



WHITE PAPER

IPv6: Open For Business?

A Review of IPv6 Technology Positioning
And Current Take-up
In the Enterprise Sector

September 2003

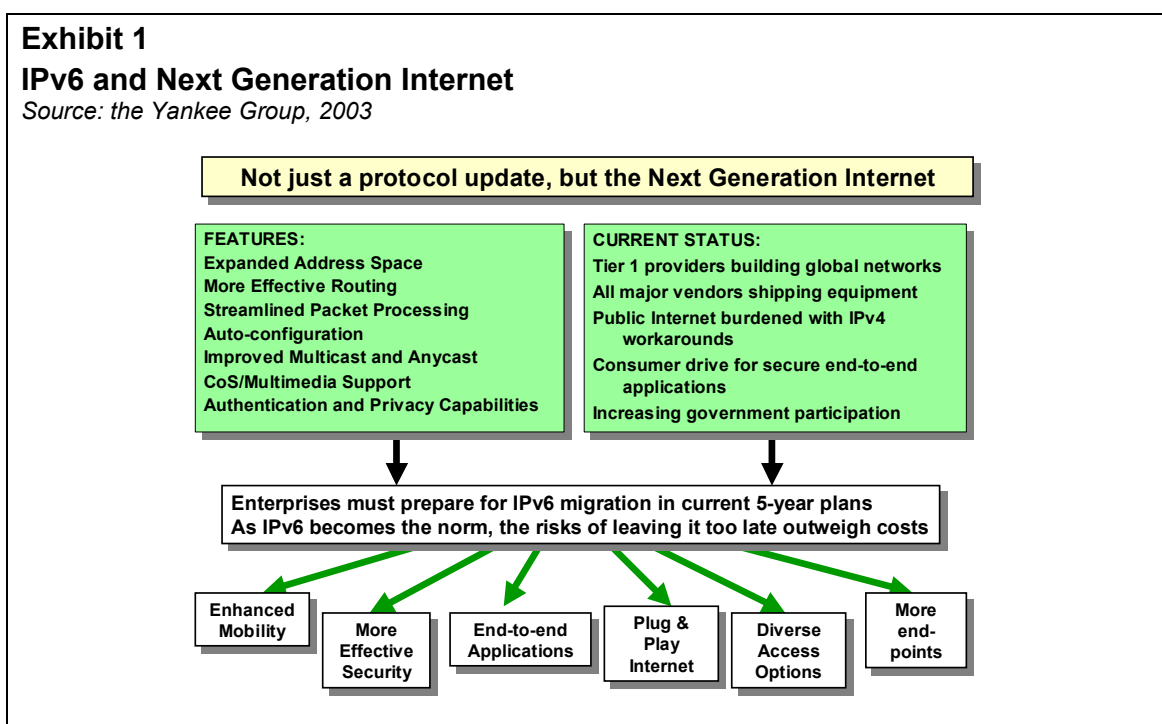
Table of Contents

| | |
|--|-----------|
| EXECUTIVE SUMMARY | 3 |
| I. INTRODUCTION | 4 |
| II. BROAD POSITIONING DESCRIPTION OF IPV6..... | 4 |
| The Evolution of IPv6 | 4 |
| <i>IPv6 Addressing</i> | 5 |
| <i>What about IPv4?</i> | 5 |
| III. ESSENTIAL CONSIDERATIONS FOR IPV6 | 5 |
| Who's Got the Address? | 6 |
| Transition Strategies | 6 |
| IV. POSITIONING THE STAKEHOLDERS..... | 7 |
| Service Providers and Operators | 9 |
| Equipment and Systems Vendors | 9 |
| Enterprise Users..... | 9 |
| Consumers and Others | 10 |
| V. OPERATOR POSITIONS AND PROFILES | 10 |
| NTT Communications..... | 10 |
| <i>Service Offerings and Target Markets</i> | 11 |
| <i>General Outlook for IPv6</i> | 11 |
| Sprint..... | 12 |
| <i>Service Offerings and Target Markets</i> | 12 |
| <i>General Outlook for IPv6</i> | 13 |
| British Telecommunications (BT) | 13 |
| <i>Service Offerings and Target Markets</i> | 13 |
| <i>General Outlook for IPv6</i> | 14 |
| Summary | 14 |
| VI. IPV6 BUSINESS CASE FOR ENTERPRISE | 15 |
| Enterprise IPv6 Migration | 16 |
| <i>Overview</i> | 16 |
| <i>Assumptions</i> | 16 |
| <i>Analysis</i> | 17 |
| <i>Potential Enterprise Exploitation of IPv6</i> | 18 |
| VII. CONCLUSIONS..... | 20 |
| Recommendations | 20 |
| <i>Enterprises</i> | 20 |
| <i>Equipment Vendors</i> | 21 |
| <i>Service Providers</i> | 21 |
| <i>Application Developers</i> | 21 |
| Predictions..... | 21 |

Executive Summary

Much more than the development of a packet handling protocol, IPv6 is the next-generation architecture for the public Internet and IP networks in general. IPv6 embraces a family of protocol and operating principles and perhaps more accurately should be referred to as IPng (IP next generation) after the IETF directorate, which from 1991 stewarded its progress. IPv6 offers a wealth of extended features and functionality. After almost a decade of development and trials it is starting to move into commercial and consumer utilization. However the technologies used in existing IPv4 infrastructure have continued to evolve functionality and performance, which up until now has obviated an urgent need to shift to IPv6.

Exhibit 1 encapsulates the key features of IPv6, and its current state of development. This Report explores both these themes in detail, examining the implications of IPv6 for each of the stakeholder: service providers, equipment vendors, and end-users.



Many pieces of the puzzle are now in place. Major service providers have been active in preparing their backbone IP networks for IPv6, and have made suitable peering arrangements, and implemented an array of interworking technologies to allow for co-existence of, and facilitate a gradual migration from IPv4. The major vendors are now shipping IPv6 compatible systems, both for the network core, and for end-user devices. However, although consumers are starting to drive demand, with increased use of end-to-end and home networking, adoption by enterprises is still lagging.

By providing a generic business case study, we argue that enterprises must start to include a solid migration strategy in their current mid-term (5 year plan), and that delay will only increase the business risks in the long term. While there is as yet no 'killer-app.' that would require a shift to IPv6, there are also a number of specific additional benefits that IPv6 can bring to an enterprise. These include improved security, simplified administration, better mobility and greater flexibility.

I. Introduction

By now the rapid growth of the Internet and the impending shortage of Internet Protocol (IP) addresses have been well documented. Internet Protocol Version 6 (IPv6) is the next-generation protocol developed by the Internet Engineering Task Force (IETF) to replace the current addressing scheme, Internet Protocol Version 4 (IPv4). Despite its promise, IPv6 has been slow to catch on, partly because of concerns over the cost and complexity to upgrade networks, but also because engineers have created temporary solutions to solve some of the problems with IPv4. Private addressing, network address translation (NAT), and application layer gateways (ALGs) have been adequate quick fixes to relieve some of the pain that might otherwise have been felt. However, major vendors have been shipping IPv6-compliant or capable products for around two years. Covering a spectrum from operating systems to network components, IPv6 capability is currently being offered to the service providers, enterprise and consumer markets by the likes of Juniper, Cisco, Hitachi, NEC, Sony and Microsoft.

