Internet 2 – WWW
Where, When and Why?

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Abstract

After the World Wide Web and other great inventions of the academic world, comes Internet 2. The new Inter-University project is rapidly evolving into a powerful consortium. 181 universities, 60 American companies and a few dozen international institutions are collaborating to create the communications technologies of the future. Their main focus is to rid themselves of the terrible congestion that exemplifies the Internet and create a new fast multimedia connection between research institutions. They promise that all this will be done far from the intrusion of the private market, a market that, according to the four fathers of Internet 2, "stifles creativity".

The foundations of Internet 2 are comprised of two main technological notions. The first is the Gigapop, which is a regional network's interconnection point to the new Internet 2 cutting edge services. Some types of Gigapops are being constructed so that Internet 2 members can connect solely to Internet 2 services, while other Gigapops are being constructed to connect non Internet 2 members to various other services, such as the old Internet (a.k.a. the commodity Internet or Internet 1).

The second technological notion is QoS, which stands for Quality of Services and is a new method of sending information around more efficiently. The basis of QoS is to create priorities for the information sent. In this way crucial medical information will have priority when compared to chess game simulations.

The implementation of these two notions, together with other innovative technologies, requires a vast amount of funding, which is partly private but mainly governmental. The methods discussed here for budgeting and funding of institutions for the Internet 2 project are interesting and are a main force in the shaping of Internet 2. Moreover, they will also influence important infrastructure and technical decisions yet to be made, such as routing methods, protocols and speeds that will shape and mold I2.

The following research deals with both the technology and infrastructure needs and the advantages to be gained by the Internet 2 project worldwide. This is the first time that readers are exposed to a comprehensive survey of the financial and technological aspects gained from the implementation of the project.

Keywords: Communications, Infrastructure, Internet 2, Financial Aspects, Gigapop, Internet

Introduction

General

During the past decade, federal R&D agencies, the academic community and private companies have worked together to develop many of the Internet's technologies. This partnership has created a multi-billion dollar industry.

Internet 2 (I2) is comprised of over 181 US research universities. These universities, working with federal research agencies and leaders of the information technology industry, teamed up to create the next stage of Internet development.

The Internet 2 project is a collaboration for the development of a Next Generation Internet (NGI) for research and education that will include enhanced network services focusing on multimedia applications. The work is developmental and pre-competitive in nature (Bakos 1998).

It was agreed upon that charter membership in the project remains open for a limited time to additional institutions that are in a position to commit the resources necessary for

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full participation. Today more than 250 institutions have committed themselves to participate in Internet 2.

Objectives

The objectives of the Internet 2 project were set as follows:

- To maintain a common bearer service to support new and existing applications
- To move from best effort packet delivery to a differentiated communications service
- To provide the capabilities of tailoring network service characteristics to meet specific applications requirements
- To achieve an advanced communications infrastructure for the Research and Education communities

The need for a wide range of possibilities for data transmission is obvious and includes mainly current and future applications from the domains of Medicine, Education and Commerce. The list below emphasizes some of the current and future needs that encouraged the professionals to establish and develop the project (Brown 1999).

- The idea that transmission rates, error rates, and other characteristics can, to some extent, be guaranteed in advance is known as Quality of Service or QoS. High Quality of Service and an efficient "one-to-many" broadband data transport including support for multimedia and shared information processing will be required for the broad use of distance learning (a.k.a. e-Learning).
- Leaders of the international research community are in need of high capacity infrastructure and selectable quality of service so that they can make effective use of national laboratories, computational facilities and large data repositories.
- Medical researchers require support for remote consultation and diagnoses over highly reliable and predictable communications lines.
- Physicists, and especially those who deal with vast astronomical or geophysical datasets, have similar needs.
- As commercial transaction data reaches research focus, financial and economic analysts will need real-time access to masses of data.

A major impediment to the realization of these applications is the lack of advanced communications services in the current commodity Internet -- there is no test case, as yet, by which to prove their effectiveness, much less to implement them on a wide scale.

