6LINK – IST-2001-34056

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LIST OF IST IPV6 PROJECTS

IST No.	Project	Start Date	End Date	Website	Leader	email
IST-2000-25153	6WINIT	2001-01-01	2002-12-31	www.6winit.org	Prof. Peter Kirstein (UCL)	p.kirstein@cs.ucl.ac.uk
IST-2001-32603	6NET	2002-01-01	2004-12-31	www.6net.org	Theo De Jongh (Cisco)	tdejongh@cisco.com
IST-2001-34056	6LINK	2002-03-01	2005-02-28	www.6link.org	Mat Ford (BT)	matthew.ford@bt.com
IST-2001-32161	Euro6IX	2002-01-01	2004-12-31	www.euro6ix.net	Jordi Palet (Consulintel)	jordi.palet@consulintel.es
IST-2000-26041	NGNLab	2001-01-01	2003-12-31	www.ngnlab.org	Paul Van Binst (ULB)	
IST-2000-25394	MobyDick	2001-01-01	2003-12-31	www-int.berkom.de/~mobydick/	Hans Joachim Einsiedler (T-Nova)	hans.einsiedler@t-systems.de
IST-1999-10299	ANDROID	2000-06-01	2002-05-31		Mike Fisher (BT)	mike.fisher@bt.com
IST-1888-20393	LONG	2000-12-01	2002-11-30	long.ccaba.upc.es	Carlos Ralli Ucendo (TID)	ralli@tid.es
IST-1999-10504	GCAP	2000-01-01	2001-12-31	www.laas.fr/GCAP	Michel Diaz (LAAS-CNRS)	diaz@laas.fr
IST-2000-28584	MIND			www.ist-mind.org	Siemens	
IST-2000-26418	NGNI	2001-01-01	2002-12-31	www.ngni.org	Latif Ladid (Ericsson Telebit)	latif.ladid@village.uunet.lu
P1113	Tsunami		2002-12-31	www.eurescom.de	Uwe Herzog	herzog@eurescom.de
	GTPv6	2001-01-01	2004-12-31	www.ipv6.ac.uk/gtpv6/	Tim Chown (UoS)	tjc@ecs.soton.ac.uk

IST POJECTS ACTIVITY MATRIX

Project / main issues	Architecture	Protocol	Fixed/wireless	Applications	Security	QoS	Standards	Trials	
6WINIT	X	X	Wireless	Clinical	X	?	X	X(multisite)	
6NET	X		Fixed	Business	X	X	X	XXX (NRENs)	
6LINK	IPv6 Cluster support project: Compilation of results, faciliatation of standards contribution, Cookbook								
Euro6IX	X	X	X	Business	X	X	X	XXX (pre-commercial	
NGNLab	Testbed	XX	F/W	From users	X	XX	X	Interop	
MobyDick	X	X	W	Available applns			X	X (multi-standards)	
ANDROID	Mgmt	X	-	?	?	?	X	X	
LONG	Testbed	X	F	ISABEL-IPv6	?	X	X	Two sites	
GCAP	X	XX	?	?	?	?	X	X	
MIND	X	X	W	X	?	?	X	X	
NGNI	Thematic Network project to develop the NGN roadmap including IPv6, QoS, security, standards,…								
Moebius	X	X	W	Healthcare	?	X	?	X	
WINE	WLAN	X	W	Available Applns	?	X	X	X	
Tsunami	X	X	F/W	Applns test	X	XXX	X		
GTPv6	Testing	X	F	Available Applns.	?	XXX	X	X	

Collaborative Activities and Networks

TEIN

For Korea, ETRI has established the TransEurasia Information Network (TEIN). This is a new continental network between Asia and Europe. At the moment, it can be accessed by GEANT via Renater 2. This allows access to the KOREN and APAN with both IPv4 and IPv6. With TEIN, we will have more collaboration between Europe and Asia. At the moment the collaboration between ETRI and the Europeans comes mainly under the auspices of 6WINIT. However, ETRI also wishes to join 6NET. If that comes about, the TEIN link may become more the province of 6NET; the actual work on mobile stacks and collaborative conferencing would remain 6WINIT activities. In this case the relationship between the TEIN link and 6WINIT, will be the same as between 6WINIT and the rest of the 6NET network. More information about TEIN is available at http://www.teinet.org/ or http://noc.koren21.net.

NTTv6net

NTT has a worldwide experimental IPv6 network (NTTv6net). NTTv6net is connected to five major IPv6 Internet exchanges, AMS-IX (Holland), 6TAP (USA), SIX (USA), PAIX (USA) and NSPIXP6 (Japan). Figure 2 shows its current structure. It has more than 40 BGP peer relationships with other organizations.

Internet2

Internet2 is a consortium being led by over 180 universities working in partnership with industry and government to develop and deploy advanced network applications and technologies[i]. The primary goals of Internet2 are to:

- create a leading edge network capability for the national research community;
- enable revolutionary Internet applications;
- ensure the rapid transfer of new network services and applications to the broader Internet community.

The Internet2 organisation in the US is responsible for promoting the deployment and adoption of next-generation Internet including IPv6. UCL has presented and demonstrated the EHR server work to a healthcare representative of Intenet2 and discussed the 6WINIT London

Demonstrator. Internet2 is forging links between UCL, OpenEHR and the American Academic Medical Centres in order to facilitate greater information sharing and possible future collaborative demonstrators.

6BONE

The 6bone is an IPv6 Testbed that is an outgrowth of the IETF IPng project that created the IPv6 protocols intended to eventually replace the current Internet network layer protocols known as IPv4.
The 6bone is currently a world wide informal collaborative project, informally operated with oversight from the "NGtrans" (IPv6 Transition) Working Group of the IETF.
The 6bone started as a virtual network (using IPv6 over IPv4 tunneling/encapsulation) operating over the IPv4-based Internet to support IPv6 transport, and is slowly migrating to native links for IPv6 transport.
The initial 6bone focus was on testing of standards and implementations, while the current focus is more on testing of transition and operational procedures.

6REN

ESnet (Energy Sciences Network, a US national level Research and Education Network) has focus on helping Research and Education networks worldwide to start providing IPv6 services. Started in October 1998, aimed at providing production IPv6 transit service towards operationally robust IPv6 networks.

EURESCOM

The Tsunami IPv6 Project

Project P1113 (running time 2001-2002 ?). Objectives of this project are:

- The setup of a network environment with new IPv6 features.
- Gain experience and single out problems in the deployment of the recently released standards in an operational multi-provider environment which will be set up by all providers in the coming years.
- The case for new IPv6 services built on these features will be investigated.

- Sample applications for such ISP services will be demonstrated.
- The test bed built up in Armstrong will be used and expanded by the new project.

IPv6 Task Force briefings

Infrastructure Working Group Report

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.

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.**

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.

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 :

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[1] Including all major operating systems providers.

- 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 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].

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

[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.

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 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.

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.

NEXT GENERATION APPLICATIONS WORKING GROUP REPORT

Introduction

Millions of people navigate the Internet today with relative ease. Unlike early netizens, they don't have to rely on news groups, bulletin boards, and word of mouth to find their way around. Gone are the days when using the Internet required learning arcane commands to copy files or send e-mail. But, despite the user-friendliness of Web browsing, there is still a lot of software "plumbing" that the people who set up networks have to grapple with on a daily basis. Each entity on the Internet, for instance, needs a unique address. The trouble is that, like phone numbers, the addresses are getting used up. Ease of use has led to exponential growth, which has raised the question: Can the method by which data is sent from one computer to another on the Net -- the Internet Protocol, or IP -- keep up with the demand? The current version of IP is IPv4, and it has been in use for over 20 years; a remarkable fact in itself when one considers the commercialisation of the “web” has only occurred significantly in the last 5 years.

