GLOBAL IPV6 STRATEGIES:
FROM BUSINESS ANALYSIS TO OPERATIONAL PLANNING

Patrick Grossetete
Ciprian Popoviciu
Fred Wettling

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Americas Headquarters
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USA
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About the Authors

Patrick Grossetete, manager of product management at Cisco, is responsible for a suite of Cisco IOS software technologies, including IPv6 and IP Mobility. He manages Cisco participation in the IPv6 Forum and is a regular speaker at conferences and industry events. Patrick is coauthor of *Deploying IPv6 Networks* (Cisco Press). In June 2003, he received the "IPv6 Forum Internet Pioneer Award" at the San Diego summit. Patrick joined Cisco in 1994 as a consulting engineer. Before joining Cisco, Patrick worked at Digital Equipment Corporation as a consulting engineer and was involved with network design and deployment. He received a degree in computer science from the Control Data Institute, Paris, France.

Ciprian Popoviciu, PhD, CCIE No. 4499, is a technical leader at Cisco Systems with more than ten years of experience in data and Voice over IP communications technologies. As part of the Cisco Network Solution Integration Test Engineering (NSITE) organization, he focuses on the architecture, design, and validation of large IPv6 network deployments in direct collaboration with service providers and enterprises worldwide. Ciprian is a regular speaker or chair at conferences and industry events and contributes to various technology publications. He is an active contributor to the IETF standards, a senior member of IEEE, a member of several academic advisory boards, and a coauthor of *Deploying IPv6 Networks* (Cisco Press). Ciprian holds a BS from Babes-Bolyai University, Romania, and an MS and Ph.D. from the University of Miami.

Fred Wettling manages architecture and strategic planning for Bechtel Corporation, one of the world's premier engineering, construction, and project management companies. Fred is one of 20 Bechtel Fellows out of a population of 40,000. He has extensive experience in project and office startups, major technology transitions, innovations, and technology operations at 20+ Bechtel projects and offices. Fred is active within and outside of Bechtel promoting standards-based technology interoperability that supports global enterprise business needs. Fred is a member of the IEEE, North American IPv6 Task Force, and IPv6 Forum, and is executive director of the IPv6 Business Council. He served as the Network Applications Consortium (NAC) chairman for five years. Fred was selected as one of the 50 most powerful people in networking by *Network World* from 2003 to 2006. He is a senior member of the Cisco Enterprise and Federal Technical Advisory Boards and served on the President's National Security Telecommunications Advisory Committee (NSTAC) Next Generation Network Task Force as a subject matter expert.

Contents at a Glance

CHAPTER 6

Planning Your IPv6 Migration

To this point, the goal of this book has been to help you understand the trends and strategies for adopting and leveraging IPv6 as part of natural technology evolution to sustain growth and specific business and competitive differentiators. The market overviews and the concrete examples presented in the case studies should enable decision makers to see the opportunities offered by IPv6 and to become familiar with the adoption experience of businesses in their market segments. Regardless of the conclusions drawn from an accelerated adoption or a continual monitoring of the technology, planning for IPv6 is essential to all businesses. The potential disruptive effects of not implementing IPv6 make an old saying applicable to this technological evolution: "There is absolutely no substitute for genuine lack of preparation."

Plan for IPv6 in the IT Environment

Planning for IPv6 takes a multidimensional effort, and a comprehensive approach to this undertaking is essential to its success. As a foundational technology, IPv6 touches all aspects of the IT ecosystem, as shown in Figure 6-1. The network is the platform that ties together people, services, devices, and information resources. The network facilitates communication among people, people's use of services and devices, and their access to information. The network also enables devices to communicate with each other and with services to leverage information. Figure 6-1 represents just a few of these interactions among the elements of the IT environment. IPv6 is not just about the IP network infrastructure, which in fact might be the simplest problem to solve; it is also about all these components and their interactions.

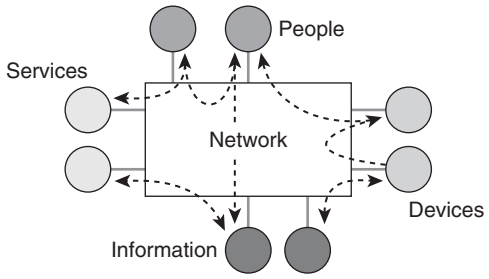

Figure 6-1 *Interactions in the IT Environment*

There is also the important temporal dimension of IPv6 planning. The title of this chapter, without a time scale attached to it, might lead to visions of daunting tasks with flag-day migrations that lead to dramatic disruptions. Because nobody really knows when the last IPv4 packet would be sent through a network, the full migration to IPv6 is a long string of protocol integration steps. Planning for IPv6 migration has to focus on the protocol integration and its co-existence with IPv4 as well.

A complete and global perspective of the IT environment reveals the multiple facets of an IPv6 integration planning effort. Figure 6-2 translates the generic concepts presented in Figure 6-1 into the following building layers of the IT environment:

- **Infrastructure:** Assets that support IT services and communications in an organization. Multiple infrastructure changes are needed with the implementation of IPv6; these changes go beyond apparent network transport upgrades. Individual, self-contained computing units must be IPv6-addressable and communicate using IPv6 as the preferred protocol over IPv4 from the operating system and through other local software such as browser and office automation (OA) applications. Attention also needs to be paid to infrastructure services used throughout the organization, starting with basic naming services, such as DNS and DHCP (v6). Common shared infrastructure services such as file, print, database, and web services are part of the IPv6 transformation.
- **Information:** Data essential for performing and supporting business functions. Information itself will generally not be changed when IPv6 is turned on. However, IPv6 does offer new alternatives in information access and sharing. Secure end-to-end IPv6 communications should be explored in the context of different information assurance (IA) and intellectual property paradigms.
- **Applications:** Software tools that enable users to perform business functions. Application development and certification processes ensure that IPv6 is used as the preferred communications protocol. This may not be possible with legacy third-party applications. Beyond qualifying existing applications to use IPv6, new applications are now possible that

could not be achieved or easily developed with IPv4. Development environments, service-oriented architecture (SOA), web services, and maintenance routines should be updated to include IPv6.

- **Business functions:** The tasks that individually or in various combinations achieve the objectives of a business. Changes to core business functions can sometimes be supported by new capabilities offered by IPv6. Perhaps new ways to meet and interact with customers, develop products, or execute a task with IPv6 would be applicable. Readers should consider the way in which telephones or the Internet changed their organizational business functions as an example of infrastructure-enabled business function transformations.

These layers are bordered by two overarching structures, as indicated in Figure 6-2:

- **Processes:** Governance and methodologies that are used for the integrated management of the environment. IPv6 should be quickly integrated into existing IT processes and architectures such as development methodologies, certification processes, purchasing, and enterprise portfolio management. Enforcement of IPv6 requirements should be accomplished through IPv6 changes to quality assurance (QA), configuration management, and production deployment processes.
- **Standards:** Architectures and technical standards that provide the structure for integrating components at all levels. Standards interrelationships should be examined. We discussed earlier that IPv6 support is required for other standards such as 3GPP IMS (IP Multimedia Subsystem) and CableLabs DOCSIS. Organizations should carefully explore the current standards they are using, the emerging version of the standards, and any dependencies on IPv6.

