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Contents

This report was derived from work undertaken by four IPv6 Task Force working groups (Next Generation Applications, IPv6 Trials, IPv6 Infrastructure and Mobile Services) between April and December 2001, each of which also produced their own working group reports. This main report makes recommendations for EU Member State governments, for the European Commission, for industry, and for industry and standards bodies.

Executive Summary

The findings of the IPv6 Task Force are detailed in this main report. They include the following key messages:

- The Internet has evolved over a period of over 25 years, a period in which the method by which all Internet applications communicate, the Internet Protocol (IP), has remained the same. IP version 4 (IPv4) has persisted with the same addressing method for all Internet devices (akin to telephony numbering) for those 25 years; in the 1970's the IPv4 designers never foresaw the future growth of the Internet. That rapid growth demands an expansion to the IP communication and addressing method; the shortage of IPv4 addresses could become critical in many parts of the world, including Europe, by 2005.

- A new version of the IP communication and addressing method for the Internet, called IPv6, has been designed over the past 7 years by a vendor-neutral body called the IETF. For the full development and future potential of eEurope to be realised, for 3G services to be widely deployed, and for the general benefit of business and society, early adoption of IPv6 is of key importance. While 3G is a focus for IPv6, other application areas will benefit, including home networking, peer-to-peer services, and GRID computing.

- The core IPv6 specifications are ready, and most major vendors are shipping commercially supported IPv6 products. Open source systems such as Linux also have IPv6 built-in. Early adopters are porting existing applications to be able to use IPv6, and are beginning to develop new IPv6 applications; the application porting process itself is not a complex one.

- The worldwide IPv6 test bed network spans over 50 countries. Some early commercial network deployments exist with IPv6, predominantly in Japan. Europe has some early IPv6 test bed deployments, but these are in their early stages. The US has few significant deployments, but it fared well in the original IPv4 address space allocations. IPv6 standards development for advanced features is ongoing, and will take time to complete.

- IPv6 systems can be deployed in parallel with IPv4 systems. There is no "Y2K" flag day; it is expected that IPv6 will slowly replace IPv4, until IPv6 becomes the majority protocol on the Internet. Some use of IPv4 may coexist with IPv6 for many years to come.

- For Europe to be able to seize the opportunity to accelerate the deployment of IPv6, and to thus give the new eEurope and novel 3G applications the best competitive edge, a number of key actions need to be taken. These actions apply to national governments, to the European Commission, to vendors and to various fora and standards bodies. The actions are detailed at the conclusion of this report, and include calls for incentives for wider IPv6 trials, promotion and awareness raising activities, and careful consideration of regulatory and policy issues.

While IPv6 deployment should be market-led, this Task Force feels that the recommendations in this report should be considered of critical importance for the future development of the Internet in Europe.

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.

As a response to these anticipated developments, the European Council at its meeting in Lisbon on March 2000[1,2], set the objective for Europe to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion. In June 2000, the Commission presented to the European Council, held in Santa Maria da Feira, the comprehensive Action Plan[3] "*e*Europe 2002". The aim of this Action Plan was to ensure that the targets set by the Lisbon European Council were reached by defining the necessary measures to accomplish the objective of "An Information Society for All". It identified three main objectives (a cheaper, faster secure Internet; investing in people and skills and stimulating the use of the Internet) where action at European level would add value, and it detailed a number of policy actions in connection with these objectives. These actions included affordable access, by businesses and citizens to a world-class communications infrastructure and the rapid development of a wide range of competitive online services. In parallel, public administrations at all levels were requested to deploy tangible efforts to exploit new ICT technologies so as to make information as accessible as possible.

Europe has demonstrated its leadership in mobile communications and digital TV. However, the uptake of the Internet has been relatively slow. These different sectors of the communication industries are currently converging, giving Europe the opportunity to capitalise on its technology know-how, to strengthen its competitive edge, to harness its educational excellence, to release its entrepreneurial potential and to successfully make the leap to the wireless Internet world.

1. IPv6 and the future Internet

According to population estimates, 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

[1] Lisbon European Council, 23-24 March 2000: Presidency conclusions, http://europa.eu.int/council/off/conclu/index.htm

[2] *e*Europe – An Information Society for All, Communication on a Commission Initiative for the Special European Council of Lisbon, 23-24 March 2000, http://europa.eu.int/information_society/eeurope/action_plan/index_en.htm

[3] *e*Europe 2002 Action Plan, http://europa.eu.int/information_society/eeurope/action_plan/actionplantext/index_en.htm

to have the potential for Internet access. It would not be acceptable to stay with the current Internet Protocol (IPv4) that simply cannot 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.