The Novelty

A number of technical and practical considerations underlie the overall architecture of the Internet 2 infrastructure. One of these is the need to minimize the overall costs of participating campuses. This is achieved by providing access to both the commodity Internet and advanced services through the same high-capacity local connection circuit.

Another catered need is the accommodation of other campus programs and projects. This is done by means of a flexible regional interconnection architecture. For example, a metropolitan area network service might offer high capacity Internet services to students and faculty members.

The new, key element in this architecture is the "Gigapop" ("gigabit capacity point of presence") that presents a high capacity, state-of-the-art interconnection point where I2 participants may exchange advanced services traffic with other I2 participants. Campuses in geographic proximity will join together to acquire a variety of Internet services from the regional Gigapop.

The definition of the I2 Gigapop is “the connection node among I2 member campuses, other I2 Gigapops, and local networks that serve local I2 members”. This definition holds, even if, the I2 Gigapop operator provides other services to I2 members or services to non-members.

For wide-area advanced services, a single interconnect service among Gigapops will suffice at first. Service providers will be able to offer attractive advanced services as technologies migrate into the private sector. The design of Internet 2 must optimize the campus's ability to acquire services from the widest variety of service providers. The overall architecture of Internet 2 is shown in Figure 1.

Each campus (such as Alpha and Baker in Figure 1) will install a high-speed circuit connection to its chosen Gigapop through which it will gain access to common Internet as well as advanced Internet 2 services. The Gigapops will then join together to acquire and manage connectivity among themselves, in an organization that is temporarily called the Collective Entity (CE) and whose structure and