In considering the answer to this question it is very important to consider the requirement for end-to-end global addressing, e.g. the ability of a user travelling with an IP-enabled device to contact and interact with an IP-enable device in their home.

Equally important, will that method be flexible enough to grow, evolve, and support the features that the new Net economy will require?

The answer is a resounding “yes” with, and only with, the introduction of IPv6, a significant enhancement that maintains everything that's good about IP and adds much more. Making IP more scalable -- and added features to improve it based on the huge amount of actual experience with the Internet, sustaining the open, standards-based benefit of an end-to-end network model and recognising that end-to-end IP security is a must. So it's one of the many additions included with IPv6. End-to-end security is an option with IPv4, but with IPv6, it's standard.

These days, people are more mobile. Everybody seems to be taking laptops, pagers, PDAs, and wireless phones with them wherever they go. With time, these devices will all be IP-enabled, and there simply won't be enough IPv4 addresses to allow all such devices to be globally reachable.

Finally, and perhaps most important, is making IP easier for administrators to manage. IPv6 is more scalable, so more addresses can be allocated. But that implies more systems, so IPv6 includes a number of auto-configuration features, enabling the missing ease-of-use functionality of plug & ping to the Internet, generating a raft of next generation applications that should be agnostic of the underlying infrastructure. In short, the best attributes of IP were kept and added more where it was needed and could do the most good, making it more scalable and adding functionality that wasn't even imaginable 20 years ago.

So, a special commitment is needed to progress the European industry and the public at large to deploy IPv6 as the solution for tomorrow's demands on the Internet.

Trends related to next generation Internet applications

Trends related to new applications:

- We will be confronted with a large diversity of devices, such as:
  - Handheld and mobile (cellular phones, PDA's, webpads, portable computers)
  - Wearable (on the body and in clothes)
  - Embedded smart devices, sensors and actuators
- Evolution in networks, such as:
  - Several variants of wireless networks (in-door and out-door) with their own characteristics with respect to bandwidth, set-up, etc. and which offer ad-hoc as well as controlled connections.
  - Several types of wired networks, within premises as home, car, public buildings and as access networks
  - More and more networks will move to the always-on connected types and bandwidth as well as Quality of service will continue to improve
  - Roaming of mobile devices across networks is needed; this includes horizontal handover across cells from a network as well as vertical handover across different networks.
- New types of services:
  - Infotainment services offering all kinds of media formats in need of support for non-streaming as well as streaming data, including real time captured streaming data
  - Multi media communications services, including video-conferencing and shared applications (e.g. shared viewing with Instant Messaging or audio/video conference)
  - Location-based services for people on the move
  - An increase in push-based services
  - Inter-device communications
  - Mobility of users as well as devices and applications is required

People with their electronic out-fits will move through all kinds of handoff-aware spaces which will have their networking facilities. People expect that these spaces are aware of their presence and support them in their activities and give them access to services mentioned above. This puts high demands on:

- Ease of use:
    - No system administrator
    - Interoperability across several transport networks
    - Ad-hoc network connections
    - Broadband always-on
- Mobility (horizontal and vertical handover)
- Dynamic configurable and adaptable networks and services
- Safe and secure
- Quality of service
- Address ability of devices

Some of these needs can be fulfilled by IPv4 together with a number of extensions. IPv6, however, covers most of these needs through: address space, auto-configuration, neighbour discovery and mobility support.

A person with his own electronic "aura" moves around and will be part of several environments where he wants to be recognized and be able to use the facilities from this environment in a transparent way.

Examples of applications

Multi-user networked games

Multi-user networked games are an important class of applications. These applications require fast communication between the partners involved to exchange instantly the game commands between the participants. Connecting game machines to the network should be a trivial task. Mobile game machines using cellular networks will come up and put those requirements also on the underlying networks. A need for high bandwidth will grow for games that use scenes from the real world as context.

Collaborative working

In this context, we see applications in the enterprise world. Following outlines some emerging applications:

- In offices, such as video-conferencing including remote application sharing. Applications like these require connections between the end-terminals; quality of service management with respect to bandwidth for video as well as low delay for interaction with remote application sharing; secure connections and security at application level.
- Distributed engineering support environment to data consistency and workflow. Peer-to-peer technology offers new opportunities to this complex problem. Security, community support and management are essential to this kind of applications, with links to profile management and authentication for role-based access control to data as well as application functions.
- Mobile employees using all kinds of portable equipment or devices at different locations. These mobility aspects put strong needs on the mobility of persons and devices across several networks. This translates into needs in terms of roaming across networks; adapt to different network characteristics (adapting the kind or format of data to i.e. available bandwidth); adapt to different device characteristics with respect to i.e. display properties and of course strong security requirements with respect to authentication and secure transport.

Distributed learning using video-conferencing technology is another example of the use of collaboration technology. Several examples exist, from Spain up to the north of Sweden. The use of multicasting which is part of IPv6 is proven to give the results. Also the use of SIP to set-up a session is recommendable since this would allow to use a mix of computer based devices, PDA and multi-media phones in one session.

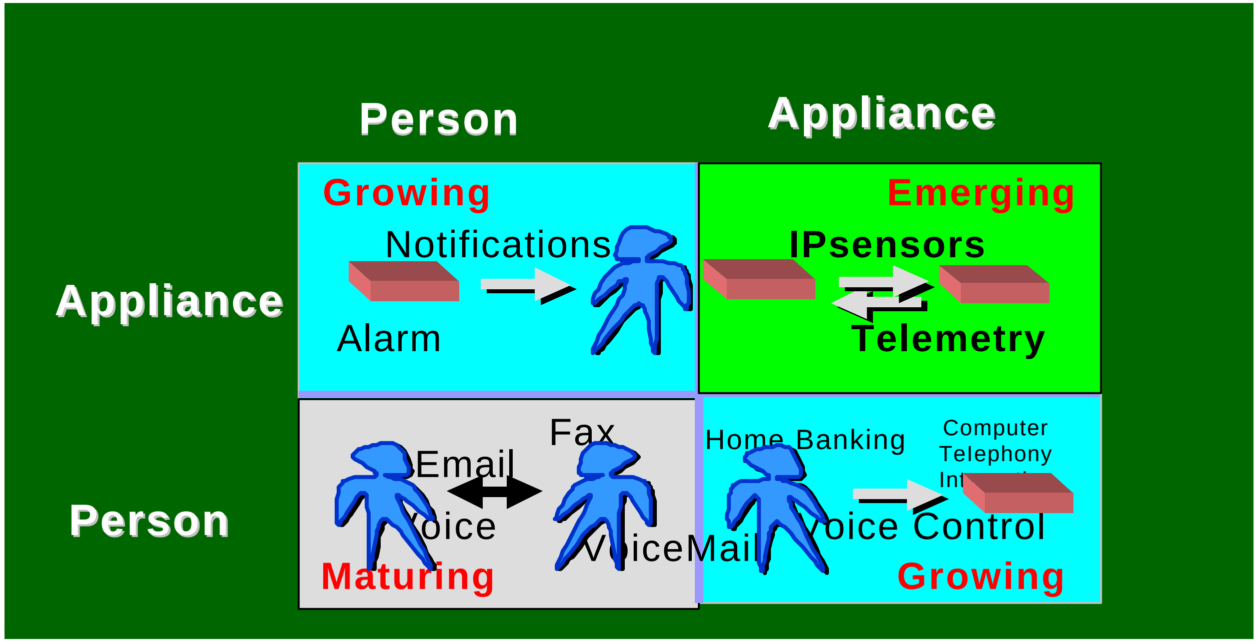
Home networking

It is expected that a home network will be a collection of heterogeneous network media (such as Ethernet IEEE1394, Wireless LAN, Bluetooth, Zigbee, power line and maybe HomePNA), which are expected to work seamlessly together. Access by the owner from remote locations is

expected to put tough requirements on access control to keep out intruders. The broadband connections and the always-on connection offer opportunities for new kind of applications especially in peer-to-peer applications. To make this possible we need:

