6DISS

IPv6 Dissemination and Exploitation

Briefing Paper on:

IPv6 Deployment and Associated Risks (for Strategists)

1 Introduction

Over the last decade, the Internet has been increasingly recognized as a key factor for world economical development and improvement of its citizens' lives. What is not widely known to Internet users though is that Internet Protocol version 4 (*IPv4*) is the cornerstone for all communications over the Internet. Its use is usually transparent to the users.

IPv4 is limited to some four billion addresses in theory, though in practice the usable address space is less. Today, less than 20% of the IPv4 address space remains to be assigned, and there is a clear understanding that that address space will in effect be exhausted in the coming years[1], probably by 2010[2]. While some address space may be traded or reallocated from existing 'owners', availability of significant address space will be limited. Then the question to be answered is whether it is acceptable to prohibit access to the Internet to those not already connected at the time that all the IPv4 addresses have been allocated, or should we instead be using all possible means to allow the Internet to continue to grow?

The Internet Protocol version 6 (*IPv6*), a redesigned version of IPv4, aims to overcome the limitations of its predecessor and address the challenges of the future networks. IPv6 was designed more than 10 years ago to allow the Internet to expand beyond the capabilities of the IPv4 address space. Moreover, IPv6 corrects or optimizes some features of the IPv4 protocol. IPv6 address space is, relative to IPv4, abundant for the foreseeable future. With IPv6 having been designed, implemented, tested and (in limited amounts) deployed over the last 10 years, it must be said too that there is no other alternative now than IPv6 to overcome the Internet address problem.

2 Current state of IPv6 deployment in Europe

The core IPv6 standards are stable, to the extent that they can be deployed today. This status is reflected by the fact that the IPv6 Working Group in the IETF has been closed and replaced with one entitled '6man' which is responsible for the maintenance, upkeep, and advancement of the core IPv6 protocol specifications. No further core IPv6 standards developments are seen to be required; the '6man' Working Group will address protocol limitations/issues discovered during deployment and operation. In parallel, the research community and the IETF are working on specifying associated protocols and mechanisms (e.g. IPv6 on Customer Premises Equipment, IPv6 on WiMAX, IPv4-IPv6 transition, IPv6 firewalls, IPv6-only networks, and an improved solution for multi-homing), so that the capabilities and functionality of IPv6-enabled networks are being continuously extended.

The first step towards the adoption of IPv6 is the deployment of IPv6-enabled backbone networks. Large scale deployment testing has been performed in the context of European Commission funded projects and already most if not all of the National Research and Educational Networks (NRENs) offer production-quality IPv6 connection services in dual-

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[1] Conservatively estimated as 2010. ARIN (the American Registry for Internet Numbers) already decided (7th May, 2007) - in view of the limited IPv4 addresses still available - to advise the Internet community that migration to IPv6 numbering resources is necessary for any applications which require ongoing availability from ARIN of contiguous IP numbering resources, see http://www.arin.net/v6/v6-resolution.html

[2] http://www.cisco.com/web/about/ac123/ac147/archived_issues/ipj_8-3/ipv4.html

stack mode alongside IPv4. Commercial IPv6-enabled networks are gradually emerging and IPv6 transit traffic exchanged at European Internet Exchanges is steadily increasing.

Today, all common, current operating systems have sufficient support for IPv6, while high-end consumer electronics are beginning to support IPv6 as a transport protocol and a significant portion of new applications (or their upgrades) include IPv6 support as an extra feature.

Some 50% of the IPv6 address allocations are within the RIPE region, however the number of IPv6 deployments in European public and commercial sectors is still limited. IPv6 operational knowledge also lags behind IPv4. Few commercial applications or services take advantage of IPv6 (unique) features, and, thus, the majority of IPv6-ready applications use IPv6 as a supplementary transport protocol to IPv4. However, as new application domains emerge, these may be best placed to become new green field IPv6 deployments.

