

IPv6—The new-generation Internet

Latif Ladid

IPv6 helps network architects revisit fundamental IP-related issues such as IP address shortage, security, quality of service, mobility, multicasting, and network management.

In 1977, Dr. Vint Cerf—Senior Vice President of Internet Architecture and Engineering at MCI WorldCom, and an Internet pioneer credited as being the father of the Internet—confidently asserted that “32 bits should be enough address space for the Internet.” Today, as honorary chairman of the IPv6 Forum, Dr. Cerf’s strong voice calls for the immediate adoption of IPv6, in order to “take the Internet where no other network has gone before.”

The author describes how Ericsson Telebit, through its sound pioneering strategy regarding IPv6 technology and marketing, has facilitated the creation of the IPv6 Forum, thereby addressing the critical limitations of the current Internet—security, quality of service and address space—and building robust foundations for the new-generation Internet.

Introduction

Now that they have the millennium bug behind them, network architects might think some relaxation is in order. But there is no rest for the weary. Indeed, we must now turn our attention to IPv4. However, because operators are not faced with the same stroke-of-midnight deadline pressuring them to make the move to IPv6, and because there are so many ways of making the transition from IPv4, a simple perusal of the options can be confusing. Add to this all the smoke and noise surrounding the subject of IPv6, and it is easy to see why some network operators are dragging their feet.

Difficult as the decision to migrate might be, however, it has to be made. Despite strict rationing, the IPv4 address space is rapidly being depleted as more nodes and networks are added to an already overburdened Internet routing structure. In theory, IPv4 can support as many as four billion unique ad-

resses. But the actual allocation of space has locked up nearly 75% of these addresses—in the early days, a limited number of entities, such as MIT and AT&T, were each allocated Class-A IP addresses (today, each controls more than 16 million addresses). As a consequence, companies that today apply for IP addresses must make do with a fraction of the remaining Class-C addresses.

In contrast to IPv4 (which has 32 bits of address space), IPv6 has 128 bits of address space, pushing the theoretical limit of unique IPv6 nodes to roughly $3.4 \cdot 10^{38}$ or about 340 billion billion billion billion unique addresses. Put another way, if every person on earth had a single IPv6 network with as many as 18,000,000,000,000,000,000 nodes on it, the IPv6 address space would still be almost completely unused.

The Internet protocol (IP) has its roots in early military networks of the 1970s. But during the past decade, IP has made an unstoppable conquest of the world’s networks. Today, IP has established itself as the primary vehicle for our global system of electronic commerce, enabling a vast array of client/server and peer-to-peer computing applications. Although the IP success story took years to unfold, many people who work in the networking community still express surprise that it happened at all, considering the strength of the opposing forces: OSI, SNA, DECnet, NetWare, and so on. But what is perhaps even more amazing is the industry’s dawning realization that the time has come to make retirement plans for the current version—IPv4.

IPv6 represents a big package of capabilities, of which addressing is the most visible component. The addressing issue gets a lot of attention, but it is only one of many important issues that IPv6 designers have tackled. Other capabilities have also been developed in direct response to critical business requirements for scalable network architectures, improved security and data integrity, integrated quality-of-service (QoS), automatic configuration, mobile computing, data multicasting, and more efficient network route aggregation at the global backbone level.

Matters of time

At the 1999 annual conference of the Association for Computing Machinery’s Special Interest Group on Data Communication (SIGCOMM99), Sandy Fraser, Chief Scien-

BOX A, ABBREVIATIONS

CIDR	Classless interdomain routing	IPv4	IP version 4
DHCP	Dynamic host configuration protocol	IPv6	IP version 6
DS	Differentiated services	ISP	Internet service provider
DVMRP	Distance vector multicast routing protocol	MOSPF	Multicast open shortest path first
GPRS	General packet radio service	NAT	Network address translation
ICANN	Internet Corporation for Assigned Names and Numbers	PDA	Personal digital assistant
IETF	Internet Engineering Task Force	QoS	Quality of service
IP	Internet protocol	RSVP	Resource reservation protocol
IPng	Next-generation IP	TC	Traffic class
IPsec	IP security mechanism	UMTS	Universal mobile telecommunications system
		WAN	Wide area network
		Y2K	Year 2000

tist at AT&T, expressed concern over the architecture of the Internet. Is it scalable? Why have we not yet migrated from IPv4 to IPv6? Has the vaunted Internet Engineering Task Force (IETF) ossified?