1.1. Internet communication and addressing

To a user of the Internet, computers are addressed by their domain name, e.g. in the Web context you might use *www.ipv6-taskforce.org* as the web address of the IPv6 Task Force, or *editor@ipv6-taskforce.org* as the e-mail address of an 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.

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 can never be fully utilised[4] and because of large allocations per ISP or per site in the early days of the Internet.

The new Internet Protocol version, IPv6, in development since the early to mid 1990's, has now matured to the state where vendors are delivering early commercial products and initial deployments are being made. IPv6's major advantage is that it uses 128-bit addresses, enough to offer globally unique IP addresses to any device wanting it for the foreseeable future. Given that all Internet communications use IP, the importance of the availability of globally reachable IP address space for all cannot be stressed enough.

[4] The Host-Density Ratio for Address Assignment Efficiency, RFC3194, http://www.ietf.org/rfc/rfc3194.txt

1.2. IPv4 address shortage

The risk of global IPv4 addresses becoming critically scarce by 2005, coupled with the uneven distribution of the address space between Northern America and the rest of the world, is sufficiently serious for action to be taken now and swiftly, thereby promoting the achievement of the Lisbon Strategy objectives. While IPv4 addresses may never be completely exhausted, their availability will become increasingly scarce, particularly for large-scale requirements (such as those of mobile operators). Scarcity implies an undesirable cost to those wanting IP addresses.

Without sufficient global IP address space, applications are forced to work with mechanisms that provide local site addressing – loosely the equivalent of the early days of telephony where users had to interact with one (or more) operators to place a call. Such mechanisms (i.e. Network Address Translation, or NAT) restrict the end-to-end transparency of the Internet. While NAT has to some extent delayed the pressure on IPv4 address space for the short term, it places severe restrictions on application communication. While a client behind a NAT device can communicate out to servers on the Internet (the “client-server” communication model), that same client cannot be guaranteed to be accessible when external devices wish to establish a connection to the client (as typified by the “peer-to-peer” communication model).

The need for always-on environments (such as residential Internet through broadband, cable modem, or Ethernet-to-the-Home) to be globally contactable precludes NAT-style IP address conversion, pooling, and temporary allocation techniques, and the “plug and play” always-on consumer Internet appliance requirements further increases the address pressure. Rather than connecting temporarily via dialup, with a temporary IP address taken “at random” from a pool, users and applications of the future need permanent connectivity with dedicated IP addresses. IPv6 should remove the requirement for use of NAT because global addresses will be widely available.

IPv6 reintroduces end-to-end security and communication that are not always readily available through a NAT-based network. The plug and play feature of IPv6 makes IP device deployment, for example in the home, much easier for vendors – end users should not need to configure their network appliances (and with IPv4, users would have to configure NAT routers, which is unacceptable for commodity deployment).

1.3. IPv6 address allocations

In Europe, the IPv6 production address space is managed and allocated to ISPs by RIPE NCC[5]. 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

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

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 Internet Registries – RIPE NCC, APNIC[6] and ARIN[7] – that are responsible for IP address allocations 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).

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 have no chance to obtain a single static IPv4 address for their home network. 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 limit the availability of static IP addresses.

The combination of the availability of multiple globally reachable IPv6 addresses for a home network, along with broadband access, enables a whole new range of remote home management applications to be enabled (e.g. multiple web cameras, or wireless temperature sensors) that are far more complicated to offer (both technically, and for ease of use) with IPv4.

1.4. Future Internet applications

Accessing and using the Internet, whether via a computer, a mobile communicator/phone, or a TV set-top box, will become commonplace in the coming years. The eEurope Action Plan specifically addressed the next generation Internet, including mobile Internet, and emphasised the need for a vastly increased Internet IP address space (as offered by IPv6, and IPv6 alone), commensurate with anticipated medium and long-term requirements. Indeed, the projected hundred-fold increase in Internet traffic in a few years, the expected development of peer-to-peer communications, the rapid development of broadband access infrastructure such as xDSL, the necessity to cope with the demand for machine-to-machine communications, all point to the urgent need for a rapid evolution towards IPv6.