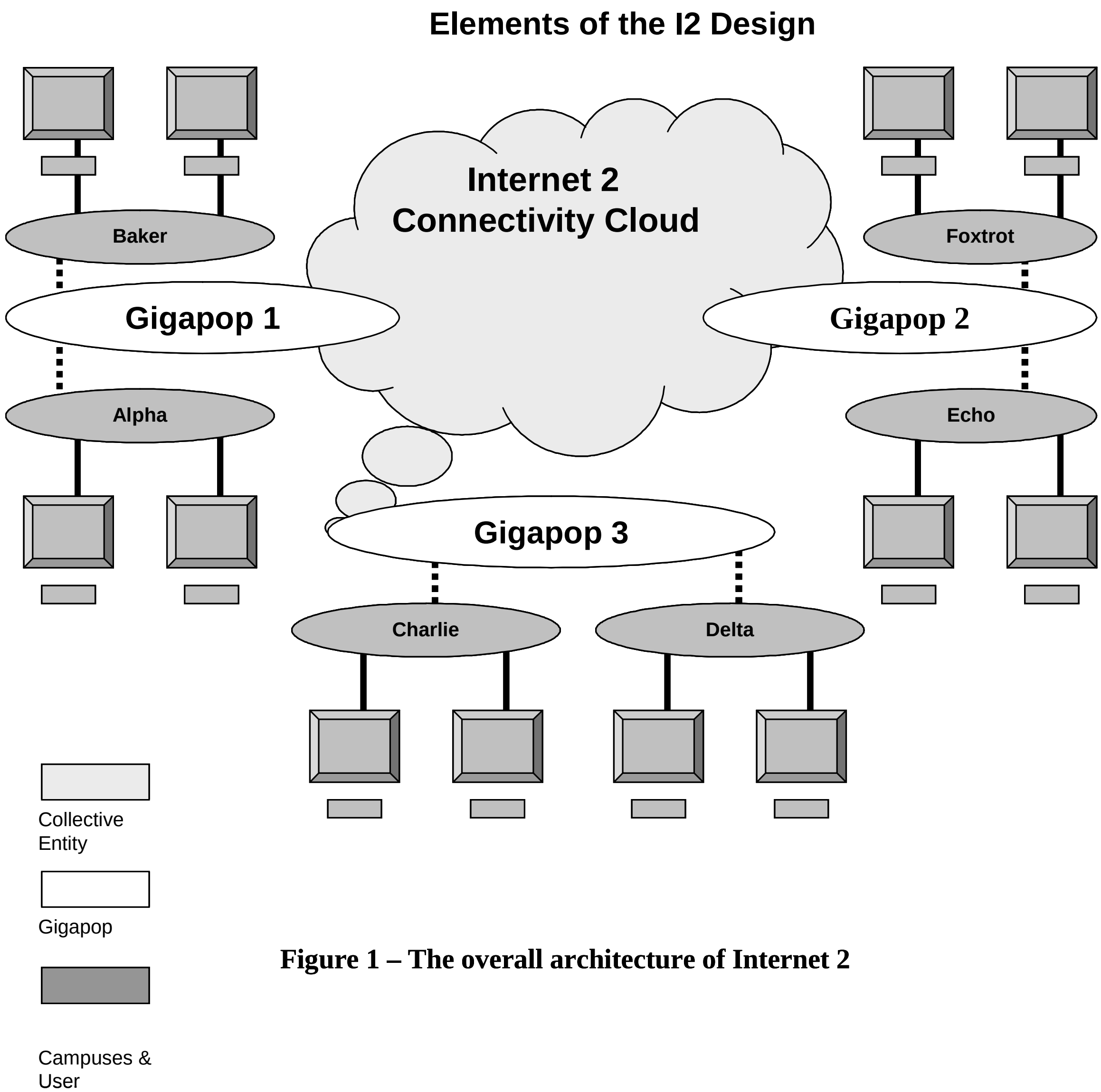

Figure 1 – The overall architecture of Internet 2

legal form remain to be determined. Potentially there could be a wide range of services available at the Gigapop, limited only by the economics of the market and by the absolute priority and insulation of I2 services.

To meet the requirements of both applications and developers of Internet 2, there must be advanced-services support both within the campus and among the Gigapops. Among the Gigapops, the wide area interconnect service must support differentiated Quality of Service (QoS), as well as highly reliable and high-capacity transport. Since these capabilities are not yet available in the commodity Internet backbone, a special purpose inter-Gigapop interconnect network has been established by the Collective Entity.

The Gigapop concept can greatly increase market competition among Internet service providers and help ensure cost-effective I2 services in the long run. It might become a common way for end-user networks to acquire a wide variety of communications services, from basic Internet transport through caching and content provision (Gillmor, Angus et al. 1999).

The Internet 2 concept consists of four major technical components:

- Applications that require I2-level services and equipment such as those outlined by the Applications working group.
- Campus networks connecting Gigapops to their end users in laboratories, classrooms and offices.
- Gigapops that consolidate and manage traffic from campus networks.

- I2 interconnections among the Gigapops.

Cuttings across these components are:

- The protocols for specifying and providing connectivity, especially with specific Qualify of Service (QoS) dimensions.

- The network-management tools, data and organization necessary to keep everything running.

- The accounting and cost-allocation mechanisms required, reasonable negotiating, efficiency, and productive distributions of costs across I2 members.

Some Gigapop operators will provide additional connectivity as well. For example, they may serve other networks and end users beyond those within the I2 Gigapop consortium. Nevertheless, this must be done in such a way that it does not spill over into the I2 network "cloud" and ruin the clear dichotomy between the commodity Internet and I2 so that I2's efficiency is preserved.

The overall scope of I2 applications requires next-generation network services on an end-to-end basis. This implies very significant upgrades to most campus networks. I2 members are responsible themselves for bringing their campus networks up to I2 standards.

Financing the Project in the USA

The myriad of I2's expensive technology requirements, have caused the costs of the project to be very high. The Internet 2 initiators have been aware of this issue from the very beginning of the project and as a first step every university has been asked to raise special funds to participate in the project and connect to the new network.

The US financial market immediately recognized the project's enormous potential, both for technological research and development and for the project's future contribution to the US economy. Therefore, many industrial companies donated funds to the universities and to the project's institutes (Shemer 2000).

In addition, to help finance highly scientific projects such as I2, the US government has formed the NSF. The National Science Foundation is an independent U.S. Government Agency responsible for promoting science and engineering through programs that invest over $3.3 billion per year in almost 20,000 research and education projects in science and engineering (Shemer 2000).

In the following sections we will discuss the different financial aspects of the project from the cost and funding points of view.