One of the problems surrounding the IPv6 debate is that there is no specific date by which all IPv4 addresses will have dried up. Optimists claim that IPv4 has a few good decades left. Pessimists warn that it has only a few years. Regardless, there is a big push on for IPv6. Nations like China and Japan—which did not receive much IPv4 address space—are major proponents, as are nascent industries. Providers of next-generation mobile digital telephony and vendors of networked appliances point out that they will need IP addresses for millions of devices.

There is also movement on the part of the IETF, whose next-generation Internet protocol (IPng) working group continues to plug away at IPv6 specifications and the newly formed IPv6 Forum—to promote the new IP protocol, in order to build the new Internet.

Get moving!

Says Vint Cerf, “Most people who make applications do not know what the IP address space looks like. If anybody should be paying attention to this, it is the ISPs, most of whom are betting the farm on NAT (network address translation) boxes in the near term.”

Network managers who think the long-term time frame allows them to put off their IPv6 decisions should think again. It is not too early to begin planning, deploying, and testing IPv6 networks. By preparing for the transition now instead of later, they can build a solid knowledge base and avoid the kind of chaotic response that characterized so many year-2000 programming (Y2K) efforts.

Addressing and routing

IPv6 helps solve several of the problems currently found within and between enterprises. On the global scale, IPv6 will allow Internet backbone designers to create a flexible and expandable global routing hierarchy. The Internet backbone (which is where major enterprises and ISP networks come together) depends on the maintenance of a hierarchical address system that is similar in nature to that of national and international telephone systems. For example, large,

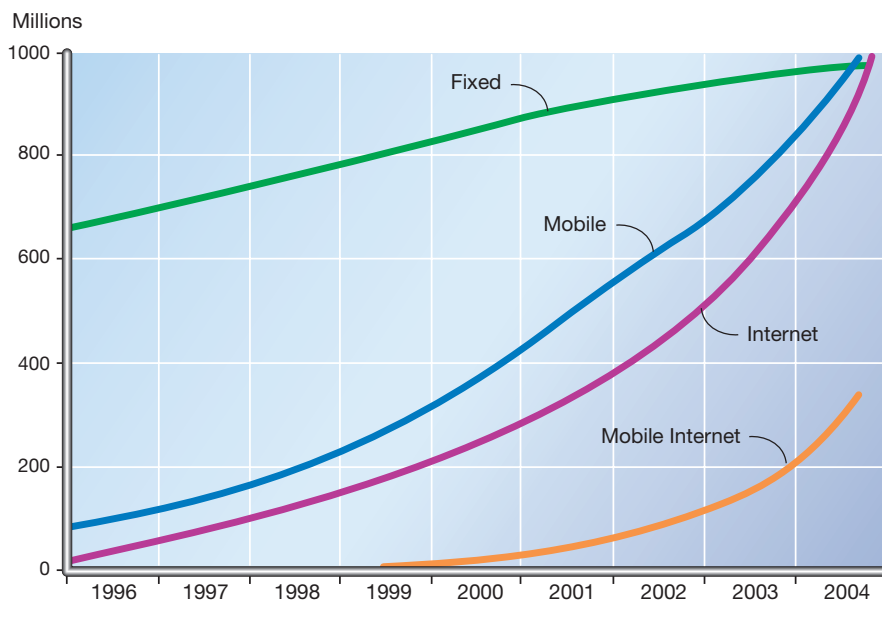


Figure 1
In light of the forecast growth (subscribers) of fixed and mobile telephony and the mobile Internet, it is not too early for network operators to begin planning, deploying and testing IPv6 networks.

BOX B, THE IPV6 FORUM

Mission

The IPv6 Forum is a worldwide consortium of 70 leading Internet vendors and research and education networks. The mission of the IPv6 Forum is

- to promote IPv6 by dramatically improving market and user awareness of IPv6 through the creation of a robust and secure next-generation Internet; and
- to allow worldwide equitable access to knowledge and technology, thereby embracing a moral responsibility to the world.