In the context of UMTS (3G) licensing by Member States, the Commission issued a Communication[8] on 3G also stressing that the implementation of the current Internet Protocol (IPv4) is considered to limit the full deployment of 3G services in the long run. The proposed new IP version, IPv6, would overcome this addressing shortage and enable additional features (described later). Implementing IPv6 in mobile networks will also allow for wireless machine-to-machine interconnection, thereby considerably boosting the scope for novel 3G-application development. Any delay in the transition to all-IPv6 networks, which will require several years of effort, risks hindering the deployment of these advanced 3G service features at a later stage.

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[6] APNIC: http://www.apnic.net/

[7] ARIN: http://www.arin.net/

[8] The Introduction of Third Generation Mobile Communications in the European Union: State of Play and the Way Forward, COM(2001)141, http://europa.eu.int/ISPO/infosoc/telecompolicy/en/com2001-141en.pdf

Note that with IPv4 NAT, usually using what is known as "Net 10" addressing, a network is limited to approximately 16 million addresses. However, because of the inefficiencies in address utilisation[9] and performance issues for large-scale NAT, in reality a privately addressed IPv4 NAT network may struggle to handle 5 million devices. Thus an operator considering deploying a network that will grow to more than a few million connected devices, should consider deploying IPv6 for its addressing benefit alone.[10]

In its Communication[11] to the European Council meeting held in Stockholm, the Commission stressed that the deployment of high-speed networks is primarily a task for the private sector operating in the competitive environment for communication services. It further emphasised that the new Internet protocol was required in order to enlarge the global IP numbering space and thereby facilitate the development of mobile Internet and the deployment of new and more secure services.

While 3G is important, other application areas will benefit from IPv6. These include home networking, collaborative working, entertainment systems, wide-scale embedded systems (e.g. IP-enabled sensors), medical environments and in-car systems. Where applications wish to address large numbers of devices remotely, where peer-to-peer communication is desired from any network to any network, only IPv6 can deliver a scalable, robust and secure solution. With IPv6, It will become possible to communicate from mobile 3G devices to home network appliances, something that is significantly difficult (and costly) to achieve large-scale with IPv4.

IPv4 applications are already being converted (ported) to also support IPv6. However, there will also be novel applications that will emerge only when IPv6 is prevalent, and applications developers can work freed from the shackles of restrictive IPv4 bolt-ons such as NAT. The porting effort is not necessarily a significant one[12]; the challenge lies in integrating IPv6 applications in an IPv4 world, such that systems using either protocol can communicate during the ongoing drift towards a majority IPv6 Internet.

1.5. 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, Africa and Asia. IPv6

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[9] The Host-Density Ratio for Address Assignment Efficiency, RFC3194, http://www.ietf.org/rfc/rfc3194.txt

[10] It is theoretically possible to run a NAT inside a NAT to increase the size of a private network, but this adds even more complexity and scaling issues to the general IPv4 NAT problem.

[11] *e*Europe 2002: Impacts and Priorities, A communications to the Spring European Council in Stockholm, 23-24 March 2001, COM(2001)140, http://europa.eu.int/information_society/eeurope/action_plan/index_en.htm

[12] A Linux version of the highly popular Quake game for the PC was ported to support IPv6 by two people in under two days: http://www.viagenie.qc.ca/en/ipv6/quake/ipv6-quake.shtml

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.

The Internet could also achieve a far better penetration in developing countries 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. Failure to provide access to digital technology to countries in the developing world would be to essentially deny them an opportunity to participate in the new economy of the 21st century.

1.6. 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.
- Support for hierarchical address aggregation, making Internet backbone more scalable.
- Autoconfiguration, easier network renumbering, and much improved plug and play support.
- Simplified IPv6 data packet header for routing efficiency and performance.
- Security with mandatory implementation of IP Security (IPSec) support for all fully IPv6-compliant devices (IPSec implementation is not mandated in IPv4).
- Improved support for Mobile IP and mobile (and ad-hoc) computing devices.
- Enhanced multicast networking support.

These benefits equate to flexibility, easier administration, increased network performance, enabling improved business models and potential new applications for a broad range of organisations, notably SMEs.