Estimated Project Costs

The overall costs of the I2 project is divided into three sections :

- Infrastructure

- Membership

- Gigapop

Infrastructure

The infrastructure is currently comprised of two parts that will merge in the future (McKgrow 1997, McKgrow 1998).

- vBNS – Very high performance Backbone Network Service (vBNS): a network that will connect up around 100 research institutions, and already links five National Science Foundation supercomputer centers, at 2.4 gigabits per second. Begun in 1995, the vBNS was a $50 million, 5-year NSF project with MCI. The vBNS was built, financed, and controlled by the Federal Government for its own uses, such as NASA.

- Abilene project – Built by UCAID for the development of a nationwide advanced network to serve as the backbone for the Internet 2 project. Abilene supports the efforts of the more than 180 universities working on the Internet 2 project.

Membership

Membership cost to join UCAID – Since the Internet 2 is a project of the UCAID, which covers its core operational costs by collecting membership fees, universities currently pay $25,000 per year. Other members, such as non-profit affiliates and private corporations, pay $10,000 per year.

Upgrading costs **-** The estimated average cost is about $500,000 per year for a university to upgrade the campus equipment and network connections. This self-funded investment is required to join UCAID and the Internet 2 project. In reality, most universities are doubling or even tripling this investment on a yearly basis.

Table 1 below specifies the breakdown of estimated costs per member, to join and be active in the Internet 2 project. As can be seen, these costs are relatively high.

Item	Cost
Annual membership fee	$25,000
Upgrading the campus network infrastructure	$500,000-$2,000,000
Connection to national backbone	$100,000-$400,000
Connection to national high performance backbone	Depends on geographical location.
On-campus staff assigned to Internet 2 project	Varies, typically from one half-time to one full-time person assigned

Table 1 - Breakdown of estimated costs per member

Gigapops

Universities in the same geographical area join in order to share the expenses of building and operating Gigapops. As an estimated budget per university in a "band of three university Gigapops", each university is likely to receive a $350,000 grant from the NSF.

The estimated costs of implementing the Gigapops total approximately $250,000 per year for each one of the three universities (Shemer 2000).

All the values are based on today's best-proposed solution, and were taken from Stanford University's proposed budget for the I2 project.

Annual ongoing expenses (General & Administrative) for Gigapop and university

There are operational and other ongoing expenses, such as salaries, maintenance, etc. To estimate these expenses, the budget proposal for the Internet 2 project of Boston University that became part of the project was adopted (Ashton, E. 1999). The university's funds are spent on the following: salaries, equipment, network, pilot projects, just-in-time training, marketing, direct expenses and facilities costs. All these expenses amount to approximately 1.1 million dollars per year, for a period of five years.

The Project's Funding Resources

Four sources of funding have been identified for this project:

- Project revenues
- Industry
- Government
- University self-funding from the current budget

Revenues

"Internet 2 started out as a very arcane research project among scientists. Once the technological development by the university has been proven to be workable and viable, it will be adopted by the public sector.... [The common user] can expect to use the advanced capabilities of Internet [2] in five years," he said. "The potential is really exciting." (Burlington 1999).

One of the goals of Internet 2 is to develop and deploy applications that will ensure a high return on investment (ROI) especially for the private sector. It is not possible to forecast all the implications of Internet 2 applications on the total revenue.

For an idea of what is expected, the following are some examples of projects that are currently under development and of great commercial potential:

- Digital libraries featuring streaming high-fidelity audio and video content, large bitmap scanned images that appear instantly on the screen, and new forms of data visualization.
- Immersion environments that let individuals at different locations share a single virtual environment and communicate and interact in real time.
- Music instruction with high-fidelity, multi-channel, multi-party audio and video; interactivity, ensemble playing and music/dance improvisation; synchronization of audio, video, and annotations.
- Telemedicine, including remote diagnosis and monitoring.
- Computation- and data-intensive applications, such as the correlation of physical and social science data involved in evaluating population movement in the context of a region's climatic changes.

Industry Involvement and Support

Internet 2 university members are working closely with IT industry leaders to develop and implement the project's goals by establishing Internet 2 corporate partnerships.