Objectives

To this end the objectives of the IPv6 Forum are

- to establish an open, international forum of IPv6 expertise;
- to share IPv6 knowledge and experience among members;
- to promote new IPv6-based applications and global solutions;
- to promote interoperable implementations of IPv6 standards;
- to cooperate with efforts to achieve end-to-end quality of service; and
- to resolve issues that obstruct IPv6 deployment.

Support

“In terms of business and technology, Ericsson’s vision of IPv6 is clear: it enables the performance

and service offerings mandated by mobile infrastructure (GPRS, UMTS), broadband networks, consumer electronics and terminals, and the interoperability and management thereof. Therefore, Ericsson extends its full support to the IPv6 Forum.”

—Jan Uddenfeldt, Senior Vice President and Technical Director of LM Ericsson

“IPv6 is here and now, so let’s take the Internet where no other network has gone before!”

—Dr. Vint Cerf, Chairman of the Internet Societal Task Force and “father” of the Internet

“We’ve known for some years that IPv4 was heading toward its limits, and the IETF has been working on IPv6 since 1994. Now, the basic standards have been agreed on and are being implemented, and it is time to move forward.”

—Dr. Brian E. Carpenter, Chairman of the IETF Internet Architecture Board, and Program Director at IBM’s Internet Division

“The IPv6 Forum’s noble objectives will be to promote this new technology on a worldwide basis, sharing knowledge, experience and interoperability, and creating common grounds for the new Internet of the next millennium.”

—Latif Ladid, President of the IPv6 Forum and Vice President of Ericsson Telebit.

central-office phone switches only need a three-digit national area code to route a long-distance telephone call to the correct local exchange.

The current IPv4 system also uses an address hierarchy to sort traffic to networks that are attached to the Internet backbone. Without an address hierarchy, backbone routers would be forced to store route table information on the reachability of every network in the world. Obviously, given the current number of IP subnetworks in the world, and the growth of the Internet, the task of updating and managing such a route table is not feasible. Thanks to the address hierarchy, backbone routers can use IP address prefixes to determine how traffic should be routed through the backbone. In recent years, IPv4 has begun to use a technique called *classless interdomain routing* (CIDR), which uses bit masks to allocate a variable portion of the 32-bit IPv4 address to a network, subnetwork, or host. CIDR permits “route aggregation” at various levels of the Internet hierarchy. Thus, backbone routers can store a single route table entry that can be used to reach many lower-level networks.

A drawback to CIDR is that it does not guarantee an efficient and scalable hierarchy. To avoid maintaining a separate entry for each individual route, routes at lower levels of the routing hierarchy (which have longer prefixes) must be collected together (or “summarized”) into fewer and less-specific routes at higher levels of the routing hierarchy. Legacy IPv4 address assign-

ments that originated before CIDR and the current access-provider hierarchy often do not facilitate summarization. The lack of uniformity in the current hierarchical system, coupled with the need for rationing IPv4 addresses, greatly complicates Internet addressing and routing. These issues affect high-level service providers and, consequently, individual end-users. Moreover, the renumbering of IPv4 sites (for example, when a user changes from one ISP to another, or when an address is maintained and improved or routes are aggregated) is unnecessarily complicated, and thus more expensive compared to IPv6.

Transition architecture

There is no getting around the fact that IPv6 will have to interoperate with—or tunnel through—IPv4. The good news is that IPv6 does not create order dependencies: network architects can upgrade their hosts first and then the routers, or their routers first and then the hosts. They can even upgrade some hosts, some routers, and leave the rest alone. The question, “which of the three main interoperability mechanisms (tunnels, translators, or dual stacks) will predominate,” remains open.

Nodes that know

Until service providers build IPv6 backbones and offer IPv6 services, end-to-end IPv6 will require tunneling through IPv4 networks. This is accomplished by encapsulating an IPv6 packet into the payload of an IPv4 packet. An IPv6 node originates the IPv6 packets, which are encapsulated in IPv4 and forwarded through the IPv4 network. The node at the end of the tunnel uncouples the IPv4 packet, exposing the IPv6 packet for delivery to the destination node.