2. IPv6 deployment

At present, IPv6 is gradually being introduced. However this process needs to be accelerated to prevent the current IPv4 shortcomings from hindering the further development of the Internet, to ensure a more open and competitive arena for the provision of new generation services, and to avoid much higher transition costs if that process is delayed.

2.1. IPv6 standards development

The IPv6 standards, as implemented by vendors, are designed, tested and approved by the Internet Engineering Task Force (IETF)[13]. The IETF is a vendor-neutral organisation that spans the globe and that has working groups (WGs) in a wide range of areas.

To date there are over 40 IETF standards (RFC documents) on IPv6, with a similar number in the draft (design development) stage.

In the wireless area, standards are developed by 3GPP[14] and 3GPP2, and the ITU[15]. The work of 3GPP and 3GPP2 is critical as 3G is seen as a prime area for early commercial IPv6 deployment.

Standards bodies (e.g., 3GPP and 3GPP2) for wireless data services are preparing for the future, and IPv6 provides the end-to-end addressing required by these new environments for mobile phones and residential Voice over IP (VoIP) gateways, with integrated autoconfiguration (plug and play), QoS, and security features. Mobile IPv6 improves on IPv4 in many ways, including the option to exchange data directly between mobile devices, rather than routing all data via a “home agent” device – the removal of such “triangular routing” is a major advantage for IPv6.

While the IETF sets standards, it does not mandate policy, nor perform advocacy. The Internet Society (ISOC)[16] has an important educational role, while the IPv6 Forum[17] is a key marketing platform for IPv6 technology.

2.2. IPv6 R&D in Europe

Significant efforts have been devoted to research and development of key IPv6 issues in the context of fifth Framework Programme. Responding to the conclusions of the Stockholm Summit, the Commission stepped up its R&D efforts. A large number of IPv6 projects totalling some 55 Million € of community funding is currently operational, including two large-scale trials (6NET[18] and

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[13] The Internet Engineering Task Force: http://www.ietf.org/

[14] 3rd Generation Partnership Project: http://www.3gpp.org/

[15] The International Telecommunication Union: http://www.itu.org/

[16] The Internet Society: http://www.isoc.org/

17 The IPv6 Forum: http://www.ipv6forum.org/

18 The 6NET Project: http://www.6net.org/

Euro6IX[19]) with others due to come up on-line shortly. These trials are fully complementary to the efforts deployed at national level in the context of National Research and Education Networks (NRENs) and at European level in the context of initiatives such as GÉANT[20]. 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.

2.3. 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 and have now launched an IPv6 promotion council[21].

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.

2.4. IPv4 and IPv6 integration

While IPv6 offers a bright future for the Internet, IPv4 will not go away overnight. As IPv6 is being deployed today, it is done so alongside IPv4. The first IPv6 deployments began in 1996, from which emerged the 6bone IPv6 testbed network[22], now spanning over 50 countries and 1000 sites. Commercial IPv6 deployments are happening, led by Japan, and in countries where IPv4 address allocations have been historically lower (in particular in Asia).

A smooth migration, supporting integration of IPv4 and IPv6 during the transition is advocated. It is possible for IPv6 site networks to be connected via an IPv4 ISP network, by “tunnelling” the IPv6 data in IPv4 data packets. This will enable customers to leverage their existing investment of

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

[20] The GÉANT Project: http://www.dante.org.uk/geant/

[21] IPv6 Promotion Council: http://www.v6pv.jp and http://cwg.v6/keel.net/apwg/en/index.html

[22] The 6bone project: http://www.6bone.net/

today's IPv4 services, while preparing for a seamless migration to IPv6 as additional IPv6 devices come online. The IETF has devised a wide range of transition and integration techniques, enabling providers to pick those methods best suited to them. The Industry is encouraged to continue to aggressively bring the cost and performance benefits of emerging technologies, such as IPv6, online as standards-based solutions.

Ultimately many IPv6 deployments will be "native", i.e. pure IPv6, rather than islands of IPv6 connected by means of the existing IPv4 Internet. Such infrastructures are starting to appear, mainly in Japan.

3. The road forward to IPv6

The future of network services lies in convergence, of voice, video and data to a unified IP architecture. Such integration will have significant benefits, and open up new opportunities for business and to offer services for residential users in Europe. For example, the combination of VoIP (voice over IP), wireless LAN and SIP (Session Initiation Protocol) technologies could have a significant business impact: Already today, a user is able to run VoIP through an IP-enabled handset over a wireless local area network to a local SIP gateway which communicates via IP to another SIP gateway at the recipient's site.