Internet 2 corporate partners have pledged significant efforts to turning Internet 2 into a reality.

Fourteen of UCAID's corporate members have been recognized as Internet 2 partners. They have committed over $1M in goods, services, and cash donations to the universities in particular and to the project in general. In total, over $20M have been contributed by the industry.

The following are among the companies that are giving financial assistance to the project:

3com, Advanced Network & Services, AT&T, Bay Networks, Cabletron Systems, Cisco Systems, Fore Systems, IBM Corporation, Lucent Technologies, MCI Communications, Newbridge Networks, Nortel, Qwest Communication, StarBurst Communication.

Federal and Government Support

"By building an Internet infrastructure that is faster and more advanced, we can keep the United States at the cutting edge of Internet technology, and explore new applications in distance learning, telemedicine, and scientific research " said President Clinton. The US government recognizes the importance of Internet2, and finances the university by special funds (Burlington 1999).

Twenty-three Internet 2 members were among the 29 research institutions winning the NSF grant this year. The National Science Foundation awards allow them to connect to the very high performance Backbone Network Service (vBNS) and to communicate with other Internet 2 members at speeds up to 100 times greater than is possible through today's Internet. These grants bring to 100 the number of Internet 2 institutions connected to the vBNS.

The universities can finance some of their expenses by winning a prestigious grant from the US National Science Foundation. These grants are typically $350,000 for a two-year period and the universities have mainly used them to build out their campus networks and buy local loop connections to their Gigapop.

In addition, universities that are awarded the grant may be eligible for reimbursement by the NSF of the registration and connection fees to Abilene.

Technical and Functional Overview

Considerations

Functional Requirements

A key function of the I2 Gigapop is to exchange traffic with specified bandwidth and other Quality of Service attributes between connected I2 member networks and the core I2 network. To achieve this goal, a Gigapop must satisfy a variety of specific functional requirements.

Protocols

Since the Common Bearer Service of Internet 2 is IP, any Layer-3 device in Gigapops obviously supports IP. This is true as Layer-3 devices, also known as Network Layer devices are those which are concerned with knowing the address of the neighboring nodes in the network, selecting routes and Quality of Service, and recognizing and forwarding to the transport layer incoming messages for local host domains.

IP version 4 is the current standard, but the Internet 2 project helped move the community on to IP version 6. All Gigapop Layer-3 devices will support IPv6 in addition to IPv4, as soon as stable implementations are available.

IP is not the only protocol in the TCP/IP suite. All the usual supporting protocols are assumed to be available when needed. In addition, IGMP (supporting multicast) and RSVP (supporting resource reservations) are expected to be very important to this project, and should therefore be available in all relevant Gigapop devices.

Routing

The Gigapops are responsible for implementing all usage policies pertaining to Internet 2. For example, the vBNS is used to provide inter-Gigapop connectivity; Gigapops must therefore send only traffic destined at other I2 sites to their vBNS connection. Note that physical connectivity to a Gigapop does not imply either permission or ability to exchange traffic with any other entity having a connection to that Gigapop. Routing policies of the Gigapop are used to enforce not only the Internet 2 rules, but also the bilateral peering agreements that control local traffic exchange at Gigapops.

Speed

The bit rate of connections into a Gigapop or between Gigapops varies widely, depending on the number and intensity of the I2-based applications running on its member campuses. It is up to the Gigapop itself to make sure that it has an adequate capacity to handle the anticipated traffic load. The switches, providing the primary interconnectivity in a Gigapop and the links from those switches to adjacent Gigapop routers, should be sized so that packet loss within the Gigapop nears zero.

Use Measurement

Costs for inter-Gigapop connectivity are not yet known. Furthermore, other Gigapop costs will vary according to circumstances and services offered. Hence, it is not possible to say very much about requirements for cost accounting. Obviously, whatever pricing mechanisms are selected, they must be technically supportable. Gigapops must therefore share the usage statistics necessary for proper allocation of costs across I2 members.