Transition strategies

IPv6 transition strategies vary. In some cases, entire networks can be upgraded to create small reservoirs of IPv6 support surrounded by oceans of IPv4. In these instances, the nodes in the IPv6 networks will not necessarily have to support IPv4. However, to support external interoperability, the devices at the network borders must support IPv4. Internal IPv6 nodes can communicate directly with one another and, through tunnels via dual-IP routers, with other IPv6 networks.

BOX C, IPV6 VERSUS IPV4

Streamlined formula of IPv6

IPv6 streamlines and enhances the basic header layout of the IP packet, greatly improving on IPv4. In IPv6, some of the IPv4 headers were dropped and others were made optional. The redesigned, simplified packet structure will partially offset the bandwidth cost of the longer IPv6 address fields. The 16-byte IPv6 addresses are four times longer than the 4-byte IPv4 addresses, but thanks to retooling, the total IPv6 header size is only twice as large.

Beyond the streamlined packet format, IPv6 features improved support for header extensions and options, changing the way IP header options are encoded to allow more efficient forwarding. Optional IPv6 header information is conveyed in independent “extension headers”

located after the IPv6 header and before the transport-layer header in each packet. Most IPv6 extension headers are not examined or processed by intermediate nodes (which was the case with IPv4). IPv6 header extensions are now variable in length and have less stringent length limits. IPv6 gives network software designers a very straightforward technique for introducing new header options in the future.

Option fields have already been defined for carrying explicit routing information created by the source node. These fields also facilitate authentication, encryption, and fragmentation control. At the application level, header extensions are available for specialized end-to-end network applications that require their own header fields within the IP packet.

Alternatively, by upgrading individual nodes to support IPv4 and IPv6, operators can create a sort of “raisin-bread” architecture, with individual nodes linking directly with one another on the same link or through tunnels with remote IPv6/IPv4 nodes. This approach allows organizations to upgrade nodes one at a time for access to remote IPv6 nodes and networks. On the other hand, it also complicates matters by requiring the manual configuration of tunnels, in order to access IPv6 resources.

The IPv6 infrastructure

The IETF has done its part in developing IPv6 protocols. The Internet Corporation for Assigned Names and Numbers (ICANN) has published the policy document on IPv6 address allocation and assignment (see www.arin.net/). Since 1996, nearly 400 networks in more than 40 countries have connected to the 6bone IPv6 network (Box D).

Rolling it out

Early implementers have many options for building IPv6 support into their networks. Numerous router vendors support IPv6, including 3Com (USA), Compaq Computer Corporation (USA), Ericsson Telebit (Denmark), Hitachi Ltd. (Japan), Nokia Telecommunications (Finland), and Northern Telecom Ltd. (Canada). The Linux kernel also includes IPv6 support. Microsoft currently offers an alpha version of an experimental IPv6 stack that reportedly works with Windows NT and the beta version of Windows 2000.

Managing the transition

Networking vendors will eventually fold IPv6 support into all their products, just as they currently support IPv4. According to several experts, the costs of implementation will be comparable to that of installing a new operating system release. In fact, supporting IPv6 should ultimately save money. The move to IPv6 is not as costly as making a transition to nested NATs—a nightmarish situation in which the ISP uses its own NAT address space, but routes its customers’ packets within a backbone that uses its own, unique, NAT address space.

Overall, the cost of running an IPv6 network is less than that of running an equivalent IPv4 network. This is because IPv6 is smarter than IPv4. For example, IPv6 nodes

can automatically configure themselves with the correct version of the dynamic host configuration protocol (DHCPv6). Also, thanks to the neighbor discovery functionality, an IPv6 node can be plugged into any network and, without the need for human intervention, seek out a stateless autoconfiguration server and be configured to interoperate. These features make for true plug-and-play network access. Through neighbor discovery, nodes can automatically determine which routers on their links are available and can be reached. Moreover, the assignment of IP addresses is simplified at the organizational level.

What then, is the best way of testing the IPv6 waters? Early implementers can build islands of IPv6 connectivity without affecting overall network connectivity. Research groups often support IPv6 in this way, whereas other groups might add branches of IPv6 support as needs dictate. For making the transition from the outside inward, organizations can place IPv6 routers at the network edges to allow connectivity with and through IPv6 networks. In this scenario, organizations connect to IPv6 backbones and tunnel IPv4 traffic through them.

IPv6, Yes! NAT, No?