IPv6 will facilitate access to IP based services and applications using a wide range of access technologies. Mobile Operators will be able to deliver their services irrespective of the type of access (e.g. UMTS, Wireless LAN) as well as providing a seamless Internet experience to their customers. Users can connect to whatever web sites they choose, log in to their corporate intranet (and be reached from that network), do voice over IP, get streaming audio/video, use whatever network applications they need. They will not be constrained to the limited set of value added network services the wireless operators will offer through their own portals. As a base protocol for a converged network, IPv6 is a significant enabler.

In the initial phase of GPRS/UMTS with a few millions of terminals, IPv4 is a perfectly reasonable solution, but to offer a scalable service that will cater for over a billion terminals, IPv6 is an imperative. By rapidly adopting IPv6, the European Mobile industry has a unique chance to investigate and pioneer the future, together with all other Internet related players, be they fixed, cable, xDSL, ISPs etc. In so doing they will acquire a competitive edge which can be explored and exported.

There should be no reason for address space exhaustion in IPv6, and no need to resort to expensive and inefficient, non-scalable workarounds like schemes based on NAT. With simplified network renumbering methods, IPv6 will make network mergers easier to achieve, and the availability of the global address space of IPv6 will reduce the pressure for sites to use local, private addressing and NAT (which can cause problems when two sites merge that use the same private IP address space).

While 3G operators may be the leading IPv6 adopters, IPv6 will also reach into all aspects of social life – the home, the workplace and schools and universities. It will enable end-to-end user services that have as big an impact on society as the business services will have on commerce. However, IPv6 is only an enabler. For the full social benefit broadband access to the home must become commonplace; at present xDSL and Cable Modem deployment is in its infancy, but combinations such as xDSL with wireless LANs in the home will – in conjunction with IPv6 addressing – open up avenues for consumer-electronics manufacturers and household appliance vendors to offer innovative new services.

While end-user and business requirements for advanced network services expand exponentially, IPv4 will not be able to cope. In the IPv4 world severe problems and limitations exist with band-aids such as NAT, and although these band-aids and extensions may prove valuable in the very near term, they ultimately will limit connectivity, interoperability, and performance in the long term for enterprises that are increasingly network-dependent

As the transition to IPv6 takes place progressively and at different speeds by different industrial sectors, the need will arise to develop IPv6 transition and integration guidelines that will recognise that the coexistence of IPv4 and IPv6 will last many, many years, that the phasing out of IPv4 will be soft and gradual and that there will not be a magic date imposed on any particular industry (as was the case with Y2K) to move to IPv6, but rather that there will be an incentive to act before it becomes *too* late and *too* expensive.

It is now widely recognised – as exemplified the position statements of the vast majority of router, host and mobile operators - that IPv6 will become critical to the operations and continued efficiency of day-to-day business activities in the new economy, and that there is ultimately no substitute for IPv6 when emerging multimedia, interactive, and transaction-oriented network applications start requiring high levels of connectivity.

The requirement for IPv6 implies a need for coordinated trials and tests of new IPv6-enabled devices – routers, hosts, PDAs, etc – which are more likely to succeed via both harmonisation of standards and readily available interoperability events (such as those offered by ETSI[23]). The trials and roadmap processes are critical for IPv6 systems developers and implementers.

For IPv6-enabled services to be deployed in a timely manner, it is of key importance to structure, consolidate and integrate European efforts on IPv6, to ensure that the necessary base of skilled human resources is available, that the policy approaches are fully harmonised, where needed, that the research effort is sustained, that standards and specifications work is accelerated and that all sectors of the new economy likely to be impacted by IPv6 are fully aware of potential benefits accruing from the adoption of IPv6. European Union funding towards advanced testbed deployment should be made available, and advertised widely.

A concerted effort is hence required that will enable the competitiveness of Europe to be strengthened. Standards activity needs to be harmonised, while application developers, and organisations tendering for new IP-based services, should consider the IPv6-ready status and

[23] http://www.etsi.org/frameset/home.htm?/plugtests/

future proofing of the services they intend to deploy. Policy frameworks need to be such that IPv6 deployment is allowed to proceed unhindered via natural market forces.