The Yankee Group believes that the deployment of IPv6 is no longer a matter of if, but only of when and how. Something of a **'Chicken and Egg'** scenario confronts users, vendors, service providers and developers alike. Users will not make a final move to IPv6 until key services and applications demand it, and the operators and developers of these applications and services will not move to IPv6 until they see an IPv6 user base. For particular business sectors and user groups the applications and fit for IPv6 is now beginning to resolve. The adoption of IPv6 is beginning and domestic network managers should start the IPv6 educational process to develop a migration strategy.

II. Broad Positioning Description of IPv6

The Internet is a global network with a great depth and diversity of stakeholders, encompassing operator and engineering organizations through equipment manufacturers and application software developers down to business and consumer end users. Change and evolution in its infrastructure will take time. The dispersion of IPv6 is going to rely on build-up of critical mass of user demand and operator push – the operators and providers most closely associated with core systems are now strongly committed to IPv6.

The Evolution of IPv6

The IETF formed an Internet Protocol Next Generation (IPng) Directorate in 1994, which selected the IPv6 Protocol from a set of proposals developed within the Internet community. IPv4 was then the current specification for IP packet structure, and the related processes for handling and routing the packets. The public Internet had experienced twenty years of strong growth using IPv4. An IP packet format called IPv5 had been defined for multicasting applications, and has since fallen from use. Other versions of IP have been coined since 1994 to provide for experimentation, and in limited ways to challenge the evolving IPv6 for acceptance as the public network mainstay protocol. However IPv6 remains the focus for Internet architects. Because IPv6 has seen nearly a decade of evolution it is somewhat misleading to view it simply as 'version 6', more accurately it represents best path for evolution to the next generation of Internet services and systems.

The proposal selected to begin IPv6 work in the IETF was a specification referred to as "SIP" (Simple IP Protocol). RFC 1752 documents the reasons behind selection of SIP and IPv6. The IPng Directorate considered the ideas and features from all the proposals. The major property of the IPv6 protocol is the use of fixed length 128 bit address fields and streamlining of the IP packet header. Packet header changes include removing the fragmentation control fields from the IP header, dropping the header checksum and length, altering the structure of

packet options within the header, and adding a flow label. IPv6 also improves upon the way nodes are discovered, how routing headers are defined, and mandates IPsec as IP security protocol. The IETF designed within IPv6 the ability to provide a stateless model of IPv6 for autoconfiguration of nodes, and the option of building stateless networks for cases where that is a benefit to the users. In addition there are significant advantages of IPv6 from an implementer's perspective (e.g. how bits are aligned in fields, and links to further header fields).

IPv6 Addressing

The extended address length constitutes the critical change from IPv4 to IPv6. A 128-bit address field ideally allows an address range of 2 raised to the 128th power – an extremely large quantity better expressed as 3.4 times 10 raised to the 38th power. Don't forget that there is a capability for adding headers, which could serve to extend addressing. While the address space appears almost to have real limit, practical management and allocation policies will produce limitations. Responsibility for management of IPv6 address space is distributed globally in accordance with a hierarchical structure of Internet Registries (IR), from Regional Internet Registries (RIR) down to Local Internet Registries (LIR) or ISPs.

What about IPv4?

To put IPv6 address space into context, it is worthwhile to review IPv4 addressing. The earlier specification had a theoretical address space of 2 raised to the 32 power IP addresses, but traditionally was constrained by the physical hierarchy of major enterprises and Internet Service Providers (ISPs) and the hierarchical class-based structure of IPv4 address space. The classful address assignment policy was in place until the mid-1990s and was wasteful of IP addresses. A working solution to the explosion of routing tables was to do away with the class allocations and combine several routing entries into one. **Classless Internet Domain Routing (CIDR)** provided for the definition and distribution of groups of IPv4 addresses in ranges from 1 to many. Indeed IPv6 uses a similar mechanism where routes are exchanged using the Inter-Domain Routing Protocol (IDRP).

However there is another mechanism that has been key to extending the life of IPv4 address, **Network Address Translation (NAT)**. NAT is a process, operating in a host gateway, firewall or router, that enables a single (or small group) of public Internet addresses to be shared by a much larger number of users on a private network behind the NAT device. Today NAT is built into most common operating systems and equipment. Microsoft calls its implementation "Internet Connection Sharing". Devices on the private network normally use "non-routable" IPv4 addresses, which belong to address ranges that have been set-aside for this purpose. Routers on the public Internet will discard packets with these addresses should they 'leak' on to the Internet. NAT involves unidirectional session initiation from behind the supporting gateway. Some of the drawbacks are that IPSEC won't work between endpoints (because address is changed), overheads in address translation affect performance; protocol incompatibilities occur, NAT limits implementation of application servers, and it breaks peer-to-peer applications (interactive games, VoIP, real-time collaboration and sharing). NAT dominates the Internet today, and yet it cannot support peer-to-peer applications (between the end user devices behind the NAT gateway) or security. It removes many of the security features required for a secure public Internet. The larger address space of IPv6 and its mandatory support of IPsec provide for peer-to-peer applications and levels of security that will become the norm for Internet users.

III. Essential Considerations for IPv6

We profiled the evolution of IPv6 in the preceding section and zoomed in to the particular property of size of the address space. But IPv6 entails much more than addresses and endpoints, including header format simplification, autoconfiguration mechanisms, multimedia

and quality of service support via flow labels, underlying authentication and privacy enablement, and new multicast and anycast arrangements.

Who's Got the Address?

Significant IPv6 address space has been allocated by the RIRs to ISPs and carriers. Enterprises then get their IPv6 address space from their service provider. Below is the status of IPv6 allocations from the RIRs, together with the Top Level Address (TLA) ranges managed by each of the RIRs (August 2003).

| Registry or User | TLA Range | Allocations (as at August 2003) |
|------------------|--|---|
| APNIC | 2001:0200::/23 2001:0C00::/23 2001:0E00::/23 | 9 allocations (/35), 103 allocations (/32) |
| ARIN | 2001:0400::/23 2001:1800::/23 | 8 allocations (/35), 65 allocations (/32) |
| RIPE NCC | 2001:0600::/23 2001:0800::/23 2001:0A00::/23 2001:1400::/23 | 13 allocations (/35), 220 allocations (/32) |
| LACNIC | 2001:1200::/23 | 3 allocations (/32) |
| 6Bone | 3FFE::/16 | |
| 6to4 tunnels | 2002::/16 | |

Transition Strategies

From the outset IPv6 was designed with a progressive transition from, and coexistence with, IPv4 systems in mind. There is no compatibility between systems and end-points using the two versions. It is recognized that some systems and end-points may essentially never change from IPv4, and yet will be required to interoperate with the evolving public Internet. There are two fundamental challenges for introducing IPv6 into Internet.

- Connecting between two or more IPv6 islands in an IPv4 world.
- Interworking between the existing IPv4 Internet and a new IPv6 Internet.

The former challenge is met by using gateways with dual stack and IPv6-in-IPv4 tunnels. The latter problem can be addressed by a range of approaches including the dual stack model, application level gateways, NAT technology, translation of headers of network/transport protocols using temporarily assigned IPv4 addresses, and the use of IPv4-in-IPv6 tunnels. In essence there is a mix of three basic mechanisms - **the three Ts**: Tunnels, Translators, and Two-stacks. Refer to Exhibit 4 in Section V, which portrays services offering these transition options.

