China's Next Generation Internet: The Adoption of IPv6

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Abstract

China is taking a leadership role in driving the adoption of Internet Protocol version 6 (IPv6). Eight Chinese government organizations have joined together in an Expert Committee to oversee the construction and trial of China's Next Generation Internet (CNGI). In 2006, the CNGI will connect 100 universities, 100 research institutes, and 100 enterprises using the IPv6 protocol. The education network, CERNET, has upgraded its backbone to IPv6. CERNET2 is one of the largest "production" IPv6 networks in the world and is being used to develop new standards for how best to integrate IPv4 networks into IPv6 ones. One benefit of IPv6 is that it has an authentication mechanism that eliminates address spoofing and makes for a more "trusted" network. The greatly increased address space of IPv6 makes possible the construction of a data grid that integrates the vast amount of data available through remote and micro sensors along with mobile devices and makes possible a wide variety of applications. Perhaps the most important of these is the development of a virtual world that will allow us to monitor and manage the global environment.

Introduction

There is a growing debate in the world as to whether there is a pressing need to convert the Internet to the next generation of Internet protocols, particularly IPv6. Some engineers believe that the world is running out of IPv4 addresses, a problem heightened by the inclusion of many more remote devices on the Internet requiring individual IP addresses. Also, a large number of IP addresses need to be utilized to develop a real-time virtual model of the world or what is called a Global Information Grid (GIG).

China has played a role in the world Internet community in developing IPv6 supporting technology and may be one of the first countries in the world to migrate its operational networks to IPv6. One of the major reasons that the PRC government is making this investment is that it believes that if China is a leader in implementing IPv6 technology, then domestic manufacturers will be able to leverage this expertise in order to expand their niche in the global telecommunications market.[2]

Even as significant resources by various government ministries and corporations that are dedicated to this effort, there is some concern in China as to whether IPv6 will ever become a commercial success.

Beginning around 1998, a consensus emerged among some of China's engineers and government officials to set the goal of migrating China's networks to IPv6 in order to provide a significant number of users in China with their own IP address. They realized that China, with its population of 1.4 billion people was not going to be delegated enough IPv4 addresses to reach this goal.

The IPv6 protocol was developed by the Internet Engineering Task Force in the mid 1990s to rectify some of the problems associated with IPv4. Though IPv4 supports 4,294,967,296 potential addresses, the reality is that only a few hundred million can actually be used. The IPv6 protocol supports 16 bytes (128 bits) of address space, enough to assign a multitude of addresses to each person on earth.

One of the reasons that IPv6 has not been deployed is that many of the benefits of IPv6 will only be realized if the devices a computer is communicating with also utilizes IPv6. In fact, a computer running only IPv6 can interconnect only with computers running IPv6., creating a chicken and the egg dilemma. The upgrade path becomes difficult when some of the world's ISPs are using IPv6 and the rest are using IPv4. Many American networks had been allocated enough IP addresses to last them for as long as they could possibly need them. For US based ISPs, the short-tem business needs for delaying IPv6 deployment outweighs immediate implementation.

[2] The US government is also driving IPv6 adoption in the belief that it is essential to the competitive position of the US telecommunication industry. David Power of GAO has said "if we allow others to develop IPv6 before us, they'll be the ones to develop the killer application." (Albanesius, 2005)

MCI (the former Worldcom) provides a significant part of the Internet's core routing. The dire financial straits of the company have seriously reduced MCI's political will to lead the world's migration to IPv6.

China, on the other hand, is developing the political will to implement IPv6. Through much maneuvering, many of China's leading institutions have spent a great deal of time developing China's plan for Next Generation Internet (CNGI). Because China's backbone networks are distinct and are implementing IPv6 differently, the CNGI moniker covers the whole national IPv6 conversion process.

This national process is supported at the highest levels of the Chinese government including the Chinese State Council, the executive head of the government. CNGI has become a national priority for the National Reform and Development Commission (NRDC), the government organ responsible for coordinating state planned development efforts. Reporting to the NRDC is an expert committee that represents the government departments with a stake in IPv6 deployment.

The Chinese Education and Research Network, CERNET, has been a technical leader in his process with the backing of its patron the Ministry of Education. The Chinese Academy of Science, which does not report to the Ministry of Education, started computer networking in China. The Chinese Academy of Engineering (CAE) while marginalized in the development of the Internet in China, has found new prominence as a leader of the CNGI initiative.

The Ministry of Information Industries (MII) oversees five national telecom backbones: China Telecom, China Netcom, China Unicom, China Mobile, and China Railcom. Under the CNGI plan each of these networks is implementing its own IPv6 strategy and interconnecting with the other networks on both a peer to peer basis and at two Internet Exchanges (IX), one in Beijing and the other in Shanghai.

By the first half of 2006, the goal of China's Next Generation Internet project is to have 100 universities, 100 research institutes and 100 enterprises utilizing the IPv6 protocol. It is not clear to some of these organizations whether they will be doing anything that they could not do based on the IPv4 protocol. There is concern that there are no applications that will drive the use of IPv6 beyond the trial stage.

CERNET2 in 2006 has implemented native IPv6 as its backbone network protocol and is using this "production" backbone to support all of its applications. The CSTNet/Netcom backbone is supposed to be completed in 2006. China Telecom is deploying CN2, its IPv4/IPv6 dual stack network between 2006 and 2008. The other backbone networks are implementing trial IPv6 networks. Depending on the results of these trials and consumer demand, these providers will upgrade their networks to the IPv6 protocol.

The Internet content providers in China such as the portals Sina and Sohu have not made any commitments to support access to their sites using IPv6. These portals are independent of the government, though licensed by it, and have not up to this point seen any economic advantage in making the investment necessary to support IPv6.

The Chinese government is committing significant time, money, and effort to the CNGI initiative. There is a risk that this investment will be in vain, but it is possible that the CNGI platform will trigger the development of new innovations that will help China take more of a worldwide leadership role.

Is IPv6 needed?

There has been significant debate for more than 10 years about how quickly IPv6 addresses will run out and whether China will get all the network addresses it needs. The press often runs stories such as one in *China Da*ily titled "IP Address Supply Facing Crunch," where the author asks:

> What do China, Stanford University, Massachusetts Institute of Technology and Princeton University have in common?
>
> Answer: China and the three US universities have roughly the same number of Internet protocol (IP) addresses, a globally unique number identifying each machine on the Internet.
>
> According to statistics from the China Internet Network Information Center (CINIC), by the end of 2004, China had 94 million Internet users and 41.6 million computers connected to the Internet.
>
> Demand for access is fast increasing and the shortage of IP addresses has become a problem for the country.
>
> But help might be at hand with a new generation of IP addresses called IPv6…
>
> Despite an increase in the number of IP addresses of China, the United States, Japan, Germany, the United Kingdom, and the Netherlands got 48% of them and the addresses that China registered were only one-eighth of those of the United States and one-sixth of those of Japan (Baijia, 2005).