It is expected that the EU IPv6 Task Force activities should continue, and that they should be linked to a Global IPv6 Task Force initiative, to further the determination of best practice for future IPv6 deployment.

4. Actions to be taken at EU level

In light of the above, a series of recommendations pertaining to the implementation of IPv6 by all relevant ICT sectors in Europe is given below. These recommendations which are seen as key measures to be taken to accelerate the pace of the introduction of IPv6 in a wide scale are addressed to the Member States, European Commission and to the Industry at large (including all the involved parties such as RIPE NCC, ETSI, 3GPP, IETF, UMTS Forum, CENTR, GSMA, ISPs associations, the research community etc.).

4.1. Actions for EU Member State governments

EU Member states are called upon to:

A.1 Increase their support towards IPv6 in the networks and services associated with the public sector, including educational institutions, in the context of public applications requiring the use of new Internet generation tools and technologies. Moreover, IPv6 should be considered in application procurements.

A.2 Establish and launch educational programmes on IPv6 tools, techniques and applications, so as to significantly improve the quality of training on IPv6 at professional level, and create the required base of skills and knowledge.

A.3 Promote the adoption of IPv6 through awareness raising campaigns and co-operative research activities, by small and medium size enterprises, Internet service providers and wireless service providers and operators, so as to educate the stakeholders, boosting their technological know-how and strengthening their ability to operate on a European if not international basis.

A.4 Continue to stimulate the wide spread use of Internet across Europe and encourage the integration of IPv6 through the creation of a favourable, stable and harmonised policy environment and by avoiding fragmented approaches, mandatory deployment time-lines or excessive fees. Broadband access to the home, in public areas, small and medium size enterprises is a key requirement to maximise the benefit of future end-to-end, converged network services.

A.5 Strengthen the financial support towards national and regional research networks *(NRENs)*, with a view to enhance their integration in European wide networks, *such as GEANT,* and increase the operational experience on novel Internet services and applications based on the use of IPv6.

A.6 Provide the required incentives towards the development, trials and testing of native IPv6 products, tools, services and applications in the new economy sectors such as consumer electronics, telecommunications service provisioning, IT equipment manufacturing, construction, transportation, public education and health, banking, insurance and trade. It should be understood that the move towards native IPv6 is a major step for Europe to strengthen its position in the Mobile Industry.

A.7 Establish a National or Regional IPv6 Council tasked with:

i) The assessment, at national or regional level, of current developments and degree of take-up of IPv6, as well as with the formulation of guidelines and dissemination of best practises relating to the efficient transition towards IPv6. The IPv6 Council should be guided by the imperative need for harmonisation and by the economical benefits achievable through the wide spread IPv6 technology in all ICT sectors and should duly take into account the requirements for an all inclusive information society as well as the digital divide dimension.

ii) Developing measures aiming at the alignment of IPv6 integration schedules favouring a cohesive IPv6 take-up and ensuring that Europe gains a competitive advantage on the next Generation Internet.

iii) Encouraging active participation of technology experts in the work of European and International standards and specification bodies involved with IPv6 matters, such as IETF, 3GPP, RIPE, ETSI.

iv) Drawing the attention of potential IPv6 systems or application developers to funding opportunities available at a national or European level.

4.2. Actions for the European Commission

The European Commission is called upon to:

B.1 Initiate a discussion of IPv6 policy matters at European level so that the implications of IPv6 are taken into account appropriately in future policy initiatives and raise awareness notably on address allocation, privacy and security issues.

B.2 In the context of the 6^{th} Framework programme, strengthen its R&D support towards further development of native IPv6 high-speed and high capacity network infrastructures and large scale trials and testing of IPv6 based services at European level, in full complement of national and regional network initiatives.

B.3 Set the basis for the launching, in the context of the 6^{th} Framework Programme, of a set of IPv6 based European wide Integrated Projects and Networks of Excellence, with the required critical mass of human, equipment and financial resources. Action should be taken to enhance the integration of such Projects across all Next Generation Internet areas.

B.4 Encourage the research and manufacturing communities to produce a European Code Base for IPv6, notably by funding projects in the 6^{th} Framework Programme that commit towards this code development work and produce open source code and implementations and by stimulating the establishment of a virtual “European IPv6 Centre of Excellence” initiative, where open source solutions for IPv6 could be studied and developed.

