the term MORPHnet from Multi-Modal Organizational Research and Production Heterogeneous Network. MORPHnet was envisioned as an architecture capable of concurrent support for production and experimental network services through Virtual Production Network Services, "the concept of a variable 'bar' of production-level service to facilitate both the smooth introduction of new capabilities and the concurrent support of production and experimental

NewNet provides the most flexibility to provision concurrent experimental and production services.

activities.” This “bar” represents the point where multiple services run on a single infrastructure.

Through Internet2's new unique carrier agreement, unlike its predecessor Abilene or other network facilities, NewNet has the ability to dynamically provision its carrier-quality transport layer, providing the lowest possible “bar” on which to base concurrent experimental and production services, and thus provides the most flexibility to provision production and experimental networks concurrently. As a consequence, NewNet is capable of supporting the next generation of Abilene without compromising Abilene’s near five 9’s of reliability, while at the same time providing temporally dynamic wave services for researchers and experimental applications.

4 Architecture

The architecture of NewNet consists of: the national footprint; the connection to the regional optical networks (RONs) and the equipment and interfaces to support those connections; and the ability to support services to the research and education community, including campus researchers and community wide participants. The basic architecture is similar to previous networks, backbone to regional to campus. However, the network itself is completely different. It is no longer an IP network like those found in the commercial sectors of the Internet. Rather, it is a hybrid network that supports layer 1 dynamic and static services along with innovative new techniques at layer 3. Its most important feature is the ability to experiment with new protocols and ideas for the research and education community.

In defining the architectures, several crucial design goals were considered. They include, but were not limited, to the following:

- **Develop an innovative optical system on a national footprint to serve the broad research and education community.** The goal is to serve all Internet2 members – campuses, affiliates, sponsored participants, SEGPs, and corporate participants – and to enhance the ability to serve a wider community. All current RONs are to be supported.
- **Develop a hybrid network capable of providing point-to-point services together with an IP network.**
- **Every connector (RON) connects to a NewNet backbone ring in a metro location not requiring extensive backhaul.**
- **The community retains complete control of the layer 1 optical system, including provisioning and switching wavelengths and sub channels.**
- **The community does not have to concentrate on reliability and sparing. The carrier is responsible for an SLA.** The carrier provides the operational support, allowing the community to focus on networking. The carrier will monitor the system, but control of the system is left to the community, allowing the development of new and dynamic services.
- **The system is capable of supporting network research in a wide variety of ways**, including the ability to set up networks at will for research communities.

- **A minimal Conditions of Use (CoU), allowing full participation from the entire community in providing new services and capabilities.**

The following sections describe the national backbone topology and the architecture of the optical nodes. The last section describes some of the services currently being defined. Community input is sought with respect to all of these ideas.

The System

NewNet is provisioned on fiber that is only used by the community and maintained by the carrier. The dedicated fiber is not provided by an IRU but rather as part of the network system as a whole for the period of the agreement. It should be noted that there is significant financial advantage to the community, if the community does provide fiber under an IRU with the carrier. The carrier contract allows for this to be accomplished through an agreement with NLR.

The fact that the system lies on dedicated fiber has substantial advantages. Dedicated wave equipment currently used by the carrier will provide the waves for the system. That wave system is provided by Infinera, which supports advanced technologies with substantial add/drop capabilities and significant advantages in provisioning and redundancy. For example, once the system is provisioned, accomplished in groups of ten waves at a time up to a total of 80 waves, all waves are active. Provisioning a static wave is accomplished by simply installing the endpoint interfaces. This is far different from most current optical systems where many interfaces must be installed along the entire path.

NewNet is an innovative hybrid optical network deployed nationally over 13,000 miles of dedicated fiber providing complete control of the optical layer and highly granular lightpath services that can be provisioned dynamically

Moreover, since the system is completely dedicated to Internet2, it is possible to leap beyond the carrier's standard offerings to utilize the advanced technology provided by Infinera. For example, while the carrier may not wish to migrate to 40 Gbps waves on its production system, it is possible for the NewNet wave system to incorporate such technologies early in the deployment. It is even likely that 100 Gbps capabilities on a single interface will be available in the next few years.

The system will also incorporate a grooming capability – the ability to provide sub channels through waves using either an Ethernet or advanced SONET infrastructure. Deterministic circuit services with SONET STS-1[2] granularity supporting advanced SONET services (e.g., GFP[3], VCAT[4], and LCAS[5]) will provide sub-channel capabilities

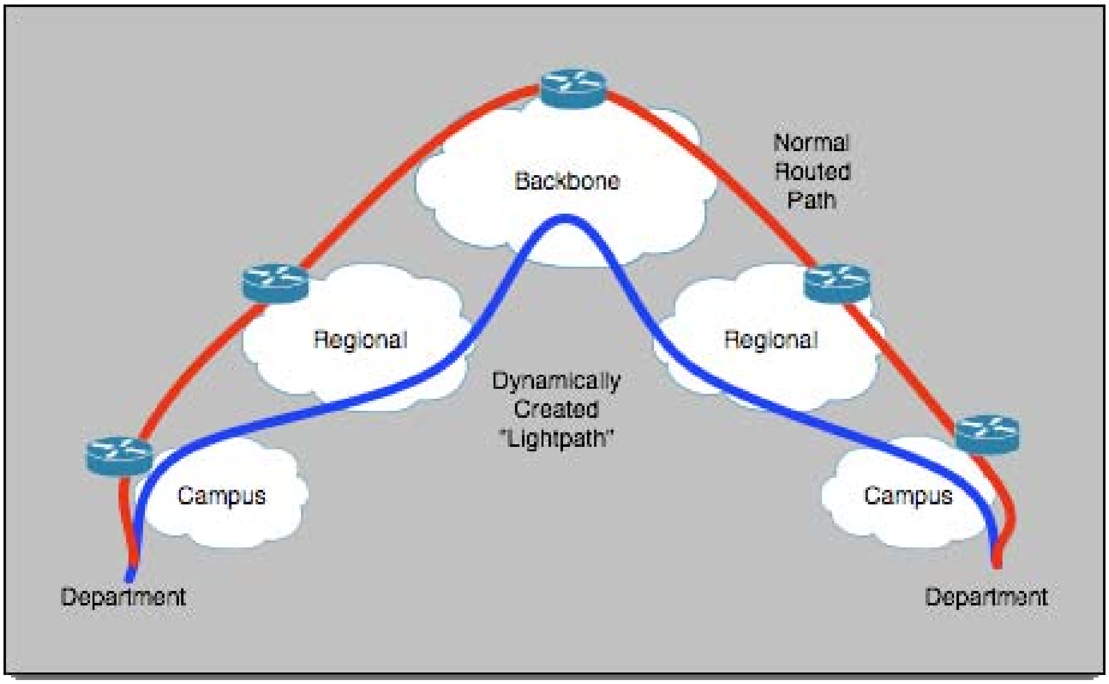
[2] Synchronous Transport Signal 1, the basic unit of SONET transmission. 51.840 Mbps.