- Plug and play for networked devices. Set-up and management of these networks should be easy not requiring special skills. The IPv6 auto-configuration facilities were designed to address this issue.
- Device and service discovery are important to make applications work also in an environment where devices can be switched on and off or mobile devices entering or leaving the network.
- Security facilities to protect your home network from intruders are an important aspect. The IPsec facilities will offer the right mechanisms for built-in implementations. The NAT implementation is showing its limitations of end-to-end transparency and security.
- User and device Mobility, inside the home as well as outside, is an important function. It should be possible to contact a person wherever he is and the users of the home network should able to access the applications wherever they are.
- Since the home network will consist of a couple of network media that are expected to work together, bridging and routing within such an environment are important.

InfoCom Application Areas



Ambient Intelligence

The combination of ubiquitous computing, ubiquitous communications and intelligent social user interfaces allows for the implementation of electronic environments that are sensitive and responsive to the presence of people. Those environments should recognize the users and tailor themselves to the needs of the users. They should be adaptive to changes in the environment and can anticipate the desires of the users. An important aspect in these environments are "smart" devices, more and more sensors and actuators will get networked and will be able to

participate in intelligent environments. A specific example in this context is networked devices, which use biometric authentication technologies. The ubiquitous communication part of course is central in this context. Besides the needs with respect to quality of service, security, and mobility, which have been mentioned, already these applications put strong requirements on auto-configuration and dynamic reconfiguration. The document "Scenarios for Ambient Intelligence at 2010" available at http://www.cordis.lu/ist/istag.htm contains detailed scenarios describing possible applications.

Conclusions

For the next generation applications, we are confronted with a number of challenges:

- Ease of use: no system administrator, auto configuration (discovery & registration), zero administration
- Interoperability across several heterogeneous networks
- Safe and secure
- Manageable quality of service
- A lot of devices: need for (fixed) addresses
- Mobility
    - Devices across locations and networks,
        - Ad-hoc connections,
        - Transparent hand-off (horizontal and vertical),
        - Adaptation to network characteristics,
        - Auto-configuration (discovery, disconnect)
    - Persons across devices and network,
        - Access to preferences, profiles and rights
        - Adaptation to devices characteristics
        - Devices reservation/sharing
        - Portable sessions
    - Programs across devices,
        - Safe and secure portable code

IPv6 will contribute to a solution for a number of these challenges.
Examples of suggested projects where this should be explored are:

- Using IPv6 as the universal network layer across a mix of heterogeneous networks such as Ethernet, Wireless LAN, Bluetooth, Zigbee, power line and investigate the implications with respect to QoS, auto-configuration, device and service discovery. An important aspect is the development of middleware which allows dynamic (re)-configuration of services based on network and devices characteristics (e.g. the use of transcoders) and the dynamics related to device and service discovery in a changing environment. Standards to exchange this kind of administrative information, negotiation on which services to use and the aspect of reserving devices or services in the future (i.e. to program the recording of broadcasts) are needed.
- The use of peer-to-peer technology in the entertainment and infotainment industry. Peer-to-peer technology to access and manage data in a distributed storage environment will become more and more important, not only for business environments but also in the consumer world. This will increase when consumers are going to capture more and more assets in a digital format. An example is the fast growing market of still image cameras, which can be expected to be followed by digital video recording.
- Remote home control and home security. With the growing application of “smart” sensors and actuators that can be connected to i.e. home networks and by the always-on connection to access networks can be reached from anywhere. Of major importance the issues related to secure remote access and the small footprint of software in these devices, which could be sprinkled around, as smart dust.
- Person centric applications such as multi-media communication. It should be possible to contact a person wherever he is. VoIP in combination with unified messaging applications are a good approach. The requirements for real time audio and video put high demands on the quality of service. The use of SIP to set-up calls offers facilities for selective use of media based on network and terminal characteristics. A special issue is to determine location independent uniform naming scheme for persons.
- Applications in vehicles such as:
    - Driver support by location-aware systems, continuous up-to-date navigation support, traffic management
    - Passenger infotainment services, including location-aware services
    - Logistics and fleet management
- Ambient intelligent environments, smart rooms, smart kitchens, houses or offices

Recommendations

- Educate all stakeholders targeting infrastructure suppliers like network providers, service provider and equipment vendors addressing the benefits in their specific trade. It is also important to demonstrate that while migration has its cost, failure to migrate to IPv6 in a timely fashion will incur greater costs in the long run.
- Disseminate the IPv6 application opportunities in all kinds of industrial forums and consortia. It should be noted that IPv4 was not designed as an enabler for the Web; the Web emerged many years after the introduction of IPv4. Likewise, the global addressability and

features of IPv6 may not be met with an instant “killer application”, but these will follow from the restoration of the original end-to-end principle of the Internet.

- Promote the roll-out of IPv6 products e.g. IPv6 connectivity in consumer-electronic devices by 2005. While not all such devices may be IP-enabled for Internet connectivity, those that are should be IPv6-enabled. Auto-configuration should make home network appliances easy to use; devices that are Internet ready can be expected to be favoured in the marketplace.
- Support projects that explore new applications that take real advantage of the IPv6 features, e.g. remote IP-enabled sensing and monitoring. This will be a new market of innovative application where Europe can have an advantage over the USA and Far East.
- European chip manufacturers are encouraged to develop an "IP chip" (IPv4 and IPv6) to enable IP sensor technologies that promise a raft of next generation applications by 2004. IP connectivity would take the place of other forms of communication (e.g. serial port protocols). One may expect IP-enabled devices to also utilise wireless LAN or Bluetooth media.
- European entertainment vendors are encouraged to develop IP-based games that take advantage of the peer-to-peer networking model for transparent end-to-end IP communication by 2004. Such models reduce the requirement for supporting and managing communal player servers, and allow players to make direct contact.

- European security vendors are encouraged to develop IP-based biometric authentication technologies by 2005 (using voice, fingerprint, face, hand scanning, iris or any combination of these).

- The European education sector is encouraged to introduce video conferencing using end-to-end IPv6 with its mandated multicasting features. The introduction of IPv6 on the GÉANT pan-European academic backbone will aid such applications. The European academic networks can gain valuable early IPv6 deployment experience.

- European car manufacturers are encouraged to deploy and test IPv6 on "Internet Car" prototypes to validate wireless and mobility methods by 2005.

- In view of the widening deployment of VoIP, European telecom vendors are encouraged to develop dual stack SIP phones. The use of IP phones will open up possibilities for new addressing methods, e.g. devices need not be addressed by traditional telephony numbering (alone).

TRIALS WORKING GROUP REPORT

Introduction

It is recognised that the Internet has become an essential element of our business and social lives and that its continuing development is essential for economic as well as social development – the future eEurope. The current Internet, that uses Version 4 of the Internet Protocol (IPv4), has certain limitations. The next generation (Version 6) of the Internet Protocol (IPv6) overcomes these limitations and will enable the Internet to grow and reach its full potential to serve the needs of industry and society.