Not surprisingly, not everyone is a proponent of IPv6. Antagonists argue that address-assignment and routing problems can be controlled with other mechanisms. One such mechanism that has proven especially controversial is network address translation. Those who support NAT claim that it is the complete solution to IPv4 address problems. Its opponents, on the other hand, view NAT as a kludge that is actively harmful to interoperability, since it disables true end-to-end networking, a criterion for security—every datagram that passes across a NAT network must be converted, which makes it impossible to use IP security architecture (IPsec) protocols to encrypt or sign transmissions digitally. On the other hand, NAT makes it possible to hide entire networks behind a single IP address, which is a form of security in its own right.

Benefits of the new-generation Internet

It is as difficult today to predict the future of the Internet and electronic commerce as it would have been for the pilot of a World War I biplane to visualize jumbo jets and

BOX D, IPV6 RESOURCES ON THE WEB

www.ipv6forum.com

The home page of the IPv6 Forum, a consortium of network vendors and providers, including Cisco, Compaq, Ericsson Telebit, Hewlett-Packard, IBM, MCI Worldcom, Microsoft, Sun Microsystems and others.

www.6bone.net

6bone, which is the experimental test bed for IPv6, currently links close to 400 networks in more than 40 countries.

www.6ren.net

6ren is a free and open initiative to link research and educational networks using IPv6.

www.arin.net

ARIN is responsible for allocating and administering IPv4 addresses in North and South America, the Caribbean, and sub-Saharan Africa.

www.internet2.edu

Internet2 is described as “a collaborative effort to develop advanced Internet technology and applications vital to the research and missions of higher education.” Internet2 is expected to be involved in research and development as IPv6 gains momentum.

modern airports. We simply cannot foresee the many ways in which the Internet of the future will be used or what its full impact will be.

What we do know, however, is that the Internet is already transforming business, education and entertainment—nearly every aspect of our lives. Moreover, we know that even greater changes are on the way as the Internet becomes faster, more robust, and more versatile.

Most descriptions of the future of the Internet have focused on bandwidth. But the next-generation Internet is about much more than high-speed networks. In essence, it is about applications. The issue is not what the technology can do, but what we can do with it.

Business case for IPv6—the quality end-to-end solution

Given the ever-increasing business requirements for interactive multimedia and large bandwidth network applications, IPv6 is critical to the continued viability of enterprise internetworks and the public Internet at large. Despite its importance and the efforts of some of the brightest minds in the network industry, the birth of IPv6 has been attended by a number of somewhat misleading myths and portrayals that can easily distract network owners who are in the process of crafting a forward-looking net-

work strategy. Considering the mammoth implications of migrating our global inter-network infrastructure to an updated protocol, some confusion is to be expected. But if the IPv6 myths are perpetuated indefinitely, the Internet might languish with a 20-year-old set of protocol components, while end-user and business requirements for advanced network services expand exponentially. Now is the time to clear the air.

Reliability and scalability

One of the biggest differences between the present-day Internet and the new Internet is that we will be able to rely on the new Internet; it will be available when we want to use it. End-users will always be online and can start using the Internet without first having to run through an elaborate dial-up and logon sequence. Similarly, access will be ubiquitous—that is, not only will end-users be able to connect to the Internet instantly, but the sites and applications they want to use will also be accessible—they will not vanish and reappear as network load fluctuates.

Privacy and security

To realize the full potential of the new Internet, end-users must be able to trust on-line information and transactions as much as or more than they trust hardcopy documents. As digital information becomes a major commodity, it must be protected and authenticated. What we see must be the same as what was sent and what we get. We must be able to control our data and protect our privacy in cyberspace. This requires easy-to-use, inexpensive, universally available mechanisms for security and authentication. In particular, we need a fail-safe means of

- ensuring the confidentiality of data sent over the Internet;
- proving that private data will remain private;
- verifying that a message was sent and received properly;
- authenticating individuals and information on the Web;
- proving that someone signed an electronic document; and
- certifying that a transaction took place at a given time.

Quality of service: speed and differentiated services

Today, most users of the Internet spend a large percentage of their time online just

Figure 2
Most descriptions of the future of the Internet emphasize bandwidth. But the next-generation Internet is about much more than high-speed networks—the real issue is not what the technology can do, but what we can do with it.



waiting—waiting to get connected to a website, waiting for pages to load, and waiting for software to download. In contrast, the next-generation Internet will provide us with the speed we need.