Chinese engineers are taking the predictions of a dire shortage of IPv4 addresses with a grain of salt. They point to the website of APNIC, the Asia Pacific Network Information Center, where there are a number of position papers that argue that there will be enough IPv4 space on the Internet for at least the next 15 years (APNIC, 2006).

One reason for this optimism is the popularity of NATs (Network Address Tables). NATs have significantly dampened the demand for IPv4 addresses. A NAT routes all traffic for the network it supports through one publicly visible static IP address. All the addresses for the computers behind the NAT can not be seen by the rest of the Internet. In addition to reducing the number of IP addresses that are needed, NATs also contribute to network security by hiding an organization's computer addresses.

One of the main reasons cited for the need for more IPv6 addresses is that IPv6 supports both end to end computing and provides an alternative to dynamic routing. In dynamic routing, IP addresses are assigned when they are needed. With static routing, each device has its own permanent IP address. Clearly, dynamic routing needs to draw from a smaller pool of IP address than does static routing. There is a lot of discussion in the Internet community as to the importance of static IPv6 routing to enable new applications such as those built on 3rd Generation (3G) and 4th Generation (4G) Mobile. Up to now, no such applications have emerged and mobile networks have been able to support all sorts of remote devices without IPv6.

One of the most important features of IPv6 is its mandatory support for IPSec, the Internet security protocol. Though this is a good reason to use IPSec, IPSec has been written in a way that even IPv4 can utilize it, though on an as needed basis. More importantly, by supporting end to end connectivity, IPv6 makes it possible to track the IP address of sources of traffic. This feature makes it possible to eliminate IP-spoofing attacks, simplifies identity authentications, simplifies network administration and IP address-based network accounting and billing.

Another reason that IPv6 is touted is its ability to auto configure itself and connect automatically to a network, taking a load off administrators. This is particularly valuable when a device is continually moving between networks.

Finally, IPv6 also makes for a more robust network by simplifying routing. It cuts down on the number of routes that a router must keep track of and reduces the chance of route flapping, a dangerous condition that can result In Internet outages.

IPv6 is a more robust protocol than IPv4, though the reasons for upgrading are not completely compelling.

Drivers of China’s Next Generation Internet

If the case for IPv6 is not compelling, why has China decided to take the risk?

China has had the political will at the highest level to drive the diffusion and evolution of the Internet. In January of 1996, the Chinese State Council embraced the Internet as key to the economic development in China though it chose to channel all international Internet traffic through four backbone networks.

The seeds for this choice go back to the late 1980s with discussions among Chinese engineers and intellectuals about the possibility of leapfrogging the West in terms of information technology. China, they recognized, was 100 years behind the West in industrialization, but it had the opportunity to jump ahead in terms of the informatization of society (Foster and Goodman, 2001).

By taking a leadership role in IPv6 research and implementation, the Chinese government hopes to create an environment where Chinese manufacturers can leverage this research to develop and sell next generation Internet products.

> “IPv6 is the hope of China’s IT (information technology) industry,” said Wu Hequan, Vice President of the Chinese Academy of Engineering…”The emergence of IPv6 has offered a chance not to be missed” for China to close the technological and and even take a leading role in the NGI era, as China is able to initiate the R&D of IPv6 almost at the same time as developed countries,” he explained (Boru, 2004)

In order to support the development of a domestic router industry, the National Development and Reform Commission (NDRC) has required half of the routers on CNGI networks to come from Chinese companies. The NDRC earmarked 50 million Yuan (US$6.02 million) in 2004 to domestic IPv6 router manufacturers for R&D (People’s Daily Online, September 9, 2004).

Huawei has been very involved in IPv6 research in China. It is extending its line of IPv6 compatible routers and has been picked to supply routers to China Netcom’s Next Generation Internet and to the northern portion of China Telecom’s CN2.

Tsinghua University has developed their own router company, Bitway Networks, based on its research on CERNET2. Bitway’s core router, the Bitway 12416 achieves speeds of 320 billions bits per second. In addition to a core router, Bitway produces a range of edge routers. Bitway routers are used throughout the CNGI, which includes network infrastructure being implemented by China Telecom, China Mobile and China Netcom, as well as CERNET2 (Parthajit, 2006).

Most of the domestically produced routers support dual stack technology where IPv4 and IPv6 can be supported concurrently easing the transition between IPv4 and IPv6. They also support native IPv6 networks.

One of the obstacles that the CNGI faces is the lack of mobile handsets that support IPv6, a very big opportunity for Chinese manufacturer’s to get in at the ground floor.

Organizational Support for IPv6 Networking in China

IPv6 Expert Committee

The governmental Expert Committee responsible for coordinating China's Next Generation Internet (CNGI) project is made up of representatives from:

- National Development and Reform Commission (NDRC)
- Chinese Academy of Engineering (CAE)
- Ministry of Science and Technology (MOST)
- Ministry of Education
- Ministry of Information Industries (MII)
- Informatization Office of the State Council
- Chinese Academy of Science (CAS)
- Natural Science Foundation Commission

The formation of the Expert Committee in 2004 for CNGI reflects the fact that in China no one ministry has overall responsibility for the Internet or has the clout to implement a nationwide initiative with regards to IPv6.

Back in the 1990s, a Leading Group spanning various government stakeholders was established to negotiate the role of these stakeholders in regards to the Internet specifically and telecommunications in general. It was this Leading Group that decided which Ministries could operate their own Internet backbones (Foster and Goodman, 2001).

One of the major decisions of this Leading Group was to allow both the Ministry of Education (MOE) and the Chinese Academy of Science (CAS) to have one of the four interconnecting backbone networks in China. Neither CAS nor MOE had control over the other in the Internet space.

In addition, power over the commercial Internet was split up between the Ministry of Electronics which was responsible for the China Golden Bridge Network and the Ministry of Post and Telecommunications (MPT) which was responsible for ChinaNet.

When the Ministry of Information Industries (MII) was created in 1998 by the merger of the Ministry of Post and Telecommunications and the Ministry of Electronics, many expected this new ministry to have primary control over the telecommunications industry.

The fact that the Ministry of Science and Technology (MOST) was not integrated into MII has created a situation where MII and MOST compete to set and develop standards for the information industries.

Also, the State Administration for Radio, Film and Television (SARFT), which was responsible for cable networks, was not brought under MII's control, creating a great deal of conflict over control of the convergence of the Internet and cable.

Because of conflict between various ministries, many of the decisions about the Internet were pushed up to the PRC State Council. The State Council set up its own Informatization Office which provided staff to support the State Council's role in the decision-making process.

In a way very typical of the Chinese, government departments involved with the Internet are continually competing with each other and forming alliances to maintain their own turf. In addition, various government departments can not risk being left out of the CNGI initiative in the event that IPv6 is adopted and "killer" applications are developed.[3]

National Development and Reform Commission (NDRC)[4]

It is very significant that the CNGI has become a national priority to be overseen by the NDRC. This reflects the fact that some of the members of the State Council, many of whom are engineers by training, were convinced of the strategic advantage of implementing IPv6. The CNGI has become part of the 863 program that sets national priorities for technological development in the tenth Five Year Plan.