The standardisation, implementation, trialling and deployment of IPv6 will however take a number of years. This report is from the Trials Working Group of the IPv6 Task Force and sets out a framework for IPv6 trials in Europe and recommends actions that should be taken to accelerate the introduction of IPv6 in Europe. This report in particular deals with IPv6 trials, other reports from the IPv6 Task Force deal with Mobile Services, Infrastructure (Internet) and Applications.

General IPv6 Trials Framework

This section introduces the concept of a general IPv6 trials framework. A framework for IPv6 trials is important to ensure that the work done in the various trial initiatives is maximised by eliminating duplication and enabling maximum sharing of relevant knowledge. Also the framework will facilitate co-ordination of trial activities. This will enable trial areas that are being overlooked to be identified as early as possible; hence mechanisms can be put in place to ensure all aspects of IPv6 trials are adequately being addressed. It is believed that an IPv6 trials framework will help to ensure that IPv6 is ready for commercialisation when market forces dictate.

Figure 1 depicts the generic IPv6 trials framework, it is based on there being a number of activities in the standalone testbed area that will feed into a number of IPv6 trials activities. The testbed and trials will enable a number of roadmaps to be produced:

- IPv6 equipment roadmap
- IPv6 networks roadmap
- IPv6 services roadmap

All the various initiatives in both the testbed and trials areas will produce results but it is the roadmaps that will capture and combine the knowledge from all the initiatives. These will be an invaluable resource for companies and people working outside the trials framework. It is

the availability of this high quality information that will enable these people to develop their networks, products and services more efficiently and effectively to meet the emerging IPv6 marketplace.

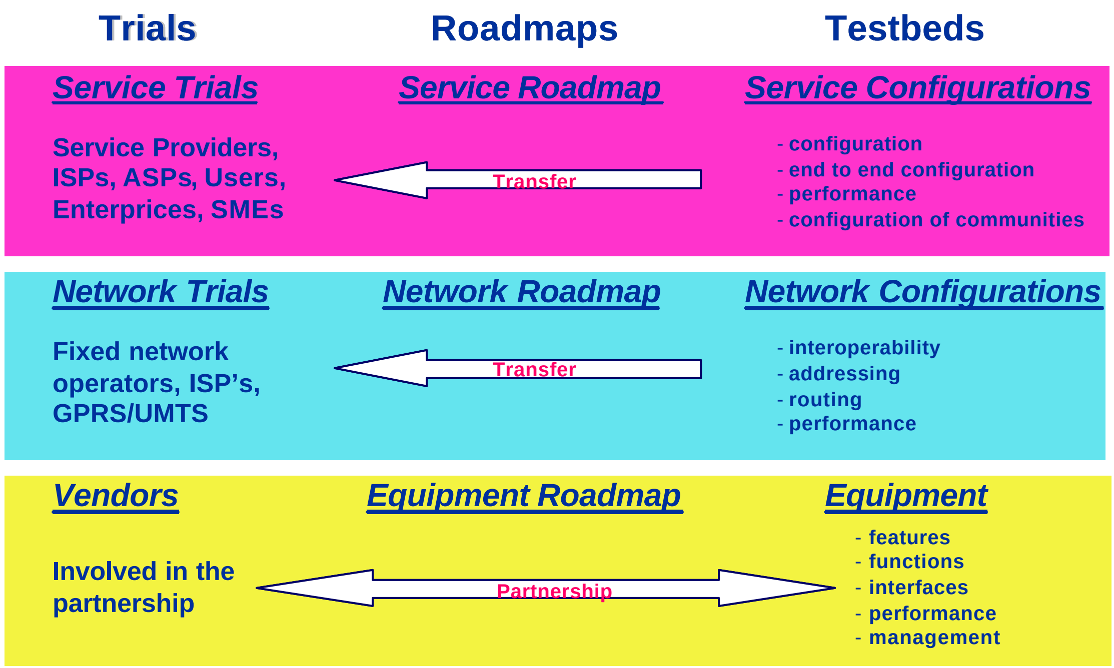


Figure 1 – Generic IPv6 Trials Framework

In slightly more detail the types of people and organisations involved in the testbeds will predominately be R&D establishments, academia and professional conformance testing houses. Three types of testbeds have been identified:

- **IPv6 Equipment Testbeds**

  These are predominately to test individual pieces of equipment e.g. routers. In many cases this will be done in partnership with equipment vendors. The early model is that vendors get R&D and academic establishments to evaluate their early prototype equipment. This is already happening with many vendors collaborating with R&D and academic establishments to evaluate their pre-production products. The next stage is for independent conformance testing to be undertaken by independent professional

conformance test houses. There is some evidence that this is just starting to happen as network IPv6 equipment in certain areas starts to reach maturity. Of course this cycle of evaluation and conformance testing will be ongoing as new devices with increased performance and functionality are developed.

- **IPv6 Network Configuration Testbeds**

  This is where complete networks are built and are proven, in particular it is the interaction of various technologies and features that are being checked. In the core network area the interaction of routers supporting technologies such as MPLS, SDH, ATM, SONET and WDM that need to be checked. In the ISP area interactions such as DNS, Interworking, AAA, dial-up and xDSL need to be checked and proven to work between different vendor equipment. The major players in this area are, when the technology is being proven, R&D and academic establishments but as commercial products become available professional consultancy is being used increasingly. Work has already started in this area but many facilities that are required for large-scale ubiquitous IPv6 deployment have yet to be proven. Knowledge gained from proving a technology in a constrained testbed, i.e. from the R&D and academic establishments, is invaluable to the IPv6 network trials area where technologies are being proven on more costly geographically disperse networks.

- **IPv6 Service Testbeds**

  It is here that the service differentiators of IPv6 are proven, namely that the features of IPv6 allow new innovative services to be developed. The IPv6 service testbeds will also check that IPv6 will still support the base services that we currently enjoy on IPv4, but, more importantly, it is new revenue-earning services that will be tested. At the moment this is probably the least developed of the three testbed areas. Once again the results and knowledge gained here needs to be transferred to the trials area dealing with services.

On the left hand side in the figure of the generic IPv6 trials framework is the trials area. The trials area is where networks and services are deployed and trialled in a pre-commercial environment to ensure that everything is technically and commercially (peering, billing etc agreements) in place for large scale deployment of IPv6 networks and services. It is therefore essential that these trials are driven by the final IPv6 commercial players i.e. IPv6 vendors, IPv6 network operators, IPv6 ISPs, Virtual ISPs, Service Providers, ASPs, Enterprises and end users. This should not preclude academic organisations, with their wealth of IPv6 experience, being involved. Three trial areas have been identified:

- **IPv6 Vendor Trials**

Some vendors do trials, in private, with a particular network operator to trial their equipment in a particular configuration. More often vendors are interested in providing equipment and taking part in network trials with a group of network operators. In this way they get experience of their equipment being used in a multi vendors, heterogeneous network under realistic conditions.

- **IPv6 Network Trials**

  This is the area where large scale networks are deployed to test all aspects of the technology. It is essential that these trials are led and conducted by industrial players because they will be responsible for the IPv6 commercial networks of tomorrow. It is however essential that academic organisations, with their wealth of IPv6 experience, are also fully involved. IPv6 will touch every aspect of the Internet and the emerging Mobile Internet. In fact IPv6 needs to be flexible enough to meet all the diverse deployment situations that IPv4 currently fulfils as well as the emerging home and mobile environments. It can therefore be seen that many different network trials are required to prove that IPv6 is robust, flexible and scaleable enough to meet all deployment scenarios.