A wide variety of mechanisms have been defined and documented. Exhibit 2 provides a list and brief descriptions for the most popular approaches, and their scope of coverage. Hence we see a rich "IPv6 Transition Toolbox" which will provide for effective migration in many different situations.

Exhibit 2**IPv6 Transition Mechanisms**Source: *the Yankee Group, 2003.*

| Transition Mechanism | Description |
|--|---|
| To enable IPv6 node: IPv6 node only | |
| Dual Stack Model [draft-ietf-ngtrans-dstm-05.txt] | A dual stack node has both IPv4 and IPv6 processes available. DSTM provides a method to assure connectivity based on the use of IPv4-over-IPv6 tunnels and the temporary allocation of a global IPv4 address to hosts requiring such communication. Limited Dual Stack approach is possible where only "server" hosts have dual stack; new "client" hosts have only IPv6. |
| To connect node and network: IPv6 ⇔ IPv4 network ⇔ IPv4 | |
| NAT-PT [RFC 2766] | Network Address Translation - Protocol Translation (NAT-PT) is used to translate connections between IPv6-only and IPv4-only hosts. Connection is implemented with special equipment, that translates IP headers and uses address mapping (based on SIIT). Also NAT-PT may include DNS-ALG for DNS queries translation. |
| TRT [RFC 3142] | IPv6-to-IPv4 Transport Relay Translator (TRT) provides for direct connect between IPv6 and IPv4 hosts. Similar to NAT-PT, but only on the transport level, not network. Sites require a gateway for {UDP, TCP}/IPv6 in {UDP, TCP}/IPv4 and vice versa translation, and a DNS server for IPv4 to IPv6 address mappings. No modification to the end hosts is needed. Also called TCP/UDP relay. |
| To connect node and network: IPv6 ⇔ IPv4 network ⇔ IPv6 | |
| Configured Tunnel [RFC 2893] | This is a manually configured tunnel through IPv4 network for general uses. |
| ISATAP | Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) treats the site's IPv4 infrastructure as a link layer for IPv6 with no requirement for IPv4 multicast. ISATAP enables intra-site automatic IPv6-in-IPv4 tunneling whether globally assigned or private IPv4 addresses are used. Forms 64-bit interface ID from IPv4 address plus special reserved identifier. |
| 6to4 [RFC 3056] | Automatic tunneling of IPv6 over IPv4 (Public). Derives IPv6 network prefix from IPv4 global address. |
| Teredo | Automatic tunneling of IPv6 through NAT devices (Private). Derives IPv6 network prefix from public server used to traverse NAT. Previously known as Shipworm. |
| IPv6 over MPLS or PE6 | IPv6 tunnels over MPLS paths using systems at the Provider Edge (PE); this requires the service provider to have MPLS architecture. |

Internet planners see three essential phases to the evolution of the public Internet.

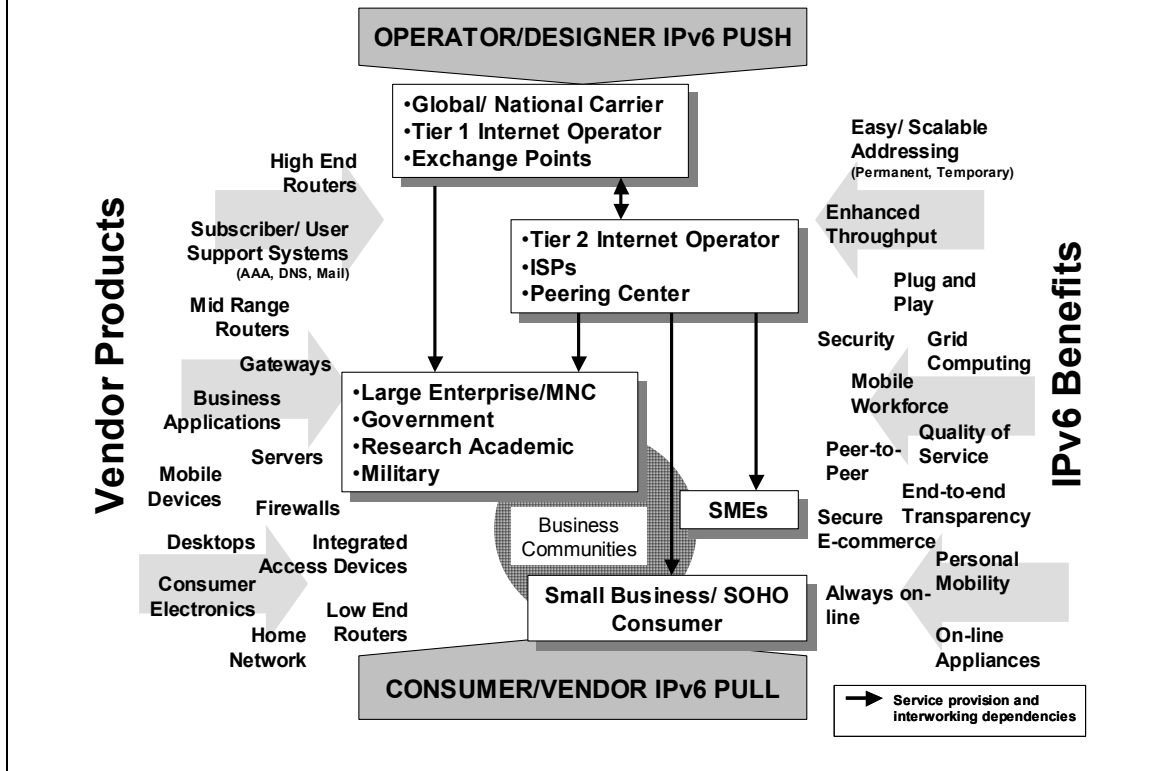
- **Phase 1.** Internet is IPv4-based, with IPv6 islands (IPv6 networks or hosts). Tunnels interconnect the islands. Fixed networks mostly use translators for IPv4 or IPv6 support. Mobile networks need to use dual stack terminals. This is the case today.
- **Phase 2.** Concurrent IPv6 and IPv4 Internets. IPv6 is not fully extended. Translation would be common, and tunneling would be used for connecting IPv6 islands across IPv4. Dual stack would be common for mobiles
- **Phase 3.** Internet is IPv6 based, with IPv4 islands. Tunneling or translation would be required for IPv4 sites. Mobile terminals would interface directly with their globally routable addresses.

IV. Positioning the Stakeholders

Anyone that uses the public Internet, or simply uses IP technology, will benefit from IPv6. There will of course be different priorities and different means for exploiting IPv6.

Exhibit 3
Service Provision Dependencies and the 'Flow' of IPv6

Source: the Yankee Group, 2003



It will be helpful to position the stakeholders and their paths of interaction. In Exhibit 3 we indicate the dependencies and connections between the main components of supply and demand on the public Internet. At the top of the structure are the major backbone and facility operators, and as we move down the diagram we follow the flow of service provision to intermediary operators and then finally to end-users. Note that we show two way flows of service and interaction amongst the top players because there is a strong interdependence for operations and business development. With the evolving status of IPv6 deployments, the various players in the diagram may be using tunneling or other transition strategies to exchange IPv6 traffic. This will be facilitated by the resources at the players at the higher layers of the structure.