The NDRC has funneled financial resources to the CNGI project. It has allocated 1 billion Yuan (US$ 124 million) to building the CNGI infrastructure, half of which went to CERNET. It also used its leadership role to convince the other backbone networks to invest over 40 million Yuan (US$ 5 million) in CNGI. As noted earlier, one of the priorities for NDRC is the development of the high speed router industry in China and it has directly allocated funds for research and development (R&D) in this field.

Wu Hao, Vice Division Chief of the High-Tech Bureau of NDRC, represents the NDRC on the CGNI Expert Committee.

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[3] A "killer" application is one that is so compelling people are driven to upgrade to the new technology that makes it possible. The application "kills" the old technology.

[4] The NDRC is also known as the State Development and Planning Commission.

Informatization Office of the State Council

As noted earlier, the Informatization Office is made up of the staff of the State Council. Informatization, as noted earlier, is the term used in China for the transformation of society in the information era, much as the term industrialization is used to describe the proceeding era. The Informatization Office oversees a wide range of activities. Nevertheless, given the priority that the State Council places on CNGI, CNGI has remained a high priority for the Office.

Chinese Academy of Engineering

The Chinese Academy of Engineering (CAE) is in charge of the CNGI effort. In particular, CAE will be conducting the interoperability testing between the networks. The Chair of the CNGI Expert Committee is Wu Hequan, Vice President of the Chinese Academy of Engineering.

Ministry of Science and Technology (MOST)

The CNGI has proven to be a good project for MOST with its emphasis on standards creation. Wang Baily, Director of High Tech Development Center at MOST has taken a leadership role in the development of China's router industry by supporting routing R&D. MOST has a strong relationship with NDRC and plays a key role in the implementation of the 863 projects.

Ministry of Information Industries (MII)

MII has oversight responsibility for the commercial Internet backbones: China Netcom, China Telecom, China Mobile, China Unicom, and China Railcom. There are a number of research centers associated with MII, such as the Beijing University of Post and Telecommunications (BUPT) that have conducted IPv6 research. MII is however somewhat cautious about the economic impact of IPv6 and is much more focused on the deployment of 3rd generation mobile.

Ministry of Education

Providing China's university students with access to high speed Internet has been a top government priority. The decision of Ministry of Education and the State Council's decision to throw their weight and resources behind the Chinese Education and Research Network (CERNET) since 1994 has made CERNET one of the leaders of the Internet in China and the world.

The Ministry's decision to support CERNET2 has resulted in very significant research into the challenges of deploying IPv6 and have paved the way for CNGI.

The visionary behind CERNET is Dr. Wu Jianping Director of Tsinghua Network Center and Director of CERNET. Professor Wu works tirelessly to cultivate relationships with the PRC leadership, relationships that have resulted in CERNET's access to research and deployment funds. Dr. Wu has also played the key role in Tsinghua's development of high speed routers and the spinning off of the Bitway router company. Working closely with Professor Wu is Tsinghua Professor Dr. Xing Li. Dr. Li, who got his PhD from Drexel, started work with IPv6 in 1996 and has been the chief technologist behind CERNET2.

Chinese Academy of Science (CAS)

There have been two forces behind the Chinese Academy of Science's (CAS's) CNGI efforts. The Computer Technology Institution, led by Dr. Li Guojie, has led Chinese Academy of Science's IPv6 research efforts. The Chinese Network Information Center (CNNIC) has run the Chinese Science and Technology Network (CSTNet) which is being upgraded to support IPv6. CAS has a wide range of research objectives and is continually weighing its priorities. Its wide range of scientific projects provide a host of applications that can be run on CNGI such as:

- Grid computation
- Scientific data grid
- High energy physics
- Virtual observatory
- Remote sensing
- Micro-sensing
- Geoscience
- Web-based public science education
- E-science.

CAS has aligned with China Netcom to upgrade CSTNet to an IPv6 network that will support 100 research institutions by the end of 2006.

Natural Science Foundation Commission (NSFC)

The NSFC, by providing funding for researchers, plays a significant role in the development of CNGI and has a seat on the CNGI expert committee. NSFCNet was one of the first IPv6 networks in China.

Goals of China’s 8-Ministry Collaboration Project

According to The China’s IPv6 Council’s white paper on The *Deployment of IPv6 in China*, it is the responsibility of the Expert Committee to develop the goals for the China Next Generation Internet project (China IPv6 Council, 2006). Few projects in China have had support from 8 ministries at the national level. This is particularly true in the field of research projects in the telecommunications area.

Developing shared infrastructure requires mediating between the different stakeholders. The white paper claims that the Expert Committee will develop a strategy for implementing a National Engineering Center and a National Project Lab. The Expert Committee also has the responsibility of driving the establishment of IPv6 Internet Exchanges in Beijing and Shanghai and also ensuring bilateral peering between all 7 of the IPv6 networks. The Expert Committee has set up criteria for testing the interconnection of the networks and the applications that must be supported by CNGI.

The Expert committee recognizes that it must work closely with the commercial telecom operators: China Telecom, China Netcom, China Mobile, China Unicom, China Railways, and China Satcom. For IPv6 deployment to be a success, these operators will have to invest there own funds. Though each of the operators is predominately government owned and is guided by MII, they are partially responsible for making their own spending decisions and their own decisions on how to implement IPv6 into their networks.

China’s Networks

Chinese Education and Research Network (CERNET)

CERNET was established in 1994 under the authority of the Ministry of Education and with the approval of the State Planning Commission. It now supports 1,500 universities and approximately 20 million end users.

In August 2003, CERNET won a bid to undertake the largest next generation network backbone in China. In order to differentiate this new network from the existing IPv4 network, the IPv6 based network was named CERNET2.

By October 2003, CERNET2 was operational between Beijing, Shanghai and Guangzhou. In January of 2004, CERNET2, in conjunction with eight international IPv6 networks announced the opening of global IPv6 services. In March of 2004, CERNET2 was officially opened as a trial network and by December of 2004 was connecting universities in 20 cities with a 20 gigabit transmission rate.

Currently, CERNET2 connects 25 Points of Presence (Pops) distributed in 20 cities around China and provides high speed IPv6 services for more than 100 key research universities and institutions and interconnects with domestic and international networks.

CERNET has its own fiber between many of its larger universities and was able to implement different versions IPv4-IPv6 solutions on different wavelengths in their fiber optic networks. As a result, the financial cost of running co-existing solutions was minimized. Under the moniker, CERNET2, China’s universities have built a variety of implementations that facilitate the migration to IPv6. They have tested dual stack solutions where IPv6 and IPv4 are run concurrently as well as single stack IPv6 networks. CERNET2 has implemented IPv6 tunneling in IPv4 using tunnel brokers. One of the great advantages of IPv6 over IPv4 is that IPv6 provides much better aggregation and simplification of Internet routes. However, there have been certain challenges. CERNET2 has been able to test complex implementations of routing systems, including multihoming where networks are connected to multiple ISPs. Using CERNET2’s complex test bed, Tsinghua University developed its own advanced IPv6 router, Bitway Unisplendor. This router has written into its software expertise gained from CERNET2’s research, including expertise with routing IPv4 in native IPv6.