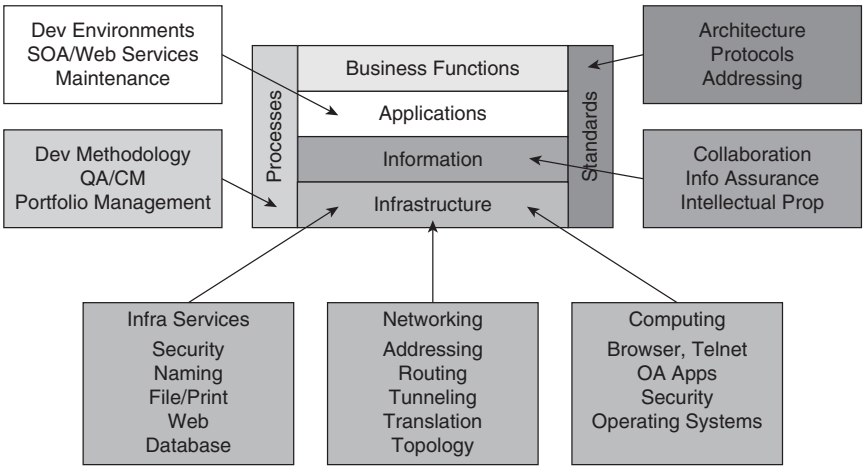

Figure 6-2 *High-level Reference Model for the IT Environment*

The IPv6 integration plans must be detailed for each IT environment element highlighted in Figure 6-2. These considerations are integrated in the major planning steps identified in this chapter:

- **Define the objectives:** Identify the scope of the project, its timeline, and the phases of implementation.
- **Assess the IT environment:** Inventory the IT assets to assess the changes required for IPv6 capabilities in the context of the identified integration objectives.
- **Review the operational and governance policies:** Tie the integration plans into the business and organizational structures to ensure the success of all aspects of adoption at all levels of the organization.
- **Initiate and support technology education:** Provide the individuals in the organization with the appropriate level of IPv6 knowledge and awareness.
- **Leverage the IPv6 industry experience:** Learn from the IPv6 experience of others in order to streamline the integration process and increase its chances of success.

We provide recommendations in this chapter for each of the previous steps of the IPv6 planning effort and how they can be used by both early and late adopters. Each recommendation is complemented by a concrete example of its application. Many of this chapter's examples come from Bechtel, a representative of an emerging category in the theory of technology adoption: an early planner (detailed in Chapter 5, "Analysis of Business Cases for IPv6—Case Studies"). Examples of other early planners include Comcast Corporation and the U.S. Postal Service, which recognized early the complexity of this planning process and initiated it well in advance of the actual technology deployment. Early planners often become early adopters.

Define the Objectives

The ramifications of IPv6 adoption depend on the scope of its integration. Although IPv6 will ultimately become ubiquitous throughout the organization, the initial steps in its integration might vary in terms of depth and coverage. Some organizations might decide that IPv6 deployment is not a priority at this time and choose to update only their security policies and monitoring/management capabilities to deal with potential IPv6 threats. Other organizations might fully commit to IPv6 and plan a complete strategy for its integration in all aspects of the IT environment.

There are four major aspects to defining the scope of an IPv6 integration project and its planning:

- **Alignment with strategic objectives:** Identify strategic value of the change.
- **Project goals:** Define what will be achieved.
- **Project scope:** Identify the areas of the IT environment that will be affected.
- **Project timeline:** Identify the time scale, metrics, and milestones for the project and its financial impacts.

The textbook project management elements are described in the following sections to provide IPv6 examples for them using companies included in Chapter 5.

Alignment with Strategic Objectives

Organizations should ensure that the implementation of a new technology has strategic value to an organization. This alignment requires an understanding of the business and the capabilities of the new technology. The change may not have immediate and direct short-term ROI, but may be the foundation for other more significant changes over time. The alignment discussed below is applicable within the Bechtel context. Each organization should make its own assessment based on its strategic business and technology objectives.

Bechtel is a global leader in the development, support, and management of industrial infrastructure. As with any significant technology transformation, Bechtel is approaching IPv6 in the context of its strategic applicability. Its constantly evolving project-based environment has several implications. They see IPv6 as one of the technology enablers to address its changing business. Bechtel established IPv6 project goals to address the combination of changes in its business and evolution of technology, including the following:

- **Volatile infrastructure:** Bechtel works on scores of concurrent large projects annually, each with an average life of 30 months. Some of the more complex projects are served by several global locations concurrently. The process of creating, tearing down, and moving populations and networks on a regular basis has created an increased demand for infrastructure agility, especially in the area of rapid project deployment. IPv6 can aid in rapid project mobilization and demobilization.
- **Highly mobile workforce:** People are moved and hired to support project execution. Getting the right people engaged at the right time involves a mix of global information access combined with travel. Reducing travel dependencies improves performance. IPv6 capabilities support improved and more secure communications to project participants, anytime and anywhere.

- **On-demand collaboration:** Many of organizations have an increasing degree of integration with customers, business/joint-venture partners, suppliers, and other external people. The transition to "snap-your-fingers quick" secure collaboration requires changes in network and security paradigms that can be improved or enabled with IPv6.
- **Dynamic intellectual property and IA needs:** Collaboration with multiple constituents requires an increasing reliance on securely sharing intellectual property and providing a high level if IA. In this more collaborative environment, information used in project execution may be controlled by Bechtel or some of its business partners. The dynamic management of sensitive information requires information security while fixed or in transit. Complexity and agility are both increased with the introduction of new paradigms, such as peer-to-peer computing.
- **Constant tech evolution:** Developing and maintaining industry leadership requires ongoing assessment, exploitation, and deployment of technologies that improve business operations. Like many other dynamic companies, Bechtel sees IPv6 as an enabler for transformation, just as web, database, and other technologies have been in the past.
- **Engineering systems convergence to IP:** IT is becoming more involved in areas outside of the traditional comfort zone. This is particularly apparent in industrial automation as building, plant, and process automation systems transition to IP-based communications. The IPv4 address shortage becomes a much more relevant and urgent issue when considering everything from building badge readers to motor-operated valves in an industrial plant.
- **IPv6 insertion from others:** Bechtel has selected the option to plan for change rather than being forced to react to it. Linux, Windows Vista, and other core computing technologies are now shipping with IPv6 turned on by default, generating IPv6 traffic that has to be under control. Bechtel's IPv6 project plans are designed to ensure that new technologies inserted into its environment work securely and effectively when production deployment starts.