IPv4 carries a differentiated services (DS) byte and IPv6 carries an equivalent traffic class (TC) byte, intended for the support of simple differentiated services. IPv4 and IPv6 can each support the resource reservation protocol (RSVP) for more complex QoS implementations. The IPv6 packet format contains a new 24-bit traffic-flow identification field that will be of great value to vendors who implement quality-of-service network functions. Although these products are still in the planning stage, IPv6 lays the foundation, allowing a wide range of QoS functions (including bandwidth reservation and delay bounds) to be made available in an open and interoperable manner. An additional benefit for QoS in IPv6 is that a flow label (allocated within the IPv6 header) can be used to distinguish traffic flows for optimized routing. Furthermore, the flow label can be used to identify flows even when the payload is encrypted (for instance, when the port numbers are hidden).

Thanks to IPv6 flow labels, the network can identify streams of packets that need special handling. Flow-based routing can give internetworks some of the deterministic characteristics associated with connection-oriented switching technology and virtual circuits. For example, desktop video or audio streams can be assigned a flow label that tells routers that a controlled amount of end-to-end latency is required. Flow labels can also be used to give traffic flows a specific level of security, propagation delay (for example, satellite transmission), or cost. Experimental work with non-standard IPv4 QoS implementations has already shown that it is feasible to convey video and audio streams across the mesh internetwork topologies without excessive degradation. IPv6 paves the way for a production application of this sort.

Ubiquitous access

Today, when we walk into a home or office, we typically see one or more computers. Imagine walking into a home and seeing dozens or even hundreds of computers, PDAs, and other devices—all connected to the Internet. Imagine a world where almost everything with a value exceeding USD 10 or 20—whether it is a refrigerator, a shirt, or a bicycle—contains a tiny smart card that

can communicate via a wireless link to the Internet. In such a world, connectivity will be as commonplace as air—our watches, trees, even our dogs will broadcast data. A wristwatch could serve as a pager. Sensors on trees around a house could tell us—or a sprinkler system—that the trees need watering. A dog's collar could tell us where he is. Best of all, misplaced car keys will be able to tell the Internet where they are.

Mobility

For several reasons, IPv4 has difficulties managing mobile computers:

- Mobile computers need to use a forwarding address at each new point of attachment to the Internet—with IPv4, getting this address is not always easy.
- Good authentication facilities, which are not commonly deployed in IPv4 nodes, are required to inform any agent in the routing infrastructure about the new location of the mobile node.
- In IPv4, it can be difficult for mobile nodes to determine whether or not they are attached to the same network.
- In IPv4, mobile nodes usually cannot inform their communication partners about a change in location.

Several aspects of the design of the IPv6 protocol are directly beneficial to, and go beyond merely providing dial-up support for, mobile computing. Improved processing of destination options, autoconfiguration, routing headers, encapsulation, security, and anycast addresses contribute to the logical design of mobility for IPv6. So much so, in fact, that a European satellite network is already introducing IPv6 as its main communication protocol. The mobility advantage of IPv6 can be further emphasized by the addition of flow-label management, which gives mobile nodes even better quality of service.

Multicast and anycast

One of the fastest growing business requirements for internetworks is the ability to transmit a stream of video, audio, news, financial data, or other timely data to a group of functionally related but geographically dispersed end-stations. This is best achieved by means of network-layer multicasting techniques. Typically, a server sends out a stream of multimedia or time-sensitive data. A multicast-capable network can then automatically replicate the server's packets and route them to each subscriber in the multicast group using an efficient