[3] Generic Framing Procedure. ITU-T G.7041. This is one way to encapsulate variable-length information such as Ethernet inside SONET channels

[4] Virtual Concatenation. This allows one larger stream to be placed on multiple smaller (not necessarily contiguous) SONET channels. It allows more efficient use of the network.

for Ethernet connections of lower bandwidths for hosts at the edges of the network. The ability to provide point-to-point services down to the campuses through the RONs will be provided by an advanced grooming device that has yet to be determined. The goal is to provide lightpath capabilities provisioned within seconds that last for durations of hours. In the figure below, the normal IP routed path is pictured in red, while a "lightpath" pictured in blue uses only layer 1 equipment.

Figure 1



Existing connections to the Abilene IP network will be maintained and migrated to NewNet. Over the next three years, it is proposed that NewNet evolve to a simplified connectivity model. Within three years, each fully participating RON is expected to provision two 10 Gbps connections to the hybrid backbone, one for IP and one for point-to-point services. A similar model is envisioned for RON-to-campus connectivity, and to ensure cost-effectiveness and flexibility as needed, other bandwidths will be available to support corporate connections and the network research community.

Topology

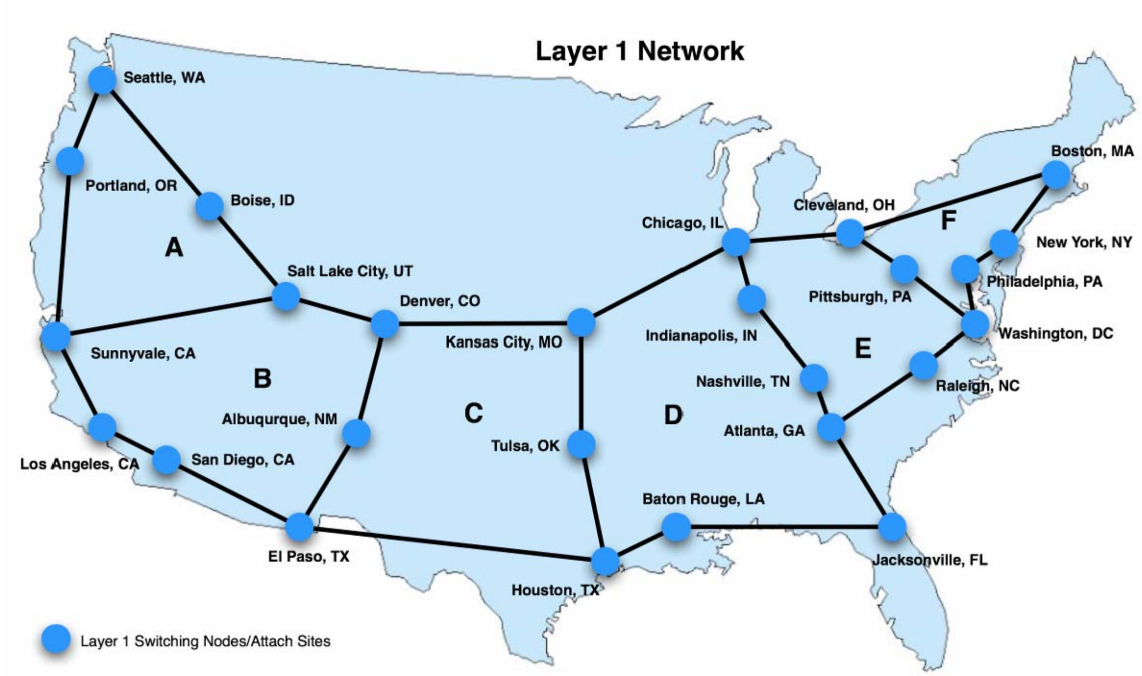
The topology consists of optical nodes connected by waves maintained by the carrier that connects to RONs and other participants. The carrier footprint primarily determines the

[5] Link Capacity Adjustment Scheme, ITU-T G.7042. With VCAT, this allows additional bandwidth to be allocated (or deallocated) on demand. For example, if a 1 Gigabit Ethernet channel is only using 10 Megabits, you only need to allocate a single STS-1, but if it ramps up to 500 Mbps, you can add additional capacity to support the stream.

topology of the network, but the use of the Infinera gear allows for great variability in drop/add locations. The preliminary design consists of 26 optical nodes pictured below, but individual RONs and connectors can initially request changes in the proposed design.

The NewNet design encourages aggregation at the RON layer in the hierarchy. Approximately 20 to 24 connectors are expected to support regional aggregations, but additional, lower bandwidth connections are expected.

