Future Prospects for NSF's International Connections Program Activities

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Abstract

The National Science Foundation's (NSF) plans for ensuring that the U.S. research and education (R&E) communities will continue to be able to interact over the Internet with colleagues and resources abroad are discussed. NSF has recently transitioned from the custom-provided NSFNET Backbone national transit service for mid-level networks to service provision by several interconnected general purpose ("commercial") Internet service providers. It is anticipated that the plan for international services will be to "ratchet" up the capacity of transoceanic links well beyond the current T1/E1 levels, while minimizing NSF's role in direct service provision, much as NSF has done in the case of domestic service. In addition, NSF's role in facilitating the Internet connectivity of other countries in support of the R&E communities is likely to continue, and demonstration projects in advanced international-scale telecommunications technologies may also be supported.

1 Introduction

In 1991, the National Science Foundation awarded a five-year cooperative agreement with Sprint for International Connections Management to NSFNET (ICM). The purpose was to consolidate the management and engineering of connections between the U.S. research and education (R&E) communities and similar communities abroad. From the initial two links of 128 kbps each to Stockholm and southern France, the project has grown along with the Global Internet to the point that the two E1 links to Stockholm, 2 E1 links to London and T1 and E1 to Paris that will exist in early 1995 are not likely to be sufficient for more than a few months to meet capacity demands. In addition, the ICM project has made it easy for other countries to connect to the Global Internet by providing an infrastructure for interconnection and by making modest "port management fee" payments on behalf of the connecting countries. Latin American and Caribbean countries (in partnership with the Organization of American States) are connected to the ICM infrastructure, as are a growing number of Asian and Pacific countries. As an indication of the growth in demand for such countries Malaysia's initial 64 kbps connection is to be replaced with a T1; South Africa struggles to keep up with its demand as it looks toward 256 kbps and seeks ways to fund T1 bandwidth, and Costa Rica is on the verge of an upgrade from 64 kbps to 128 kbps for its R&E network, and a possible tie-in with RACSA's (the PTT) own international service for a 256 kbps link.

Meanwhile, the domestic NSFNET backbone service has transitioned from a custom-provided national transit service for mid-level networks to service provision by several general purpose ("commercial") Network Service Providers that interconnect at Network Access Points. The NSFNET mid-level networks are themselves undergoing transitions to more general purpose service provision, especially as some are being purchased by commercial interests. So, as the demand for intercontinental connectivity continues to soar (in some cases, doubling every few months!), NSF anticipates a future in which every-day ("commodity") networking will be provided by general purpose service organizations, and the international links will be similarly provisioned. Our international connectivity strategy is to attempt to "ratchet" the busiest intercontinental link capacities to the 34 - 45 Mbps range in the near term with an eye toward SONET/SDH capacities of 155 Mbps and higher in the longer range, while at the same time minimizing NSF's role in direct service provision.

At this writing, the precise path to those ends is far from clear. However, a new solicitation for International Internet Services (IIS) has been drafted and is undergoing internal review. Regarding the IIS solicitation, NSF is considering multiple awards in as many as four categories:

High-Bandwidth (at least 34 Mbps) Production-Quality Services,

International Internet Connectivity Services,

High Bandwidth (at least 155 Mbps) Experimental Service & Demonstrations, and

Emerging Technology Experimental Service & Demonstrations.

The following sections provide a glimpse into NSF's thinking about the new IIS, but it should be understood that these thoughts are *preliminary and unofficial*.

2 Background

As of March, 1995, the Internet included more than 50,000 networks. These networks interconnect millions of computers and tens of millions of users throughout the world. The NSFNET Program supports connections to the Internet for research and education with the goal of establishing a ubiquitous computer networking infrastructure for that community.

The domestic NSFNET backbone (national transit) service has just completed a transition from a single service provider to service provision by several general purpose ("commercial") Network Service Providers (NSPs) that interconnect at Network Access Points (NAPs) to ensure full connectivity among the NSFNET regional networks, Figure 1.

