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INTERNET FOR EVERYONE
IPv6 2005 ROADMAP RECOMMENDATIONS

Executive Summary

The emergence of the Internet as a fundamental technology for commercial and social activity has been recognised by the European Commission with the launch of the eEurope initiative. The Internet has grown rapidly in the past five years, to a scale well beyond that which the original Internet designers envisaged over twenty years ago. It is imperative that the European Internet should be able to grow to meet the future demands of commerce and society, for business, for learning, to enable new markets to be realised, and to enrich the lives of European citizens.

The Internet relies on a data communication method called the Internet Protocol (IP) to transfer data between machines on the network, be that data Web pages, e-mail, online gaming or otherwise. All Internet applications communicate using IP; it is the basic enabler of every service on the Internet; it is thus critical that IP is able to scale for the Internet of at least the next decade.

Future network growth requires that Internet-enabled devices can be assigned and use a globally unique IP address, in a similar way to the telephone numbers that identify individual phones. The current version of IP, IPv4, has been in existence for over twenty years, but has a limited address space, not even enough for one IP address per person on the planet. Its successor, IPv6, in development by the IETF for eight years, offers relatively unlimited address space. The IPv6 core standards were completed in 1999, and vendors started shipping commercial IPv6 products in earnest in 2000. As a result a number of early IPv6 deployments already exist, notably in Japan.

The scarcity of IPv4 address space, for example for both commercial and home users, restricts the applications that can be run into both business and home networks. A technique known as Network Address Translation (NAT) allows multiple devices to be “hidden” behind one or more real IPv4 addresses, but NAT breaks the end-to-end principle of the Internet, preventing the evolution of next generation applications that demand IP address space, and connectivity *into* business premises and home networks (e.g. from IP-enabled mobile handsets). IPv6 delivers that address space, and is thus a key factor for the well being of the future European Internet.

The wireless Internet (3G) will most likely lead the IPv6 revolution, though IPv6 will also pervade further, into the home, the workplace, into cars and into consumer electronic devices. IPv4 has been in use for over twenty years, yet the World Wide Web was not conceived until ten years after the introduction of IPv4. By deploying IPv6, new, innovative applications will be realised, some of which can be developed now, but many of which will follow in years to come, as eEurope evolves.

This report overviews IPv6, describing the features of IPv6 that will be key enablers for new applications and services. It describes the road forward for IPv6, including the requirement to integrate IPv4 and IPv6 services as the gradual overall transition to IPv6 occurs. There is no IPv6 "flag day" as there was for Y2K, but the earlier that IPv6 transition is begun, the less costly that transition will be in the long run, and the sooner IPv6's benefits can be exploited in eEurope.

IPv6 is the only solution that provides the vastly increased IP address space that will allow the European Internet to grow and to scale into the next decade and beyond. The base IPv6 protocols are ready now, but deployment, which should be led by market forces, requires a number of factors to be addressed, as recommended by this report.

Introduction

At the dawn of the 21st century, information and communication technologies (ICT) are revolutionising the functioning of the economy and society, and are triggering new ways of producing goods, trading and communicating. The further development of ICT into the 21st century, will have a wide-range and long lasting impact not only on the economy, but also on every aspect of people's lives, leading to radical transformations and far-reaching changes. Indeed these changes are not just about technology, they are primarily about creating wealth and generating new business opportunities, sharing knowledge, bringing communities closer together and enriching everyone's lives.

IPv6 and the future Internet

According to population estimates from the US Census Bureau, the world will be home to about 9 billion people in 2050. Whatever the economic constraints may be, we must clearly plan technically for all of these people to have the potential for Internet access. It would not be acceptable to produce a technology that simply could not scale to be accessible by the whole human population, under appropriate economic conditions. Furthermore, pervasive use of networked devices will probably mean we will see many devices per person, not just one.