Figure 2

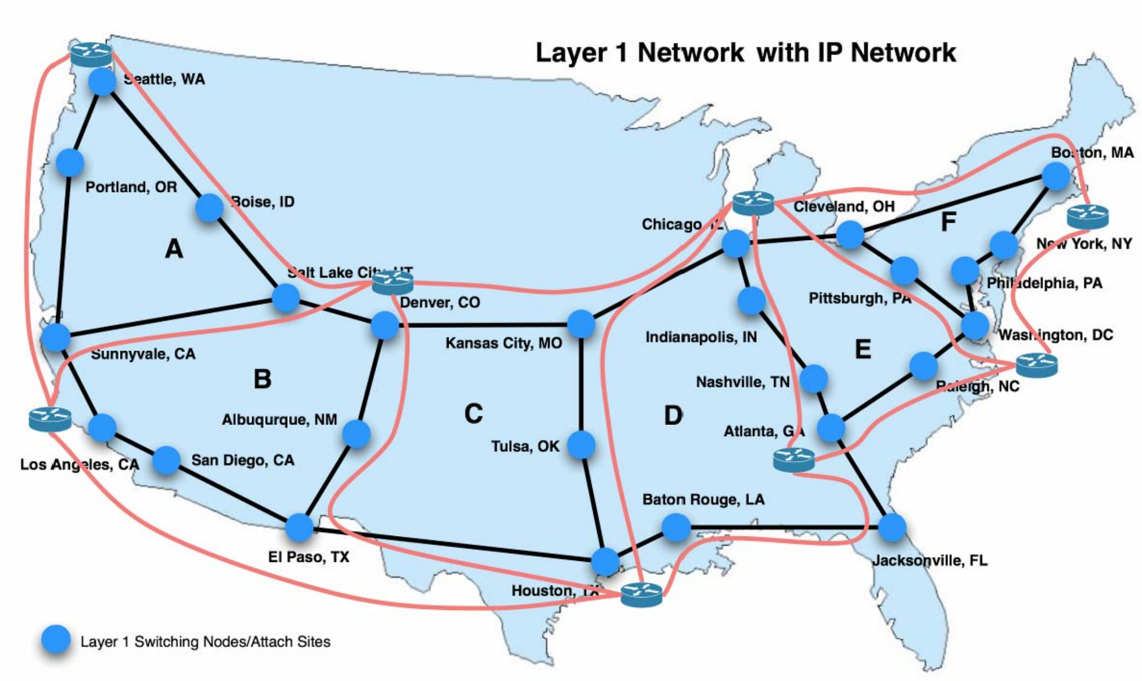


The new IP network, corresponding to the current Abilene network, is built on top of the optical network. The IP backbone is provisioned across the waves in the system, and each RON connects to the IP network through the optical system. Since the carrier provides an SLA for the waves on the system, the IP network will have carrier-quality provisioning, which is expected to be minimally three 9's (99.9%) uptime, but is likely to be closer to five 9's (99.999%).

Moreover, there are substantial redundancy options. The Infinera platform can provide control plane redundancy for IP connectors, and SONET restoration is also a possibility. These options will be determined by consulting the community as a whole.

The IP network will initially use Internet2's existing Juniper routers. These routers remain state of the art and are capable of migrating to 40 Gbps services. Because NewNet is a hybrid network providing point-to-point services, the number of routers on the IP backbone is likely to be reduced. Community input is planned for these options. The following diagram shows a possible IP network using 8 routers, where the current Abilene network uses 11.

Figure 3: Not Final, Subject to Community Input



> **Summary:**
>
> Initial Deployment: 10 x 10 Gbps wavelengths on the entire footprint
>
> Capacity: 80 x 10 Gbps
>
> Scalability: Potential migration to 40 Gbps and 100 Gbps capabilities
>
> Reliability: Carrier provides standard levels of assurance for wavelengths
>
> Flexibility: Support for dynamic provisioning and sub-wave add/drop

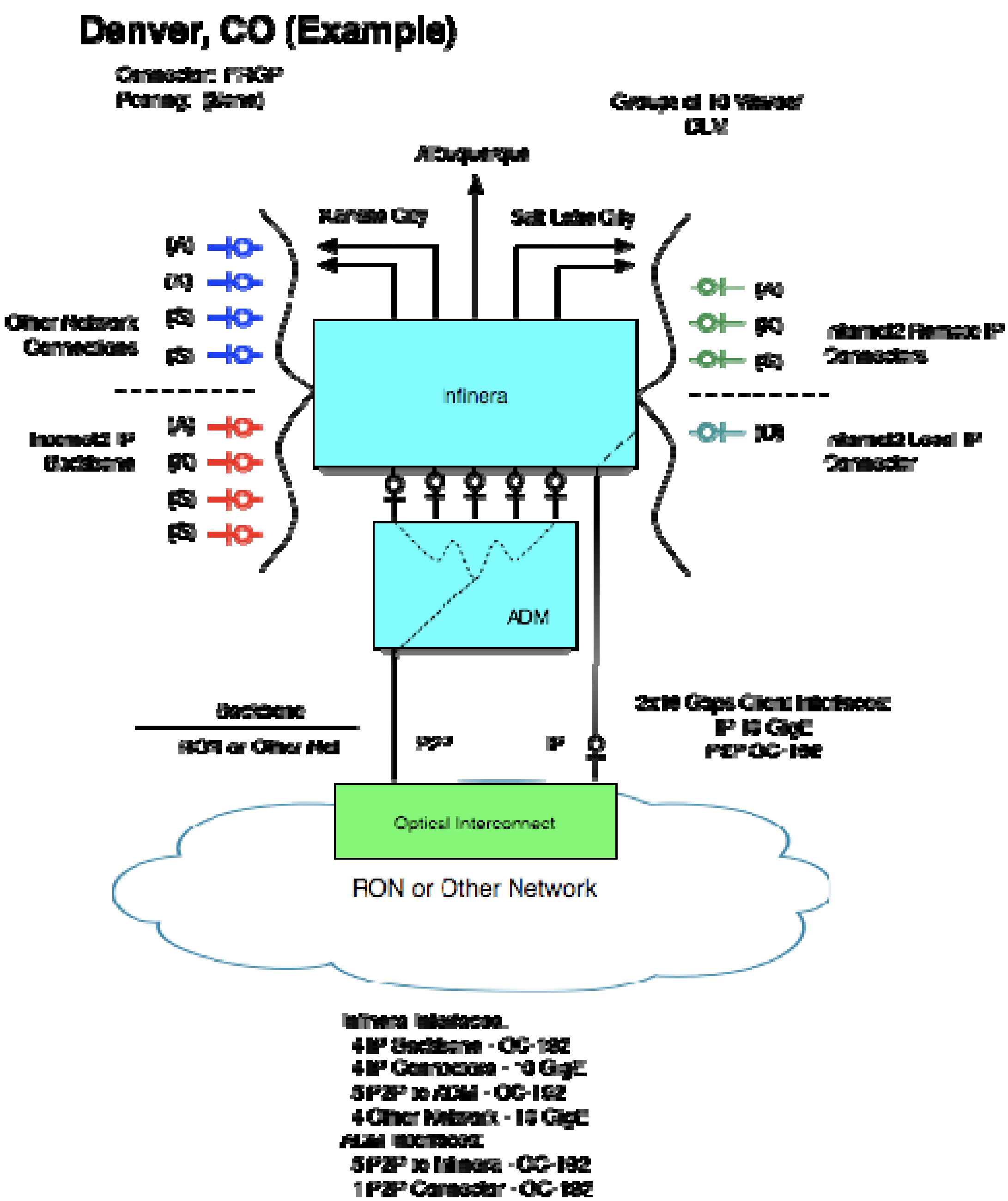
Node Architecture

The architecture of each of the optical nodes consists of the Infinera platform together with the grooming devices. A proposed goal over the next three years is to migrate to a standard connection model, one for point-to-point services and one for IP services, each supporting the hybrid nature of NewNet. The point-to-point services connect to the grooming devices. The IP services, which are likely to remain static in the near future, connect to the Infinera gear. The current thinking is that two 10 Gbps connections could be supported by the RONs as the standard model, but community input is important on this issue. There may also be special cases where it will take additional time to migrate to this model or where aggregation is difficult to achieve. Note that since extensive backhaul is not necessary for the RONs, two 10 Gbps connections should be possible over dark fiber.