Sustainable IPv6 direction setting will in essence come from the top down. The IPv6 'push' has been growing over recent years, and it is fuelled by the operators and network designers who are driving the expansion of the Internet. This is complemented by the 'pull' from consumers and vendors who demand the next generation products and promise of the Internet. In the middle are the business and enterprise users, who more than other players need a commercial case for IPv6. The dominant traffic patterns of the Internet arise from interactions shown as the shaded area, which connects the major user groupings. It will be the business communities, and their need for interworking, that will finally solve the IPv6 "Chicken and Egg" situation. An important component here may be the military – it has been long associated with Internet evolution, and most military and Defense organizations have now identified a clear roadmap for IPv6, which will stimulate vendors and users in general.

The left part of the diagram in Exhibit 3 portrays the types of IPv6- capable products that are on offer to the users at various levels of the IPv6 'flow'. It is not rigorous, but should help to clarify what items are on offer. In a complementary way the right side of the diagram portrays the IPv6 benefits and where they are best targeted. Many of these benefits are to do with

capability of the protocol and systems, rather than being built-in. In many cases he applications and end-user devices will need to be equipped correctly to deliver these benefits

Service Providers and Operators

Service providers and operators understand the true value equation for IPv6. Service providers are closely coupled to the design efforts of the Internet, and are motivated to enhance scale and flexibility.

| IPv6 Restraints | IPv6 Drivers |
|---|---|
| Life extension for profitable enterprise VPN services. This would include services based on special CPE and gateways, MPLS VPN approaches and other. (IPv6 removes the 'value-add' that is currently being used to extend functionality on current Internet systems.) | Revenue from new applications and uses of Internet through IPv6 |
| Continued control and sale of restricted IPv4 addresses | Revenue from consulting to assist business clients in upgrades |
| How to cover additional costs for changing to IPv6 systems | Ultimately reduced administration (for IPv6 elements) |
| | Less restrictions on address space |

Equipment and Systems Vendors

Essentially all major equipment providers support IPv6 and IPv6 migration today. This can be taken to apply to current models of equipment and roadmaps. However not all existing equipment or operating systems may be capable of supporting IPv6.

The support of IPv6 does not mean that the vendor is actively promoting implementation of next generation IP. Indeed it can be considered that the interests of major vendors in the enterprise and business markets are better served in supporting the flexibility requirements and work-arounds that have been developed to extend the life of IPv4. These features deliver instant benefit to users via IPv4, and may demand increased hardware performance and the deployment of equipment to additional sites. When these considerations are applied to the managed solutions and managed networks on offer from service providers, and the additional service edge devices and management systems that are required, then more systems are likely to be shipped. So the life extension of IPv4 can create a lucrative short-term market. And of course transitions to IPv6 will eventually occur, and revenues will flow at that time.

| IPv6 Restraints | IPv6 Drivers |
|---|---|
| Continue to compete with other vendors in the existing IPv4 technology space, using proven benefits and differentiators | In the long term, the facile properties and greater scale of IPv6 means that more end-points will be deployed. So product consumption will generally increase |
| Encouraging IPv6 take-up may change the balance of power in the overall supply of product. For example simpler core systems move equipment value to the edge of the Internet | IPv6 basic attributes in the long run provide no greater return than other networking or management features in the network or IT product. However new applications will increase the value and help to sell more units |
| | The Military organizations around the world are making commitments with hard deadlines for IPv6 performance. This will generally stimulate feature inclusion and lower cost modules |

Enterprise Users

In Section VI the IPv6 enterprise business case will address some detailed considerations in this area. The attraction to IPv6 will vary according to the type of business undertaken by the enterprise and the current implementation of network and IT components.

| IPv6 Restraints | IPv6 Drivers |
|---|--|
| Most enterprises are seeking to maximize the business life of IT resources - if it 'ain't broke don't fix it' | Simplified administration, lower support costs in the long term |
| Most places that enterprises want to visit or interact with will use IPv4 for a long time yet | |
| Lack of proven stability in IPv6 configurations and systems performance | Business opportunities with consumers who have IPv6 endpoints, especially mobiles and consumer electronics |
| Lack of internal experience, resources for deployment | |

Consumers and Others

In many ways consumers are the biggest driver for IPv6 adoption, demanding Internet expansion to support more on-line devices via consumer electronics evolution, higher mobility, new forms of entertainment and so on. They will provide pressure indirectly to the industry by demanding from their service providers the scale and features that IPv6 can deliver. They want the interactivity, the mobility, and security for electronic transactions as they move to being on-line more often via an increasing range of consumer electronic devices – phones, cameras, music players and PDAs.

| IPv6 Restraints | IPv6 Drivers |
|--|--|
| Lack of awareness of IPv6 potential, and what it means for new ways of doing business or being entertained | Long-run costs for placing devices on-line will decrease |
| No experience in operating and maintaining IPv6 equipment | New applications arise from personal and consumer devices that are network-enabled and accessible through IPv6 scale and flexibility |

V. Operator Positions and Profiles

As mentioned in the previous section, the major carriers and Tier One Internet operators are in a position to strongly influence the evolution towards, and take up of, IPv6 technologies. In this section we profile three major players who are strongly influencing IPv6 developments in Asia Pacific, Europe and North America.

NTT Communications

NTT has had a long association with IPv6. NTT Laboratories carried out pioneering work, which has been developed and commercialized by NTT Communications. The company's strategy was to be an early developer of IPv6 for two main reasons: as a Tier 1 ISP, it offers IPv6 connectivity and full support to other ISPs; and in a broader sense, it aims to be a pioneer in building a 'new Internet', in which IPv6 enables new applications and benefits, such as increased security and flexibility for end user enterprises and consumers.

- In 1996, NTT commenced research at NTT Laboratories on its global IPv6 backbone, which was connected to the US-based 6bone. At the IETF, NTT Communications contributed to various standards to promote the implementation of IPv6 broadband access services. At APNIC, it contributed to defining the global standard for address assignment policy.
- NTT Communications acquired a sub-TLA address block in autumn 1999, and started operating a global IPv6 backbone, spanning Japan, the U.S. and Europe.
- As a result of its development activities, it started to offer domestically the world's first dual stack service incorporating plug-and-play functionality.
- Under the Japanese Government's eJapan Initiative, NTT Communications conducted trials for video multicast for e-learning, ultra high-speed wireless LAN, VoIP, etc. Also,

as part of the activities of the IPv6 Promotion Council, it has contributed to the testing of various applications. Operating a portal site, 'ipv6style.jp', NTT Communications is contributing to promoting and educating the public about IPv6.