- **IPv6 Service Trials**

  One of the major stumbling blocks for IPv6 is the current lack of services. This area is therefore essential for the early successful deployment of IPv6. Services, both existing and novel new services, are required for all the areas where IPv6 will be deployed, i.e. fixed, home, mobile, etc. This service trials area will utilise the network trials as a platform to test, evaluate and prove the complete spectrum of services.

The centre of the generic IPv6 trials framework is a set of roadmaps. These roadmaps, in the three areas of equipment, networks and services, will provide an invaluable source of information that will enable everyone to evaluate the implications that IPv6 will have on their company.

Recommendation - Develop roadmaps for the introduction and deployment of IPv6 services, equipment and networks. A systematic approach should be taken to analyse and identify areas that need special attention for an efficient introduction of IPv6, particularly with the help of trials. These roadmaps will help to identify missing areas for trial activities that could be catalysed by the EU, national governments and industry fora. The production of these roadmaps is essential for the timely deployment of IPv6 in Europe and beyond.

	Fixed Network	Mobile Network	Enterprise Services	Public Services
IPv6 Services Roadmap	IPv6 Connectivity IPv4/v6 Tunnels IPv6 VPN Addressing Native IPv6/PPP xDSL	• IPv6 Mobile Portals • IPv6 Web • Mobile access services • VoIPv6 IPv6 DNS • IPv6 DHCP • IPv6 Multimedia • Games On Line • Mobility services • Security	• IPv6 VPN's • IPv6 QoS • IPv6 Connectivity • Addressing • Security	• IPv6 Connectivity • IPv4/v6 Tunnels • IPv6 VPN's • Addressing • Native IPv6/PPP • xDSL • IPv6 Web • IPv6 Servers • IPv6 DNS • IPv6 DHCP • Games On Line • IPv6 portals
IPv6 Equipment Roadmap	• Core Routers (P) • Edge Routers (PE) • BAS (xDSL) • IPv6 DNS • Firewall • Interworking	• SSGN • GGSN • IPv6 DNS • Firewall • Terminals	• IPv6 DNS • Firewall • Client Routers (CE)	• Terminals • IPv6 Appliances (cars, fridges,PDA's) • Personal Routers
IPv6 Network Roadmap	• Backbones • ISP Networks • xDSL access • Dial access	• GPRS core • UMTS core • UMTS Reel.5 network	• IPv6 LAN • IPv6 WLAN • Intranet	• Home Networking

Figure 2 – Examples of what the IPv6 Roadmaps could contain

Figure 2 gives some suggestion as to the areas that the three roadmaps could cover.

Generic IPv6 Trial Framework Discussions/Recommendations

In this section each element of the generic IPv6 trials framework is discussed in detail and recommendations made.

Testbeds

There is currently considerable activity in the testbed area and a well established collaborative research environment within the EU and elsewhere that supports this type of activity. It is felt that enough facilities are in places but people need to be encouraged to take advantage of the existing facilities in the IPv6 area.

Recommendation – Publicise existing collaborative funding opportunities and projects with the aim of encouraging more IPv6 activities. The EU, European Governments and Industry fora should raise awareness in their area of influence for the upcoming infrastructure improvements towards IPv6 and the benefits to participate in trial activities from a very earl point in time, to gain a competitive position in the Next Generation Internet.

Vendor Trials

Vendor trials and network trials very closely related, this section discussed the requirements that various vendor sectors have for network trials. Without large scale network trials the vendors and equipment manufactures have no "proving ground" for their equipment.

Network equipment

From network equipment manufacturers' point of view, the existence of advanced trials is essential to validate and evolve any new technology, this is especially true for IPv6 which is one of the fundamental technologies of the Internet.
In most IPv6 products the introduction of IPv6 is being done in four distinct phases:

- **Software based support**

Initially all new features, functions and protocols defined by the standardisation bodies are implemented by manufactures in software. This allows for a fast and cost effective development cycle.

- **Hardware accelerated support**

When a degree of stability and acceptance is achieved, the features implemented in software are then transferred to platform-specific hardware components so that the range of interfaces supported is broader and the performance higher. It is important to notice that the development time of hardware-specific components is significantly higher.

- **Management support**

In parallel to the previous areas, another development area focuses on the management of the new technology, product, service or solution that is introduced. Initially, a simple MIB-based approach will allow for individual network element management. In a later stage, more complex management architectures based upon sophisticated applications with IPv6 support will be introduced. Today this is one of the areas where there is still a significant amount of work to be done by the standardisation bodies.

- **Interoperability**
  Finally, the interoperability of the equipment of different manufactures needs to be tested and assured. Procedures for equipment certification should take this into account. It is worth nothing that as part of a certification scheme or outside it, attendance at interoperability events (sometimes called bake-offs or plugfests) is seen as a simple, efficient and cost effective way of helping companies iron out potential problems and avoid the creation of products that are not interoperable. ETSI operates such tests already for IPv6.

Every new technology must evolve from development to deployment through a trial-and-acceptance stage. The supporters of this trial stage are usually the developers of the new technology (manufacturers), researchers, large corporations interested in the early adoption, or institutions on behalf of the benefiting communities. Technology manufacturers rely upon this stage to move from simulation to final product, from laboratory to the market.

However, the evolution of current Internet infrastructures to the new IPv6 protocol prompts operators to embark on projects with profound implications and transformations on the existing network architectures. Adding these implications to the demand for specialised resources, costly early-adopter risk factors, and a long investment-to-return cycle, makes this migration a very high investment for an operator and/or manufacturer to incur alone.

The combination of the above constraints generates, at the current stage, a cyclic impasse, whereby the developer cannot deploy without a field trial, and the recipient cannot support the field trial alone.

These constraints are understandable in the light of the evolution in large common infrastructures, used by the public community today. As with the railways, bridges, or telephone systems, these infrastructural progresses are very broad in scope, and therefore not wholly containable in the laboratory. Also, having wide communities as potential recipients, these projects need to be born out of partnerships between the scientific community, the manufacturers, the operators, and the governments, on behalf of the common welfare.

Recommendation – As one efficient way to pool expertise and benefit from collective test beds, it is encouraged to support the setting up of interoperability events in particular organized by a neutral organization such as those organized by ETSI and supported by the eEurope initiative.

These events are an opportunity for engineers from competing organizations to meet together in a commercially secure environment, to share experiences and improve interoperability between their implementations.

Home environments (including white goods, etc.)

Home and industry automation (including white goods, security devices, alarm/surveillance systems, entertainment devices), should be able to take advantage of features such as the massive address space, ease of plug and play, and the end-to-end connectivity offered by IPv6 to offer new services and applications. ADSL and wireless networks are examples of technologies that will enable advanced home networking, which in turn will increase the need for IPv6. At present most homes have at most one IP-enabled device (a PC), and that does not always need to be globally addressable. As users begin to demand access to devices in their homes (e.g. webcams, document and image/video servers, programmable white goods, etc), global, static IP addresses (and associated names) will be required. Equipment manufactures in this area need large scale trial networks to test their emerging devices.

Security Products

Security related applications, like basic transactions, as well as complex E-commerce applications will greatly benefit from the IP6 security mechanisms. These procedures and devices once again need trial networks to prove, in practice, they work, interoperate etc.

