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1. Introduction

While the Internet continues its unprecedented exponential growth, the recent broad adoption of always-on technologies such as Digital Subscriber Line (xDSL) and cable modems, coupled with the pending integration of personal data assistants (PDAs) and cellular phones into always-addressable Mobile Information Appliances, significantly elevates the urgency to expand the address space Internet-connected systems use to find each other. The address space currently used is defined as part of the Internet Protocol, or IP (the network layer of the TCP/IP protocol suite). The version of IP commonly used today is Version 4 (IPv4), which has not been substantially changed since RFC 791[1] was published in 1981. Over that time, IPv4 has proven to be robust, easily implemented and interoperable, and has stood the test of scaling an internetwork (a network of networks) to a global utility the size of today's Internet. While this is a tribute to its initial design, moving forward to an even grander scale requires laying a new foundation.

IPv6 will continue the tradition of the IPv4 protocol, which gained much of its acceptance by defining mechanisms to tie systems together over a wide variety of disparate networking technologies. Already defined link-layer mappings for transporting IPv6 include Ethernet, Point-to-Point Protocol (PPP), Fibre Distributed Data Interface (FDDI), Token Ring, Asynchronous Transfer Mode (ATM), Frame Relay, IEEE 1394, and IPv4. From the architectural perspective, an IPv4-based infrastructure appears to IPv6-enabled systems as a single segment non-broadcast multi-access (NBMA) network. The capability to transit IPv6 over existing IPv4 networks will provide an initial reach as broad as the current Internet, limited only by the endpoints' ability and readiness to make use of it.

New capabilities such as scoped addresses (useful for restricting the default range of operations such as file & print sharing), stateless autoconfiguration (lowering the complexity and management burden), and the inclusion of IP security in all full IPv6 implementations (permitting end-to-end data authentication and integrity and privacy of connections) are expected to drive rapid adoption. In addition to the new capabilities, the technologies currently used to extend the lifetime of IPv4 (such as network address translation [NAT]) frequently break or hinder existing applications, and are already restricting the flexibility to deploy new end-to-end (peer-to-peer) services. IPv6 brings back the capability of 'end-to-end control of communications'; making networking applications simpler as the network again becomes transparent.

The conversion from IPv4 to IPv6 will be a larger task for the industry than the preparation for Year 2000. It will affect nearly all networked applications, end-systems, infrastructure systems, and network architectures. It is critical that this change be approached with responsibility to prevent costly unproductive missteps that result from broad premature availability of technologies. Unlike the Year 2000 issue, the conversion to IPv6 has no specific timeline, but as noted earlier the rate of IPv4 address consumption is rapidly increasing. Simplicity of deployment will be the key to rapid adoption.

Like IPv4 (where early deployments frequently transited X.25 networks), the IPv6 deployment will start at the edge of the network, taking advantage of framing within any available network technology. It is anticipated that Internet service providers (ISPs) will react to customer demand as the deciding factor for when to deploy native IPv6 routing, but as it takes several years to replace the network equipment this may be a slow process. To avoid a “chicken-and-egg problem”, early-adopters will be taking the approach that encapsulating IPv6 packets within IPv4 will allow incremental deployments of end systems that will in turn demonstrate the demand to the ISPs. To stay on the high performance path of the existing routers, IPv6-enabled systems will default to tunneling over IPv4 unless the ISP provides specific indication to do otherwise and a native IPv6 path exists end-to-end. The only requirement is that the systems directly connected to an ISP receive at least one public IPv4 address (the address ranges specified in RFC 1918 are not public). Subsequent systems in a home or business will receive 6to4 prefix router advertisements from the directly connected system.