Internet communication and addressing

To a user of the Internet, computers are addressed by their domain name, e.g. in the Web context you would use *www.microsoft.com* as the web address of Microsoft, or *someone@aol.com* as the e-mail address of an AOL e-mail user. While such domain names are easier for people to remember, the networked devices – such as web servers, e-mail servers or home PCs – communicate using a numeric address format and a protocol called the Internet Protocol (IP). As a loose analogy, domain names and IP addresses can be compared to people's names and their telephone numbers. The Internet Protocol requires that communicating devices, anywhere on the Internet, have unique IP addresses, so that data packets can be carried (routed) between the devices across one or more Internet Service Provider (ISP) networks.

The current version of IP, IPv4, has been in use for over twenty years, having been developed by Internet pioneers such as Vinton Cerf. However, when IPv4 was designed in the 1970's, the vast growth in the Internet was not foreseen, and at the time the Web was still many years away from conception. As a result, and given the limitations of hardware at the time, the original Internet

designers only chose to use 32 bits to represent IPv4 addresses. Those 32 bits allow 2^32, or just over 4,000 million, IPv4 addresses. While the Internet of the late 1970's contained only a handful of hosts, mainly in the USA, the Internet today has reached over 400 million regular users.

There are not, at present, enough IP addresses for every person on the planet. When one considers that homes, offices, cars and other environments may all contain many IP-enabled devices in the near future, the pressure on IPv4 address space is evident, given any one device on the network may wish to connect to any other (e.g. a computer system at a car dealership may remotely check the status of IP-enabled sensors in a car, to monitor performance and predict future problems). That pressure is heightened because IP addresses are never fully utilised, either because allocations per ISP or per site were too generous in the 1980's (some organisations have been allocated what amounts to 1/256th of the whole IPv4 address space), or because allocations have to be made in blocks of sizes that are multiples of two (computers being binary devices); thus a site with 129 devices will have to be allocated 256 IP addresses.

IPv6, in development since the early to mid 1990's, has now matured to the state where vendors are delivering early commercial product (e.g. Sun, Cisco, Microsoft, Juniper) and initial deployments are being made. IPv6's major advantage is that it uses 128-bit addresses, enough to offer a globally unique IP address to any device wanting it for the foreseeable future. Given that all Internet communications use IP, the importance of the availability of IP address space for all cannot be stressed enough.

IPv6 address allocations

In Europe, the IPv6 production address space is managed and allocated to ISPs by RIPE NCC[1]. To date, over 100 IPv6 prefixes have been assigned to top level providers world-wide, with, of the three regional registries, Europe having the most prefixes assigned, followed by Asia and then the Americas. An IPv6 prefix represents a hierarchical, aggregated block of addresses for a network, in a similar way to a telephone area code aggregating all telephone numbers in a city area (only the computer network may be spread over any distance, e.g. where a network prefix is used by a national or even multinational organisation).

The three regional registries – RIPE, APNIC and ARIN – share a common IPv6 address allocation policy. While this policy is subject to change, it currently offers a top-level provider (ISP) up to 35 bits of network address space (i.e. the equivalent of more than the whole current IPv4 address space for a single IPv6 provider), and a site receives 16 bits of network address space, which should be ample for the vast majority of organisations.

The availability of IPv6 address space should, through market forces, lead to IPv6 addresses being cheap (compared to IPv4) if not free to the end user. Many ADSL users currently pay a fee to have a single, static IPv4 address for their home network (typically £10 per month). With IPv6, not only does a home network user get a whole network of IPv6 addresses (rather than just one IPv4 address), IP address scarcity is no longer a reason for an ISP to charge for providing static IP addresses.

The combination of the availability of multiple globally reachable IPv6 addresses for a home network, along with broadband access (e.g. ADSL), enables a whole new range of remote home management applications (e.g. multiple web cameras, or wireless temperature sensors) that are not feasible with IPv4.