Project Goals

The goals of the IPv6 project are essential in defining the resources necessary for its planning and later for its implementation. There are multiple options and they are often organization- or business-specific. The following list provides several examples of IPv6 project goals of varying complexities:

- Launch of a targeted, tactical project for which IPv6 is not yet important but for which security policies and monitoring capabilities must be updated to address the presence of IPv6-capable devices.
- Establish a test environment for protocol, application, security, and equipment evaluation.
- Deploy a single application running over IPv6 or take advantage of the Microsoft Windows Peer-to-Peer Networking framework (http://www.microsoft.com/p2p).
- Insert Linux, Microsoft Vista, and Microsoft Longhorn products with IPv6 enabled by default.
- Integrate new devices such as sensors or new services such as video content distribution over IPv6.
- Get IPv6 connectivity in a part of the world that is rapidly adopting IPv6.
- Deploy the next generation of services using IPv6.

The clear definition of project goals leads to well-defined success criteria and the means for tracking the progress of the project toward achieving them.

Bechtel views IPv6 as a critical component of its next generation infrastructure that must work in harmony with other fundamental changes that support strategic business objectives. IPv6 is not the "silver bullet" but it is clearly a strategic, foundational requirement for the future, with immediate near-term benefits. Within this business context, Bechtel established an IPv6 vision for 2008 that has these goals:

- IPv6 is broadly deployed.
- IPv6 is the default in a global dual-stack environment.
- New products and services run IPv6 by default.

- Bechtel is an IPv6 industry leader.
- IPv6 is the foundation for innovation.
- Bechtel is well positioned for rapid deployment of new IPv6 products and services.

Achieving these objectives will develop sustainable IPv6 competence in Bechtel through practical experience.

Project Scope

The goals of the project identify the IT environment elements that would be involved in its implementation. Nevertheless, the nature of the project influences its coverage. For example, an enterprise that is ready to interface with regional IPv6 ISPs requires localized coverage, whereas an ISP that delivers video content in accordance with national regulation that requires the service to be available to a service provider's entire subscriber base needs global coverage. The project coverage can be defined in terms of geography (specific markets or theaters), network architecture elements (campus or data center, branch offices, core), infrastructure elements (public wireless infrastructure, broadband, cars, planes, ships, trains), services (content delivery, VoIP), and policies or standards.

The opportunities for significant transformations are great, the impact footprint is broad, and the transition to an IPv6-dominant environment will take several years. Bechtel defined a governing strategy to guide its enterprise IPv6 transformation that addresses all major aspects of its enterprise architecture related to its comprehensive IPv6 deployment highlighted in Figure 6-2:

- Applications
- Information
- Computing platforms
- Networking
- Infrastructure services
- Processes
- Standards
- Governance

In the context of the "foundation first" principle, technology/product maturity, external influences, and dependencies should be used to determine the sequence and possible degree of parallel effort that could be achieved. A basic IPv6-enabled environment is required before advanced IPv6 products and services can be successfully deployed. The logical deployment sequence selected by Bechtel was as follows:

- Client computing platforms
- Network services (DNS, DHCP, NTP, and so on)
- LAN (intra-site) and WAN (between sites)
- Server computing platforms, early applications, and basic infrastructure services
- External IPv6 network connections

Bechtel elected to start its client site of IPv6 deployment with Windows XP SP2 rather than wait for the more comprehensive features of Windows Vista. Bechtel deployed stateless address autoconfiguration (routers), network switches, DNS, web services, and similar functions on IPv6-enabled computing platforms first. In parallel, Bechtel enabled IPv6 in all application and infrastructure development and engineering environments. This broad multidiscipline approach has been successful.

Maintaining and improving security is essential to the success of the deployment. IPv6 offers new security paradigms and potential disruption to existing practices. Bechtel approached security from the perspective of meeting current and emerging requirements, not from the view of just replicating the security systems of today. Typical requirements include border/firewall rules, logging criteria, and remote access. However, Bechtel's vision of the next generation infrastructure has to meet new demands that can be enabled by IPv6, such as on-demand collaboration with others, projects without borders, and dynamic transport security in an always-on environment. Bechtel information security professionals are an integral part of its IPv6 design and verification.

Maintaining and improving management represents another important operational aspect of the deployment. Several major vendors have enabled IPv6 features on their products before fully enabling IPv6 component management over IPv6 transport. This is not always a problem. However, in some cases, Bechtel has

had to make tactical changes in management tools and process approach to get around product shortcomings.

Project Timeline

The overall migration to an IPv6-only network will probably take a long time and is likely to be achieved through either multiple projects or a single multiphase project. Similar to any technology integration, planning of each step has to meet the delivery dates while taking into consideration multiple timelines, some under the control of the organization and some not:

- Budget cycle
- Equipment refresh schedules
- Equipment and software certification cycle
- Timelines of related projects
- Manufacturer product and feature delivery schedules
- Technology standards development and adoption

NOTE

New hardware or software certification by the major service providers takes an average of 24 months. To be ready to offer services to U.S. federal agencies that need their infrastructures to be IPv6 ready by 2008, U.S. service providers had to start the IPv6 certification process by 2006.

When they decided to deploy IPv6 in their networks, the U.S. cable operators had to adjust their project schedules to two timelines: the development of the DOCSIS standard that supports IPv6 and the availability of products that would implement the new standards.

Systems integrators that cater to the federal market and were ready to support IPv6 by 2006 leapfrogged their unprepared competition ahead of the 2008 deadline for the defense and civilian government agencies.

The importance of these timelines should not be underestimated, because they can significantly impact an organization's ability to implement the IPv6 project in time to meet business needs.

Most aspects of today's IT environment relate to IP, so understanding all dependencies is important in defining the pace of the IPv6 integration. Foundational elements should be addressed first to provide an infrastructure that can be leveraged to insert IPv6 anytime a window of opportunity opens in the context of these dependencies. At the same time, longer timelines enable an IPv6 integration project to leverage dependencies to its advantage. The cost of deployment can be significantly reduced if the equipment and software are upgraded to IPv6 through a regular refresh cycle.

Metrics and Milestones

Effective project management requires the ability to objectively measure progress. Use of existing IT management tools can help in many cases. Bechtel defined a clear timeline for all aspects related to the IPv6 integration. Table 6-1 lists the major milestones of IT environment elements that were ready or enabled for IPv6. For example, in 2006, five production LANs and WANs were IPv6-enabled. The target number for 2007 was 100 network segments, and the goal for 2008 is for 95 percent of all network segments to be IPv6 enabled. In 2006, there were 1000 Windows clients enabled for IPv6 (XP or EFT Vista), and by early 2008, over 16,000 (95 percent) of all Windows clients were IPv6-enabled.

During planning, Bechtel, which is a project-oriented company, had to take into consideration the timelines of individual projects. Project managers would consider any significant technology insertion in the middle of a project to be a high risk.

Detailing the timeline for several key aspects of the IPv6 integration project provided Bechtel with the ability to track progress in a realistic manner. Saying that my network is 95 percent ready might not mean too much if the missing 5 percent makes it inoperable.