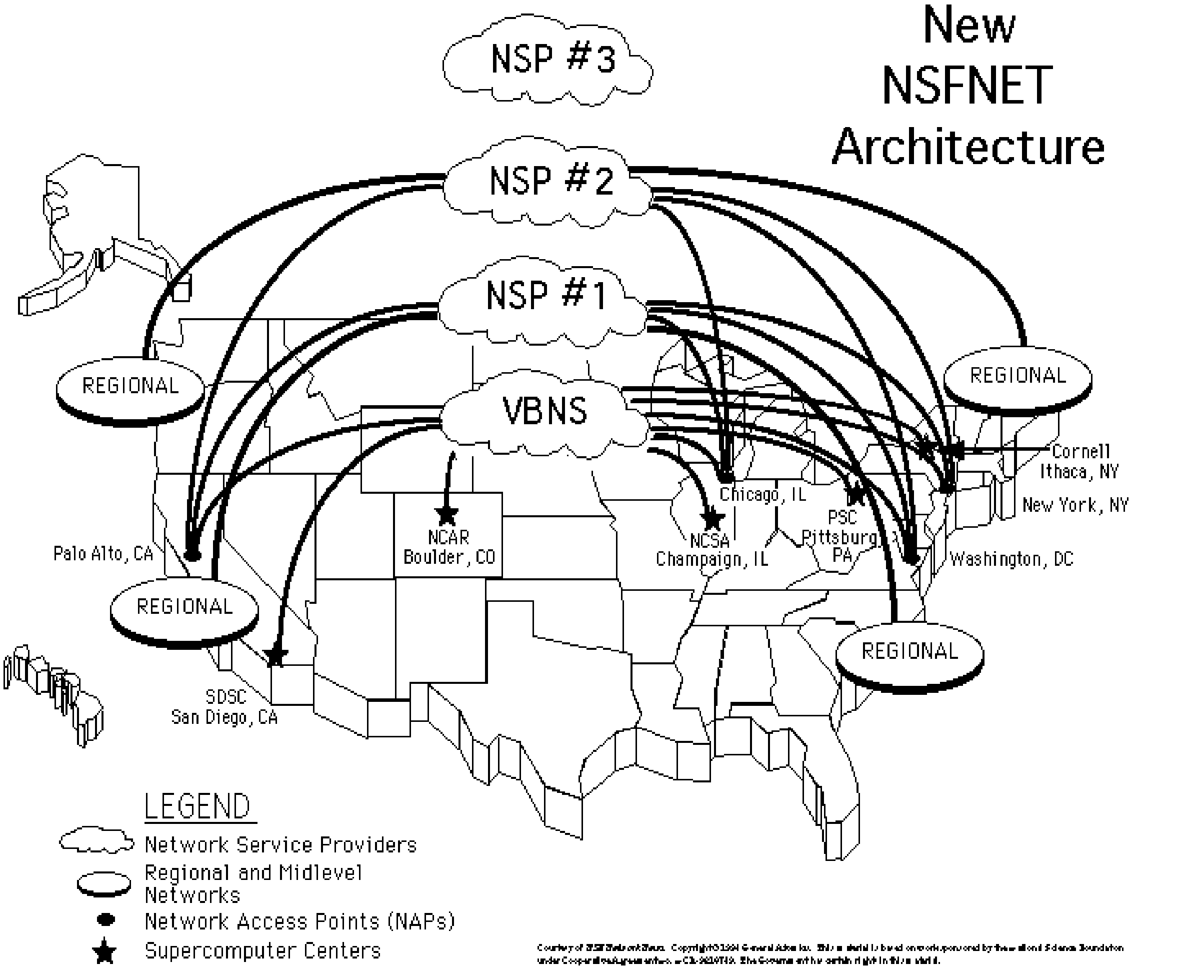

Figure 1. New NSFNET Architecture *(Courtesy: General Atomics)*

In 1990, NSF issued a solicitation for "International Connections to NSFNET" NSF 90-69. At that time, the single-provider NSFNET Backbone was operating at T1 (1.5 Mbps) capacity, and the expected capacity metric for international links was several multiples of 64 kbps, up to T1 (or the European analog, E1). The initial focus of NSF 90-69 was on connectivity with NORDUnet in Stockholm and with INRIA in Sophia-Antipolis, France, with additional connectivity needs to be fulfilled, as they became known to NSF. NSF90-69 resulted in a single award to Sprint Communications Company in the form of a five-year Cooperative Agreement. The purpose was to consolidate the management and engineering of connections between the U.S. R&E communities and similar communities abroad. From the initial two links of 128 kbps each to Stockholm and southern France, the project has grown along with the Global Internet to the point that the two E1 links to Stockholm, 2 E1 links to London and T1 and E1 to Paris that existed as of early 1995 are not sufficient to meet capacity demands.

In addition, NSF has structured the ICM project to make it easy for other countries to connect to the global Internet by providing an infrastructure for interconnection and by making modest "port management fee" payments on behalf of the connecting countries. Latin American and Caribbean countries (in partnership with the Organization of American States) are connected to the ICM infrastructure, as are a growing number of Asian and Pacific countries. As an indication of the growth in demand for such countries Malaysia's initial 64 kbps connection was replaced with a T1; South Africa struggles to keep up with its demand as it upgrades capacity to 256 kbps and seeks ways to fund T1 bandwidth, and Costa Rica has upgraded its R&E connection from 64 kbps to 192 kbps.

An overview of the context of Global Internet connectivity and use within which NSF is planning future international connectivity is given below:

2.1 We have encountered the T1/E1 "wall"