In the process of building CERNET II, the universities developed a wide variety of infrastructure including a tunnel broker, an IPv6 search engine and an IPv6 protocol tester.

Back as early as 1998, CERNET in conjunction with Nokia embarked on an ambitious research agenda with included implementations of mobile IPv6. Wherever a person is, with mobile IPv6, he has the ability to change remote devices and locations and have his connectivity automatically configured.

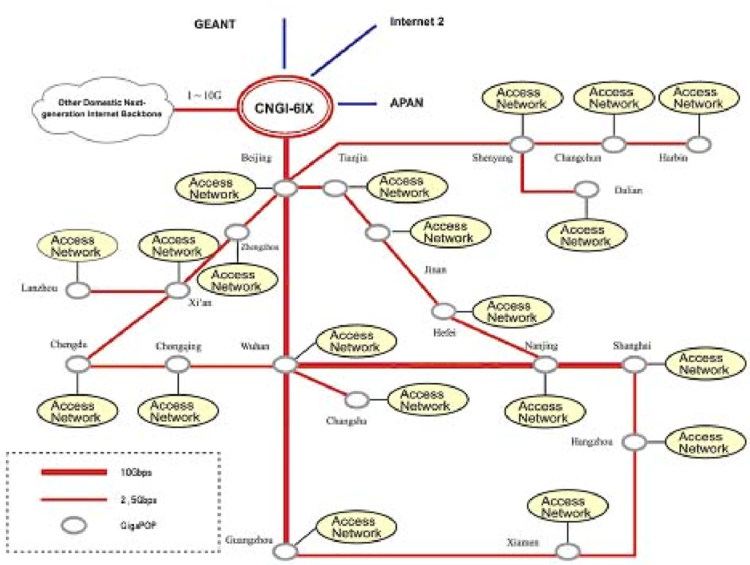
CERNET2 has been used as a test bed for large scale point to point video communications systems.

CERNET has committed to building a number of applications specifically on its IPv6 backbone including online education and a digital library for universities. High schools and primary schools will be included at a later stage in the project.

CERNET2 has also been a leader in China in terms of connecting with international IPv6 networks including the Chinese and Japanese IPv6 trial network (IPv6-CJ). CERNET2 also participated in the Second Generation of the Trans-European Information Network (TEIN2) project under the Sixth Framework Programme of the European Commission (FP6). It currently connects to Internet2 and APAN (the Japanese, Korean, and Chinese IPv6 network).

CERNET2 convinced the CNGI Expert Committee that it should run the Beijing Internet eXchange (IX) to connect the five other domestic IPv6 networks and provide them with international connectivity to other IPv6 networks (see Figure 1).

Figure 1: CERNET IX (2006)



China's Internet researchers have actively been involved in the running of the Asia Pacific Network Information Center (APNIC) which handles the allocation of IP addresses and which has provided fertile ground for planning the evolution of the Internet in the Asian Pacific Region. There has been a great deal of collaboration with

Japanese research institutions such as WIDE and there is an effort by China, Japan, and Korea to coordinate and tie together their IPv6 implementations.

Based on their research, China's scientists have become active participants in the IETF's (Internet Engineering Task Force). They have been involved in Forces, shim6, mip6 and have made presentations at mobopts and mipshop. In 2005, CERNET helped to establish the Softwires Working Group. This working group has focused on control and encapsulation methods for connecting IPv4 networks across native IPv6 in a way that will encourage multiple, inter-operable implementations. Currently, the Software Working Group is almost finished developing a problem statement for the Internet Engineering Steering Group (IESG) which is the preceding step to being considered as an informational Request for Comment (RFC). The next step will be to work on transition techniques and solutions.

CERNET also houses the Computer Network and Protocol Testing Lab. Some of its projects are listed in Table 1.

Table 1: Projects of Computer and Protocol Testing Lab (Projects, 2006)

[1] Internet Routing Protocols Tesing.
[2] Sub Project of "Theory of High Speed Information Networks and Application": "Technology of Protocol Testing of High Speed Information Networks", Jan, 2000 ~ Dec, 2002.
[3] "Integrated performance Test System IP-TEST", 2000.3 ~ 2001.4.
[4] "Core Router", 1999.8 - 2000.10.
[5] "High performance Security Router", Oct. 1998 - Dec. 2000.
[6] "Sub system of Conformance Testing System of Military Data Networks", Jan, 1998 ~ Dec, 1999.
[7] "High speed computer networks and protocol testing", 1997.12 ~ 2000.12.
[8] "muti-protocol test system", Sep, 1996 ~ Sep, 1998
[9] Sub subject of "Research of Computer Networks and the key technology" :

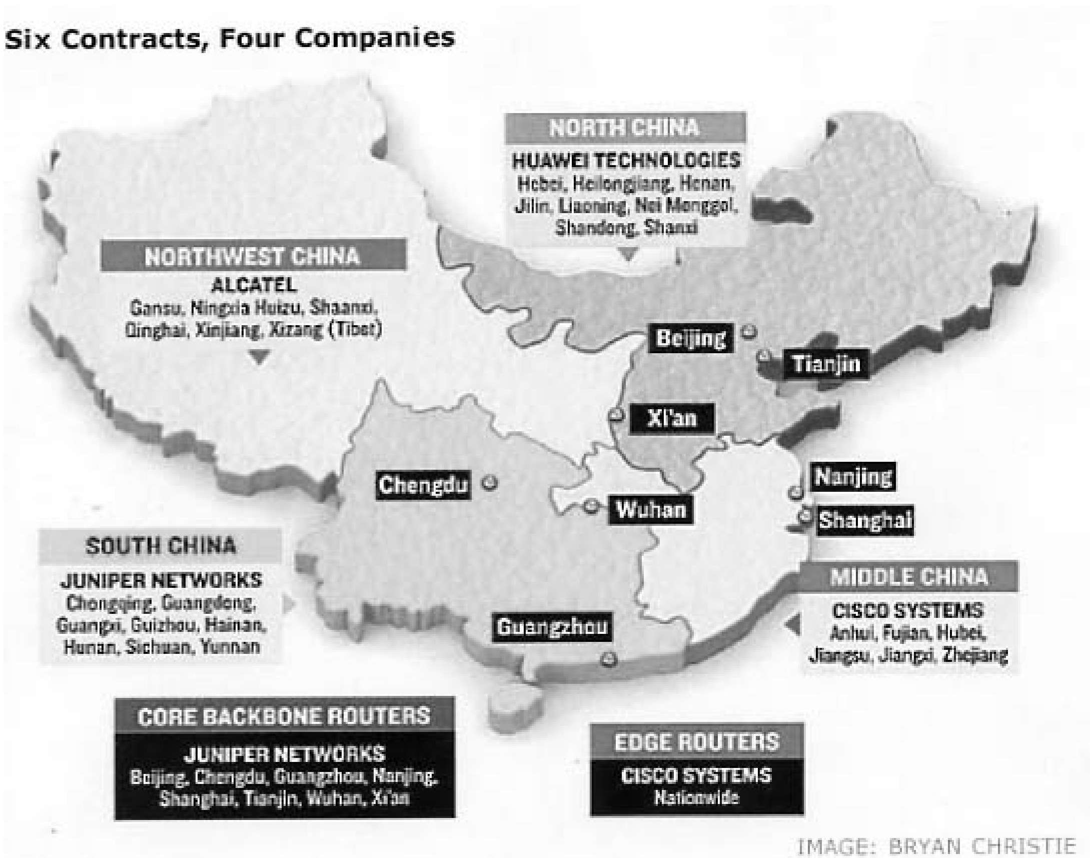
[10] "Research of Integrated Testing Environment of Communicate Protocol in High Speed Networks Based on Formal Technique", Jan 1997 ~ Dec, 1999.
[11] "Research of the theory of network protocol testing in of next generation", Jan, 1995 ~Feb, 1997.
[12] "Security Router", 1996－1998.
[13] Sub subject of "Software of Network Homemade", it passed the assessment in 1995.
[14] "Research of Protocol Conformance Testing System and Environment", 1991-1995.
[15] "Conformance Testing System of Military Data Networks", 1991-1995.
[16] "Computer Exchange System of Beijing Commodity Exchange" , July, 1993 ~ Dec,1994.
[17] "Packet switched Advanced network processor HNP"