Table 6-1 *IPv6 Integration Milestones at Bechtel (1Q-2006)*

Milestone	2006	2007	2008
Global IPv6 labs	4	5	5
LAN/WAN	5	100	95%
Windows clients	1000	10,000	95%
Websites	6 internal	25%	95%
Applications: dual-stack	30 major	90%	95%
Mobility	Wireless	Remote access	Always on
Management	Basic	Over IPv4	Over IPv6
Security	Internal only	External IPv6	Borderless projects

You may find deployment pace being constrained, to some degree, by commercial product maturity. This can be at least partially mitigated by working closely with key technology suppliers to determine in which products IPv6 is enabled and to what extent. Consider a focus on ensuring that network, computing, application, and service components are enabled in a sequence that will generate the maximum amount of meaningful end-to-end IPv6 activity. Sometimes an immediate incremental change has advantages over waiting for all IPv6 features to be available in the next version of a product.

Project Plan Development

From this point on, the planning discussion focuses on projects with a larger scope, projects that pursue the integration of IPv6 in an existent infrastructure. The process is in great measure incremental and evolutionary, similar to the experience of adopting the web. The following steps are to be expected:

- Assess the current state.
- Define the future state.
- Perform a gap analysis.
- Develop a strategy to achieve the future state.
- Prioritize activities while considering dependencies.

Assess the IT Environment

After the strategic perspective on IPv6 is established at the business level and the scope of the IPv6 project is defined, the next step is to understand the environment in which the new protocol is integrated. This exploration of your IT environment landscape should take place in the context of the reference architecture described in Figure 6-2. Review the high-level reference models and planned technology initiatives for each layer that will be touched by a change in network protocols. You will find that many aspects of the IPv6 integration can be covered through minor changes in existing standards and processes. Established processes and procedures for technology changes should be used to the extent possible.

The assessment process corresponds to a deep analysis of the "Internet penetration" in your organization. Often, this is seen as an inventory of the network devices to evaluate their readiness to support necessary IPv6 features. In reality, this process is far more complex than that, and the transport infrastructure assessment is sometimes the least complex aspect of it. IPv6 is not a feature; it is an update of the TCP/IP network layer, so any device, service, or application that uses this protocol stack is in the scope of the assessment. All these elements of the IT infrastructure and the policies governing them must be inventoried in order to understand what they need to support IPv6. The IT environment elements can be categorized into three classes:

- **Hosts:** For hosts, the OS must include an IPv6 stack or, more generally a dual stack (IPv4 and IPv6). The hardware configuration for a given host must comply with the OS release requirements.
- **Networking devices:** Devices must support an IPv6 feature set that matches the deployment requirements.
- **Applications:** The inventory of the applications portfolio should deliver a matrix that provides the upgrade options.

The components of each of these three categories are listed in Table 6-2.

Table 6-2 *Classification of IT Environment Elements*

Hosts	Applications	Networking Devices
Computers (mainframe, workstation, desktop, laptop, and so on).	Mandatory services such as DNS server, NTP server, network management, and so on. The IPv6 support is a *must* because these services are crucial elements to any deployment.	Routers (software forwarding and hardware forwarding based platforms).
Mobile devices (PDA, smartphone, UMPC, and so on).	Off-the-shelf applications. These are dependent on the software vendors who have to integrate IPv6 in their roadmap (for example, Microsoft Exchange 12).	Layer 3 switches (hardware forwarding and service line cards).
VoIP devices (IP phone, conference bridge, and so on).	Homemade applications (applications developed internally that would have to be upgraded for future use).	Layer 2 switches (support for device management and other L3-related features such as Multicast Listener Discovery snooping).
Video over IP devices (IP camera, video server, and so on).	New applications. These are the best candidates to deploy over IPv6.	Security appliances (firewall, IDS, VPN concentrator, hardware encryptor).
IP-enabled industrial devices (sensors, readers, and so on).	Old applications (applications that will never be upgraded to IPv6). Similar to what happened when transitioning from X.25, SNA, or DECnet to TCP/IP, there is no need to focus on applications that will get phased out in the future.	Data center networking (storage networking, load balancers, and so on).
		Network management appliances (Network Analyzer Module, testers, probes, and so on).
		Wireless infrastructure devices (Wi-Fi access point, GGSN, Packet Data Serving Node (PDSN), and so on).

The assessment process can be simplified to a certain extent. Automated tools have been developed to determine the capabilities of subsets of elements within the IT environment, such as networking devices.[1] Such tools can provide a quick, high-level inventory. However, for a complete evaluation, today's complex IP equipment typically requires lengthier and more resource-demanding assessment efforts. In a "per-application" or "per-service" integration approach, the assessment process can be simplified by reducing its scope to a subset of IPv6 features and capabilities that are necessary to support well-defined services and applications.

NOTE Identifying the OS running on a high-end router and Layer 3 switch is sufficient to indicate support for IPv6 control plane features. But to understand its full hardware capabilities for IPv6, an important detail for a deployment, the revision of each line card must also be determined.

Assessment is more than just a software/hardware inventory. It has to also include a review of the design principles and decisions applied to the existent environment. This review identifies the constraints for the IPv6 integration and highlights the opportunities where optimizations can be made based on past experience.

Product Assessment

Bechtel continues to work closely with its technology partners to understand and communicate IPv6 capabilities in ways that can be used throughout the lifecycle of each product and service that is in use or planned. They have found that a platform-based approach is very effective. Table 6-3 is an example of this approach, with platforms listed on the vertical axis and IPv6 capabilities and applications listed on the horizontal axis. Bechtel tracked vendor-reported IPv6-supportable services and devices by indicating "Y" in the IPv6 columns. This is

1. "IPv6 Capability Assessment," Cisco Systems data sheet, http://www.cisco.com/web/strategy/docs/gov/IPv6CapabilityAssessment_DS.pdf.

the first indication of areas to be assessed. The platforms are then evaluated to ensure that they have the correct hardware and software versions to support the desired features. Using a mix of vendor-supplied assessment tools and extensions to existing discovery and inventory tools will help complete the base assessment.

Configuration instructions and feature references are links under the "Doc" column. After an organization determines that a platform and feature combination is capable of supporting IPv6, it can use vendor input to document the standard configurations. This is the bridge between what can be done and how to do it.

Table 6-3 *Example of a Feature/Product Support Matrix*

	Desktop XP		**Desktop-Vista**		**Server 2003**		**Server 2008**		**Network_IOS**	
Hosts	IPv6	Doc	IPv6	Doc	IPv6	Doc	IPv6	Doc	IPv6	Doc
IPv6 address types: Unicast	Y		Y		Y	R[a]	Y	R[a]	Y	C[b]
IPv6: ICMP	N		Y	R[a]	N				Y	C[b]
—	—	—	—	—	—	—	—	—	—	—
SNMP Client			Y	R[a]	Y	R[a]	Y	R[a]	Y	C[b]
DHCP Server					N		Y	C[b]	Y	
SharePoint Server					Y	C[b]	Y	C[b]		

a. R = Reference
b. C = Config

It may not be productive to attempt to configure or deploy IPv6 on products and services for which suppliers have clearly stated there is no IPv6 support. You may find that vendors are not always clear on the extent of IPv6 support in their products.