Capacities of the European links have grown to the point that the T1/E1 limit has been encountered. The London, Stockholm and Paris links were all upgraded to T1 (~1.5 Mbps)in late 1992-early 1993, and impending congestion resulted in an order to increase the capacities of the London and Stockholm links to E1 (~2 Mbps) in early 1994 and then to multiples of T1/E1 in late 1994. CONACYT's (Mexican National Science Council) new link was implemented at E1. (Note that U.S. domestic trunks are not normally configured for E1.) Similarly, Canada's CA*net, which had connected to the NSFNET directly under a separate three-year award to Merit that was issued prior to the ICM award, went on to upgrade its connections from 2-or-3 multiples of 64 kbps to include five T1s, at CA*net's expense. During a recent visit to Ottawa, I learned that general purpose Internet service providers are competing fiercely for business in Canada. Japanese R&E interests have aggregate capacity to the U.S. that could purchase a 34/45 Mbps link, were the individual links to be consolidated. Several General purpose service providers now operate in Japan in addition to the private R&E networks. The Australian Academic Research Network's (AARNet) link to NASA has grown to about 6 Mbps.

Thus, it is clear that growth in demand for Internet services will require higher capacities than T1/E1 to several areas of the world with which the U.S. R&E communities maintain active collaborations.

2.2 There is still a need for sub-T1 services

Other countries throughout the world maintain links to the ICM infrastructure at capacities from 64 kbps to T1, usually at their own expense, but sometimes with assistance from other organizations. It is likely that the historical growth trends noted in the case of Europe-U.S. and Australia-U.S. will push many of these capacities to the T1/E1 limit in the next several years, although financing difficulties may act as a brake on rapid growth.

2.3 Emerging technologies could enable services to hitherto remote areas

There are also unmet needs for telecommunications services between the U.S. R&E communities and colleagues or resources in parts of the world that are not easily reachable by the more conventional means discussed above. Developing countries with inadequate domestic telecommunications infrastructure and a corresponding dearth of international connectivity are an obvious example. Also, remote areas of the globe where rain forest, Arctic, desert, and oceanographic research takes place are targets for future Internet connectivity. In many cases, these places may be rendered increasingly reachable with emerging (or otherwise less conventional) technologies which include satellites (at various orbital distances and either singly or in constellations), radio relay and other wireless capabilities.