1.1. General Statements and Recommendations

European Union has recognised IPv6 as a very important transitional technology for R&D, business, information society and e-commerce. Similar announcements have also come from some governments, most notably in Japan. With European positioning towards IPv6 deployment, some general aspects must be taken in account. From the infrastructure WG point of view the following recommendations have been suggested by Task Force WG:

- The European Union and State Members should prepare for transition toward a native IPv6 infrastructure as soon as possible. Native IPv6 networking topologies is and should be the final goal, although it has to be understood that hybrid IPv4/IPv6 networking is an inevitable intermediate step.
- In order to facilitate a smooth and timely transition, European Union and Member States should raise awareness of IPv6 within appropriate organisations and business entities, not forgetting SME companies. Education and public awareness among all relevant parties is seen as the key success factor in order to facilitate successful early transition towards IPv6.
- It should be understood that the move towards native IPv6 is a major step and requires time and resources. Moreover we want to stress that IPv6 is not limited to any single transmission technology, but will span over fixed core networks, wireless and cellular systems. As before, IPv6 adheres to an `hour glass´ model and enforces the end-to-end principle, both of which have been proven concepts. Europeans should be prepared to invest resources and learning-energy for a smooth medium to long-term transition.
- IPv6 technology is developed through an international collaboration and standardisation effort. The European Union should encourage European organisations to co-operate on an international level with appropriate bodies on R&D, standardisation, product development and to exchange best practices & experiences on transition technologies.

- Although, as previously mentioned, international collaboration should be encouraged, there should be also strong initiatives and mechanisms to make sure that European researchers and industry will produce relevant software (including protocol stack implementations and applications) and hardware in order to secure industrial competitiveness and expertise within Europe. In order to raise European competitiveness, visibility and to provide awareness of IPv6 technologies within schools, universities and businesses, this should be encouraged by direct initiatives to produce the aforementioned key-elements.
- The European Union and Member States should encourage the transition towards IPv6 and other next generation technologies through appropriate mechanisms. The move towards IPv6 should be driven by market-economics, and (already) demonstrable technological and commercial advantages, rather than through the imposition of regulatory guidelines by European Union or Member States. Hence, any artificial or strict regulations, time-lines, fees or regulatory mechanisms should be avoided.
- The public exchange of best practices, experiences, availability of products etc. should be encouraged at the European level. Moreover, it would be beneficial if this information (or at least links to that) could be provided easily form some central contact point for interested parties. The awareness and experience exchange could benefit also from a European level "IPv6 Magazine" that would be a good way to tell about European trials and results.

By acting quickly organisations, companies and citizens within the European Union can guarantee a smooth evolution from IPv4 to IPv6, create new business opportunities, and enable new services and better infrastructure for e-Europe. IPv6 is solving some key limitations of IPv4, and **the stakes are high to move into IPv6 infrastructure with right timing and force, Europe should grasp this opportunity.**

2. Infrastructure Framework and Recommendations

IPv6 and other Internet technologies are developed and standardised by relevant technical organisations and societies. The most notable of these is the IETF (Internet Engineering Task Force). Technical work should continue be done by these organisations and through appropriate methods. The European Union should initiate and encourage larger European activity in all relevant forums and workgroups.

The technical specifications and descriptions are done by the IETF. It is not a work for this task force to produce any new technical material or interpretations for the excellent work done in other places. There are two high quality executive briefings on IPv6 by international authorities in the field, namely by Jim Bound and Brian Carpenter. These briefings are available from ISOC (Internet Society) on the web (http://www.isoc.org/briefings/). There is also a lot of background information and links on IPv6 available from the IPv6 Forum (http://www.ipv6forum.com). The principal technical RFC within the IETF is RFC 2460. IPv6 infrastructure is available and is being deployed today. There have been (international) IPv6 test beds and trials in existence since 1996, and also commercial IPv6 core networks are in operation. There has been increasing support for IPv6 from hardware and software vendors[1]. However, the application and operating system vendors, most importantly Microsoft, should be encouraged to produce more support in order to improve application possibilities. A number of companies have produced position papers about their IPv6 policy, the list of some can be found in Appendix A.