Actions Based on Product Assessment

The outcome of the assessment should be a matrix that lists the following information:

- **IPv6 requirements for each element:** This information comes from the targeted goal of the deployment.
- **What it takes to make the element IPv6 compliant:** The added capabilities required by each element.
- **How to make each element IPv6 compliant:** Points to the procedures for making the element IPv6 ready. Documenting this information at this time is helpful during the implementation phases of the project.
- **Cost implications for making the element IPv6 compliant:** Vendors or consulting firms can provide the roadmap information for a given product and the processes already validated by others to upgrade at minimum costs.

Operational and Governance Policies

The integration of IPv6 in the IT environment, whether in the near or distant future, has wide-ranging implications. As a foundational technology, its immediate integration benefits might be less apparent to most users. This challenge, combined with the natural challenges related to its integration, can lead to adoption resistance or a tendency to marginalize it.

NOTE Often, organizations facing calls to integrate IPv6 in their network try at first to achieve the goal by mapping outdated IPv4 designs at minimal costs. Invariably, after a while, the same organizations recognize the opportunity they have to explore new options and new architectures with IPv6 and they adjust their planning efforts accordingly.

It is important to take an organization-wide, complete perspective on the IPv6 project. The commitment to the project must come from all levels of management and must be clearly represented through messaging, assignment of responsibilities, and tracking of progress. Operational and governance policies must be updated or implemented in order to reflect this commitment and to support the execution of the project. It is also important to remember that the integration of this new protocol offers an opportunity to redefine old policies in accordance with the current business realities of the organization and its future goals.

Governance Considerations

Regardless of its implementation pace, IPv6 integration is not a single, isolated, network-centric project. It is an evolution of the IT environment that gives it a strategic dimension. The success of a strategic project depends on supporting guidelines and rules that span the entire organization at all its levels:

- **Senior management visibility and support:** A clear and consistent message of commitment from the senior management is essential to making sure that each group within the organization is prioritizing appropriately the IPv6-related activities.
- **Enforcement:** Adherence to the IPv6 strategy and meeting the project goals should be a measure of the organizational, group, and individual performance.
- **Cross-functional coordination:** All groups within the organization must collaborate in addressing mutual dependencies with respect to IPv6 integration.
- **Communicate frequently at all levels:** Continued communication on the IPv6 adoption topic reinforces the expressed importance placed on the project and enables its progress to be tracked closely.
- **Make IPv6 a natural part of other activities:** Raise awareness about IPv6. Reward IPv6-related achievements and innovation.

Organizational Leadership

Effective governance requires a mix of actively engaged senior leadership, champions, early adopters, and policy enforcers. IPv6 champions must be identified throughout the organization in each of these areas.

NOTE Bechtel discussed IPv6 internally for a few years before making the transition commitment in late 2004 at the senior management level. At that point, senior managers felt that there were sufficient business drivers and that IPv6 technology and supported products had reached the required level of maturity and global industry adoption. Bechtel's federal global business unit was identified as the organization with the highest immediate need, based in part on the 2003 DoD mandate. Over the following two years, Bechtel has identified additional IPv6 opportunities. Through this process, Bechtel tied the need and pace of IPv6 adoption to its business-related IT strategic planning. The approach is parallel in several ways to the introduction and development of web technologies over the last 13+ years. IPv6 continues to be part of the IT planning process. Senior management buy-in and support, senior IT leadership oversight, and the other critical success factors identified previously made a significant difference in the progress of the IPv6 adoption project.

Enforcing the governance and guidelines is essential with the many interdependencies that characterize the IT environment. Thus, it is important to highlight the role of gatekeepers in ensuring the proper and complete implementation of IPv6-related requirements.

As shown in Figure 6-3, gatekeepers play a significant role in enforcing the implementation of the IPv6 policies in the functional groups (Development and Engineering, Quality Assurance and Configuration Management, Production) by tracking the handover process between these groups.

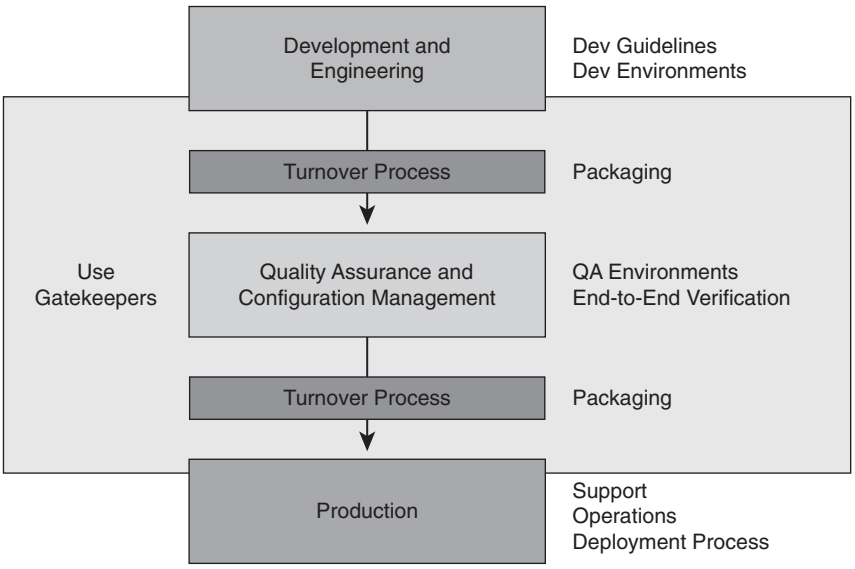

Figure 6-3 *Role of Gatekeepers in the Consistent and Optimal Integration of IPv6*

Well-defined IPv6 entrance and delivery criteria help its organic integration throughout the IT environment.

Policy Considerations

IPv6 adoption requires the implementation of specific policies that facilitate its integration and reduce the deployment costs and the operational risks. At the same time, IPv6 offers an opportunity to revisit existent policies and improve them in the light of past experiences and the future goals of the business.

There are multiple areas of the IT environment in which IPv6-specific policies will be required, and they should be identified during the assessment

process. Some of the larger-scope policies that apply to any business are the following:

- **Update purchasing policies:** Regardless of whether the IPv6 deployment is a short-term or long-term project, the best way to reduce the potential cost of integration is to add IPv6 requirements to every purchasing policy in an organization. When IPv6 standardization was in its infancy, it was more difficult to request features that were still evolving. Today, the core IPv6 specifications are stable and a base feature set can be expected from most vendors. The requirements are identified through the design process and are related to concrete IT environment elements through the assessment process. This enables the organization to acquire products with the current IPv6 capabilities through the regular refresh cycle and to request vendors to implement new features as necessary for the envisioned deployment.