> **NewNet provides substantial flexibility: Every RON can obtain sub-wave length services across every wave on the NewNet backbone**

The following diagram describes a sample optical node in Denver supporting a separate, other network. 20 waves head east toward Kansas City, 20 waves head west to Salt Lake City, and 10 waves head south to Albuquerque. The device labeled ADM provides the grooming services and connects to the Infinera platform. The single interface on the ADM can provide sub-channels to any of the interfaces on the Infinera gear. The interfaces on the Infinera gear can be mapped to the waves on the backbone, providing the capability of provisioning any sub-channel from the RON to any wave on the backbone. This capability provides substantial flexibility for the entire system.

Figure 4: Not Final, Subject to Community Input



Other Circuit Services and Summary

The architecture described above provides the capability of providing a variety of circuit (or lightpath) services on NewNet, but the agreement provides additional wave provisioning capabilities on the entirety of the carrier's footprint. These we're calling "WaveCo" and form off network types of circuit services. A complete description of the services follows in the next section, but they can be summarized as:

- Services provisioned on NewNet
    - Short term dynamically provisioned circuits
    - Long term dynamically provisioned circuits
    - Long term static, full wave services
- Additional services provided by the carrier as part of "WaveCo"

The dynamically provisioned services will take time to deploy and will involve the work of the HOPI project. In order to provision such services across connectors and to the campus community, Internet2, in collaboration with the community at large, will create an outreach project similar to the multicast and IPv6 workshops to help deploy these capabilities. It may take time for these to be fully enabled to support advanced applications and research projects, just as it may take time for the community to evolve to the higher bandwidths demanded of such applications.

Future Plans

The architecture above supports a variety of future collaborations. For example, a service trial is planned with the GEANT2 network to experiment with trans-Atlantic, dynamically provisioned services between national research and education networks. The goals for such trials are substantial:

- Determine policies for national networks to interoperate at the lightpath layer
- Determine the financial implications for two national networks to interconnect at layer 1
- Determine how to support the inter-connectivity between the two national networks, both from a policy and financial point of view.

Internet2 and GEANT have agreed that users of both networks will have lightpath access across both networks at no extra cost during the service trial.

5 Services

Circuit Services

As research utilizing network resources continues to expand and the demands of applications on the network increases, it has become clear that alternatives to the shared IP bearer service on the current Abilene network must be explored and embraced. The current IP network is very efficient and effective for most types of network traffic, specifically smaller flows and multipoint connectivity that characterizes much of the network usages today, typified by lower-rate data transfers (roughly 1 Gbps), Web browsing, email, instant messaging, and the like. The current network, however, is not as well suited to traffic that: consumes very high amounts of bandwidth (5 Gbps and higher), is very sensitive to network performance, or utilizes network protocols other than TCP/IP.

The next step in the evolution of networking that will satisfy the needs of the leading-edge researchers and the most demanding applications is the ability to provision dedicated circuits on both a temporary and a persistent basis. An example of the types of traffic that would benefit from a circuit-based service would be large e-science data transfers, high-performance high-definition video conferencing, and instances where a high degree of network security is required. Internet2 views these two types of network services, IP and circuit based, as mutually beneficial to the users of the network resources. The advantages of both are available to the user as the circumstance requires. The key point is flexibility, the flexibility of the network to provide services to users that best fit their needs.

These circuit services as envisioned by NewNet can be grouped into two categories: *on-net* services and *off-net* services:

- Services Provisioned on NewNet (*on-net* services)
  - Short term dynamically provisioned services. These services would be included in the standard connection fees and through the point-to-point connection. They would be granular services (for example, 1 GigE connections) providing sub-channel capabilities. These are HOPI types of services (see http://hopi.internet2.edu) and would have durations no longer than a day, with restrictions on monopolizing connections. Scheduled services are expected to be available through these services to support connections such as CERN's Large Hadron Collider (LHC) tier 2 distribution centers and eVLBI. Two initial waves on the backbone are expected to be dedicated to this service. Call blocking can be expected on this service, except for scheduled services.
  - Long term dynamically provisioned services. These will be provisioned through the point-to-point connections, but on a different wave from the dynamic services described above. An additional cost will be associated with these services, determined by bandwidth and duration, but there will be no call blocking associated with such services.
  - Long term static, full wave services. These will be provisioned directly through the Infinera gear at an additional cost and will be for one year or more.
- Additional Services, provisioned on the carrier infrastructure (*off-net* services).
  - These are to be provided by "WaveCo" on a yearly basis by the carrier and are for RONs and other members to support connectivity that is not on the NewNet footprint. This service would cover waves for participants in NewNet.

Additional Capabilities

In addition to the advanced network circuit-based services as described above, NewNet will also embrace a number of other services that are intended to add value to the connectors to NewNet.

- **Higher Networking Speeds**: The Infinera platform that NewNet will use has several forward looking advantages including the ability to support new and higher networking speeds. A platform that scales to 40Gbps per interface and potentially higher is anticipated, representing a four-fold increase to the current interface speed. The significance of this development is that until recently, a network with a capacity of 10 Gbps could not be saturated by a single host. However, this is now possible through the advancements and commoditization of high-performance 10 Gbps network cards, central processing units and motherboards supporting ever higher bus rates. It is now well within the reach of a single server that costs less than $7,000 to saturate a current 10 Gbps capable network. The ability for NewNet to move to 40 Gbps on a per interface basis, when desired, raises the bar again by adding network longevity via the increased capacity of a single wavelength.
- **Connection to the Commercial Internet**: Providing high-speed carrier-class connections for research are central to the mission of Internet2. It is recognized, however, that the members frequently use and have need of quality connections to the Internet at large. In order to assist Internet2 members financially and to reduce management complexity and overhead, NewNet will be offering connectivity to the commercial Internet that may utilize the same connections used by the members to connect to NewNet. This offering will be at the forefront of the market in terms of price competitiveness and utilizes the services of the Tier 1 carrier partner for the highest quality service. Due to the capacity and nature of the network, it is still possible to offer research traffic an unimpeded facility and allow for commercial traffic to flow over the same NewNet infrastructure.
- **Access to Dark Fiber**: Over the past three years it has been evident that access to dark fiber is crucial to the development and advancement of regional optical networks. Over this time Internet2, through the establishment of FiberCo, has placed over 13,000 miles of dark fiber in the hands of the US R&E community and helped facilitate the placement of another 10,000 miles. Internet2 strongly believes that continuing to have this ability is vital to the community. Through the agreement with the carrier partner, dark fiber, collocation, and remote hands services will continue to be offered to the community at competitive rates.
- **Professional Services**: Establishing and operating a regional optical network (RON) that is based on owned facilities is a complex task. FiberCo is making available a suite of professional services that range from consulting on fiber availability and acquisition, to outsourced network operation center (NOC) services, equipment procurement, testing and deployment, and asset tracking. This effort to provide these supporting services is undertaken to strengthen and facilitate the success of the RONs operating across the United States.