China Telecom (CN2)

China Telecom has had a number of IPv6 trial projects and is now building ChinaNet Next Carrying Network (CN2), its sixth generation IP backbone. The network will operate at 10 Gbps per second and can be upgraded to 40 Gbps in the future. CN2 will be based on Multiprotocol Layer Switching (MPLS) which will concurrently support IPv4 and IPv6. CN2 will provide all 236 cities in China's 31 provinces, autonomous regions, and municipalities with IPv4 and IPv6 services.

China Telecom has invested 1 billion RMB (US$ 125 million) in CN2. The core routers for CN2 are from Juniper, with edge routers from Cisco and Metropolitan Area Networks (MANs) from Huawei, Cisco, and Juniper (see Figure 2). China Telecom, as a commercial service, realizes that its major challenge is to develop application services that make its expensive investment in its CN2 sustainable.

Figure 2: CN2 Equipment Providers (Cherry, 2005)



CN2 is China Telecom's contribution to CNGI, but it is clear that the majority of traffic on CN2 for the foreseeable future will be based on IPv4. CN2 is China Telecom's attempt to move its traffic off the old Public Switched Telephone Network (PSTN) and onto an IP based network. Using Huawei softswitches, CN2 will support Voice over IP (VoIP):

> "China Telecom has been very systematic in its testing of the equipment, but softswitch technology has been mature for around two years," says Guo Haiwei, vice president of Huawei. "Of course, the significance of NGN (of which softswitch is just a part) does not simply lie in PSTN replacement. It is a converged platform that can enable carriers to move forward with new services (cost effectively) while simultaneously supporting legacy services." (Wieland, 2005)

CN2 is also engineered to support IP TV, high quality VoIP, video streaming and 3G applications. One feature of CN2 is support for Universal Personal Telephones (UPTs) where customers have one unique number for their office, phone, and home devices—so when called, all devices ring simultaneously or sequentially according to customer's preferences. CN2 will support eight classes of service with VoIP given top priority (Wieland, 2005).

China Netcom

In 2001, China, in an effort to force competition, divided its landline providers into two competing government-owned entities: China NetCom, the northern province based provider, and China Telecom, the southern province-based provider. Each landline provider was authorized to compete in each other's territory and has made its own set of alliances. Further complicating matters, certain infrastructure is jointly owned and shared.

In addition to its Chongqing IPv6 WAN developed with the Chinese Academy of Science, China Netcom implemented an IPv6 trial in Hunan Province. It also worked with the Beijing Internet Institute (BII) to develop 6TNet, a complex test bed that showcased many IPv6 services (see Figures 5). In 2005, it started, along with the Chinese Academy of Science, the implementation of their portion of the China Next Generation Internet. Hunwei NE5000E, NE80E, and NE40 routers are being used.

China Netcom and Olympics

The Chinese see the Beijing Olympics of 2008 as a great opportunity to demonstrate their position as a world leader in information technology. They want to provide the media covering the Internet with a robust IP backbone, partially based on IPv6, that will support high bandwidth connectivity to the rest of the world. It is believed that this platform will have higher bandwidth, lower latency, and be more economical than competing technologies such as dedicated satellite links. In addition, using Internet technology, remote viewers will be given access to the games in ways never before seen.

China Science and Technology Network (CSTNet)

The Chinese Academy of Science's network is called China Science and Technology Network (CSTNet). CSTNet connects the research institutions in China. CAS has committed to the CNGI Expert Group to connect 100 research institutions with IPv6 by the end of 2006. In order to implement this CAS, has partnered with China Netcom to implement their portion of the CNGI.

China Unicom and China Mobile

China's two mobile telecommunication providers are building IPv6 networks for the CNGI trials. Many observers believe that it will be mobile IP that will pave the way for new innovations and that China Unicom and China Mobile will benefit the most from China's adoption of IPv6.

China Railcom (Tietong)

China Railcom is a telecommunications company based on the communications network that the railways setup on their right of ways. China Railcom is participating in the CNGI evaluation.

China Satcom

China Satcom is a government owned corporation set up to provide services based on China's satellite infrastructure. It does not seem that China Satcom is participating in the CNGI trials, a fact that may be due to China Satcom's commercial immaturity.

Municipalities

A number of local governments have committed to digital projects that are linked to IPv6. Beijing has made the biggest commitment including 80 million RMB (US$ 10 million) for the digital Beijing project of which 24 million RMB (US$ 3 million) is earmarked for IPv6 projects. In addition, 50 million RMB (US$6 million) will be spent on IPv6 projects associated with Digital Z-Park.

As noted earlier, China Netcom is working with the Beijing government in implementing an advanced telecommunications infrastructure, including IPv6, for the 2008 Olympics.