Real-Life Case of Updating Purchasing Policies

Let's evaluate a real-life case of updating purchasing policies. At the beginning of 2005, a service provider was running an IP network based on Cisco 12000 series routers equipped with Engine 0, 2, 3, and 4 based line cards. Under pressure from a couple of its customers who requested IPv6 connectivity, the service provider did a network assessment, which clearly identified the need to upgrade all line cards to Engine 5 in order to offer IPv6 services at production level and on a large scale. Eighty line cards were identified for the update. An immediate upgrade (considering an average price of $200,000 per line card) would have cost: $80 \times \$200{,}000 = \$16$ million.

When tying into the refresh cycle of 3 to 5 years, the service provider evaluated that the upgrade could be done over the next 24 months, making the integration of IPv6 transparent and removing the cost of an immediate upgrade. To meet immediate needs, Engine 3 line cards that support IPv6 in hardware as well were redeployed where required. In conjunction with features such as IPv6 over MPLS—also known as 6PE (RFC 4798) and 6VPE (RFC 4659)—the service provider can deliver the services where and when needed with minimal costs. By mid-2007, the network was fully upgraded and ready to offer IPv6 services to any customer.

- **Update development policies:** IPv6 must become an integral part of all internal development efforts. Even if the IPv6 deployment is not imminent, it is important to institute as early as possible rules requiring internally developed applications to be IP version agnostic. The IPv6 requirements across products must be clearly defined and adherence to them must be enforced.

  The development policies should also encourage the exploration of new implementation approaches that leverage capabilities that are specific to the IPv6 protocol (self configuration) or the IPv6 environment (sufficient addresses to support peer-to-peer computing).

NOTE From a product development perspective, Cisco defined and maintains an internal IPv6 Architecture Baseline document to which all products must adhere.

- **Update security policies:** Current IT security policies will have to be modified to account for IPv6-related vulnerabilities and the coexistence of the two protocols. The review and update of the security policies must start well in advance of the actual IPv6 deployment. Devices might establish, without the express knowledge of the user, dynamic tunnels for IPv6 traffic and open security holes.

NOTE The new Microsoft Windows Vista operating system establishes dynamic IPv6 over IPv4 tunnels for certain applications if it does not detect native IPv6 connectivity. At a minimum, organizations must enhance their monitoring capabilities to keep control of this traffic.

- **Redefine entrance and acceptance policies:** Entrance and acceptance criteria for IT environment elements must be updated to include IPv6 requirements as defined by the integration projects. Observing and evaluating product compliancy with IPv6 standards are significant parts

of the entrance and acceptance policies. This is especially important in the early phases of product acquisition, because manufacturers might take a more liberal perspective on protocol implementation or might have to deal with non-IPv6-ready designs of their products. A more interesting perspective on this topic is that of reevaluating the existing entrance and acceptance policies and adapting them (IP version agnostic) based on past experience.

NOTE As part of its IPv6 integration plans, Comcast Corporation restructured and tightened its requirements related to IP product acceptance.

- **Define content availability policies:** Content should be made available over IPv6 and not only over IPv4. All absolute URLs on a corporate website should be banned; only relative URLs that support IP version–agnostic access should be used. Content accessibility can be updated for IPv6 support during periodic content review and maintenance.

The identified policies must be paired with appropriate owners within functional groups and with gatekeepers for the interface between the functional groups. Compliance should be constantly monitored and reported.

Project Execution Policies

Bechtel used governance oversight to change relevant IT policies to make IPv6 "part of doing business." These are some of the policies changed or introduced in the context of the IPv6 adoption project:

- **Stop the bleeding:** Bechtel determined that it was important to stop perpetuating IPv4 dependencies. It installed cost-avoidance changes in purchasing policies and development activities to avoid buying, developing, and deploying technologies that would have to change.

- **Ensure nothing breaks in production:** IPv6 is new territory for most IT people. Bechtel has modified testing procedures, release notices, change management work orders, and related processes to ensure IPv6 compliance and minimize risk of adverse impact with production deployment. Enabling the "gatekeepers" with IPv6 tools and conformance authority is critical to success.

  Figure 6-4 presents schematically Bechtel's developed approach to building scalable components that can be broadly deployed to multiple sites. Potential risks are contained in an isolated multisite lab environment until that environment is determined to be stable, secure, and manageable. From there Bechtel uses standard procedures for moving new or modified technology into production. This includes formal turnover from development to QA followed by controlled change management when moving into production. At each state transition point, controls have been inserted to ensure IPv6 compliance. The basic process applies to all hardware, software, and network changes.

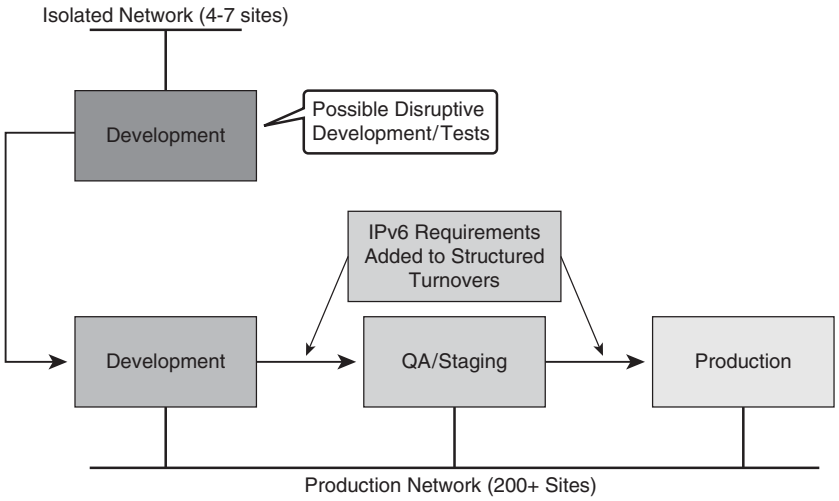

Figure 6-4 *Technology Insertion Process at Bechtel*

- **Use natural change mechanisms when possible:** Bechtel is capitalizing on proven technology change processes for its IPv6 transformation to the extent possible. For example, when upgrading an OS on a computing or network platform, Bechtel will ensure that all IPv6 features are included and enabled as part of the change. The same approach is being used for all software and hardware. The incremental approach has helped Bechtel develop a broad competence and deploy IPv6 in several IP areas in parallel.
- **Actively engage key technology partners:** Bechtel maintains regular active dialogs with key technology product and service providers, partners, customers, and industry consortia. The information and experience sharing has been mutually beneficial.

As the newness wears off, IPv6 becomes an understood and respected technology that is often just another check box on a configuration or test plan.

Initiate and Support Technology Education

The proper planning of the IPv6 integration project, the development and implementation of complete related policies, and the seamless deployment of the technology depend on the staff's familiarity with IPv6. All planning steps presented so far in this chapter cannot be successfully implemented without a good understanding of the various aspects of the technology. The scope of the project cannot be clearly defined without the strategy team understanding the protocol characteristics and its potential. Assessment cannot be effectively performed without understanding the IPv6 features that must be supported by various elements of the environment. Entrance/acceptance and security policies cannot be updated without an understanding of the standardization state of the protocol and its features. The successful deployment of the protocol requires an operations team that is familiar with managing and troubleshooting IPv6. For these reasons, initiating IPv6 training very early and scaling it to match the project evolution is essential to its success.