Recommendation – It is recommended to perform trials that show the benefits of IP security in IPv6. One of the main hurdles of widely used IP security is the lack of a functional Public Key Infrastructure (PKI). It is therefore recommended to the EU, European Governments and Industry to start trials with IP security in IPv6 and the parallel implementation of a PKI.

Automotive Platforms

The car is an area where IPv6 could bring a revolution. It is however a technically very challenging environment, being very cost sensitive, hostile in terms of temperature, vibration etc and, of course, mobile. Trial networks are essential for long term tests to be performed on automotive platforms.

Aviation Equipment

The EU has made a statement and produced a paper about the idea of a single European sky. But in Europe there are many different players in the aviation business operating different systems and procedures, change is slow because of safety and security concerns when updating

equipment. This is set against a background of ever increasing air travel and the inherent delays that this is causing. The following are some of the issues facing the single European sky idea:

- For the concept of a Single European Sky to be implemented the air frame manufactures and air lines need to update their equipment.
- Networking and communications will play a vital role in this. In fact airlines are independently looking at some of this for maintenance reasons. However for Air Traffic Management to improve, communications needs to be enhanced. This will also facilitate new ideas and methods for managing the air space, distributing work load etc.
- The main issue is safety and security. Secure transmission of data will always be an issue and guaranteed delivery of data - no denial of service - is another security point. QoS will play a role in it, too.
- Mobile ad-hoc networks using group communication (multicast). This is important because the idea is that aircraft could communicate within a cell area for certain navigation information. These networks being created as aircraft join and leave the area.
- Security in group communication in a mobile environment. The ATC centre will need to perform group communication and be sure of a secure delivery and not tampered with. Also Airlines may wish to send eminence information to their fleet and vice versa which must not be tampered with as it will have safety issues. e.g. engine data, aircraft performance in certain weather conditions
- Quality of Service: What is QoS and can QoS be changed depending on the changing networking environments, e.g from high bandwidth networks to low bandwidth ones. Applications being notified of these changes instead of just hanging.
- Share communication form passenger, air line operational data and ATC data will all have different levels of priority. But could, in certain circumstances, the maintenance information - if related to safety - take precedence over ATC data.
- Reliable Multicasting with security in a mobile environment with a changing sub network. Guaranteeing group communication if an aircraft moves to a low bandwidth environment.
- Peer to peer communication in a mobile environment. Not having to use a ground station. Aircraft communicating with each other in a less dense environment with poor connection to the ground e.g over the Pacific or Atlantic. Messages could be routed to aircraft where there is no coverage via an aircraft that has coverage.

There is a large number of issues here that although mentioned in relationship to the aviation manufactures have a lot in common with other areas, all these features need to be tried and proven on large scale trial networks.

Network Trials

In the previous sections dealing with vendor trials several different equipment manufacturing segments have been discussed and many requirements for large scale network trials identified. Without these network trials the equipment manufactures have nowhere to prove practically their equipment - this is the first requirement for network trials. The other is for the commercial organisations that will deploy IPv6

in all areas (core, access, home, mobile, enterprise etc) to gain experience of the technology in terms of deployment, technical and architectural issues, management, interoperability, peering and billing. The ISP and UMTS areas are discussed in slightly more detail below but the other areas of Internet Exchanges, Corporate networks, backbone providers, home networks etc are equally important.

Internet Service Providers

For IPv6 to be ubiquitously available Internet Service Providers will have to embrace the technology and invest heavily in their infrastructures to provide IPv6 support and interworking between IPv6 and IPv4. The large scale deployment of IPv6 is not a simple task and covers many areas:

- Access – dial, xDSL, AAA, DNS
- Core – tunneling, MPLS, dual stack, routing protocols
- Features – Security, QoS, Multicast
- Operational support systems (OSS) – massive area
- Interworking of devices, applications and services with IPv6 and between IPv6/IPv4
- Address allocation and its potential architectural implications
- Mobility – Mobile IPv6

The telecommunications industry globally is currently in a depressed state and hence commercial organisations are finding it difficult in invest in technologies and trials where the "pay back" is several years. For IPv6 to be successfully deployed it is essential that these commercial organisation are involved in the network trials. Currently the existing EU sponsorship favours academic organisation with 100% funding whereas commercial organisation get 50% and are often asked/obliged to provide interconnection bandwidth either free or below cost. Increasing the level of funding to 100% for commercial organisation would encourage them to actively take part in network trials and hence speed the deployment of IPv6 in Europe. Of course 100% funding is only cost recovery and hence may still not attract overwhelming participation.

Recommendation - To stimulate the involvement of commercial organisations in the network trials area the EU, the national governments and industrial institutions should investigate and support new ways to facilitate network trials, like increasing funding levels in projects with high network requirements, and support for smooth transitions from successful pre-commercial trials to full commercial operations. Particularly Small and Medium Enterprises (SME) should be encouraged to step in the IPv6 area by actively participating in trials to support their transition towards IPv6.

UMTS Mobile Operators

UMTS (3G) is an area where IPv6 has been specified as a requirement (3GPP Rel. 5 for the IM Domain). Many of the issues that will face the mobile operators when they introduce IPv6 are the same as those facing the fixed operator except that mobility brings in the extra constraint of limited bandwidth that is expensive and error prone. Some of the issues are:

- Mobile IP advantages/disadvantages of the use of mobile IPv6 within the Network
- Interworking between IPv6 and IPv4 parts of the network and to other networks. How to deal with IPv4 only terminals, i.e. with IPv4 addresses, in an IPv6 network.
- QoS issues - general and e.g. when tunnelling IPv6 over IPv4
- Issues related to IPv6 minimum header size and air interface.
- Interoperability within 3G Network – ISP – Fixed Network (IPv4/IPv6).
- Mobile Services: IPv6 Server (Mobile portals, Web, DNS, DHCP), Multimedia services (focusing on Streaming and Conversational QoS on IPv6), etc.
- Application: Portability from IPv4 to IPv6.

Once again commercial organisations and operators need to be actively involved as proposed above.

Transition Strategies

The transition between, and integration of, IPv4 and IPv6 will be a special challenge for network operators and service providers, as well as for corporate networks and private users. Ideally the non-technical Internet user should not recognise the transition as such, but this will not happen by itself. Several transition mechanisms and tools are developed by the IETF, but the appropriate usage of these tools will be of high importance for the transition period. Some strategies, for example in ISP environments have been investigated but it is proposed to investigate other areas, like Intranets, Internet dialup users and the whole application and services are.

Recommendation – A special effort should be taken by the EU, national governments and industry to simplify the transition from IPv4 to IPv6 as much as possible, so transition cost, time and know-how should be minimal for regular users, which will, in turn, accelerate the transition from IPv4 to IPv6. Trial activities should be started with a special focus to ease the transition from IPv4 to IPv6.

Service Trials

Services generate the revenue that will drive further investment and hence this is a critical area. Currently activity in this area is light, the companion applications report from the IPv6 task force is providing further information on IPv6 application development.

The raw development of applications are very important in the IPv6 area but the combination and interaction of the applications with each other and with the features and functionality of the network provide the user with added value services. It is this service trials area that will investigate and prove via large scale deployment on top of the network trials these complete services.
A couple of service trial areas are outlined below.