Facilitating Regional Aggregation

Gigapops are by definition aggregation points for digital traffic, but in some areas, digital transport costs may encourage a hierarchy of aggregation and exchange points within a region. In such instances, the Collective Entity plays a constructive role by coordinating cost-effective regional Internet 2 connectivity for affiliated institutions. A key goal of brokering such lower-level exchange points is to maintain consistency throughout the entire Internet 2 infrastructure.

Technology Transfer

Just as Internet 2 has, as one of its goals, the transfer of next-generation Internet technology to the commodity Internet, so Gigapops are aimed at playing a key role in the transfer of technology to member institutions. Although details will vary from one area to the other, there exists an important opportunity for Gigapop operators to share information with member institutions on deployment and management of their emerging multicast and multi-QoS campus networks.

Collaborations among Gigapops

Although multi-QoS and multicast connectivity among all Internet 2 members is an explicit and important goal of the project, not all I2 members are involved in every advanced application experiment. Indeed, some of these experiments will involve institutions served by a single Gigapop. However, a likely scenario will be for several Gigapops to collaborate on specific application experiments and other projects. For example, multiple Gigapops might work together with a private enterprise to facilitate improved connectivity for asynchronous and distance learning from member institutions to their constituents’ homes, just as Gigapops may facilitate local traffic exchange among commodity Internet Service Providers in their region.

Other Gigapop Services

It is not unreasonable to envision that Gigapops might accommodate storage facility capabilities in the form of caching nodes or even content servers in support of their participants’ activities.

Since the collection of operational data within Gigapops is a basic requirement, large capacity disks may be assumed to be on site. Caching could prove very effective in reducing demand on wide area links for some types of services. Similarly, content located at the Gigapop would be readily available to the attached I2 participants as well as to the wide area links.

As an optional service for some I2 participants, ATM or other link level capacity might be made available upon special arrangement with the Gigapop operator(s). ATM or Asynchronous Transfer Mode comes here into mind as it is a highly dedicated-connection switching technology that organizes digital data and transmits it over a physical medium using digital signal technology.

Gigabit Capacity Point Of Presence (Gigapop)

Structure and Services

Logically, a Gigapop is a regional network’s interconnection point, providing access to the inter-Gigapop network for, typically, several I2 members. Structurally, Gigapops will be implemented by one or more universities, although there may be exceptions. For example, the Collective Entity might be called upon to operate certain Gigapops; universities might operate others on behalf of neighboring institutions (as well as themselves) and some might be operated by commercial entities.

Physically, a Gigapop is a secured and environmentally-controlled location that houses a collection of communications equipment in the form of hardware devices. Circuits terminate there both from Internet 2 members' networks and from wide-area data-transport networks. I2 members' networks are assumed to be non-transit networks; that is, they do not carry traffic between a Gigapop and the general Internet. Gigapops will serve end-user non-transit networks through appropriate IP route management. I2 Gigapops will not serve commercial transit networks, nor will peering be allowed among such networks via the Gigapop’s routing infrastructure. Inter-Gigapop links will ONLY carry traffic among Internet 2 sites.

The Gigapop's key function is the exchange of I2 traffic with a specified bandwidth with other Quality of Service (QoS) attributes. In addition, standard IP traffic can be exchanged with commodity Internet service providers who have a termination at the Gigapop, in order to eliminate the need for separate high speed connections between the participant's campus network and other ISP exchange points. In many cases Gigapops will serve customers and purposes beyond the simple communication among I2 applications developers. In particular, Gigapops may link I2 campus networks to:

- **Other metropolitan area networks** in their communities, for example to provide local area education (e-Learning).
- **Research partners and other organizations** with which I2 members wish to communicate.
- **Other dedicated high-performance wide area networks** e.g. government networks created for the government's research units.
- **Other network services** e.g. commodity Internet backbone providers.

Gigapops will operate with minimal staff on-site. Operational support will be provided by a small number of I2 Network Operations Centers (NOC). However, no end-user support services will be available.

Gigapops must also participate in I2 operational management by collecting data on utilization, and by sharing with one another and with campus-network operators the information necessary to schedule, provide, monitor, troubleshoot, and account for I2 network services.