- **Voice over IP (VoIP)**: One of the more recent and potentially disruptive technologies to emerge over the past few years has been VoIP. This technology has the ability to dramatically reduce operational expenses related to telephone service and can add a significant number of features that are not possible or very difficult and expensive to implement under the current telephony model. By leveraging the strengths of a carrier partner, Internet2 can now offer VoIP transit services at the highest level of reliability.
- **Disaster Recovery**: The past year has served as a painful lesson on the vulnerability that all face and the devastation that natural occurrences can wreak. The events of Katrina in the Gulf, tornadoes in the Midwest, the ever present threat of earthquake in the West, volcanic activity in the Northwest, violent storms out of the Atlantic, as well as man-made calamities like September 11, 2001, all reveal the need for geographically distributed facilities that can provide the restoration and resumption of critical services of an impacted entity. NewNet with its multiple high-speed links and presence in distributed carrier collocation facilities provides easy access to geographically diverse sites that can be utilized for disaster recovery.

6 Network Usage Policy

Over the last five years, a considerable evolution in the U.S. higher education community's connectivity requirements and capabilities has taken place. Last year's Group A Report identified the emerging needs of network researchers, computational scientists, and other leading scholars for new services of customized type, duration, and reliability – beyond the single advanced Internet Protocol (IP) service currently offered through Abilene. Furthermore, the development of facilities-based regional optical networks and further expansion of these networks' presences in major carrier facilities has created concentrated opportunities for interconnecting these networks and their services with others within the community as well as within the commercial sector.

Correspondingly, the network utilization policies governing NewNet must evolve to support this significantly more complex network model. While some in the community recently have advocated the development of networks explicitly without any such policy, it appears to Internet2 that use policies are necessary for legal reasons as well as matters of organizational compliance and prioritization. We propose two streamlined use policies to govern NewNet. The first policy – the Terms of NewNet Use – will encompass the underlying optical network and other dedicated, point-to-point services offered over this network. The Terms of Use will be based on the following principles:

- The use of the NewNet facility shall be consistent with the broad set of non-profit objectives of the U.S. research and education community and its affiliates, including, but not expressly limited to research, clinical, teaching, and governmental purposes.
- Internet2 will seek to maximize the ability of NewNet to support the broad collaboration requirements of the Internet2 membership and their affiliates to

interact with the broadest scope of domestic and international networks and collaborating organizations.

- Each organization utilizing the facility will be responsible for complying with all technical and operational standards developed for NewNet, and will avoid actions that adversely impact the performance or stability of the facility itself or those experienced by other user(s).
- The facility shall not be used for illegal, classified, life-safety, or unrelated commercial activities.

A second policy – the Terms of Transit – will apply to the follow-on IP network replacing Abilene and overlaying a subset of NewNet optical circuits. Terms of Transit will be based on the same principles as the Terms of Use with the addition of the following clarifying principle:

- Internet2 will seek to maximize to its members the value of IP transit by expanding connectivity through peering with commercial networks including content providers (e.g., Google, Akamai) and other regional and national service providers (i.e., tier 2 ISPs).

7 Engineering

Engineering support for NewNet will be drawn from members of the Internet2 community and the Internet2 staff. Building on our experience in designing, developing, and maintaining Abilene, HOPI, and NLR, we expect operational support to fall into three broad categories: control plane activities and dynamic provision of basic services, application and advanced services support in hybrid networks, and engineering, monitoring, and management.

Control Plane and Dynamic Provisioning

The Dynamic Resource Allocation via GMPLS Optical Networks (DRAGON) project is conducting research and developing technologies to enable dynamic provisioning of network resources on an inter-domain basis across heterogeneous network technologies. The DRAGON architecture leverages the emergence and maturing of optical network technologies to develop and demonstrate the power and flexibility of a "hybrid" packet and circuit switched network infrastructure. Open-source GMPLS software is a key component of the IP control plane which has been shown to do provisioning across domain boundaries and multiple network technologies with robust levels of authentication, authorization, and accounting.

The Mid-Atlantic Crossroads (MAX), multi-state, metaPoP consortium, is an important collaborator in the DRAGON project. The MAX team has played a key role in the HOPI Testbed Support Center, developing and deploying DRAGON-based control plane and dynamic provisioning technologies. They will continue to develop and support such technologies for NewNet, transitioning them from the testbed environment to operational deployment. They will also collaborate with partnering backbone network providers (including both international partners and federal network providers) to enable such dynamic provisioning across heterogeneous networks.

Application and Advanced Services Support

Internet2 intends to target key application communities in the arts, humanities, and science communities and work with them to understand the challenges and opportunities posed by NewNet's dynamic provisioning capabilities. MCNC, operators of the North Carolina Research and Education Network (NCREN), have provided support for applications and advanced services on the HOPI testbed. They will continue to provide application support for NewNet, focusing on existing applications that can be modified to take advantage of the dynamic provisioning aspects of the new network and new applications made possible by NewNet's capabilities.

Engineering, Monitoring, and Management

The [Global Network Operations Center] (NOC) at Indiana University (IU) has extensive experience supporting network operations for Abilene, HOPI, and other networks. They will continue to support engineering, monitoring, and management activities for NewNet, including active and passive network monitoring (e.g. availability data, aggregate traffic, connector-specific statistics, Netflow reports, outage data, perfSONAR interfaces to performance data, router interface data, and traffic maps); problem reporting, problem management (e.g. alerts, tracking, problem identification and notification, escalation, problem resolution, and customer satisfaction contact); change management (e.g. notification, preparation, scheduling, coordination, monitoring, assessing, and testing); tools, and documentation (for policies, procedures, tools, and services).