3 IPv6 advantages from the technical perspective

IPv6 exhibits numerous technical features which, when compared to IPv4, make it a more powerful and flexible framework to deploy future network applications and services. In brief, the most important key features of IPv6 protocols are:

- **Increased number of IP addresses**: IPv6 allows billions of new devices to be connected over the Internet, such as mobile devices, consumer electronics, sensors, transportation monitoring equipment, etc. The new IPv6 address space improves the Internet scalability by expanding the number of potential addresses from to 2^{32} (IPv4) to 2^{128} (IPv6).
- **Auto-configuration:** IPv6 standards describe techniques that enable IPv6-ready hosts to set their (networking) operational parameters and automatically become able to establish communication channels with other hosts.
- **Security:** The standards mandate the support of IP (layer) Security (IPSec) at all IPv6-enabled hosts, allowing the secure exchange of digital information. Thus even if IPSec is not immediately required, support for it should be present in IPv6 devices. IPv6, though, does not solve the problem of the secure exchange of keys.
- **Mobility:** The Mobile IPv6 (MIPv6) model is simpler than its IPv4 counterpart, e.g. hosting networks do not need to distinguish mobile nodes. In the future, IPv6 will allow entire networks to seamlessly change their Internet connection.
- **Multicast**: Multicasting is widely used in IPv6 networks and improves the efficiency of communications among multiple hosts. Also, the expansion of (IPv6) multicast address space and the explicit address scoping simplify the provisioning of multicast services.
- **Extension headers:** The support of extension headers allows protocol-level information to be carried in addition to the basic IPv6 header. Additional protocols and services, such as IPSec and Mobile IPv6, can easily be integrated on top of the basic IPv6 protocol. Furthermore, the fixed-size of the basic IPv6 header can reduce the cost of electronics in high-performance routers.

4 IPv6 as an innovation technology

The technical advantages of IPv6 over its predecessor can become the foundation of new innovative products and services. The following list enumerates some of the most important characteristics of future IPv6-ready networks:

- **End-to-end communications:** IPv6 restores the end-to-end communication model by eliminating the need for Network Address Translation (NAT) gateways. The simpler end-to-end model also makes application development, deployment, debugging and operation much simpler and cheaper. Overlay networking environments, such as peer-to-peer networks, can be more easily setup and managed, while software development can focus on the application/service logic rather than overcoming the IPv4 networking inefficiencies.
- **Secure communications:** Unlimited address space and the support of IPSec simplify the establishment of secure communication channels among IPv6-enabled hosts, by using end-to-end encryption. However, security aspects at other layers of the networks will not be improved, e.g. anti-virus protection within applications.
- **Mobility - Ubiquitous communications:** Mobile IPv6 provides a scalable and efficient mechanism for reaching nodes while they change their point-of-attachment to the Internet. Unlimited address space and auto-configuration techniques simplify the provision of such services as a mobile node changes its connected network. IPv6 may become the only base communication protocol for a diverse set of devices (e.g. mobile phones, PDAs, sensors, etc.) connected via different access technologies (e.g. WiFi/WiMax, UMTS, etc). Alternative technologies exist or may also emerge in the future, but IPv6 is envisaged to become the lowest common dominator in digital communications. The vast majority of current IETF standardisation work on mobility is focused on IPv6 rather than IPv4.
- **Reduced Operational Cost:** The deployment of IPv6 protocols will reduce the management overhead of future networks. The large address space, the removal of NAT gateways, the auto-configuration features, the integrated support of IPSec and mobility are some key factors that will lead to a reduction in operational costs. One large cable operator is already migrating to IPv6 to manage its own network elements.

5 Some risks of (not) adopting IPv6

- Despite the fact that IPv6 is foreseen to become the prevailing technology at some point in the future, markets - and all the Internet actors - have to take into account the potential risks of (or not) adopting IPv6. These are discussed in the following paragraphs:
- **Addressing the User needs:** The first user need to assess is the availability of Internet resources (of which one resource is the number of addresses) needed to provide services over the Internet to (new) customers. Regarding purely the question of addresses, if IPv4 + NAT (and other workarounds) can satisfy the user needs (without hindering the service), then there is no overwhelming reason to take the risk of adopting IPv6 at this stage. However, if it is foreseen that any address problem could become critical, then IPv6 deployment must be considered as the obvious way to proceed. This evaluation should be carried out regularly. Given the short remaining

lifetime of new IPv4 allocations, it would be prudent to be embarking on such a plan today, since a controlled implementation may typically take 2-3 years.