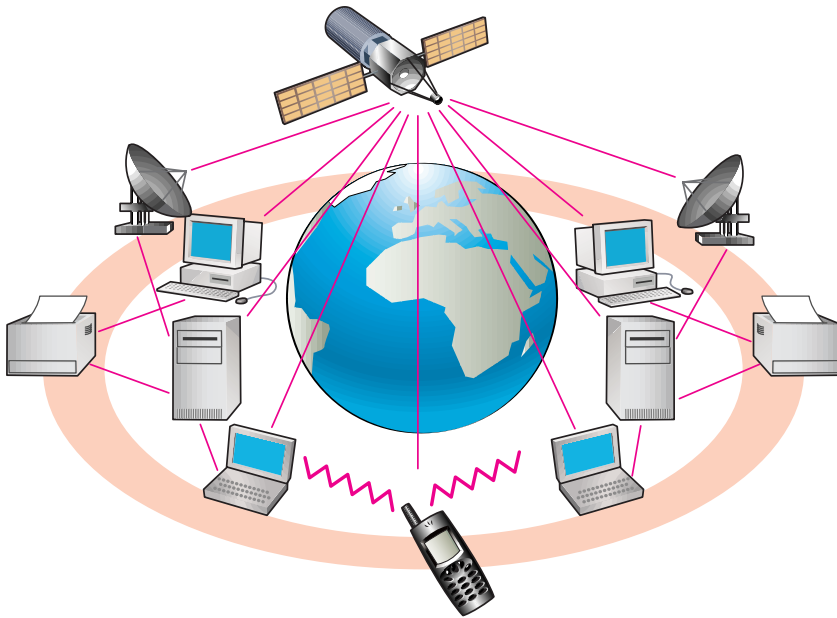


Figure 3
IPv6 offers superior processing of destination options, autoconfiguration, routing headers, encapsulation, security, and anycast addresses.

path. Routers use multicast protocols—such as the *distance vector multicast routing protocol* (DVMRP) and the *multicast open shortest path first* (MOSPF) protocol—to converge dynamically a packet distribution “tree” that connects every member of the group with the multicast server.

New members join the multicast group by sending a “join” message to a nearby router. The distribution tree is then adjusted to include the new route. Multicast services imply that a server can send a single packet that will be replicated and forwarded through the internetwork to the multicast group on an as-needed basis. Because this method conserves server and network resources, it is superior to unicast and broadcast solutions. Multicast applications are also being developed for IPv4, but IPv6 greatly extends the IP multicasting capabilities by defining a very large multicast address space and a scope identifier that is used to limit the degree to which multicast routing information is propagated throughout an enterprise. Multicasting is an important feature of IPv6 that replaces the

IPv4 broadcast feature by supporting both unicast and multicast functions.

Anycast services are another innovation of the IPv6 specification that is not found in IPv4. Conceptually, anycast is a cross between unicast and multicast: two or more interfaces on an arbitrary number of nodes are designated as an anycast group. A packet addressed to the group’s anycast address is delivered to only one of the interfaces in the group, typically the “nearest” interface in the group according to current routing protocol metrics. This is in contrast to multicast services, which deliver packets to every member of the multicast group. Nodes in an anycast group are specially configured to recognize anycast addresses, which are drawn from the unicast address space.

Collaboration and conversation

The present-day Internet is a powerful medium for communication, whether one-to-one, one-to-many, or many-to-many. In the future, new applications and interfaces will make it even easier and more intuitive for persons to collaborate in cyberspace. New media technologies will allow users

- to “walk” into a room thousands of miles away for a business meeting;
- to visit a “virtual showroom” and have a sales person demonstrate, say, a three-dimensional computer model of the car they are thinking of buying; or
- to sit inside a 360-degree panoramic, video display and “travel” to a rock concert in, say, California. These new tools for collaboration will enable users to communicate *at least* as effectively online as they do in person.

The world of wireless mobility

Imagine being able to carry a calendar and contact list on a foldable, featherweight piece of electronic paper, or of being able to say to the computer, as you head out the door to lunch, “Prepare a report on our competitors’ strategies.” Or how about sending your “virtual self” to a meeting while you attend another—that is, of actually being in two places at one time?

These visions of personal computing could become reality in less than five years. In fact, Compaq, Ericsson, IBM, and Hewlett-Packard are now working on technologies that will enable a world of pervasive, transparent computing in which processing power is embedded into virtual-

BOX E, MAJOR MILESTONES IN THE MAKING OF THE INTERNET

1969 – 1985	Basic packet network research
1974	Internet design first published
1983	First major deployment
1986	First router companies
1989	WWW; MCI mail/Internet link
1990	ARPANET retired; first commercial services (UUNet, PSINet)
1994	Commercial WWW (Netscape)
1995	NSFNet retired, competitive backbone
1998	New IANA/ICANN

ly every manufactured item, from alarm clocks to coffee cups. What is more, these devices will be connected wirelessly and seamlessly.