B.5 Encourage the development and deployment of DNSv6/DNSsec and Public Key Infrastructure (PKI) and promote the development of secure networking applications and environments through the trials, deployment and use of IPsec protocols.

B.6 Mobilise its resources, notably in the context of the eEurope Action Plan, towards the preparation and launch of an IPv6 training and education programme, with the objective of securing the availability of skilled human resources in all aspects of the new Internet generation services.

B.7 Carry out a thorough and long range socio-economic and market study addressing the key sectors of the new economy that are to be impacted by the integration of IPv6 networking infrastructures, tools, services and applications. Such a study should notably address aspects relating to the benefits generated by IPv6, namely security, privacy, user friendliness and easier management as well as their associated policy aspects.

B.8 Take all required actions aiming at the continuation of the work already performed within the "IPv6 Task Force" with an enlarged participation and renewed mandate. Concerning the enlarged participation, the Task Force is requested to strengthen the participation of senior representatives of all economic and industrial sectors likely to be impacted by IPv6, include representatives of national or regional IPv6 Councils and integrate appropriate representatives from candidate countries. Concerning its renewed mandate the Task Force is requested to:

i) Ensure a working liaison with on-going work on IPv6 carried out in standards fora and industrial bodies such as ISOC, IETF, ITU-T, ICANN, RIPE NCC, 3GPP, ETSI, IPv6 Forum, Eurescom, ETNO, UMTS Forum and GSMA, e.g. to harmonise activity, to encourage the fair availability of IPv6 addresses.

ii) Provide a regularly updated review and plan action ("the European IPv6 Roadmap") on the development and future perspectives of IPv6 in order to co-ordinate European efforts on IPv6 and to assist the pan-European integration of and transition to IPv6.

iii) Conduct studies, develop guidelines and IPv6 integration benchmarks, exchange best practices and launch awareness campaigns (to educate the stakeholders).

iv) Establish collaboration arrangements and working relationships with similar initiatives being launched in other world regions with a view to align IPv6 work programmes, promote innovation, develop global IPv6 concerted actions and disseminate best practises.

B.9 Organise a high level conference or summit aimed at raising IPv6 awareness, its development status and perspectives, its economic and policy dimensions and the actions required to consolidate and harmonise European efforts.

B.10 Submit the results of the work of the IPv6 Task Force to the Spring European Council of 2002.

4.3. Actions for European industry

European Industry is called upon to:

C.1 Fully participate in the R&D activities to be supported in the context of the 6th Framework programme, with a view to put in place an integrated and structured set of IPv6 activities, covering the full range of IPv6 aspects, from basic research through the development of service enablers and associated software suites, to the large scale trialling and testing of IPv6 features, for a diversity of applications, in a European wide environment.

C.2 Actively contribute towards the acceleration and alignment of on-going IPv6 work within standards and specifications bodies and urgently develop key guidelines permitting the rapid integration of IPv6 infrastructures and interoperability of IPv6 services and applications, especially in the context of 3G mobile communications, but also for VoIP and areas such as home networking.

C.3 Support and fully participate in interoperability events organised notably by ETSI, which provide opportunities for the collective testing of different IPv6 implementations and applications.

C.4 Address the multi-vendor interoperability issues impeding the wide-scale deployment of PKI and to conduct extensive trials with IP security in IPv6 and the parallel implementation of a PKI.

C.5 Contribute actively to the work of the IPv6 Task Force, ensure the collectively increase of IPv6 awareness and permit its members to individually derive their own perspective of the IPv6 business case and their own IPv6 integration strategy.

C.6 Devote efforts towards the establishment of a European wide, vendor independent, training and education programme on IPv6.

C.7 Consider in their strategic plans that the majority of mobile devices, and a growing number of household and consumer-electronic devices will require some form of IP connectivity and that the simplest way to offer these devices the fullest range of services is to have a unique globally routable IPv6 address available for all network-enabled components.

C.8 Seek to develop innovative IPv6-enabled devices, e.g. biometric security devices, “IP in a chip” embedded systems components, in-car sensor devices. Seek to design and implement innovative peer-to-peer applications where appropriate, e.g. peer-to-peer gaming in the entertainment industry.

C.9 Take early steps to gain experience with IPv6 and to accelerate the offer of IPv6 capable services or consider on a priority basis how best to rapidly evolve towards IPv6.