2.1. IPv6 Advantages

The general technological view we want to stress is that IPv6 technology is already available in the market place. There are several enhancements in IPv6 over the present day IPv4. EU IPv6 Task Force discussions by industry, operators and the research community have focused upon the following key issues relevant for the short to medium term :

- First, the larger **Address Space** of IPv6 is seen as a crucial benefit. It was felt that the address space extension alone, especially taking into account requirements from wireless and cellular networks, could be a driving force to move IPv6. This is especially important for Europe and Asia. Depending on roadmaps and uncertainty related to mobile phone IP address requirement, it seems clear that between 2005-2009 the IPv4 address space problems will reach a crisis. It is clear that the NAT (Network Address Translation) mechanism and other “band aid” mechanisms are not desirable in the long run (see also later point).
- Secondly, better **autoconfiguration** support through IPv6 was seen as a useful property, especially when one considers consumer and lay-people requirements.
- Thirdly, IPv6 addressing is assigned in an **aggregated** hierarchical fashion from the outset. IPv4 has Classless Inter-Domain Routing (CIDR), but CIDR has resulted in (static) global IPv4 addresses being hard to acquire, and large IPv4 block allocations being less likely to be honoured. IPv6’s aggregated addressing should reduce the size of the Internet’s backbone routing table, making routing more efficient. Its fixed-length IP header (with separate extension headers) can make packet processing more efficient.
- IPv6 has improved mobility features, meaning that Mobile IPv6 can be used in a more scalable, efficient way than IPv4 (though a principle advantage remains the IPv6 address space – note that a Mobile IP device needs at least two IP addresses while roaming, and these must be global if global, transparent peer-to-peer communications are required).
- Support for **security** through IPSec was quite often cited as an important IPv6 issue. But it was felt that data security and privacy issues require their own treatment, and in the case of IPv6 security and privacy issues are thought not as important a benefit compared with the address space and autoconfiguration benefits.
- The migration to IPv6 will make (restore) a cleaner design and **end-to-end principle** with a classical “hour glass” model. In short one can say that due to evolution of entropy within today’s Internet, the present day IPv4 is actually losing features due to all the “band-aid” methods and extensions that are added into it. This has potentially very serious consequences

[1] Including all major operating systems providers.

for both fixed and mobile Internet evolution in the market place. Hence, although the move to IPv6 will initially bring in some interoperability and API problems, in the long run it will enhance and restore the *overall* strength of the Internet, enabling as-yet unforeseen applications.

We want to stress to policy-makers that the transition to IPv6 can be managed smoothly and progressively. There is no single "year-2000" overnight switching problem in IPv6. Hence, the IPv6 and existing IPv4 systems will co-exist for some time. But the preparation for transition should be started well in advance, as it would be good to be ready as soon as possible. Moreover, a well-planned transition makes it safer, easier and *cheaper.*

Finally, the WG is stressing the point that requirements and the present state of the art in networks (e.g. available address space) varies highly from continent to continent and country to country. The European Union and its Member States must move faster and should aim to be *at least* on a par with Japanese efforts towards native IPv6 transition. They should not look to the United States for leadership in IPv6 transition[2].

2.2. Specific Recommendations

The more specific statements, suggestions and recommendations that were raised from the infrastructure point of view are summarised as follows

1. The question on IPv6 is not "if", but "when". The technology is available, verified and there are well-recognised reasons to have a transition to IPv6. The exact timing of transition towards hybrid IPv4/IPv6 on a large scale[3] and fully native IPv6 networks, is a rapidly evolving issue. However, the road map is clear enough to say that transition preparations should be started as soon as possible and movement will be most probably extremely fast between 2005-2010 – at least in Asia and Europe. Wireless and mobile considerations are important driving forces for IPv6. The main 3G-standardisation body, 3Gpp, has opted for IPv6. In fact, the European Union should support a rapid movement towards a policy wherein operational traffic would be put into existing IPv6 networks.
2. We point out that the overall transitional period will require both time and resources, and shall not be a rapid "over-night" process. There was a consensus within the WG that the infrastructure will evolve through islands and edges towards more and more common full & native IPv6 networking. The transition will affect almost all networks, including fixed core networks, wireless and cellular systems (probably including digital-TV data transmission). Hence, the European Union and Member States should recognise that the change is large and prepare for it sufficiently.
3. We suggest that the European Union and Member States arrange a high-level summit to discuss on the transition and its requirements. This summit should be for high-level policy-makers, including major policy-makers from the commission, governments and CEOs, and

[2] As a short example we point out that some companies alone in the U.S.A. have more reserved IPv4-address space than what is allocated for whole (large) countries in other continents.