- **Proper planning:** The early adoption of IPv6 - as with any other new technology - creates a competitive advantage for the leading companies. It strengthens their position in the market as it enhances their service portfolio and increases their flexibility in the provision of innovative services. Investments for the (early) IPv6 adoption - e.g. upgrading the installed base and increasing the technical expertise in the company - can be high, if not planned ahead. Similarly, high investments are required when a company is forced - due to market conditions - to integrate IPv6 in a short period of time, e.g. due to infrastructure upgrades which are not aligned with equipment life cycle. Consequently, there is an optimal period of adopting IPv6 by a company where capital costs are minimised. In most cases, capability can be acquired very cheaply as part of a natural procurement cycle, but if IPv6-specific requirements are not included in tenders, additional costs may arise if a quick migration is later required.
- **Gap analysis:** Analysts have to identify if IPv6 (and its extended features) are a necessity for the everyday operation of each particular department of a company. In some cases, each unit of a company will transit independently to IPv6. The current and future status from the business / technical / functional / operational perspective have to be identified during a gap (transition) analysis process. Prior to the initiation of any transition phase, the key prerequisites have to be clearly identified.
- **Operational costs:** Deploying IPv6, in addition to IPv4, will increase the operational cost of a network, as both (IPv4 and IPv6) protocols have to be maintained. In the long term, however, the management of services over IPv6 will decrease the operational costs, as (for example) NAT gateways will not be necessary. However, if the cost of maintaining IPv4 is relatively inexpensive, then the cost savings of moving to IPv6 will be minimal. Companies have to carefully choose the proper time to integrate IPv6 in their operational procedures in order to avoid unnecessary extra costs.

6 Overall Recommendations

The IPv4 and IPv6 protocols will continue to co-exist in the Internet for many years. Gradually, more and more traffic will be carried over IPv6 until IPv4 traffic will eventually be eliminated. It is impossible to predict when this will happen, as there are no apparent “IPv6 killer applications” today and IPv6 commercial offerings are still limited. However, IPv6 widespread deployment in the commercial sector will happen in the coming years as it has been achieved in the academic world, and it will clearly be better to manage this move in an orderly manner, than to be forced to react hurriedly to external market forces at the last moment. Those companies and governmental agencies which have not started to take actions are already falling behind (eg. one large cable operator is reported to be two years into a 4-year deployment plan; this is clearly a huge advantage over its competitors).

The following list shows the more-strategic issues to consider when planning an IPv6 deployment campaign:

General actions:

- Make an inventory of equipment in the organisation that is not able to support IPv6 and the cost of its replacement.

Specific actions for companies

- Identify any strategic advantages for the company of introducing IPv6 technology in its network operation or its product portfolio.
- Estimate the cost of postponing your transition plan to IPv6.
- Prepare a business plan for the deployment of IPv6 services or products. Define the minimal mandatory IPv6 capabilities.
- Set a schedule for IPv6 deployment and identify missing functionality.
- Increase IPv6-awareness to all technical and administrative levels of your company. This includes a broad training plan for staff.
- Avoid degrading commercial IPv4 services while introducing new IPv6 services.
- Inform potential customers of the advantages of your new (including IPv6) technologies (this may however be phrased in a way that doesn't explicitly mention IPv6 directly).

Specific actions for governmental agencies

- Invest in research infrastructures that deploy IPv6 protocols and test/enhance IPv6-enabled products or services.
- Facilitate knowledge transfer among educational/research institutions and commercial companies - coordinate dissemination activities.
- Fund activities that have limited market (financial) interest but can significantly impact society.
- Design and schedule a transitioning plan to IPv6 for infrastructure and services within governmental agencies, provided that operational advantages can be justified.
- Inform citizens and the markets about the advantages of IPv6 and explain the potential impact to the society.
- Provide financial incentives to specific markets in-line with other societal priorities, but avoid introducing legislation that enforces the deployment of IPv6 technology.