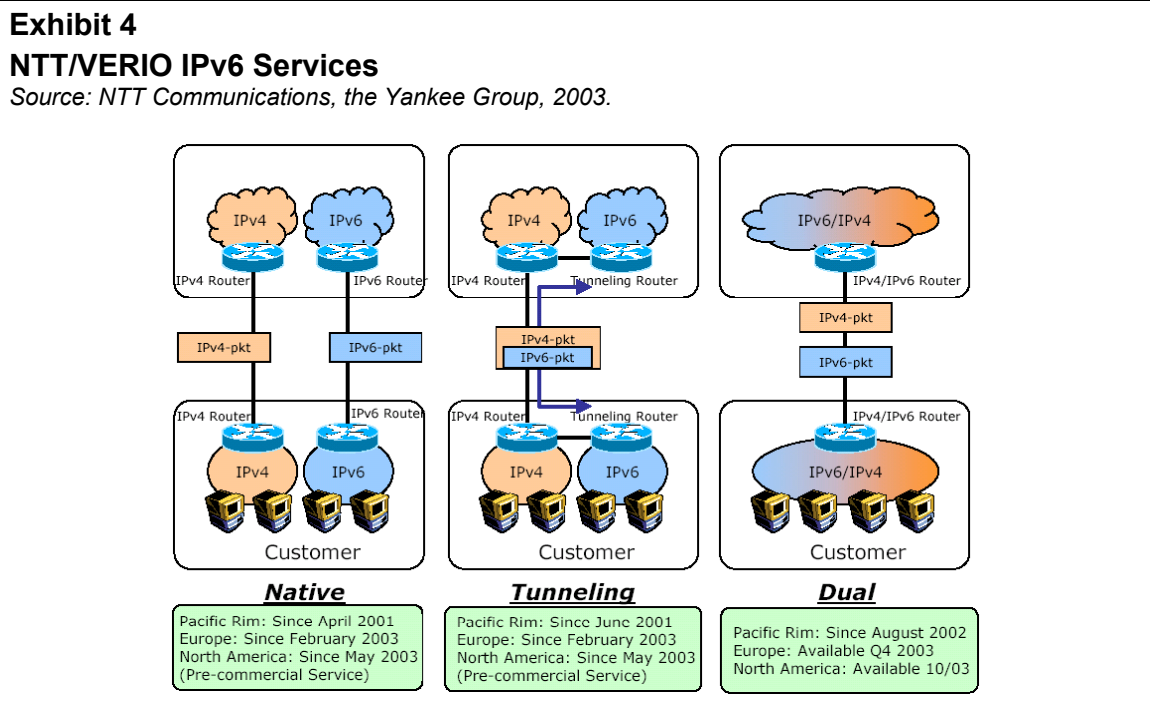
- At the 2002 World Communications Awards, in recognition of its IPv6 work NTT Communications won "Best Technology Foresight" award for "incredible foresight and significant leadership in creation, standardization and realization".

Service Offerings and Target Markets

NTT Communications is already offering commercial services using IPv6. After building a substantial global IPv6 backbone it launched IPv6 services in April 2001. As a Tier 1 ISP, it has been successful in selling native IPv6 connectivity to its ISP users, which it believes represent the 'low hanging fruit', as they will have to prepare for IPv4 exhaustion at a early stage.

Further down the chain, end-user enterprises see less, if any, urgency to migrate simply to address the exhaustion of IPv4 space. For them, the costs of migration to IPv6 must therefore be offset by a compelling business case. NTT Communications is in the process of developing end-user applications that capitalize on the features and advantages of IPv6, and is now offering services to early adopter enterprise.

As most equipment vendors are offering IPv6 compatible equipment both for the core and edge of the network, most of the cost in migrating to IPv6 is in upgrades of management software, and in education of network operators and technical staff. By June 2003 NTT Communications and its subsidiaries including Verio had built out substantial IPv6 infrastructure and services to cover Asia Pacific, North America and Europe. Exhibit 4 provides a status summary.



General Outlook for IPv6

NTT Communications believes that potential applications will be based around IPv6's ability to facilitate end-to-end (device-to-device) IPsec VPNs. This will be of benefit to MNCs and

other enterprises with multiple locations, which have to configure NAT when setting up IP-VPNs based on IPv4.

A number of specific examples of this include the following.

- **Managed IPsec VPN:** NTT Communications provides management of the customer's IPsec network via a server on the provider's network. This allows users to quickly establish quickly, and operate secure networks economically.
- **Monitoring service:** aimed at operators of IDCs and other secure facilities, NTT Communications will provide a network that enables sensors with IPv6 addresses to be monitored centrally.
- **Open end 2 end:** IPv6 network enabling devices on a LAN to be accessed from outside.

NTT Communications believes that the enterprise market for IPv6 services will grow over the next year or two. It also predicts growth in the consumer market and believes that this is potentially the biggest opportunity for IPv6. However, it recognizes that the consumer market is very nebulous, and that it will be necessary to partner with a variety of different players. It is working closely with a number of consumer electronics companies, which are developing IPv6 compatible broadband routers for home-networking use, as well as terminal devices such as cameras, CD players, and DVD players.

Sprint

Sprint was an early adopter of IPv6 in an experimental stance, and not only keeps an active test-bed for IPv6, but is also involved in the evolution and standardization of the protocol.

- Since 1997, Sprint has been actively involved in the standardization, testing, and deployment of IPv6.
- It was an early adopter of the 6Bone and IPv6 test bed, founded and administered by the IETF working group ngtrans (now disbanded).
- Sprint has built a 3-continent wide IPv6 network that tunnels IPv6 packets over SprintLink (the IPv4 Sprint IP backbone).
- Today Sprint offers IPv6 address space both from ARIN and from the 6bone working group.

Service Offerings and Target Markets

Sprint has IPv6-speaking routers in New York City, Washington DC, Seattle, Ft. Worth, and San Jose in the U.S., and a router in Brussels, Belgium, in Europe. Customers who wish to connect to Sprint's IPv6 backbone may do so by building a tunnel from their CPE (or any device inside their network) to the nearest Sprint IPv6 router. Sprint is offering IPv6 services to key networking industry participants such as ARIN (the RIR), Cisco and Microsoft.

Sprint peers with many other IPv6 players, and today has a well-connected IPv6 network. It does peering via BGP4+ through a combination of IPv6-over-IPv4 tunneling and through various native IPv6 exchanges within the U.S. and internationally.

In addition to connectivity and IPv6 address space, Sprintv6.net also provides DNS forward and reverse services free-of-charge for IPv6 (This service description applies only to Sprint's IPv6 deployment). When Sprint delegates a prefix to a customer, it requests that the customer gives an IPv6 or IPv4 address of its IPv6 DNS server, and will delegate that zone down to them. The root server for IPv6 currently is ns.isis.edu.

General Outlook for IPv6

The development of IPv6 had two fundamental and original intentions:

- Solve the addressing depletion problem (provide for enough addresses to cater for the foreseeable future);
- Scale the routing table, where demand had outpaced developments in forwarding ASICs and memory availability.

Sprint operates one of the largest IPv6 networks in the world, connecting to over 300 IPv6 entities globally. Today this network is largely dominated by interest both in network education and in research, and is awaiting widespread commercial adoption. For these customers it supports IPv6 with 6over4 tunneling. In addition, it has expertise with the dual-stack environment, and will be offering 6to4 gateways in the future.

Sprint will let the market dictate its transition strategy. Sprint has a plan in place to offer native IPv6, but in the interests of keeping costs low for customers it will implement IPv6 only at such time as customer demand will justify its inception. Sprint's strategy has been to demonstrate IPv6 capability. Its services are aimed to help customers investigate network evolution, and to assist them in taking the next small steps.

Sprint is currently working within the IETF on IPv6 multi-homing solutions and on general issues in IPv6 deployment and development.

British Telecommunications (BT)

BT has a long history of involvement in IPv6 technologies, including the following major IPv6 milestones and activities.