Pan European University Wireless Trials

Services driven by IPv6 mobility in the wireless environment are an important market that needs to be tested and evaluated. One area where these services could be tested is via trials on the Campus of different universities. University students (young people) and their teachers are early adopters of innovative technologies and would provide an idea environment to fully test and evaluate any services. The trial could be across many universities in Europe and could have a considerable user base (potentially millions of students in Europe).
The topics and issues that this large scale service trial could address are:

- IPv6 applications
- Mobile IPv6
- Security
- Wireless (WLAN)
- QoS
- Authentication, Authorization and Accounting
- Ad-hoc connectivity in hot spot networks
- Terminals (PDA's, PC's etc)

This would be a major initiative using a community of people that are willing to use the latest technology, it would involve applications, services as well as mobile and fixed network trials.

Recommendation – Instigate an initiative to trial wireless IPv6 applications and services in a Pan European University Wireless Trial.

IP-Telephony

Currently the majority of voice traffic is circuit switched, predictions are that this will move to the IP domain within the next few years. Within the UMTS environment, as well as in the circuit switched environment, voice traffic in the IP domain will be carried via IPv6 and use the SIP protocol. People's expectations of a "voice telephone call" and the characteristics of voice traffic are demanding for IP, i.e. people expect a black and white quality of service i.e. you get busy tone or you get good speech quality (though it is interesting to note that cellular quality is

seen by many as a trade-off for convenience, if the price is right). Technical parameters (objective parameters) that are necessary to meet those expectations include:

- delay
- jitter (variation in delay)
- lost/misordered packets.

The above list includes only some of the issues that need to be investigated, for example the interworking IPv4/IPv6, IPv6/PSTN and SIP/H323 also need investigation.

Voice is such a fundamental part of any future network that special facilities should be put in place to encourage investigation and trialling. VoIP is projected to reach a high penetration by 2010 and a different naming scheme (e.g. ENUM) could be used to replace or complement traditional phone numbers especially as large countries may be running out of phone numbers by that time by that time. It is not recommended that users get an "IPv6 address for life"; rather they should have expectation of the use of *a* global IPv6 address.

Recommendation – Investigate the adoption of facilities to encourage the research, development and trialling of VoIPv6. In view of wider deployment of VoIP by 2005, European telecom vendors are encouraged to develop dual stack SIP phones by 2003 and perform related trials.

Entertainment

Within the home there is a proliferations of intelligent entertainment devices, e.g. set top boxes, games consoles, etc. The significant benefits of IPv6 networking to these devices and the services they offer should be investigated and trialled. It is felt that the entertainment market could be a significant driver for the introduction of IPv6 into the home; in addition to peer-to-peer gaming (which can reduce server overhead costs for game companies) console devices could be used for messaging. This is just one example of (end-to-end) service convergence that is enabled by IPv6.

Framework Co-ordination

If the benefits of the IPv6 trial framework are to be realised it needs a body/organisation to support it. This body would be responsible for the co-ordination of all the activities that fall within the framework, in particular:

- **Research Gaps**

  One of the great benefits of having a co-ordinated approach to the IPv6 trials area is that duplication and gaps can be identified and recommendations made to enable IPv6 to reach a stage for commercial deployment earlier than would otherwise be the case.

- **Standards**

The various trials activities will almost certainly identify areas where the current standards are either inappropriate or missing a "piece" for large scale deployment. The framework co-ordination body can bring together all these standards related issues and suggest how, at a European level, they can be tackled in an appropriate and timely manner. It is felt that this may involve a change to the current EU project structure because projects between interested parties need to be established very quickly in some cases to address these standards related issues promptly.

- **Roadmaps**

It is felt that the production of the roadmaps in the areas of equipment, networks and services will be a very significant source of information that will enable IPv6 to be ready for commercialisation early than otherwise. It will be the responsibility of the framework co-ordination body to co-ordinate the production of these roadmaps.

Recommendation – Establish a co-ordination body to oversee the IPv6 trials framework.

Recommendation – Investigate ways to establish rapidly projects to address standards related issues.

Summary and List of Recommendations

This document outlines an IPv6 trials framework and discusses the various testbeds, trials and roadmaps that makeup the framework. The advantages of the framework are highlighted in terms of making IPv6 ready for commercialisation earlier. This is achieved by a combination of encouraging trials in a number of areas, being able to identify early trial gaps and providing a comprehensive set of roadmaps that will stimulate industry. Specific recommendations are made to enable this to happen:

Recommendation - Develop roadmaps for the introduction and deployment of IPv6 services, equipment and networks. A systematic approach should be taken to analyse and identify areas that need special attention for an efficient introduction of IPv6, particularly with the help of trials. These roadmaps will help to identify missing areas for trial activities that could be catalysed by the EU, national governments and industry fora. The production of these roadmaps is essential for the timely deployment of IPv6 in Europe and beyond.

Recommendation – Publicise existing collaborative funding opportunities and projects with the aim of encouraging more IPv6 activities. The EU, European Governments and Industry fora should raise awareness in their area of influence for the upcoming infrastructure improvements towards IPv6 and the benefits to participate in trial activities from a very earl point in time, to gain a competitive position in the Next Generation Internet.

Recommendation – As one efficient way to pool expertise and benefit from collective test beds, it is encouraged to support the setting up of interoperability events in particular organized by a neutral organization such as those organized by ETSI and supported by the eEurope initiative.

These events are an opportunity for engineers from competing organizations to meet together in a commercially secure environment, to share experiences and improve interoperability between their implementations.

Recommendation – It is recommended to perform trials that show the benefits of IP security in IPv6. One of the main hurdles of widely used IP security is the lack of a functional Public Key Infrastructure (PKI). It is therefore recommended to the EU, European Governments and Industry to start trials with IP security in IPv6 and the parallel implementation of a PKI.

Recommendation - To stimulate the involvement of commercial organisations in the network trials area the EU, the national governments and industrial institutions should investigate and support new ways to facilitate network trials, like increasing funding levels in projects with high network requirements, and support for smooth transitions from successful pre-commercial trials to full commercial operations. Particularly Small and Medium Enterprises (SME) should be encouraged to step in the IPv6 area by actively participating in trials to support their transition towards IPv6.

Recommendation – A special effort should be taken by the EU, national governments and industry to simplify the transition from IPv4 to IPv6 as much as possible, so transition cost, time and know-how should be minimal for regular users, which will, in turn, accelerate the transition from IPv4 to IPv6.

Recommendation – Instigate an initiative to trial wireless IPv6 applications and services in a Pan European University Wireless Trial.

Recommendation – Investigate the adoption of facilities to encourage the research, development and trialling of VoIPv6. In view of wider deployment of VoIP by 2005, European telecom vendors are encouraged to develop dual stack SIP phones by 2003 and perform related trials.

Recommendation – Establish a co-ordination body to oversee the IPv6 trials framework.

Recommendation – Investigate ways to establish rapidly projects to address standards related issues.

Recommendation – IPv6 is a worldwide protocol and hence the early introduction of IPv6 in Europe needs to co-ordination and take account of similar initiative around the world. European trials need to link and be co-ordinated with other initiatives around the world.

INDUSTRIAL POSITION PAPERS AVAILABLE

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	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	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

REFERENCE TO THE LIST OF KNOWN STANDARDS

IPv6 Specification

RFC 2460: Internet Protocol, Version 6 (IPv6) Specification

Addressing

RFC 2373: IP Version 6 Addressing Architecture
RFC 1881: IPv6 Address Allocation Management
RFC 1887: An Architecture for IPv6 Unicast Address Allocation
RFC 2374 : An IPv6 Aggregatable Global Unicast Address Format
RFC 2450 : Proposed TLA and NLA Assignment Rules
RFC2928: Initial IPv6 Sub-TLA ID Assignments
RFC2471 : IPv6 Testing Address Allocation
RFC 2375 : IPv6 Multicast Address Assignments
RFC2526: Reserved IPv6 Subnet Anycast Addresses
RFC 2732 : Format for Literal IPv6 Addresses in URL's

Drafts in discussion:

R. Hinden, S. Deering, IP Version 6 Addressing Architecture , Internet Draft, draft-ietf-ipngwg-addr-arch-v3-06.txt , July 2001.