Logical types of Gigapops

There are two major logical types of Gigapops:

- **Type I Gigapops** are relatively simple. They serve only I2 members, route their I2 traffic through one or two connections to other Gigapops, and therefore have little need for complex internal routing and firewall services.
- **Type II Gigapops** are relatively complex. They serve both I2 members and other networks to which I2 members require access. This type has a rich set of connections to other Gigapops, and must therefore provide mechanisms to route traffic correctly and prevent unauthorized or improper use of I2 connectivity.

A type I Gigapop omits some of the connections seen in Figure 2. For a Type I Gigapop, the connections on the right side of the diagram would be limited to one or two other Gigapop connections, one or two local ISPs and a connection to a commodity Internet carrier. The different types are mentioned here because some traffic situations may erupt where members have significant traffic going to and coming from diverse locations elsewhere, while others will involve relatively simpler and smaller aggregations, whose drainage needs are more modest.

Given the rapidly growing numbers of I2 and prospective members, the Gigapop consortia may have to add some core switching nodes whose sole function is to connect Gigapops to one another.

External connections to Gigapop ATM Switching Elements may be direct SONET circuits from campus ATM switches or other Gigapop locations, or full ATM service from commercial carriers. ATM Switching Elements serve to multiplex the link level bandwidth through permanent or switched virtual circuits (PVCs or SVCs). In this way, the intra- and inter-Gigapop connectivity can be optimized and a separate bandwidth can be allocated for testbed or other special purpose requirements.

Scope, Context and Timeline

Internet 2 must encourage the development and deployment of advanced real-time multimedia applications and the network's infrastructure and service differentiation needed to support these applications. Since I2 connectivity is limited to members only (a relatively small number of educational institutions), this effort is not a substitute for the commercial Internet. However, it is expected that it will influence the commercial Internet.

I2 will be a standards-based but pre-competitive production network and not a network research experiment. A key guiding principle is to use off-the-shelf technology wherever possible. Implementing I2 raises some research questions that distinguish I2 from commodity service procurement. The queries related to the network itself (as opposed to specific application areas) include:

Network service requirements. In particular, what network QoS levels are really needed for advanced real-time multimedia applications?

- **Protocols for delivering different QoS levels**. In particular, how much "state information" must be maintained in routers and/or switches to deliver high-quality differentiated service?
- **Management.** What are the administrative implications of a multi-QoS network, especially from network-management and cost-allocation perspectives?