Eventually, as the technology matures, we will no longer see it or give it a thought. Data will become mobile and move in a number of devices ranging from cellular phones, smart phones and personal digital assistants (PDA) to electronic books and paper.

An abundance of wireless bandwidth will enable the proliferation of these devices. The bottlenecks associated with wireless data transmission will be eliminated within the next few years, thanks to new wireless technologies based on UMTS and Bluetooth. For example, third-generation cellular networks with (mobile) transmission speeds of up to 384 bit/s will be available in Asia this year, in Europe in 2001, and in the USA in 2002 or 2003.

In the not-so-distant future, networking will become completely transparent, as 802.11 wireless technology (which runs at 11 Mbit/s and is expected to transmit data at 54 Mbit/s) is integrated transparently into the wide-area network (WAN). This will allow users to be connected to a campus LAN at all times, regardless of their actual location. When users physically leave the campus area, their connections will be seamlessly transferred to a WAN.

By the year 2003, the volume of Internet commerce could reach USD 3.2 trillion and represent 10% of the world economy. But is the Internet ready? Given that major investment sites (such as Charles Schwab & Co.) and consumer auction sites (such as eBay) are struggling to keep up with current levels of online activity, it becomes clear that the Internet and the merchants that use it have a long way to go before they can successfully handle millions or even billions of round-the-clock transactions.

Fortunately, help is on the way in the form of redundant (robust), self-healing networks, a new Internet communications protocol, and better security—besides handling hundreds of millions of customers and billions of different devices, electronic commerce sites will also have to fend off hackers and electronic terrorists.

Conclusion

With its immense address space, the IPv6 solution defines a multilevel hierarchical global routing architecture. Using CIDR-

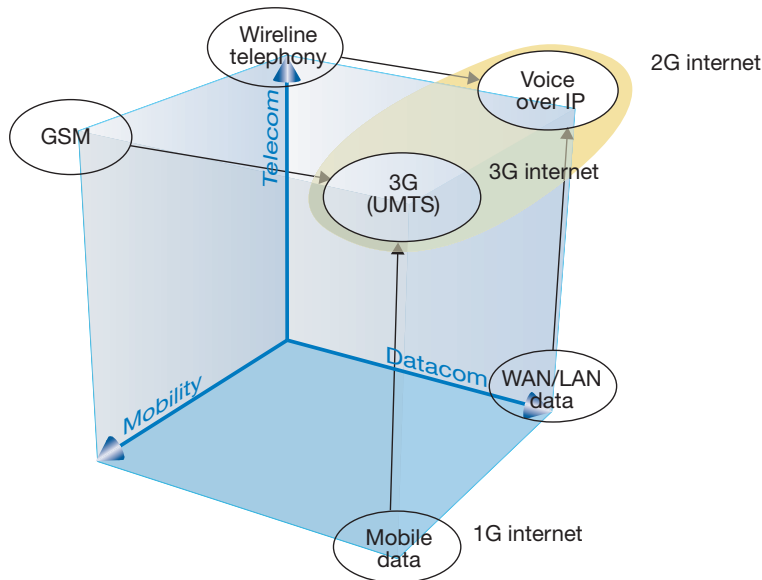


Figure 4
IPv6 is a key enabler of the New Telecoms World.

style prefixes, the IPv6 address space can be allocated in a way that facilitates route summarization and controls the expansion of route tables in backbone routers. The vast availability of IPv6 addresses eliminates the need for private address spaces. ISPs will have an abundance of addresses to allocate to small businesses and dial-in users that need globally unique addresses to fully exploit the Internet. Using an example from crowded telephone networks, one might say that IPv6 eliminates the need for extensions, giving every office direct communication lines without requiring operators (automatic or otherwise) to redirect calls.

As the Internet becomes the true global medium, we are going to need the innovations and persistent efforts of individuals to build a network that is capable of supporting a variety of services in a robust manner. According to Metcalf's Law, the value of a network is equal to the square of the number of people who use it. Think of it this way: when you join a network, you not only get to enjoy its facilities, but your presence also increases the value of the network for others.