D. Harrington, Link Local Addressing and Name Resolution in IPv6 , Internet Draft, draft-ietf-ipngwg-linkname-01.txt , January 1997

M. Blanchet, A flexible method fo managing the assignments of bits of an IPv6 address block , Internet Draft, draft-ietf-ipngwg-ipaddressassign-02.txt , March 2001.

R. Draves, Default Address Selection for IPv6 , Internet Draft, draft-ietf-ipngwg-default-addr-select-05.txt , June 2001.

J. Yu, IPv6 Multihoming with Route Aggregation , Internet Draft,
draft-ietf-ipngwg-ipv6multihome-with-aggr-01.txt , August 2000.

F. Dupont, Multihomed routing domain issues for IPv6 aggregatable scheme , Internet Draft,
draft-ietf-ipngwg-multi-isp-00.txt , September 1999.

S. Deering, B. Haberman, B. Zill, IP Version 6 Scoped Address Architecture , Internet Draft,
draft-ietf-ipngwg-scoping-arch-02.txt , March 2001.

B. Haberman, D. Thaler, Unicast-Prefix-based IPv6 Multicast Addresses , Internet Draft,
draft-ietf-ipngwg-uni-based-mcast-02.txt , June 2001.

Multihoming

Drafts in discussion:

R. Draves, Default Address Selection for IPv6 , Internet Draft, draft-ietf-ipngwg-default-addr-select-05.txt , June 2001.

J. Yu, IPv6 Multihoming with Route Aggregation , Internet Draft,
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F. Dupont, Multihomed routing domain issues for IPv6 aggregatable scheme , Internet Draft,
draft-ietf-ipngwg-multi-isp-00.txt , September 1999.

Internet Control Message Protocol

RFC 2463 : Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6)

Drafts in discussion:

A. Conta, S. Deering, Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6

(IPv6) , Internet Draft , draft-ietf-ipngwg-icmp-v3-00.txt"> Internet Control , June 1999.

Hop by Hop Options
RFC2711: IPv6 Router Alert Option
RFC2675 : IPv6 Jumbograms

Multicast
RFC2710: Multicast Listener Discovery (MLD) for IPv6 .

Path MTU Discovery
RFC1981: Path MTU Discovery for IP version 6

Header Compression
RFC2507: IP Header Compression
RFC2509: IP Header Compression over PPP
RFC2508: Compressing IP/UDP/RTP Headers for Low-Speed Serial Links

Packet Tunneling
RFC2473: Generic Packet Tunneling in IPv6 Specification

Domain Name System
RFC 1886: DNS Extensions to support IP version 6
RFC2874 : DNS Extensions to Support IPv6 Address Aggregation and Renumbering

Draft in discussion:
M. Crawford, IPv6 Node Information Queries , Internet Draft, draft-ietf-ipngwg-icmp-name-lookups-07.txt , August 2000.

M. Crawford, Discovery of Resource Records Designating IPv6 Address prefixes , Internet Draft, draft-ietf-ipngwg-prefix-rr-disc-00.txt , November 2000.

Transition Mechanisms
RFC2893: Transition Mechanisms for IPv6 Hosts and Routers
RFC 2185: Routing Aspects Of IPv6 Transition
RFC3056: Connection of IPv6 Domains via IPv4 Clouds without Explicit Tunnels

Routing
RFC 2080 : RIPng for IPv6
RFC 2740 : OSPF for IPv6
RFC2283 : Multiprotocol Extensions for BGP-4

Drafts in discussion:
R. Minnear, R. Hinden, IGRPng for IPv6 , Internet Draft, draft-minnear-igrpng-00.txt , November 1996.

Renumbering
RFC2894: Router Renumbering for IPv6

Security
RFC 2401 : Security Architecture for the Internet Protocol
RFC 2402 : IP Authentication Header
RFC 2406: IP Encapsulating Security Payload (ESP)
RFC 1828: IP Authentication using Keyed MD5
RFC 1829 : The ESP DES-CBC Transform

Neighbor Discovery
RFC2461: Neighbor Discovery for IP Version 6 (IPv6)
RFC3122: Extensions to IPv6 Neighbor Discovery for Inverse Discovery

Auto Configuration
RFC2462: IPv6 Stateless Address Autoconfiguration
RFC3041: Privacy Extensions for Stateless Address Autoconfiguration in IPv6

Drafts in discussion:

J. Bound, Dynamic Host Configuration Protocol for IPv6 (DHCPv6) , Internet Draft, draft-ietf-dhc-dhcpv6-19.txt , June 2001.

C. Perkins, Extensions for DHCPv6 , Internet Draft, draft-ietf-dhc-dhcpv6exts-13.txt , May 2000.

D. Thaler, Analysis of DNS Server Discovery Mechanisms for IPv6 , Internet Draft, draft-ietf-ipngwg-dns-discovery-02.txt , July 2001.

R. Draves, Default Router Preferences and More-Specific Routes , Internet Draft, draft-ietf-ipngwg-router-selection-00.txt , May 2001.

Program Interfaces

RFC2553: Basic Socket Interface Extensions for IPv6

RFC 2292 : Advanced Sockets API for IPv6

Drafts in discusssion:

R. Gilligan, S. Thomson, J. Bound, W. Stevens, Basic Socket Interface Extensions for IPv6 , Internet Draft, draft-ietf-ipngwg-rfc2553bis-04.txt, January 2001.

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OSI NSAP Mapping

RFC1888: OSI NSAPs and IPv6

Mobility

Drafts in discussion:

D. Johnson, C. Perkins, Mobility Support in IPv6 , Internet Draft, draft-ietf-mobileip-ipv6-13.txt , November 2000.

IPv6 over Different Media

RFC2464: A Method for the Tranmission of IPv6 Packets over Ethernet Networks
RFC2467: A Method for the Tranmission of IPv6 Packets over FDDI Networks
RFC2470: A Method for the Tranmission of IPv6 Packets over Token Ring Networks
RFC2529: Transmission of IPv6 Packets over IPv4 Domains without Explicit Tunnels
RFC2497: A Method for the Transmission of IPv6 Packets over ARCnet Networks
RFC2472: IP Version 6 over PPP
RFC2491: IPv6 over Non-Broadcast Multiple Access (NBMA) networks
RFC2492: IPv6 over ATM Networks
RFC 2590 : Transmision of IPv6 Packets over Frame Relay Networks Specification

Drafts in discussion:

D. Thaler, Transmission of IPv6 Packets over IEEE 1394 Networks , Internet Draft, draft-ietf-ipngwg-ipngwg-1394-02.txt , July 2001.

Network Management

RFC3019: IP Version 6 Management Information Base for the Multicast Listener Discovery Protocol
RFC2851: Textual Conventions for Internet Network Addresses
RFC2465: Management Information Base for IP Version 6: Textual Conventions and GeneralGroup
RFC2466: Management Information Base for IP Version 6: ICMPv6 Group
RFC2452: IPv6 Management Information Base for the Transmission Control Protocol
RFC2454: IPv6 Management Information Base for the User Datagram Protocol

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[i] See http://www.internet2.edu