2.4 The Research and Education communities and the burgeoning Internet

Since the implementation of the ICM award in 1991, many developments have been influencing Internet growth and with it, the demand for international connectivity. Among them:

2.4.1 Growth of the general purpose Internet service sector

Many enterprises of all descriptions are served by Internet service providers, not just the R&E community. This is especially the case in the U.S., the former Soviet Union, South Africa, many Asian countries including Japan, Hong Kong, and China, most European countries, and a growing number of Latin American countries including Argentina, Colombia, Costa Rica and Ecuador. Other countries are following suit. Recently, there has been speculation that Telecom Australia, the major telephone service operator in Australia, would purchase AARNet from the Australian Vice-Chancellors' Committee. Telecom is expected to operate a commercial Internet service which could provide services both to AARNet's current academic and research clients as well as expand into other commercial markets.[1] It is not unlikely that R&E

1 Private communication with Geoff Huston <G.Huston@aarnet.edu.au>, 20 April 1995.

networks in other countries may one day be integrated into the framework of general service provision.

2.4.2 Use by other government agencies

Governments in the U.S. and abroad and at state and federal levels have also adopted the Internet to carry out their work, and recently, U.S. Government agencies have begun to seek Internet services at a rapid pace.

2.4.3 Adoption by global disciplinary research endeavors

The High Energy Physics and Human Genome research communities were early adopters of Internet technology to link their globally distributed research programs. More recently, the public health and medical information communities, distance education and social science communities have also begun to adopt Internet technology. Much of this research is funded by the research arms of other agencies in the U.S. and abroad.

2.4.4 Entry of the development sector

Following closely on the heels of the R&E community, the international development community (e.g., United Nations Development Program and non-governmental organizations) has adopted the Internet as a means of accomplishing its work; this includes entry of important international lending institutions such as the World Bank and regional development banks

2.4.5 New Applications, Increased Demands

Keeping pace with Internet growth, and maybe even helping to drive it forward, an array of tools for resource discovery, navigation and collaboration have appeared. Most have been offered free to end-users, though commercially-supported versions are also appearing. Adoption has been rapid. Client-server resource discovery and retrieval applications have encouraged explosive demand for moderate bandwidth uses, and higher bandwidth applications such as audio and video multicast can strain even the highest-capacity international connections. Also, new applications involving distributed high performance computing, remote visualization and imaging, and multimedia transport, together with the growth in aggregate traffic, make the provision of increasingly high performance network services necessary.

It is important to appreciate, therefore, that the U.S. (and other countries') R&E communities will account for a smaller and smaller fraction of an ever-growing pie, though the size of their own pieces continues to grow. The NSFNET Program will increasingly rely upon a networking infrastructure provided by interconnected network service organizations operating in a competitive environment. This suggests an implementation strategy that embeds services for the U.S. R&E communities as much as possible in the context of a general purpose global Internet infrastructure. For that reason, NSF's forthcoming IIS solicitation is likely to focus on *services* rather than on *circuits,* and it will encourage solutions that are consistent with building general purpose global infrastructure. It is also NSF's intent to have transitioned "commodity" international Internet services that are amenable to general purpose provisioning away from NSF-support by the end of the next several years.

3 Summary of IIS Needs

IIS will be needed for **production quality connectivity at 34 Mbps** and higher link capacities between NSF Network Access Points (NAPs) and other major U.S. Internet exchange points and similar Internet access points abroad (initially, to Europe). NSF would consider funding of the U.S. portion of the IIS attributable to the R&E community for a period of approximately two years, roughly consistent with the phase out of NSF support to regional Internet service providers for national transit services. After the initial two years, it would be expected that costs would be recovered by the IIS service providers from the user base.