[3] It should be understood that there are large and wide-spread international testbeds/pilot networks operating already, and they are already growing quite fast. Hence we already **are** in the transition period of hybrid IPv4/IPv6 topology.

also *a very limited* number of top technocrats and academics. This summit should be aimed at raising awareness on issues. One outcome of a summit should be discussion and decision on how to provide continual monitoring of the transition within Europe (and its publication and public dissemination), how to freely exchange best practises and experiences and production of the European IPv6 Roadmap for next 3-5 years.

4. One should understand that different geographical areas (continental entities such as Europe, the Northern America and Asia) will evolve towards IPv6 at (highly) different rates, and even within continental countries there might substantial differences due to different requirements, business climate etc. We recommend that the European Union should recognise and accept this difference. However, the European Union should ensure that any attempt to harmonise or encourage faster rates of IPv6 transition of its members states not be too disruptive. Moreover, it is felt that each would benefit by being at the forefront of transition.

5. The transition towards IPv6 and other next generation networking technologies must be done because of demonstrable benefits and through good, commercially viable (open) practices. The European Union and Member States should not regulate strict transition times, rules or mechanisms through regulations, fees, subsidies or similar means. This kind of regulation might actually interfere with the development and free-movement towards IPv6. This means also that such strict rules should not be made for European operators, organisations or governmental offices. However, one appropriate means that give strong encouragement, help for transition and trials should be used as much as possible. Opportunities for encouraging transition could lie in providing public IPv6 and dual stack services to e.g. airports, governmental and Community buildings etc., and to provide information and technology from European R&D projects for public use, whenever it is possible. Key European R&D-projects should produce public awareness, best-practice information and education in the future for public, school, and business entities in an increasing amount.

6. It is recommended that the Community, Member States' governments etc. adopt policy guidelines for future networking contracts (including equipment acquisitions) that stipulate "IPv6 Future Proofing", i.e. new networks should be "IPv6 ready". This would also be a strong message to software and hardware vendors, and would encourage development, manufacturing and competition. This would also quite probably boost ITC-economic situation and through it would contribute to economic well being of European Economic Area.

7. The IPv6 networking technology is independent of underlying transmission technology (such as cellular networks, wireless LANs, fixed core networks). Hence, one must not limit European activities only to wireless IPv6 - although it is recognised that wireless IPv6 is one of the key R&D and business opportunities. The export and import of all necessary technical equipment, software and knowledge between countries should be as free as possible. They key-issue is to provide IP-compatibility for applications and networks, this will lead to harmonisation.

8. IPv6 technology and other next generation networking technologies beyond it are forming a continuum; it is imperative to recognise this. There are still a lot of open R&D issues related to IPv6 networks, security, quality of service, wireless aspects and next generation networking. The transition to IPv6 will not be the final step. Hence, we recommend that European Union

and its Member Countries continue to support relevant R&D and international co-operation on IPv6 and technologies beyond it.

9. The IPv6 technology, other relevant novel Internet technologies and applications, as well as some related, challenging next generation networking issues require more basic research, R&D and trials. It is felt that the 6th Framework Research Programme would be a most useful and immediate instrument to guarantee that the European Union and its Member Countries are continuing to do a good job on the field and are trying to encourage Member Countries to be at leading edge of some areas. As a recommendation, it was suggested that a high-level scientific **programme director** be appointed. The position would be a fixed period contract for someone from outside (of the present Commission staff) to fill for two to three years. The programme director would provide leadership, communications and planning for next generation and IPv6 networking research within the EU. One of his/her responsibilities would be the planning of strategic IPv6 related R&D (programmes) within the European Union. The person should have also discretionary budgetary authority to initiate relevant R&D projects.

10. It is recognised that during the deployment of the present-day-Internet the national and international research networks (NRENs) and universities had an important role as early adopters, providers of information dissemination and educational points; moreover they built momentum. Owing to changed economical and educational situations at the present, we point out that a similar leading edge early adoption cannot be expected from them *without clear encouragement and monetary help.* We would urge the European Union and Member Countries most to seek possible mechanisms for getting NRENs especially and major universities interested in IPv6 transition.