[1] RIPE NCC: http://www.ripe.net/

The digital divide

Most significantly IPv6 can help bridge the digital divide that currently exists between the developed world (in particular the US, where IPv4 address space was in good supply in the early years of the Internet) and emerging Internet nations in Eastern Europe, Latin America, Africa and Asia. IPv6 promises a level playing field for Internet Protocol application development and deployment where IP addresses are readily available the world over, not a luxury for a privileged minority.

Bridging this divide is now a global objective. But the uneven diffusion of technology is nothing new. There have long been huge differences among countries. The bitter irony of the Internet phenomenon is that while in theory the global network of networks is open to all, the vast majority of the world's population remain cut off from its economic and educational benefits. Only 8% of the world population has access to the Internet, compared to 20% to the phone system.

Affordable technologies more appropriate to developing economies could include solar-rechargeable batteries that would allow mobile phones to be used even in areas lacking electricity lines. The Internet could achieve a far better penetration through wireless access technologies, due to their dual benefit of being faster to deploy in any area (wide-scale cabling is not required) and of "giving wings" to the Internet with their mobility.

The PC era will be overtaken by the non-PC world (PDAs, Smart Cell Phones, personal network devices, etc). The I-Mode advanced mobile data communication initiative in Japan achieved more than 30M users in just two years of deployment and is perceived by its users as the Japanese Internet. Now, adding IPv6 to it would give the developing world immediate access to not only the Internet but to many next generation applications currently under development. If we fail to provide access to digital technology to countries in the developing world we are, essentially, denying them an opportunity to participate in the new economy of the 21st century.

IPv6 benefits

Viewed from a technical perspective, IPv6 has many benefits, including the following:

- Larger address space for end-to-end global reachability and Internet scalability; this is the key advantage of IPv6.
- Simplified IPv6 data packet header for routing efficiency and performance
- Support for routing and route aggregation, making Internet backbone routing more streamlined and efficient (the IPv4 Internet backbone contains data routing information for over 130,000 networks; with IPv6 this number could be dramatically reduced).
- Serverless ("stateless") IP auto-configuration, easier network renumbering, and much improved plug and play support.
- Security with mandatory implementation of IP Security (IPSec) support for all fully IPv6-compliant devices (IPSec implementation is not mandated in IPv4). Note that *use* of IPSec is not mandatory, but the presence of an implementation, allowing the user to have the option for secure communications.
- Improved support for Mobile IP and mobile (and ad-hoc) computing devices.
- Enhanced multicast networking support.

These benefits can be mapped to opportunities for improved business models and potential new application and system markets.

IPv6 in Europe

The question of when to begin a migration path to IPv6 is an issue of paramount importance to a wide range of industries, which will be producing goods with embedded Internet access, including cars and consumer electronics, as well as for fixed, mobile and wireless communications. The Communication from the Commission at the Lisbon Council Meeting 2000 states that:

- Member States should make a commitment to progressively introduce IPv6 in their publicly owned networks, i.e. those for research and administrations.
- The Commission would increase support for test beds through its research, TEN Telecom and IDA programmes.
- The Commission would invite Member States to work together with industry in an ad-hoc group, which should provide proposals by the end of 2001 in order to accelerate the introduction of IPv6. (The results of that group are presented in this report and those of the four associated Working Groups).

Responding to the conclusions of the Stockholm Summit, the Commission stepped up its R&D efforts notably in the context of the 5th Framework Programme. A large number of IPv6 projects totalling some 65 Million € of community funding is currently operational with others due to come up on-line shortly (most notably 6NET[2] and Euro6IX[3]). In its preparatory work for the 6th Framework Programme, further opportunities will be provided to the research community to conduct research on IPv6 and develop innovative tools, services and applications.

IPv6 deployment around the world

Japan took political leadership in the design of the roadmap to IPv6 when back on Sep 21, 2000 in the policy speech by Prime Minister Yoshiro Mori to the 150th Session of The Diet the Japanese government mandated the incorporation of IPv6 and set a deadline of 2005 to upgrade existing systems in every business and public sector. Japan sees IPv6 as one of the ways of helping them leverage the Internet to rejuvenate the Japanese economy.