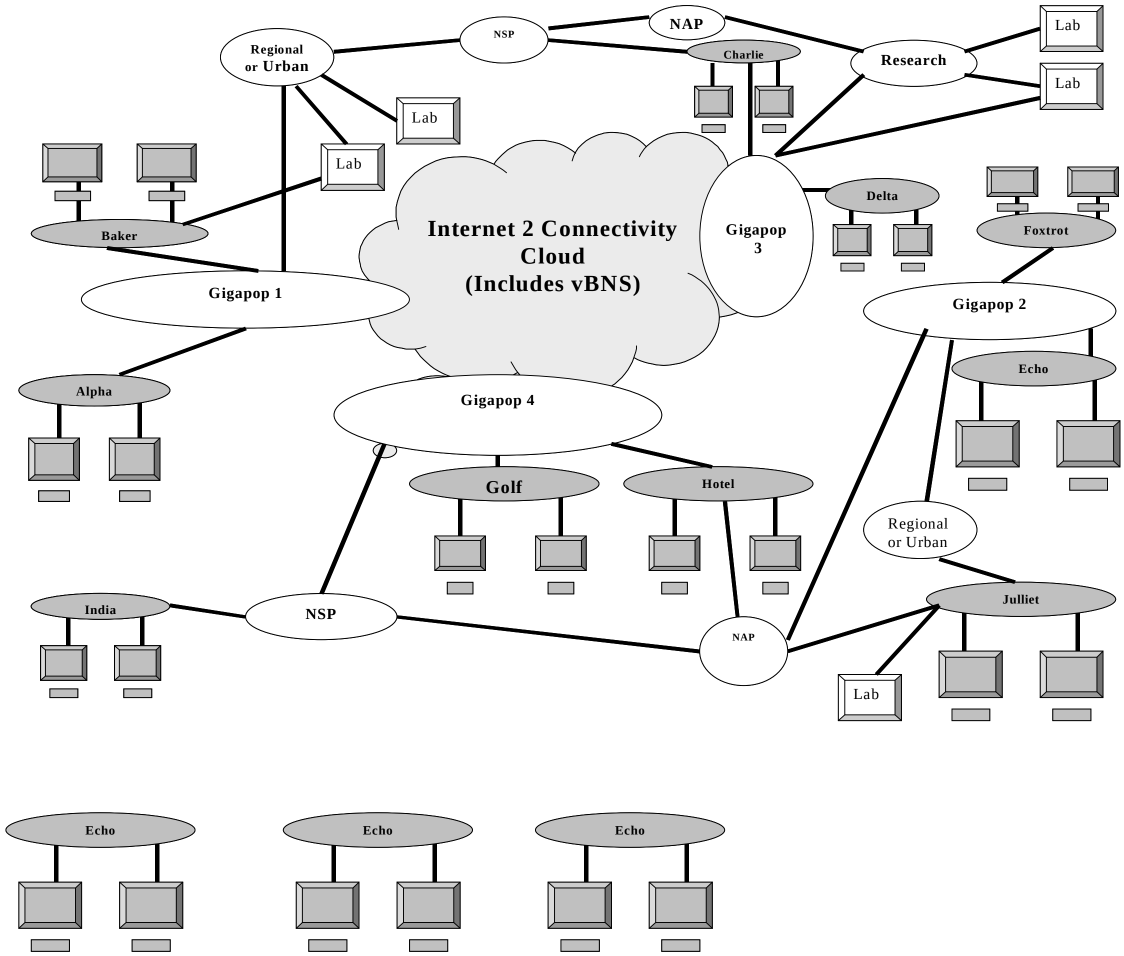

Figure 2 – Internet 2 Connectivity Cloud

- **<u>Cost Recovery.</u>** How can authorization and attribution for QoS requests be handled efficiently in a "stateless" communications service?

Looking ahead over the next three to five years, Internet 2 expects to provide an opportunity to substantially reduce the number of redundant low speed network connections presently supported by federal funds.

Another project is the Abilene Project, which is developing a nationwide advanced network to serve as a backbone for the Internet 2 project. Abilene will support the efforts of all the universities working on the Internet 2 project.

I2 seeks to complement and enhance other large-scale, high-performance networking initiatives, and to collaborate, cooperate, and join with them wherever possible. It will no longer be necessary for each federal project to pay for a separate, direct connection into campus laboratories. Instead, federal backbones can connect to Gigapops and utilize or build on campus-Gigapop linkage (Palvia 1997).

Conclusion

Internet 2 will most surely leave no field untouched. From e-Learning through video conferencing to e-Commerce through multimedia support, Internet 2's concepts of transferring data through high velocities and priority bandwidths will transform and help build many academic and research fields, especially the medical one.

The enormous improvement in the ability to transfer images, voice and data due to the I2 implementation in academic institutes mainly in the USA, Great Britain, Germany and the Netherlands, has accelerated the development and usage of important innovations such as Telemedicine in these countries.

It is evident that I2 is expanding in three major coarse ways:

- The addition of further universities in North America
- The addition of Large Scale American technology companies
- The further expansion of the I2 project in Europe, Middle and Far East.

The I2 connection of the various institutions is based on the two main ideas behind I2, i.e. the Gigapop and QoS, which are still very expensive, especially for non-profit organizations. Even with the government's help and partial funding from private firms, it remains a difficult task to keep up with the high Gigapop connection expenses and especially the technology upgrade costs. It is now mostly up to the revenues from the technological breakthroughs achieved in the I2 project to bring about more advancements in I2.

The entire I2 entity has not yet reached a solid form and therefore many technical issues, such as routing methods, protocols and speeds, still remain open. Due to this liquidity of shape, it is hard to predict figures representing the future technological and financial success of the project. Nevertheless, the recently successful experiments carried out on various I2 applications have depicted a world for which we, the regular commodity Internet users, can only wish.

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Biography

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