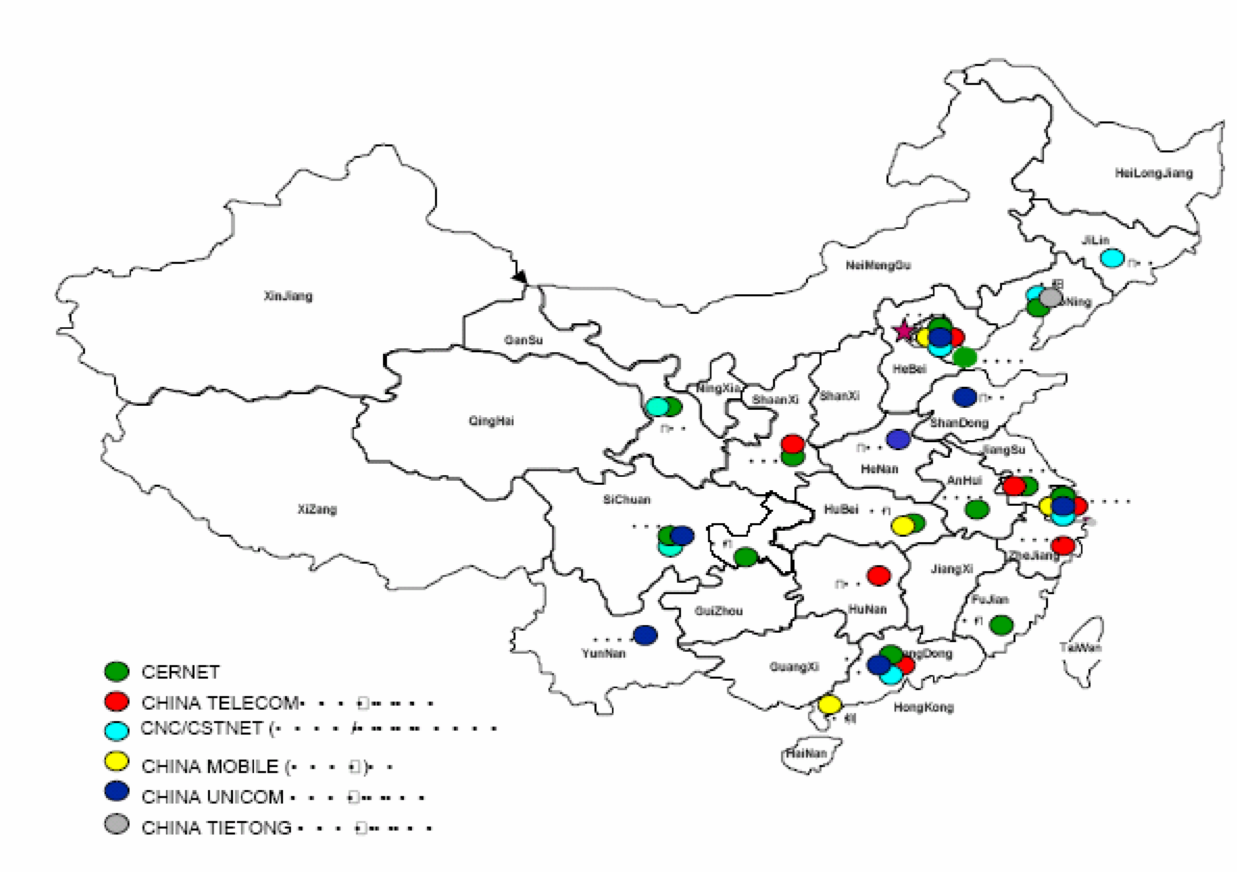
Beijing Internet Institute (BII)

BII has played a critical role in bringing different players--both telecom manufacturers and network providers—together. It has been responsible along with China Netcom for the 6TNet and has developed a number of shownets. BII also puts on events such as the Global IPv6 Summits that have been held in Beijing.

The CNGI Trial

The CNGI trial involves gigaPOPs in 20 cities (see Figure 3).

Figure 3: CNGI GigaPOPs in 20 Cities (Hulian Qian, 2005)



The networks are connected to the Beijing Internet eXchanges (IXs) in Beijing and will be connected to the Shanghai IX in 2006. There will be bilateral peering between the networks as well.

CERNET was accepted by the Expert Committee as the organization to run the Beijing IX. International connectivity to international IPv6 backbones Internet2 and APAN (the Chinese, Japanese, and Korean network) is available through the Beijing CNGI IX.

The Expert Committee has made it clear that the networks to be tested need to support IPv6 at the edges (Table 2), but is not required to be based on native IPv6. Issues of inter-network security and Quality of Service (QofS) will be investigated in the IX trial. In particular, there is a requirement that the networks be able to support Virtual Private Networking (VPN) and IP Security (IPSec) between IPv4 and IPv6 networks. The IPv6 IX testing will also cover the feasibility of content filtering through the use of Access

Control Lists (ACLs). It is interesting to note that ACL is required both on IPv4 over IPv6 networks and IPv6 on IPv4 networks, as well as native IPv6 networks.

Finally the CNGI IXs will provide an Internet broker that will allow IPv6 that is tunneled inside of an IPv4 network to access the IPv6 exchange. The CNGI IXs will co-exist with the IPv4 IX in Beijing.

The Chinese Academy of Engineering published on its website published these specifications for the CNGI trial (see Tables 2 and 3).

.Table 2: requirements for the network equipment (CAE, 2006)

1	The CNGI Exchange should be based on the IPv6 protocol but should also be completely compatible with the existing network.
2	At the edges, the nodes should support IPv6 and the edge routers should support IPv6 dynamic routing.
3	The IPv6 safe gateway platform should be based on IPsec and should maintain IPSec when tunneling from IPv4 to IPv6.
4	Secure Socket Layer (SSL) Virtual Private Network (VPN) Application Agent should support the SSL/VPN protocol for moving from IPv4 to IPv6.
5	In IPv6 and Point to Point (P2P) based network phone gateway equipment, the terminal should be IPv4/IPv6 compliant.
6	The information terminal equipment should support IPv6 tunneling transmission and support Network Address Translator (NAT) transversing of IPv4.
7	The TV top box terminal should support IPv6/IPv4 double stacks.
8	The network analysis and warning system should support IPv4/IPv6 double stack technology to satisfy the needs of the transition period.
9	The data acquisition and high performance in-time processor should provide IPv6 Access Control List (ACL) filtering and provide ACL filtering of IPv6 over IPv4 and IPv4 over IPv6.
10	Both the network layer and transmission layer should support IPv4 and IPv6 protocol processing.