- 1998: BT involved in operation of 6Bone;
- 1999-2000: Allocation of IPv6 addresses, deployment of trial network (LEANet: London and East Anglia). RIPE (European IP address registry) accepted BT's application for subTLD status in IPv6;
- 2000: Collaboration with Microsoft research (Cambridge): development of software to offer tunnel broker service ('virtual ISP') to enable tunneling from v4 to v6;
- Trials: 3G Mobile network trial at SmartTone with Ericsson; ADSL service trial (14Mbps) and native IPv6 video streaming;
- Initiatives: BT has participated in major industry and government initiatives including Eurescom, 6INIT, 6WINIT, European Commission IPv6 Task Force, and Euro6IX (with other European tier 1 carriers);
- BT's 21st Century Network Initiative: BT envisions replacing 100,000 existing remote concentrators, DSLAMs, and data multiplexers with 30,000 multiservice access hubs. This will provide for an increase in its number of DSL (digital subscriber line) customers to 5 million by 2006, from 1 million now. By consolidating networks, BT's operations costs are expected to fall by around 30%. IPv6 is a key architectural component of this initiative.

Current IPv6 activities are undertaken by BT Exact, which is BT's research, technology and IT operations business.

Service Offerings and Target Markets

BT's main activities are via IPv6 exchange in London (UK6x), an independent v6 Internet exchange. The exchange features the following network services:

- Exchange services such as layer 2 switching, basic peering, transit, 6Bone, and layer 3 infrastructure;
- Native IPv6 connections (via MAN: Ethernet, Optical/ATM, or other access media) and tunneling (long term with BGP, or short term as tunnel broker);
- Address allocation; and
- Specialized services such as IPv6 mobile agent and DNS hosting.

UK6x also offers applications including fast dual-stacked mirror, mp3 radio, Games servers, VoD Servers and a variety of other hosted services.

BT Exact also offers a set of services related to IPv6 migration including consulting, training, network design and build, internetworking, licensing, and product evaluation.

As a key initiative, BT Exact developed a toolkit of IPv6 transition and interworking mechanisms called **Ultima**. Originally developed as a 'proof-of-concept' for BT's efforts on the IETF NAT-PT specification [RFC 2766], it has been extended to perform other functions. These include: Network Address Translator-Protocol Translator (NAT-PT), including Application Layer Gateways (ALG) for DNS, FTP and SIP; Automatic Tunneling Support; Tunnel Broker; and Dual Stack Transition Mechanism (DSTM).

Each mechanism can be operated independently or in parallel with each of the others. The purpose of the development has been to investigate how the chosen mechanisms perform both singly and together, and identify and resolve issues that arise. Ultima has been used effectively in IPv6 network trials and events such as IETF 51, 6INIT network and SmarTone 3G trials.

General Outlook for IPv6

IPv6 technology is essential for the long-term scalability of the Internet, and must be considered inevitable. To this end its design has been simple and flexible, and also provides for extensibility. The only area of IPv6 technology that requires further development is that of multihoming, which is now a focus in the IETF.

IPv6 is really the only initiative on the horizon, which will allow for Internet evolution. It will allow the Internet to regain its original end-to-end transparency. Most IPv6 applications today are ports of existing IPv4 products. Shortly we should see IPv6-only applications with new levels of functionality.

Implementation costs for IPv6 are largely incremental and can be managed over a relatively long timeframe. Deployment costs can be offset against the potential loss of customers to new operators who are IPv6-enabled and the savings from reduced operational complexity (for example, simplified address space management and removal of IPv4 NATs from the network).

Summary

The table in Exhibit 5 provides summary of global supplier activity and outlook for IPv6.

Exhibit 6 summarizes the results of a quick poll amongst the service providers on the major IPv6 benefits and their ranking.

Exhibit 5**IPv6 Supplier Summary***Source: the Yankee Group, 2003*

| Service Provider | Main Activities | Outlook for IPv6 | Strategy |
|---------------------------|--|--|---|
| NTT Communications | Global IPv6 backbone with peering arrangements. Native, Dual stack and tunneling services | Major ISPs have already migrated. Enterprise and consumer markets to migrate over next two years | Focusing on developing compelling enterprise applications |
| Sprint | Global IPv6 backbone with tunneling over SprintLink. 6over4 tunneling. 6to4 gateways in near future. | Currently dominant interest is from network education and research. Does not see widespread enterprise adoption. | Prepared for eventual demand for migration. Will enable enterprises to test IPv6 when ready |
| BT | UK6x, IPv6 Exchange. 'Ultima' products for v4/v6 inter-working. Mobile/consumer deployment. | ISPs wholesale: 2004 Large enterprises: 2004. SME and consumers: 2005 | Developing network services and applications in preparation for increased demand from consumers and enterprises |

Exhibit 6**Ranking the Benefits of IPv6***Source: the Yankee Group, 2003*

| Potential Benefit or Capability of IPv6 | NTT Communications | Sprint | BT |
|---|--------------------|--------|--------|
| Address Space | High | High | High |
| End to end transparency, peer to peer | High | Low | High |
| IP Telephony | Medium | Low | High |
| Security | High | High | Low |
| Traffic management, prioritization | High | Low | Medium |
| Improved packet processing, higher throughput | Low | Medium | Low |
| Mobile user support | Medium | Medium | Medium |
| Autoconfiguration of address | High | Low | High |
| Display of technology leadership | High | Low | High |
| Meeting the demands identified by users | High | High | High |

VI. IPv6 Business Case for Enterprise

This section addresses a high-level business analysis for the implementation and usage of IPv6 for an enterprise. Before introducing the case, we observe that there are no comprehensive IPv6 enterprise migration studies yet available in the public domain. The IETF v6ops working group has been developing papers, which explore IPv6 transition approaches and case studies for service providers and enterprises. It has produced a draft paper entitled 'IPv6 Enterprise Networks Scenarios'. As yet it is in early draft, and its scope is more technical and prescriptive, than intended to present commercial considerations or a business case. A number of high-level models for service provider transition to IPv6 are extant. Takashi Arano co-chair of the IPv6 Promotion Council of Japan outlined a model for IPv4 to IPv6 migration costs in a November 2002 presentation entitled "Deployment Status and Current Business strategies in Japan". L-F Pau provides an analysis in relativity terms in a 2003 paper titled "IPv6 Return on Investment Analysis Framework at a Generic Level, and First Conclusions".

Enterprise IPv6 Migration

Overview

How best to estimate the case for deploying IPv6 in an enterprise? There are cost factors, which affect the day-to-day operating expenditure of the enterprise (both positive and negative) and other financial elements, which relate to the capital expenditure strategies of the business.

On the other hand there are factors, which present revenue generating and productivity improvement benefits to the enterprise. The following elements all represent business productivity benefits and opportunities for reducing the cost of operations and improving performance.

- Wider deployment of mobile applications and demand for enhanced mobility;
- Better support for multimedia and real-time flows, using QoS via flow labels;
- More effective security, through IPsec;
- Full enablement of peer-to-peer applications and end-to-end transparency;
- More devices on-line permanently within the enterprise, and more demand for remote access points.

In our case study, we examine a general enterprise and argue that the risks of an enterprise not preparing for IPv6 NOW will outweigh the costs involved over a five-year time period. We argue that this is the most compelling reason for an enterprise to migrate to IPv6 at this stage. We then discuss a number of specific examples of industry applications in which deployment of IPv6 delivers additional productivity and performance benefits.