NOTE Many businesses that are planning IPv6 integration report that training is one of the most expensive aspects of the project. Initiating the process early allows time for internal dissemination of information. "Train the trainer" strategies can help reduce costs.

Training Domains

The diverse population involved in the various aspects of the IPv6 integration requires diverse forms of targeted training. The right amount and level of education needed for each technical or business function must be delivered in a timely and cost-effective way:

- **IPv6 technology:** The most common form of training available today focuses on describing the protocol operation through a side-by-side comparison with IPv4.
- **IPv6 deployment:** This type of training focuses less on the protocol description and more on its integration in real networks. It has to address the specific interests of each environment: enterprise (branch office, campus, data center) versus service provider (core, broadband, wireless). It also focuses on the operational aspects of IPv6 infrastructures.
- **IPv6 security:** The unique aspects of IPv6 security must be well understood by the IT operations staff well in advance of a deployment. The security policies must be adjusted to deal with the new protocol and its use by various user and device types. New security paradigms might emerge with IPv6.
- **Networking equipment:** These are traditional vendor classes that describe the specifics of equipment configuration and operation.
- **Operating system and applications:** New versions of OSs or applications that include IPv6 require additional training for system managers and software developers.

- **Software development:** This type of training focuses on the IPv6 features that can be leveraged when developing new applications.
- **End users:** Although this type of training is for the most part IP version agnostic, it familiarizes users with new applications that run over IPv6. This training is important in ensuring the smooth adoption of applications and services deployed over IPv6.

Educational and Information Resources

There are multiple sources of information regarding IPv6, each catering to one of the categories mentioned above. Some resources are free to those who are interested in a self-study approach or are just starting to get familiar with IPv6. An example of such a source of information is the European 6DISS project (http://www.6diss.org). 6DISS is a Specific Support Action in the 6th Framework Program of the European Union. The project aims to promote widespread adoption of IPv6 by providing IPv6 training and knowledge transfer in developing regions. 6DEPLOY project (http://www.6deploy.org) is another example. The European-funded project began in March 2008; its purpose is to support the deployment of IPv6 in (i) e-Infrastructure environments, (ii) FP7 projects, (iii) developing countries (Africa, Latin America, Asia, and Eastern Europe), and (iv) industrial environments in Europe. Partners offer basic training to organizations in Europe and developing countries, and support real IPv6 deployments.

Integrators or consulting groups, such as Command Information cited in Chapter 5, often have IPv6 training, consulting practices, and "jump-start" services that can be very valuable in helping an organization achieve a solid level of competence in IPv6.

Vendors are another source of IPv6 training that is both generic and specific to its implementation in their product line.

NOTE An example training course is Cisco Networkers.[2] At Europe 2008 in Barcelona, Spain, there were several IPv6 sessions, including:

- IPv6 basics
- IPv6 advanced
- IPv6 deployment
- IPv6 security
- IPv6 Birds of a Feather (BoF)

Similar coverage is available in the Networkers sessions that cover the other theaters as well.

Several vendors include IPv6 as a separate part of their certification programs. For example, IPv6 has been included in the Cisco Academy training material and is part of all Cisco certification tests.

Only a limited number of academic institutions developed curriculums with comprehensive coverage of IPv6; hence, we will have to wait several more years for large numbers of new graduates who are IPv6 knowledgeable.

Training Assessment

Everyone does not need the same skill set or training at the same time. Just-in-time training is based on technology being a required skill set, technology being developed/deployed, and location (some sites are first). The simplified matrix example shown in Table 6-4 can be completed with the appropriate training dates for each location. The tiers refer to the level of competence required, from Tier 1 (limited basic education) to Tier 4 (the highest level of technical skill needed). The focus of the assessment should be to enable people for success at the right time.

2. http://www.cisco.com/web/learning/le21/le34/learning_networkers_home.html.

Table 6-4 *Training Matrix Example*

Function	Tier 1	Tier 2	Tier 3	Tier 4
App Development				
Architect				
Help Desk				
Information Security				
Infrastructure Engineer				
Network Engineer				
NOC				
SOC				

IPv6 Address Planning

One critical technical aspect of the IPv6 integration project is that of planning the IPv6 addressing scheme. This process must be initiated well in advance of deployment and cannot be properly executed without extensive training in the following:

- IPv6 address architecture (RFC 4291)
- IPv6 allocation policies defined by each regional registry: AFRINIC (http://www.afrinic.net/policy.htm), APNIC (http://www.apnic.net/policy/index.html), ARIN (http://www.arin.net/policy/nrpm.html#ipv6), LACNIC (http://lacnic.net/en/politicas/ipv6.html), and RIPE (http://www.ripe.net/rs/ipv6/index.html)
- IPv6 address scheme design considerations (http://tools.ietf.org/wg/v6ops/draft-ietf-v6ops-addcon/)
- IPv6 address assignment mechanisms

External input to developing competence in IPv6 addressing is very important, especially in the area of best practices. With this knowledge, the IT staff is able to select and implement the best IPv6 address space and model suited for the organization. The address space can then be acquired and the addressing plan design options can be explored.

Leverage the IPv6 Industry Experience

Most of the IPv6 deployment will occur far after the early IPv6 adopters begin to master the technology. There is no reason for newcomers not to leverage the experiences that have been documented by different organizations. Over 11 years' worth of experience with the next generation Internet Protocol produced a wealth of information that can help others understand the aspects related to IPv6 adoption, such as the protocol idiosyncrasies and deployment impact. Some of the topics that will interest organizations that haven't adopted IPv6 yet include:

- Business and technology news
- Standards compliancy and interoperability information
- Vendor and application references
- Research efforts
- Documented deployments
- IPv6 in other standards

Business and Technology News

The need for IPv6 business cases led to the creation of forums and task forces that are promoting the technology and helping with its understanding. The most active of such organizations are the following:

- **IPv6 Forum (http://www.ipv6forum.com):** The IPv6 Forum is a world-wide consortium of leading Internet vendors, Industry Subject Matter Experts, Research & Education Networks, with a clear mission to advocate IPv6 by dramatically improving technology, market, and deployment user and industry awareness of IPv6, creating a quality and secure new Generation Internet and allowing worldwide equitable access to knowledge and technology, embracing a moral responsibility to the world.