Table 3: The testing and application demonstration equipment

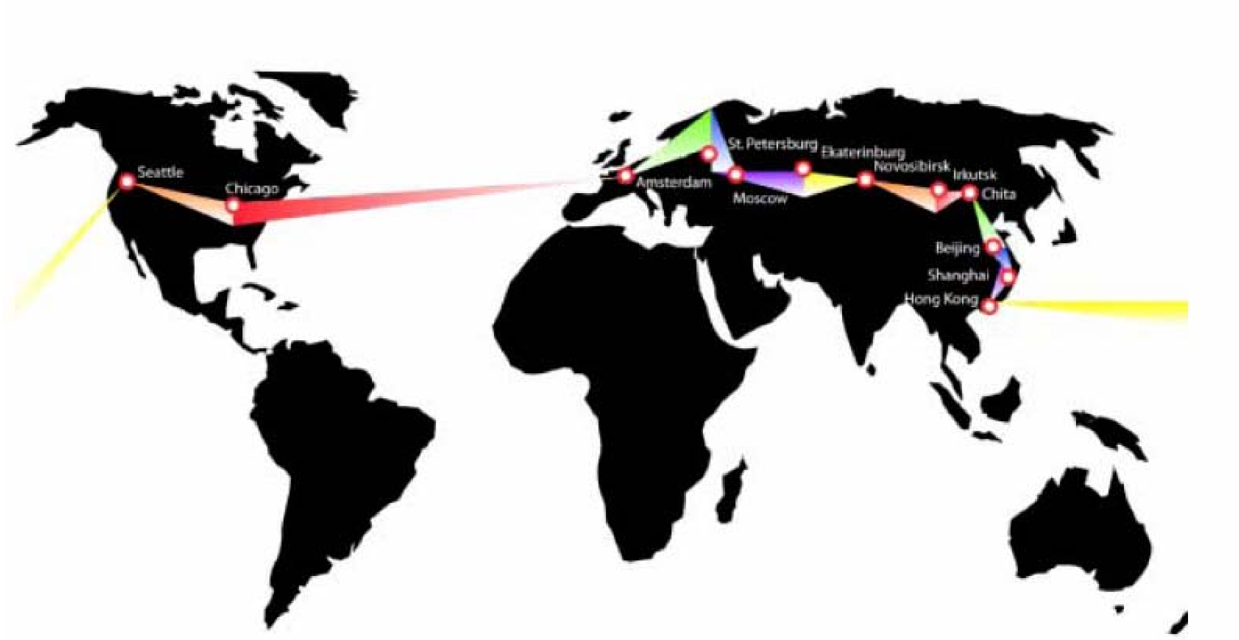
1	The wireless broadband communication system and application demonstration system should support IPv4 and IPv6 and WiFi/WiMA wireless multimedia terminal access.
2	The service demonstration equipment synchronizing Internet and mobile telecommunications should support access by a IPv6/IPv4 dual stack user terminal.
3	The video monitoring service should support IPv4/IPv6 double protocol stack.
4	The CNGI network TV testing and application system should address the problems of delay and trebling associated with network video transmission using IPv4.

International Connectivity

There have been many implementations of IPv6 connectivity between China's backbone networks and the outside world. The first international IPv6 connection was between CERNET and the 6Bone. The 6Bone was very much a test network and has since been discontinued. As mentioned earlier, CERNET2 has been a leader in China in terms of connecting with international IPv6 networks including the Chinese and Japanese IPv6 trial network (IPv6-CJ). CERNET2 also participated in the Second Generation of the Trans-European Information Network (TEIN2) project under the Sixth Framework Programme of the European Commission (FP6). It currently connects through its IX to the U.S.'s Internet2 and APAN (the China, Korea, and Japan network). Of course, CERNET2 also had multiple connections to the IPv4 Internet through CERNET's connections through Sprint, Merit, and UUNet.

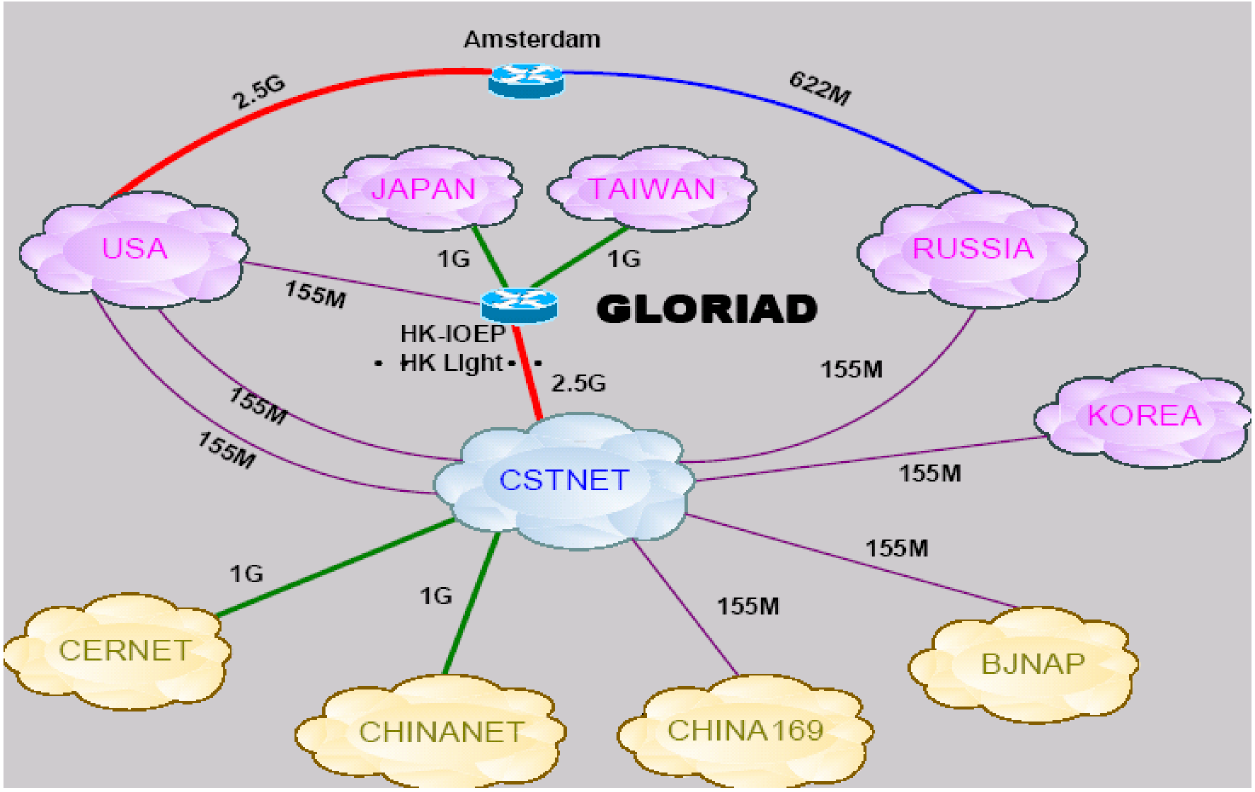
China Netcom and the Chinese Academy of Science's Congqing IPv6 trial Metropolitan Area Network (MAN) also connected to the now discontinued 6Bone. The China Telecom IPv5 Trial Wide Area Network (WAN) had a connection to the IPv4 Internet. The CN2 Network also has connectivity to the IPv4 network as well as to Internet2 and APAN through the CERNET operated IX in Beijing. Beijing Internet Institute's (BII) 6TNet connected to the 6Bone as well as the China R&D Center of French Telecom which connected to French Telecom's home network. CSTNet participates in the China-Russia-USA Joint Project Grid (GLORIAD) (see Figure 4).

Figure 4: GLORIAD: China-USA-Russia Science and Education Network (Hulian Qian, 2005)



CSTNet accessed GLORIAD through HKLight, a project that integrated it with Hong Kong and Korea (see Figure 5).

Figure 5: HK Light (Hulian Qian, 2005)



China is currently participating in the Moon6, the global effort led by the North American IPv6 Task Force in conjunction with the University of New Hampshire-InterOperabilty Lab, Internet2, venders, service providers, and regional IPv6 Task Force networks. The Moon6 is the largest permanently deployed multi-vendor IPv6 network in the world (Moon6, 2006).