Assumptions

There is huge spread in the attributes that apply to enterprises according to its size, the industry it operates in, the products that it deals with, the channels for addressing its market, the location of its offices, and more. The relevance of IPv6 will vary according to its peers in the industry, its trading partners, the location of its sites and its local ISP. For truly international relevance it will also depend on the government policies and industry forum activities in particular countries. How can we best develop some general guidelines that can be applied in a range of enterprise scenarios?

We will use general characteristics and operating patterns that have come from prior Yankee Group analysis and surveys. These include our GNS (Global Network Strategy) survey of multinational companies, enterprise IT surveys and several recent SME studies.

We will work with a model enterprise, which is represented by the following attributes.

- Approximately 60-70% of employees are located in head office. The company has a balance of employees across sales and marketing, service and support, engineering and manufacturing, and administration and financials. There are 10 remote offices. It has workstations or desktops deployed to around 90% of its staff. The staff use productivity and communications software based on Microsoft Windows. There are special in-house applications that exploit IP and the Windows operating system.
- Its network and IT budget is in the range \$300,000 to \$1 million per annum. This includes operation of an IP VPN, which couples to each site, and is used, for intranet, public Internet usage and supply chain applications. It has on-site support contracts with service providers for IT and network equipment. This support provides for hardware and software maintenance and upgrades. The enterprise operates with an IT department of around 20 staff. Perhaps several staff are qualified at levels equivalent to CCNA and MSCP.

- Desktop and network equipment is around 3 years old on average. Even though there is no policy to introduce new equipment on a definite periodic basis, the enterprise routinely assesses the reliability (MTBF), support costs and performance of its systems, and plans for new purchases on this basis.
- The company uses a five-year horizon for strategic planning and high-level business development. It must demonstrate to owners and stakeholders that it has a responsible outlook to minimize risk and maximize opportunity.

We will also assume that the following environmental characteristics are in force.

- The local tier one and tier two operators have deployed IPv6 infrastructure. In particular, an IPv6 address can be obtained from a local organization, if not from the current ISP for the enterprise.
- Consumers are demanding more open end-to-end networking and 'always-on-line' devices, which creates a growing base of IPv6 end-points.
- The company's IT support personnel receive periodic training to develop their knowledge of IT and network technologies.
- There is consensus amongst peers and providers that IPv6 will be strongly represented in the Internet backbone of the region. Mobile and wireless networks will be built out to mostly address consumer usage and applications.
- Because of the preceding characteristics, equipment vendors and local support houses offer routine support for IPv6 technologies.

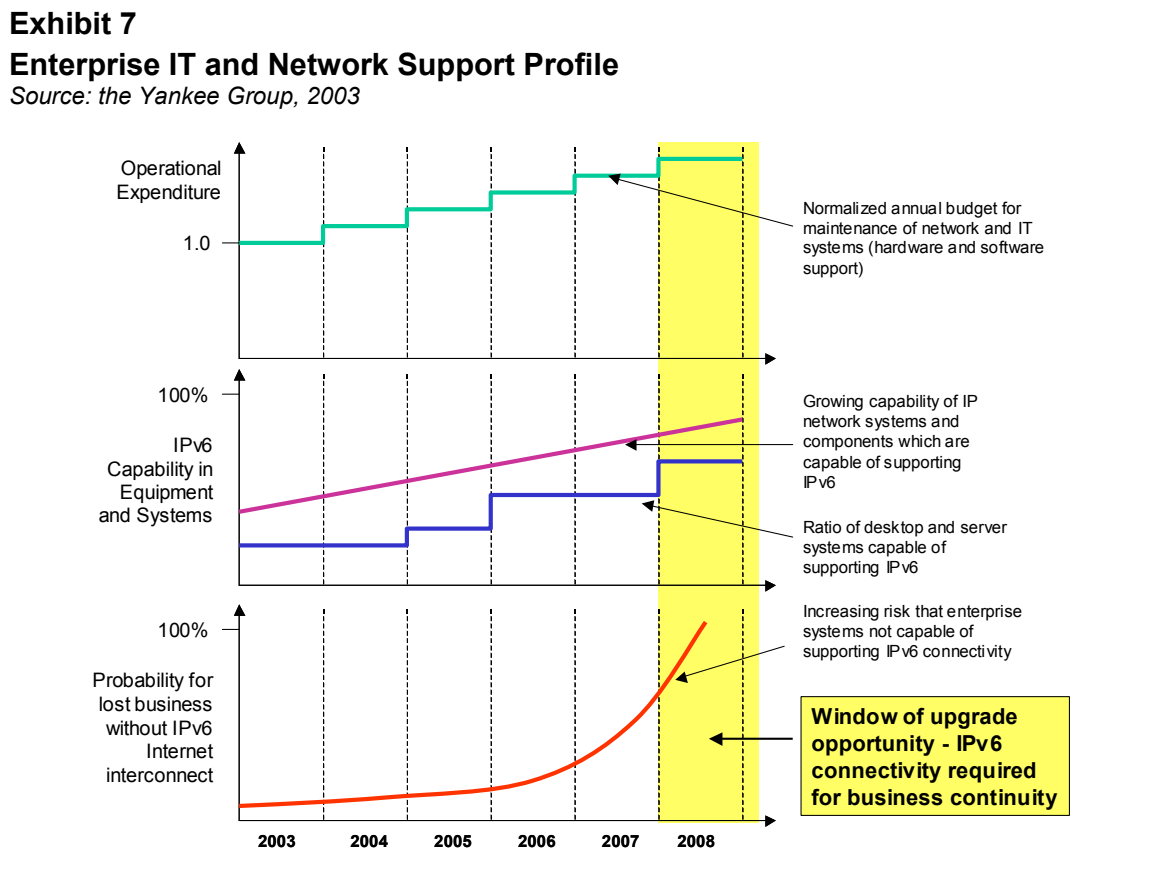
Analysis

We now offer the following analysis. In summary, the model enterprise will consider deployment of IPv6 operations for two essential reasons. Simply put, this is **because it can** (it will have basic IPv6 capability in its platforms) and there is a **business risk in not being IPv6-enabled**.

Refer to Exhibit 7 for the development of these points. In the upper chart we show the usual trend of IT and network expenditure for the model enterprise as a time line. Modest revenue growth and the need to boost productivity drive a growth in its operating and support budget. Included in this budget are hardware maintenance and upgrades to software for network and IT systems, and also to enhance performance or expand the capacity of the equipment. It is this component that guarantees the evolution of internal systems towards IPv6 capability. The middle diagram shows two growth curves as examples for the increasing support of IPv6 operation: the desktops (lower curve) take on new performance and attributes as upgrades to servers and workstations are carried out on a departmental or office basis; the network equipment (upper curve) acquires an ability to support IPv6 over this same period. At the end of five years the model company has a majority of systems that can support IPv6 and is in a position to migrate. We must note that a transition to IPv6 may require the deployment of some new equipment for parallel operation for a period - this applies to the network, and would entail minor additional expenses, and could exploit equipment spares.

So, at the end of this five-year period the model enterprise has the capacity to move to IPv6. Depending on the migration or transition that is chosen, this move will require some additional expenditure. Note that the enterprise's ISP or service provider may be able to facilitate the move by offering translation or some remote server facilities. But what is the key motivator for the move? We believe that the model enterprise will be driven by **risk mitigation**. Of course other factors to promote migration include the use of new (as yet undefined) business applications, which improve productivity or revenue, however these are

difficult to predict. The key driver for the enterprise will be that if it doesn't build up its IPv6 operations, then it is at risk of losing the capacity to undertake business.