8 Transition

This section outlines an overall transition plan for the existing IP services on the Abilene network from Qwest unprotected SONET circuits to optical links provided by NewNet.

Note that while transition of the IP network will evolve on a yearly plan, other services will be available far sooner.

Many NewNet services will be available in the next few months, before the transition of the Abilene IP network

The specific plan will be developed in partnership with the community. The plan assumes re-use of the existing Juniper T-640 routers. Thus, the transition will have to proceed in a mostly serial manner, moving sequentially around the country. The transition will rely on the existing T-640 currently located at the North Carolina ITEC, on the fact that the new IP network will likely require fewer router nodes, and that it is relatively simple to deploy dark fiber (simple jumpers in some cases) or lit services at likely router locations (tentatively Seattle, Los Angeles, Chicago, Houston, Denver, New York, Atlanta, and Washington, DC).

Internet2 expects that some connectors will want to upgrade to the new 2 x 10Gbps service when moving to the new network (if they are easily able to do so), and that others will want to maintain their existing IP connectivity initially. For purposes of having a uniform, and therefore more easily managed core, it is highly desirable that connectors move to the 10G service, or at least a 1G service. However, connectors will upgrade at their volition. The exact set of initial services will be determined with the community, in a process starting with the June 2006 community design workshop.

Transition goals:

- Only a single short disruption for any connector when moving to new service
- A more robust IP service than the current Abilene service
- No single-node network partition possibilities
- Lowest number of temporary connections, card moves, and router moves.

Current assumptions:

- A reduction from 11 to 8 router nodes
- Routers located in Seattle, Los Angeles, Houston, Atlanta, Washington DC, New York, Chicago and Denver
- Adequate dark fiber or lit service available between new and old router node locations
- Continued use of existing Juniper T-640 routers (and no new chassis needed).

General Strategy

- Target an existing router node that will not exist in the new network configuration [T]. Given above assumptions: Sunnyvale, Kansas City, Indianapolis.
- Build out new optical equipment to that node and adjacent router nodes (adjacent router nodes must be in designated cities for the new IP network configuration, but may or may not be existing routers or newly-placed routers).
- Provision circuits over the new infrastructure that run from the current router node location to adjacent router node locations. (This likely involves temporary tail circuits from new equipment at adjacent locations to old locations.)
- Populate exiting adjacent routers with interface cards to absorb target node connectors.
- Attach provisioned circuits to the adjacent locations.
- Test provisioned circuits by connecting them to router T. (This can be done serially and hopefully with a minimum of extra router interfaces.)
- Attach connector from router T to a newly tested circuit. This is the only connector service interruption, ignoring upgrades to 2x10Gbps service. It would need to be determined if the connector would rather upgrade than just transition; however, coordinating upgrades along with router moves may well prove intractable (or draw out the process longer than can be tolerated).
- Once all the connectors have transitioned off router T, then work to provision the backbone circuits to go around router T.
- Provision a circuit on the new infrastructure that goes between the adjacent routers.
- Cut adjacent routers over to using the new circuit from the existing circuits to router T. (This might need to be repeated at least once for all nodes that have more than two existing backbone links.)

- Router T can now be decommissioned, and moved to a new router location.

Except for a short interruption, transition to NewNet will not disrupt existing connectivity and services. It will use the optical capabilities to transition connections in the near term and provide support for evolution to the longer term 2 x 10 Gbps connection standard.

The above is written with the initial assumption that the adjacent routers are existing routers. However, as routers are decommissioned (starting with the existing router at the North Carolina ITEC), they will be placed in the new locations, and then interconnected with the existing routers. When an adjacent router could be a newly located router instead of the existing router, the newly located router will be chosen.

Cooperation

Since routers are being re-used, they must be able to be moved as the transition proceeds. Therefore, there will be a limited window of time when connectors must move from the old router location to the new router location. The size of the window may vary from location to location.

Therefore, the schedule for when particular nodes move will need to be formed cooperatively with all the connectors to ensure that all can move together. The upcoming design workshop will be the start of this process.

Approximate Schedule

Starting with the Qwest agreement expiration in October 2007 (thus the date for transition to be complete), the schedule will need to be worked backwards to show milestones by which events need to occur. The schedule will not be set before the discussions at the community design workshop.

However, it is important to be clear about the tight timeline in effect. If it can be assumed that it will take 3 weeks to complete a router node transition, and if all 11 are done completely serially, that is 33 weeks, or 7.6 months. Further, if the assumption holds that it takes roughly 9 months to build out the underlying NewNet infrastructure, that is roughly 17 months, which creates a much tighter timeline than is ideal.. On the plus side, the build of the new network can likely be overlapped with router movement, and router node transitions can be overlapped as well if the total number of nodes can be reduced and thus have more than one “free” router at a time. Furthermore, not all router nodes will take 3 weeks to transition from start to finish.

9 Network Research

Internet2 has always had a commitment to facilitating research – including facilitating scientific research that depends on high-quality high-speed network links, and computer networking research itself. Internet2 facilitates computer network research by allowing the network itself to be a subject of study (supplying data to network research projects, and also by changing network configurations experimentally) and by using the network as raw material (supplying MPLS tunnels, or in control plane experiments in the Hybrid Optical-Packet Infrastructure (HOPI) project). To date, this has been mostly done through the Abilene Observatory program, the HOPI project, and being partners in research grants. Internet2 also manages the Network research Facilitation Project which has provided researchers with carrier class networking equipment to enable their projects. Internet2 has a Network Research Liaison Council consisting of prominent network researchers and led by Larry Landweber to provide guidance.

Internet2 is aware of 20 research groups currently using passive data, three groups have put equipment in the Abilene nodes, three are working with HOPI, and Internet2 has worked with Caltech, Stanford, and CAIDA to perform specific experiments on Internet2 networks. In addition, other research groups simply access Internet2's large store of publicly available data.

Internet2 intends to strengthen its commitment to network research in the future. NewNet will provide point-to-point links at reasonable cost, allowing network researchers to use optical links. The Observatory program will be continued, expanding it with researcher guidance beyond Layer 3 to Layer 2 and Layer 1. Research on control planes will continue, the results of which will be necessary for NewNet's future success.

Internet2 will maintain an open stance with regard to providing data to network researchers and it will work with the research community to take advantage of the new features afforded by NewNet to provide opportunities for experimental research.