11. Although this is not an IPv6 specific point, there should be continuous monitoring on Internet use expenses for citizens and companies. It is imperative that telecommunication expenses are relatively cheap and competitive in order to encourage an information society and e-commerce development within the European Union. This will also lead to faster infrastructure deployment and demand build-up.

12. There should be continuos road-mapping and monitoring of the advancement of IPv6 within Europe.

13. Taking into account the enormity of the transition process and its technological and business challenges it is suggested that the European Union and Member States should encourage large-scale trials in order to get ‘real-life’ experience and to gain best practices. These trials should include not only NRENs, but also companies and operators. There is already a number of such a high level of excellence projects approved.

14. Consideration should be given to providing funding to a limited number of partners involved in some of the most challenging trials and R&D programs, of more than 50% of their expenses (up to full 100% coverage) in appropriate cases (this should be done with highly selective rules and for strategic purposes).

15. We recommend that the European Union encourage European Projects, researchers and manufactures to produce a European Code Base for IPv6. One mechanism could be through the 6th Framework Programme, by finding projects that will be committed towards this sort of activity. The projects that are producing practical information, (open source) code, and

implementations would be very valuable. This could be also done through a virtual "**European IPv6 Centre of Excellence**" - initiative, where the open source for IPv6 could be developed and studied. There are known examples of how to organise this sort of work or centres. The work could also take into account differing European views on security aspects as different source distributions. The European Union should encourage the development in areas, where it would be leading the deployment, implementation, and harmonisation in IPv6. The (virtual) IPv6 Centre of Excellence could play a major role in the development, guidance, supervision and distribution of different code & information. The European IPv6 Centre of Excellence could also act as a clearinghouse for codes, experiences, and project results. The program director, mentioned in recommendation nine (9), could help to organise this sort of initiative.

16. New methods to ensure capitalisation of EU project results should be encouraged and envisioned, especially those that show how to spread the real experience gained in the trials and R&D projects.

17. The European Union should also assist in getting relevant business organisations and companies (especially SMEs) aware of IPv6 transition and **of commercial opportunities that IPv6 transition will create.** We recommend that one uses suitable mechanisms through Commission, projects, and brochures, and possibly by partially funding some forums or concentration projects that may be used to spread the awareness of IPv6 transition, starting in 2002. The European activity on software, hardware and application possibilities related to IPv6 should be invigorated as quickly and strongly as possible.

APPENDIX A: POSITION PAPERS ON IPv6 AVAILABLE FROM COMPANIES

(Non-comprehensive list)

Alcatel	http://www.cid.alcatel.com/ipv6/index.html
BITS Pilani	http://ipv6.bits-pilani.ac.in/case-for-v6
Cisco	http://www.cisco.com/ipv6
Compaq	http://www.compaq.com/ipv6
Consulintel	http://www.consulintel.es/html/ipv6/ipv6.htm
Ericsson	http://www.ipv6forum.com/navbar/position/Ericsson-IPv6-statement.pdf
	http://www.ipv6forum.com/navbar/position/ipv6-ericsson.pdf
ETRI Korea	http://www.krv6.net
Hitachi	http://www.v6.hitachi.co.jp
HP (India)	http://www.hp.com/products1/unixserverconnectivity/software/ipv.html
IBM	http://www.ibm.com/software/ipv6
Mentat Inc.	http://www.mentat.com/tcp/tcp.html
Microsoft	http://www.microsoft.com/ipv6
Nokia	http://www.nokia.com/ipv6
Nortel Networks	http://www.nortelnetworks.com/ipv6
NTT	http://www.ntt.com/NEWS_RELEASE_E/news01/0004/0427.html
	http://www.v6.ntt.net/globe/index-e.html
RIPE/NCC	http://www.ripe.net/annual-report
SUN	http://www.sun.com/solaris/ipv6
Trumpet	http://www.trumpet.com.au/ipv6
6WIND	http://www.6wind.com/ipv6.html