In five years the model enterprise will deploy IPv6 to take advantage of new application classes, but justified by risk mitigation.

The Yankee Group has reviewed some risk scenarios and modeling that looks at outcome probabilities with the definition of various success factors and the weightings of these factors. This type of analysis becomes very specific to the industry sector of the enterprise, and more specific attributes related to the structure and operations of the enterprise. In some ways the analysis is parallel to the considerations undertaken for work on Y2K migrations. Through this risk analysis, we have found that it is generally possible to justify a range a values for specific additional expense to complete an IPv6 rollout.

Our timeframe is taken over a five-year period because this is a prudent horizon for business planning. Even though the enterprise may not formulate specific plans for an IPv6 migration until towards the end of this period, it will identify a target date for introduction of IPv6 technologies.

Potential Enterprise Exploitation of IPv6

In the preceding sub-section we have shown that enterprises are compelled toward IPv6 for business continuity, but there will be a significant **upside** from the new technology. Many new ways of doing business can be created, and there will be potential for enhanced operations.

Each industry will have cost saving and revenue generation opportunities. Here we consider some examples.

1) Factory automation and monitoring. Exploitation of IPv6 technologies should be planned at the outset of any major upgrade or implementation in a factory or production line environment.

Productivity and safety on the factory floor demands a structured approach to automation and telemetry systems. These systems are built up using an architecture, which delivers scalable, reliable, secure and real-time performance, with many diverse pieces of equipment and connection methods. This equipment includes devices such as motion controllers, process controllers, programmable logic controllers, smart sensors and actuator controls, as well as infrastructure components such as factory floor switches and routers.

A large manufacturing company is reviewing its approach to automation. Most of the factory devices use embedded systems that can be instantly reconfigured and reprogrammed to suit the needs of the production process. For more open flexibility, it is desirable to have network that can adapt to change.

The plethora of devices and monitors used in the manufacturing process can be assigned an IPv6 address, enabling more flexible control and operation in the factory's distributed LAN and wireless environments. The benefits will come from more streamlined systems, improved space utilization, simplified operation and monitoring.

2) Automotive industry. For over a decade automobiles and trucks have relied on increasingly numerous intelligent systems and more sophisticated in-vehicle computers.

An automotive manufacturer, which ships its vehicles worldwide, wants to put in place a facility that allows for on-line connections back to its central base whenever the vehicles are being serviced. This will allow for product management and customer service levels with unprecedented benefits. The vehicle can be identified, software can be checked, and new software and codes can be downloaded to ensure that the vehicle is optimized for its present status and type of use. Also a range of diagnostics and maintenance functions can be performed. Data logging devices can report back to the central base to guide product development and maintenance procedures. There are hundreds of end-points in each vehicle that will be used in this process.

Under current Internet service arrangements the manufacturer cannot obtain unambiguous IPv4 address space to do this at the required scale. The address range will not be ordered, efficient, or large enough for immediate needs. The application of a domain name and an IPv6 address to every device will provide an essential first step to its strategy.

3) Service provider industry. Grid computing exploits the installed base of office computers and servers in an enterprise, or better still, it can reach out across public network architectures to home computers and games consoles.

A services company in a high technology park plans to offer a grid computing service to the high-tech businesses located in the park. It plans to expand its business quickly beyond the geographical bounds of the park, and serve thousands of customers concurrently. It requires real-time networkable address space, not only to provide connection to clients and link into their resources; but also to harness the computing power on other sites. Its business model is based on delivering standard output from applications, and also from the sale of 'instructions per second'.

Local ISPs can only offer several hundred disjoint IP addresses. IPv6 will allow for security of address space and large scaling of endpoints.

4) Financial service industry. Banks and financial institutions operate large networks of employee terminals, automatic teller machines (ATM) and EFT/POS devices at merchant sites. Until now they have been using closed proprietary network architectures. An IP network, where it is employed, only provides tunneling or encapsulation.

Until the advent of IPv6 it has seen the public Internet as too restrictive and not able to grow. A local ISP could only help support 1,000 end-points with unique IPv4 addresses, which would not even satisfy the current number of ATMs that are deployed. With open end-to-end IPv6 connectivity, the whole range of terminals and devices can be effectively connected and monitored.

Also there is potential for new application development that improves security, lowers costs and generates new forms of service revenue. For example all ATMs can be simply equipped with multiple cameras and other sensory or interface devices. As required these devices can be activated and used to address the security situation or customer requirements.

VII. Conclusions

Based on a five-year planning horizon, **enterprises must develop plans now for deployment of IPv6 capabilities and infrastructure.**

All players, and especially enterprises, should develop a positioning matrix for the key IPv6 attributes. With this type of analysis it is easier to plan for specific outcomes, and prioritize the steps towards IPv6. The table below is not exhaustive and is intended as a guide only.

| IPv6 Attribute | Importance | When Needed | Cost Impact |
|---|------------|-------------|-------------|
| QoS, flow labels | | | |
| Multicast v6 | | | |
| Dynamic routing | | | |
| End-to-end transparency | | | |
| Greater number of IP-addressable devices | | | |
| End-to-end security | | | |
| Autoconfiguration plug & ping | | | |
| Mobile IPv6 | | | |
| Flexible renumbering | | | |
| Transition features (not really a value-adding attribute, but an essential element) | | | |

Recommendations

All players should plan for opportunities to deploy IPv6 technologies and systems that are ready for migration.

Enterprises

The clear need to deploy IPv6 for general business chain support is now within responsible planning timeframes.

- Plan to use IPv6 transition scenarios: ISATAP and 6to4. Plan for deployment of native IPv6.
- Enable IPv6 on Microsoft Windows XP systems today. Also check your options for Linux systems.
- Small office sites, traveling users and teleworkers should establish plans and procedures to use native IPv6, 6to4, and Teredo.

Equipment Vendors

Build and enhance IPv6 features for appliances and platforms. The following specific recommendations apply.

- Design and promote the product for the simpler, ubiquitous IPv6 Internet.
- Ensure long-term flexibility of the product with support for 6to4 tunneling and RA proxy.
- Prepare for consumer and enterprise use of mobile, smaller-footprint devices, even if you do not manufacture these units yourself.
- Device vendors use IPv6 stack in Windows CE and Windows XP. Embed it now.

Service Providers

Network providers and ISPs should take up the initiatives of all the tier one operators and build out IPv6 systems

- Offer native IPv6 services.
- Do not settle for NATs for new designs.
- Demand IPv6 support on all equipment.

Application Developers

In summary, stop waiting for enterprise demand.

- Leverage IPv6 to enable new scenarios, enhance the user experiences.
- Exploit true peer-to-peer (no longer blocked by NATs).
- For Microsoft applications, use IPv6 stack in Windows XP and Windows Server 2003 (and use the programming tools in Visual Studio .NET and .NET Framework).

Predictions

The key to IPv6 operations is **open access** to virtually **unlimited end-points**.

In short, the next generation of the Internet is inevitable. IPv4 cannot sustain the growth in end-users and the diversity of applications. IPv6 has been developed by the Internet's engineering community to be the candidate for this purpose. Only the timing and exact paths for transition are uncertain.