The Observatory Program

The existing Abilene Observatory program <http://abilene.internet2.edu/observatory/> consists of two parts. First, there are data sets collected by Abilene staff and made available to researchers. There are seven data sets currently: Utilization data (1 minute SNMP samples), Flow data (sampled 1/100), Routing data (both BGP and IGP collections from all routers), Latency data (10 packets per second among all router pairs, IPv4 and IPv6), Throughput data (20 second TCP tests among all routers pairs, IPv4 and IPv6), Router data (snapshots of "show commands" taken once an hour) and Syslog data (from the routers). The data sets have been used by a number of network research groups, and have been acknowledged in a number of SIGCOMM and INFOCOM papers.

The second part consists of data collected by separate research projects using equipment collocated in the Abilene equipment racks. The two best examples of research projects collocating equipment for data collection are the NLANR Active Measurement Project (AMP) <http://amp.nlanr.net/> and the Indianapolis router clamp installed by the NLANR measurement and network analysis group <http://pma.nlanr.net/Special/ipls5.html>. In addition, the PlanetLab project [http://www.planet-lab.org/] installed nodes in all Internet2 router nodes. This is moving toward support for experimental research, described in the next section.

The existing Layer-3 Observatory program will carry over to the new network. One thing that was discovered as part of a research grant with Jorg Liebeherr [see http://networks.internet2.edu/network-research-facilities/] is that passive data is very important; Internet2 will strive to expose more (appropriately anonymized) passive data in NewNet. In addition, the new capabilities will provide new sources of data. For example, error rates on optical circuits, and control plane state and updates. As with the existing Observatory program, as much data as possible will be exposed. Internet2 seeks input from network researchers as to what would be useful to know, and what new equipment might be useful in measuring NewNet.

Support for Experimental Research

Internet2's existing support for PlanetLab nodes inside Abilene is one way in which it has supported experimental research. There is also a plan to create an MPLS Layer-2 Virtual Private Network (L2VPN) across Abilene to create a Layer-2 Ethernet network connecting the PlanetLab nodes on Abilene for the Virtual Network Infrastructure (VINI) project. This facility will essentially provide a national scale Ethernet network for research on fundamental Layer-3 extensions or protocol replacements.

Nick McKeown's buffer sizing research has been supported by artificially reducing queues on our Juniper routers while watching network performance statistics, and by supporting the delivery of a coordinated passive data set from the Indianapolis router clamp during those experiments.

NewNet will allow the creation of cost-effective optical links to support experimental research. Links will be created on demand, or statically provisioned; they might last for days, weeks, or longer. The links might be 10Gbps, or they might be many 1Gbps links which are currently well suited for cost-effective experimental hardware. In addition, NewNet can utilize MPLS L2VPNs on the Layer 3 network for wider reach.

Thus NewNet is well positioned to support VINI, follow-ons to VINI, as well as "clean-slate" experimental network research projects like the planned GENI project [http://www.geni.net/], and the 100x100 project [http://www.100x100.org]. It can provide dedicated capacity to experimental routing and switching nodes, whether they are based on IP or some potential follow-on. In addition, L2VPNs can provide "on ramp" capability for those that want to send traffic to experimental networks.

10 Cost Recovery

Extensive financial modeling has been done for Internet2 in the development of NewNet. The agreement with the carrier extends through 2014 and takes into account specific cost recovery models for new services and anticipates a revised membership model. Final cost recovery models will be developed in the near future and input from the advisory councils and NewNet advisory groups will be incorporated into this work.

As described above, the standard connection to NewNet is expected to move to two 10 Gbps connections, one for point-to-point services, and one for IP connectivity. Commodity network services are expected to be included as part of the basic connectivity package. Preliminary estimates indicate that the cost recovery model for the basic package will be approximately the

The basic package for NewNet is expected to be two 10 Gbps connections, including commodity services. Fees are expected to remain comparable to today's current 10 Gbps connection fee to Abilene.

same as the current Abilene **single** 10-Gbps connection.

Other circuit options will also provide substantial savings to Internet2 members and participants. For example, circuits from 1 to 10 Gbps will be available from NewNet on a granularity of days and will be extremely cost effective. It will be possible for researchers to obtain such circuits for weeks at a time at very reasonable prices.

Longer term full wave services will also be extremely cost effective and available for periods of years. The costs illustrate the advantage of a strong carrier partnership having large volume capacities.

Other services are also expected to be cost efficient. Development of new services at reasonable price points will allow the community to adopt new ways of using the network.

Internet2 reserves have accumulated over time to upgrade the Abilene network to NewNet. Together with comparable membership and connectivity fees, service revenues, and a favorable payment approach with the carrier, they create a cost recovery model that supports deployment of NewNet and also builds reserves for the next upgrade beyond 2014.

11 Advisory Groups

The Internet2 bylaws provide for councils to serve in an advisory role. Internet2's current councils include the Network Planning and Policy Advisory Council (NPPAC), the Applications Strategy Council (ASC), the Industry Strategy Council (ISC), and the Network Research Liaison Council (NRLC). The latter in particular will play a major role because of the developmental nature of the network.

The advisory structure for NewNet will be considered by all of these Councils, particularly NPPAC. Similar to the oversight structure for the current Abilene, an executive committee and technical advisory committee may be convened. These two committees, or others determined upon consideration, would be expected to interact directly with the councils of Internet2.

It is important that Internet2 and the carrier develop a mutually beneficial and collaborative effort to ensure that the network system is in operation pursuant to the terms of the agreement. Therefore, an executive committee would be expected to provide a forum for the senior executives from both Internet2 and the carrier to freely exchange ideas and set priorities. It should also include substantial participation from Infinera and other partners from the vendor community.

It is also important that the community consider NewNet to be theirs. A technical advisory group could serve this purpose, and include representatives from the NOC, connectors, the carrier, and other corporate partners, as well as network researchers and others with special knowledge and interests in NewNet and advanced networking.

12 Agreement Summary

As was well known within the community, Internet2 had to make an important decision by March 31, 2006. That was the deadline for either extending the current agreement with Qwest and continuing the Abilene Network in its current form for another year, or charting a new course with a network capable of delivering the vision of the Group A Report. It had long been apparent to Internet2 staff, members of the community, and the Board that advancements in networking were quickly overtaking the capabilities of the packet based Abilene Network. Extending the Qwest agreement would not have provided the Internet2 community with timely access to the new services they required.

After months of due diligence, Internet2 selected the proposal from a leading global carrier and invited National LambdaRail (NLR) to join in the negotiations. NLR was unable to participate on the advice of its counsel and, in early 2006, Internet2 set out to negotiate the best possible agreement for the community. The agreement that was eventually reached between Internet2 and the carrier represents a substantial opportunity for the U.S. higher education community. By advancing a hybrid model for national optical networking that combines the long-term benefits of an owned national fiber footprint, the capabilities of a leading-edge optical system, and the technical expertise and operational support of a wholesale telecommunications carrier already extensively serving many Regional Optical Networks, this agreement enables creation of a premier research and education dedicated network in the United States.