China is very interested in participating in other Next Generation Internet efforts such as FIRST and GENI which explore network protocols beyond IPv6.

Conclusion

The moniker China's Next Generation Internet (CNGI) covers a wide range of projects from CERNET's implementation of native IPv6 in its backbone to China Telecom's CN2 which is primarily an attempt to move their PSTN network to IP based services. Next Generation Internet can also be applied to the adoption of protocols more advanced that IPv6.

The Chinese government is risking a significant amount of time and energy to push the adoption of IPv6. CERNET, which has been actively involved in IPv6 research from 1998, is the initiator along with CAS of this effort. CERNET's implementation of native IPv6 as the backbone of its network linking 100 universities demonstrates CERNET's commitment to finding a way to move IPv6 from the research lab into being the mainstay of a production network. In CERNET2's implementation of IPv6, CERNET's IPv4 traffic, which still makes up the majority of traffic, is tunneled through CERNET2's IPv6 network. Most other implementations of IPv6, both in China and abroad, utilize a "dual stack" implementation of IPv6 where applications using IPv6 are run concurrently both at the workstation and router nodes of the network.

Other Chinese government organizations have followed CERNET and CAS's lead and have jumped on the IPv6 bandwagon in order to be both an instigator and beneficiary of a potential sea change in networking.

At CERNET and at the other networks, there is a realization that there are very few applications that are available today which require IPv6 support. In fact, CERNET2's use of IPv6 as its backbone network protocol is one of the few practical applications of the IPv6 protocol.

At CERNET and China's other networks there is a willingness to take a risk that if China commits to IPv6 it will evolve applications that will take advantage of it. CERNET's Dr. Xing Li hopes that the open source software movement will take off in China and unleash a tide of innovation that will be driven by a new wave of Chinese programmers. Dr. Li recognizes that to date China's participation in open source programming has been minimal. In a few instances, Chinese organizations have taken open source code and localized it to Chinese business requirements. This is far from open source's potential where many people are coding new and innovative applications, applications that will take advantage of new protocols such as IPv6. If the dream of a potential Chinese open source community is realized, such a community will provide an environment that will encourage Chinese educational and research institutions to step up their commitment to innovation. Hopefully, this innovation, argues Professor Li, will extend to developing applications that take advantage of IPv6.

Even as China invests millions of Yuan, time, and energy in upgrading its networks to support IPv6, there are doubts in China as to whether a significant application will ever be based on IPv6, an application that can not be supported by IPv4. In network, parlance, a “killer” application is needed.

Many advocates of IPv6, point to mobility as a fertile ground for IPv6 based applications. Though there are many technical solutions to mobility that do not include IPv6, there is the potential for new applications that will.

The most important reason to upgrade to IPv6 is not to expand the name space or to support a new application, but to build a trusted network. Our global society has come to depend on the Internet. But the Internet is far being the secure place that it needs to be. Leadership is needed that can ensure that malicious activities such as SPAM, viruses, phishing, hacking, etc. are a thing of the past. What is required is the total adoption of IPv6 so that all Internet communications can be traced. IPv6 makes it much harder to hide tracks because it eliminates IP address spoofing. When all sources of IP traffic can be identified, it will then be possible to isolate individuals that are infringing on other’s rights to a “trusted” network. IPv6 will make it possible for a global ISP association to police itself and eliminate threats to the Internet.

Another Internet application that is beginning to be supported is scientific data mapping whereby the whole earth is placed on the Internet using IPv6 addresses. Using micro-sensing and remote sensing, a virtual earth can be constructed and monitored in real-time. CERNET2 and CAS are working with other research institutes around the world on such an application of the Internet. Such mapping could be used to address challenges that we face in terms of creating a sustainable planet in which the environment and the economy are balanced.

The U.S. government’s decision to require IPv6 adoption by 2008 not only for the U.S. DoD, but for all government agencies will spur IPv6 adoption. The U.S., like China, hopes that such a move will give its manufacturers and users the opportunity to develop applications which will give them an advantage in the world market. There is a difference between how China and the U.S. are pursuing this goal of giving their telecommunications manufacturers a leg up. The U.S.’s strategy is demand driven (having all U.S. agencies adopt IPv6), while the Chinese strategy is supply driven (getting all the Internet backbones to convert to IPv6). It is not clear which strategy is going to have the most impact on IPv6 adoption in either the U.S. or China and which will give one of the nation’s manufacturers an advantage.

In conclusion, IPv6 can possibly open up a wide range of applications involving mobility, micro-sensing, and remote sensing and can provide a way of dealing with the staggering amount of information now available by integrating this data into a real-time virtual world or Global Information Grid.

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Acronyms

ACL	Access Control List
APAN	Asia Pacific Network including China, Japan and Korea
APNIC	Asia Pacific Network Information Center
BII	Beihing Internet Institute
BUPT	Beijing University of Post and Telecommunications
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Science
CERNET	Chinese Education and Research Network
CERNET2	IPv6 implementation of CERNET
CNC	China Netcom
CN2	China Telecom's Next Generation Internet
CNGI	China Next Generation Internet
CSTNet	CAS's China Science and Technology Network
DoD	United States Department of Defense
FP6	Framework Programme of the European Commission
GIG	Global Information Grid
GLORIAD	China-Russia-USA Network
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
IPSec	IP Security Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IPv6-CJ	China Japanese Network
IX	Internet eXchange
LAN	Local Area Network
MAN	Metropolitan Area Nework
MOE	Ministry of Education
MII	Ministry of Information Industries
MOST	Ministry of Science and Technology
MPT	Ministry of Post and Telecommunications
MPLS	Multi-Protocol Layer Switching
NAT	Network Address Table
NDRC	National Development and Reform Commission
NGI	Next Generation Internet
NSFC	Natural Science Foundation of China
POP	Point of Presence
P2P	Point-to-Point
RFC	IETF's Request for Comment
SARFT	State Administration for Radio, Film and Television
SCPR	Stream Control Transmission (SCTP)
SSL	Secure Socket Layer
3G	Third Generation Mobile
TEIN2	Trans-European Information Network
PLA	People's Liberation Army

PSTN	Public Switched Telephone Network
QoS	Quality of Service
UPT	Universal Personal Telephones
VoIP	Voice over IP
VPN	Virtual Private Network
WAN	Wide Area Network

About the Author

Dr. William Foster, Ph.D. has 25 years of experience with networking technologies. He got his Ph.D. from University of Arizona. His dissertation on the Diffusion of the Internet to China was published by CISAC at Stanford University in 2001. He is part of the MOSAIC Group which has studied Internet diffusion in 40 different countries (see http://mosaic.unomaha.edu/gdi.html). Dr. Foster, between 1995 and 2001, was policy editor for the Commercial Internet eXchange (CIX), the world's first Internet Service Provider (ISP) association. Dr. Foster is currently a research scientist with the Institute for Next Generation Internet (see http://www.InstituteForNextGenerationInternet.org). His books and articles can be accessed at http://www.fosterandbrahm.com/booksandarticles.htm. He can be reached at wfoster8560@yahoo.com