C.10 Where appropriate, develop roadmaps for the design, development and deployment of IPv6 services, equipment and networks, to include technologies such as AAA, DNS, xDSL, etc.

4.4. Actions for Industry Associations

It is critical that all standards-related initiatives and activities are harmonised for the timely and efficient introduction of common, interoperable IPv6 deployments. This calls for a sustained effort from:

- Standard Development Organisations (ITU, 3GPP/3GPP2, ETSI, IETF, IEEE-ISTO, etc),
- Fora (ASP Consortium, DSL Forum, IMTC, IPv6 Forum, MPLS Forum, MSF, OIF, OMG, SDL Forum, TM Forum, TOG, UMTS Forum, World Collaboration CPR, etc)
- Industry Associations (EICTA, ETNO, EURESCOM, EUCONTROL, GSM Europe, ISP associations, White Goods Associations, etc),

regarding opportunities for partnerships on IPv6 projects, as defined in the ITU-T initiative[24], relating to:

D.1 Joint development/collaborative work (within and outside Europe)

D.2 Common standards

D.3 Education and knowledge exchange

D.4 Market intelligence

D.5 Marketing and promotion

D.6 Profiling and implementation agreements

D.7 Interoperability and conformance testing

D.8 Feedback from market and forums to Standards Development Organisations for:

- Requirements
- Finished standards
- Gaps analysis

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

5. Glossary

3G	Third generation mobile communications system.
ADSL	Asynchronous Digital Subscriber Line. Offers high-speed connectivity to the Internet over existing copper telephony wiring.
Always-on	Devices remain connected to the Internet when powered up (e.g. ADSL), rather than establishing temporary connections (e.g. dialup). Because devices need a unique IP address continuously, the rise in always-on devices demands more IP address space.
APNIC	The Asia-Pacific regional registry (equivalent of RIPE NCC).
ARIN	The Americas regional registry (equivalent to RIPE NCC).
Broadband access	High-speed Internet connection technologies, e.g. xDSL and cable modems
Cable modem	High-speed Internet access via cable television service line.
CENTR	Council of European National Top-level domain Registries
Client-server	A communication model where connections are initiated one-way, from clients to servers.
DNS	Domain Name Service. Used to map between Internet domain names (e.g. www.ipv6forum.org) and IP addresses (for use by the network).
End-to-end model	Devices communicating on the Internet do so directly without any intervening translation devices; such devices fate-share their connection.
GPRS	General Packet Radio Service. Allows Internet access from a mobile device running IP(v4) over the wireless telephony network.
IETF	Internet Engineering Task Force. Define global Internet standards,
I-Mode	Popular interactive Internet telecommunications system in Japan
Interoperability	The ability of two devices, usually from different vendors, to work together.
IP	Internet Protocol. The underlying technology by which all Internet data communication is carried out.

IPv4	Internet Protocol version 4. The current protocol.
IPv6	Internet Protocol version 6. The new protocol.
IPv6 prefix	A block of IPv6 addresses that may be used by an ISP or a site network
ISP	Internet Service Provider. Provides network/access services.
ITU	International Telecommunications Union.
LAN	Local Area Network. A local data network.
NAT	Network Address Translation. Allow multiple computers to connect to the Internet via a limited number of global IPv4 addresses. Restricts end-to-end principle of the Internet.
PDA	Personal data assistant, e.g. a handheld PC.
PKI	Public Key Infrastructure. Used to exchange keys used for data encryption.
Peer-to-peer	Communication model in which client devices may communicate directly, initiating the data exchange in either direction, without a server system.
RFC document	The document format used by the IETF to describe Internet standards.
RIPE NCC	The organisation (regional registry) that assigns IPv6 top-level prefixes in Europe.
SIP	Session Initiation protocol. Used for VoIP.
Static IP address	An IP address allocated to a device that does not change, thus allowing the device to be consistently found at that address. Important when running Internet services to that device.
Tunnelling	Using one version of IP to carry (deliver) data from another version of IP, currently most usually IPv6-in-IPv4 to link two IPv6 networks over the commodity IPv4 Internet.
UMTS	The third generation mobile communications system.
VoIP	Voice over IP. Using an IP network to carry voice data.
Wireless LAN	A local network communication over an air interface. The current 802.11b standard allows 11 MBit/s maximum throughput over a wireless LAN.
xDSL	The set of Digital Subscriber Line technologies, including ADSL.