Large-scale deployment networks and vendor implementations have been widely promoted. The IP research community has been supported by government initiatives. The Japanese initiative was very crucial to the Asian regions. Korea followed suit on Feb 22, 2001 by announcing plans to roll out IPv6. China and Japan have declared jointly in their 7th Japan-China regular bilateral consultation toward further promotion of Japan-China cooperation in info-communications fields such as IPv6.

The business case for IPv6 in the US is not yet felt, as the technical case is not that apparent, though most of the design of IPv6 and vendor implementations has been done in the US. The US was, of course, first in the “land rush” for IPv4 address space, so is not yet in as critical a position as Asia or parts of Europe.

However, IPv6 infrastructure can and is being deployed today in the market on intranets and at access points on the edge of the Internet, in particular in the Far East. Deployment is in the initial stage; users can use commercially supported vendor IPv6 implementations that began shipping in earnest in 2000. IPv6 implementations are available for many major router, server, and client products. These can be used to begin the infrastructure deployment, and can interoperate with existing IPv4 infrastructure elements. Application developers can begin porting IPv4 applications to IPv6, and undertaking innovative new IPv6 ventures.

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[2] The 6NET Project: http://www.6net.org/

[3] The Euro6IX Project: http://www.euro6ix.org/

The IPv6 2005 Roadmap Recommendations

The European Commission, further to the conclusions of the Stockholm European Council, established an industrially led IPv6 Task Force, tasked with examining the current state of the development and deployment of IPv6 and recommending priority actions to be undertaken at European level. The report of the IPv6 Task Force now issued (http://www.ipv6-taskforce.org) puts forward a number of key recommendations addressed to Member States, the European Commission and Industry at large. Beyond the overall requirement to structure, consolidate and integrate European efforts on IPv6, the report calls notably for:

- Increased support towards IPv6 in public networks and services,
- Launching of educational programmes on IPv6,
- Promotion of IPv6 through awareness raising campaigns,
- Further stimulation of Internet across Europe,
- Creation of a stable and harmonised IPv6 policy environment,
- Strengthening of IPv6 activities in the 6th Framework Programme of R&D,
- Strengthening of support towards the IPv6 enabling of national and European Research Networks,
- Acceleration of contributions towards IPv6 standards work,
- Integration of IPv6 in all strategic plans concerning the use of new Internet services.

Given the necessity for a concerted and timely effort to enable the overall competitiveness of Europe to be strengthened in this strategically important area, the report of the IPv6 Task Force, advocates that its recommendations be brought to the attention of the Spring European Council to take place in Barcelona, on 15th-16th March 2002, and thus set the deployment roadmap to be achieved by 2005.

- The following recommendations are aimed at the recognised,
- Standard Development Organisations (ITU, 3GPP/3GPP2, ETSI, IETF, IEEE-ISTO, etc),
- Fora (3G.IP, ASP Consortium, DSL Forum, IMTC, IPv6 Forum, MPLS Forum, MSF, MWIF, OIF, OMG, SDL Forum, TM Forum, TOG, UMTS Forum, World Collaboration CPR, etc)
- and industry Associations (EICTA, ETNO, EURESCOM, EUCONTROL, GSM Europe, ISP associations, White Goods Associations, etc),
- coupled with an ITU-T initiative[4].

It is critical that all standards-related initiatives and activities are harmonised for the timely and efficient introduction of common, interoperable IPv6 deployments.

- Consider opportunities for partnerships on IPv6 projects for:
- Joint development/collaborative work (within and outside Europe)
- Common standards
- Education and knowledge exchange

[4] ITU-T initiative: http://www.itu.int/ITU-T/tsb-director/forum/

- Market intelligence
- Marketing and promotion
- Profiling and implementation agreements
- Interoperability and conformance testing
- Feedback from market and forums to Standards Development Organisations for:
- Requirements
- Finished standards
- Gaps analysis

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