Considering that Internet2 was in merger talks with NLR at the time, the agreement was designed to provide for two options: 1) a forward-looking partnership to develop a system initially provisioned with a minimum of 100 Gbps of capacity nationally or 2) a more conservative scenario, developed at the Internet2 Board’s request, to move the current 10-Gbps Abilene Network to a provisioned wavelength on the commercial system (the Abilene Replacement Network or ARN) for a limited time. This would allow for the possibility of NLR’s infrastructure becoming stable and cost-effective enough to support the capabilities envisioned for the new network. In keeping with the spirit of the merger discussions, special considerations were made to ensure that the carrier agreement would be compatible with the possibility of a joining with NLR. With both options in hand, Internet2 opted concurrently not to extend its Abilene transport agreement with Qwest Communications for another year past September 2007. So as not to force a decision and allow the merger talks to follow their due course, it was negotiated that an implementation decision between the two options was not required until July 15, 2006.

Subsequently, the Internet2 Board determined that a merger with NLR would not provide a foundation for creating a unified advanced networking organization to effectively serve higher education and research. Internet2 was directed to move forward towards realizing the next generation networking capabilities to support its members’ needs.

As discussed in early sections of this document, the more ambitious dedicated wavelength system option is intended to create a strong partnership that provides the community with an advanced and scalable optical system under its control and management for the higher-level functions while leveraging the carrier’s capabilities for day-to-day support and operational reliability. Although NewNet will be provisioned with a minimum of 10 wavelengths across its entire footprint, additional waves can be added on a segment by segment basis as needed and requested by Internet2.

Beyond the optical wavelength system, NewNet creates a significant long-term partnership with the carrier. Through this arrangement, the community will be able to obtain mission-critical commodity Internet2 services at favorable pricing through the Abilene follow-on network.

As part of this agreement, Internet2 will continue to offer its very successful FiberCo dark fiber, collocation and professional services relationship for at least two more years and under terms significantly better than market rate. Internet2 members will still be able to procure long-haul and metropolitan fiber on the carrier footprint.

In addition, a collaboration framework for programmatic and technical cooperation for the advancement of NewNet will be developed. Internet2 and the carrier would be the initial members, but over time additional partners could be added. Components of this framework include senior executives and technical staffs from both organizations meeting periodically to freely exchange ideas and set priorities to accomplish mutual objectives. For the term of the agreement, the carrier will appoint a representative from the transport business unit who shall be responsible to the strategic and operational needs of Internet2 and the community. To minimize disruptions, until transition to the new network is complete, the carrier will also provide a designated project manager to work hand-in-hand with Internet2 and its members. Lastly, both parties agree to establish a framework for joint collaboration to investigate and explore new networking technologies as well as to create a Washington, DC-based advocacy group in support of higher education research initiatives.

13 Partnerships

Since its inception, Internet2 has been characterized by the partnerships that fostered the Internet in its infancy – close collaboration among universities, industry, government, and international partners. Internet2's strong and varied partnerships have been a key to its strength: by working together, the Internet2 community has been able to achieve significant gains and collectively surpass the capabilities of an individual entity. NewNet will continue this tradition.

The following are some of the partnerships that are in place or currently envisioned for NewNet. It is expected that this list will grow and change over time.

- Control plane: The broad based industry participation in HOPI has been critical in achieving the research and education community's vision of an interoperable hybrid network supporting applications end-to-end across administrative domains. The continued participation of HOPI's corporate partners will allow further experimentation and development, and will help sustain the ability of RONs, campuses and individual researchers to have access to leading edge, best of breed technology.
- Carrier: Through an extraordinary partnership with a leading global telecommunications carrier, Internet2 will be able to cost-effectively deliver a new class of hybrid networking services. These services will form a foundation for efforts to further advance the US research community's leading edge capabilities.
- Optical transport: Infinera will provide the next generation optical transport equipment that will be the foundation of NewNet. Infinera's unique technology

reduces costs and allows NewNet capabilities at price levels that are not possible on other platforms. Internet2 eagerly anticipates leveraging the capabilities offered by this ground-breaking platform. .

- Routing: The Juniper Networks routers that have handled the core routing duties on the current Abilene network since 2002 will be redeployed on NewNet. Juniper continues to be a strong supporter of Internet2 and of the community at large.
- Lambda switching: One of the key components to NewNet is the ability to dynamically provision and switch lambdas and sub-rate channels. This crucial function allows Gigabit Ethernet circuits to be established in a point-to-point manner on the fly over 10Gbps waves. The equipment-maker partner for this crucial piece has not been finalized, but all of the candidates have strongly innovative and exciting capabilities.
- Founding partner activities: Internet2 would like to recognize the founding partners of Abilene: Cisco Systems, Qwest Communications, and Nortel Networks. Without the generous and committed support of these partners, Internet2 would not have been possible. Internet2 gratefully acknowledges the significant contributions that each has made to further the goals of the research and education community. Internet2 will continue to work with these partners on their future contributions.
- International service trials: NewNet provides a rich infrastructure for a service trial with European next generation network GEANT2, to begin in July of 2006. This trial will develop inter-domain 1GigE services between hosts or clusters of hosts in Europe and the US, the technology to provide real services, and policies and cost models for providing such services.
- Federal government partnerships: NewNet will provide the basis for increased collaboration with federal agencies. Many federal agencies and laboratories will connect to NewNet and will participate in ongoing efforts to enhance its capabilities. Collaboration between the federal government's own advanced Internet initiative, the Large Scale Networking (LSN) effort within the Networking and Information Technology Research and Development Program will continue. The federal government, primarily through the National Science Foundation's International Research Network Connections program, supports many of the links with our international research and education network partners. NewNet's capabilities will have an immediate positive impact on the nation's cyberinfrastructure; and collaborations to enhance these capabilities and add new services important to the NSF and the NIH will be ongoing.

In addition, ongoing engagement with industry and academia is envisioned. Internet2 will engage Internet2 Corporate Members to collaborate and partner in support of moving forward a new level of advanced applications on NewNet and for the transfer of these capabilities to the global Internet. Internet2 values and looks forward to continuing and extending its partnerships with research and education entities across the nation and around the globe. These partnerships have proven to be invaluable to the community at large. Internet2 is proud to be a part of the global cooperative spirit.

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