International Internet Connectivity Services (IICS) Management will also be needed to facilitate the lower capacity (T1/E1 and below) connectivity of R&E communities in other countries to the Internet infrastructure in support of the international collaboration needs of the U.S. R&E communities. When such connectivity is requested to the U.S. infrastructure, needed services will include, *inter alia,* connection, transport and registration assistance for connecting to NSF Network Access Points (NAPs) and other major domestic Internet exchange points.

In addition to production-quality services, NSF will be interested in cooperative demonstration and/or experimental projects for **supporting advanced applications over broadband (155 Mbps and higher)** interconnections with high speed networks serving the R&E communities in other countries. Co-participation of the service provider(s) and the Internet community in refining the technology will be of paramount importance.

Similarly, NSF will also be interested in demonstration projects and/or experimental services based on **emerging technologies for extending Internet services to remote and/or mobile platform users** (for example: rain forests and oceanographic research vessels). Co-participation of the service provider(s) and the

Internet community in refining the technology will once again be of prime importance.

In all of the above areas, the formation of international consortia would be encouraged to facilitate coordination among diverse communities.

In order to derive the overall benefits of competition and to obtain comprehensive access to new technologies, NSF contemplates making multiple awards where it makes sense to do so.

4 Service Considerations

4.1 General

Past experience with both the NSFNET and ICM programs has shown over and over again that, in addition to technical competence and adequate facilities, the most important requirement for successful performance is flexibility and a spirit of goodwill and partnership on the part of both NSF and its awardees. This is in no small part a consequence of the dynamic and often unpredictable nature of the Internet.

4.1.1 Connect to NSF-sponsored NAPs:

All NSF awardees would be expected to serve the international connectvity needs of the U.S. research and education community by routing and carrying, directly or indirectly (by contract), all traffic (for which they provide routes) to and from the U.S. research and education networks *via* the NSF-designated Network Access Points (NAPs). Also, *via* other major Internet exchange points in the U.S. and abroad as are needed to provide full-scale connectivity. Moreover, awardees would be expected to make their routes for all such international networks/sites available to the Routing Arbiter.

4.1.2 Joint Use

If services were to be provided as part of a general purpose Internet infrastructure, measures should be taken to ensure that the R&E community would be provided with at least the fair share of capacity, priority and reliability subscribed by NSF and on terms at least as favorable as those received by any other customer of the service provider.

4.1.3 Routing, Addressing and Scheduling

Service provision should be consistent with national and global routing, addressing (and scheduling/resource reservation) architectures supported now or during the term of performance. This would include, *inter alia,* connectivity and reachability (at specified service levels) to networks attached to and reachable through NSF-supported Network Access Points (NAPs), and it may include other Internet exchange points of interest to NSF. It also would include transitioning to new Internet addressing and routing protocols (i.e., IPng).

4.1.4 Security and privacy

Awardees would be expected to participate (including participation within the Internet community) in the development and adoption of security and privacy capabilities for their services.

4.1.5 Public Information Dissemination

NSF would also encourage open dissemination of current status information by means such as:

<u>Public World Wide Web Page(s)</u> containing project descriptions and pointers to relevant information such as milestones, operational information such as outages (including trouble tickets), general performance parameters (such as circuit utilization "strip charts," circuit availability, scheduled down times), and contact information for key people and/or functions (e.g., Network Information/ Operations Centers)

<u>E-Mail lists</u> for disseminating operational status notifications

<u>Other means such as newsletters</u>.

Author Information

Steve Goldstein[2] is the NSF Program Director for International Networking. He has managed the development of international connectivity on behalf of the U.S. R&E communities for the last six years, during which time scores of countries have connected to the "International Connections Management for NSFNET" (ICM) infrastructure, and transatlantic bandwidths have grown from 64 kbps to (really soon, now) 34 Mbps.

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