- **IPv6 Task Force (http://www.ipv6tf.org):** Regional and national IPv6 Task Force chapters have been established all over the world. They offer an opportunity for local industries, educational institutions, and government agencies to shape the adoption of IPv6 in their region. Regional task forces and business councils have established their own sites:
  - North American IPv6 Task Force (NAv6TF): http://www.nav6tf.org
  - European IPv6 Task Force: http://www.ipv6tf.org/meet/tf/eutf.php
  - IPv6 Promotion Council (Japan): http://www.v6pc.jp/en/index.html

Several websites are specialized in tracking the latest IPv6 news and information. They help readers learn about vendor announcements and public deployments. Examples of such informative sites are

- **IPv6 Style (http://www.ipv6style.jp/en/index.shtml):** Japanese site that delivers interesting news about the IPv6 adoption in Japan
- **Go6 (http://www.go6.net):** An online meeting point where members of the Internet community share their experiences with IPv6 implementations and applications, and are provided with access to the latest IPv6 tools and information
- **6journal (http://www.6journal.org):** An IPv6 publications database, maintained at the University of Southampton as part of the 6DISS project

Standards Compliancy and Interoperability Information

As with any new protocol suite, the industry needs to define and ensure standards compliancy and full interoperability among products from various vendors. Over the past ten years, it was an objective of several test environments to validate the IPv6 implementations. Official agencies and events also work on testing and publishing reports on the topic. Table 6-5 provides a non-exhaustive list of organizations involved in the IPv6 certification process. Keep in mind that IPv6 is not a feature; it is the network layer of the TCP/IP protocol stack. This means that standards compliancy is only one of the multiple aspects of an

implementation. Many features are vendor-specific and are not standardized. For example, a platform might conform to the IPv6 standards, but its performance in handling specific aspects of IPv6 might be poor due to hardware designs that do not have IPv6 in mind.

Table 6-5 *IPv6 Standard Compliancy Testing*

Organization or Program	Website
IPv6 Forum IPv6 Ready Logo	http://www.ipv6ready.org
U.S. DoD Joint Interoperability Test Command (JITC)	http://jitc.fhu.disa.mil/apl/ipv6.html
Moonv6	http://www.moonv6.org/
IPv6 Promotion Council (Japan) Certification WG	http://www.v6pc.jp/en/wg/certificationWG/index.phtml
Indian Government Telecommunication Engineering Center (TEC)	http://www.tec.gov.in/act-it.html
ETSI Plugtests	http://www.etsi.org/Website/OurServices/Plugtests/home.aspx

IPv6-specific benchmarking methodologies are still emerging in an attempt to provide consistency in evaluating the IPv6 capabilities of networking devices, appliances, and hosts.[3]

Vendor and Application References

Over the years, most vendors have developed or enhanced their IPv6 implementations and published product information, technology-related white papers, and other documents related to their existent and planned IPv6 support. As examples, refer to

- Cisco: http://www.cisco.com/ipv6
- Linux IPv6: http://www.bieringer.de/linux/IPv6/

3. IETF Benchmarking Methodology WG Status Pages, http://tools.ietf.org/wg/bmwg/draft-ietf-bmwg-ipv6-meth/.

- Microsoft: http://www.microsoft.com/ipv6
- Global Crossing: http://www.globalcrossing.com/ipkc/ipkc_ipv6.aspx
- 3G Americas: http://3gamericas.com/pdfs/2008_Ipv6_transition_3GA_Mar2008.pdf

It is nearly impossible to publish a full list of vendors in a book. This is dynamic information that is best maintained and comprehensively covered on websites that list the vendors along with the IPv6 status of their products. Refer to some of the well-known sites at

- http://www.ipv6-to-standard.org/
- http://6net.iif.hu/ipv6_apps
- http://www.deepspace6.net/docs/ipv6_status_page_apps.html
- http://applications.6pack.org/

Research Efforts

As mentioned repeatedly throughout this book, IPv6 is an opportunity for innovation, because the Internet can now be expanded in market places that were out of reach in the past. These opportunities range from research projects investigating new architectures and services to OS frameworks that give software developers the opportunity to create the next generation of applications. Examples of such research projects follow:

- The European U-2010 (http://www.u2010.org) and U.S. MetroNet6 (http://www.metronet6.org/) projects focus on the use of Internet technologies for public safety.
- The European RUNES (http://www.ist-runes.org) project evaluated embedded Internet applications in a diverse range of appliances, from mobile phones to smoke alarms, from refrigerators to trucks.
- The Globus Toolkit (http://www.globus.org) is an open source software toolkit used for building grids that was enhanced to support IPv6 starting with GT3.

- The Microsoft Windows Peer-to-Peer Networking framework (http://www.microsoft.com/p2p) enables software developers to make their application "peer-to-peer capable."

Documented Deployments

Despite much skepticism, many IPv6 deployments around the world followed the initial definition, prototyping, and implementation of the IPv6 protocol suite. More interestingly, several of these deployments have fully documented their work to be used as references for other deployments. Some of the well-known references follow:

- **6bone (http://go6.net/ipv6-6bone/):** The 6bone was the initial IPv6 infrastructure deployed to test the standard and its implementation. Created in the middle of the 1990s, it ended on June 6, 2006, (RFC 3701) after validating the operational procedures to integrate IPv6.
- **6NET (http://www.6net.org), 6DISS (http://www.6diss.org), and 6Deploy (http://www.6deploy.org):** 6NET, a three-and-a-half-year European project, was run from 2001 to June 30, 2005, by the research and academic community to validate the deployment of native IPv6 networks. Research labs and universities from 16 countries participated in the project, publishing a wealth of material that is widely referenced today by the IPv6 community. The direct result of this project is the IPv6 production services available today to the European research community. Upon completing its mission to disseminate the lessons learned through 6NET, the 6DISS project closed at the end of 2007, delivering countless instructor-led classes and e-Learning materials. 6Deploy, another project sponsored by the European Commission, was launched in March 2008 with the goal of speeding up IPv6 deployment across Europe.
- **Moonv6 (http://www.moonv6.org):** The Moonv6 project is a global effort led by NAv6TF that involves the University of New Hampshire–InterOperability Laboratory (UNH-IOL), Internet2, vendors, service providers, and regional IPv6 Forum Task Force network pilots

worldwide. It is taking place across the United States at multiple locations and is a large, permanently deployed, multivendor IPv6 network.

- **Japan IPv6 Promotion Council Transition Working Group (http://www.v6pc.jp/en/wg/transWG/index.phtml:** This Working Group evaluates specific innovative deployment models (scenario, cost, architecture, and so on) and shares the results of its studies with the IPv6 community.

IPv6 deployment and operational experience and expertise continue to grow as the protocol is integrated in more and more large-scale networks. No all-inclusive recipes for IPv6 deployments have emerged, so it is important for IPv6 planners to monitor the IPv6 community resources for new ideas and experiences.

IPv6 in Other Standards

In addition to products and services, IPv6 is being adopted in standards that enterprises are implementing. Table 6-6 lists some of these standards.

Table 6-6 *IPv6 in Other Standards*

Organization	Standard	Website
WiMAX Forum	802.16	http://www.wimaxforum.org
3GPP (3rd Generation Partnership Project)	IMS (IP Multimedia Subsystem)	http://www.3gpp.org/
SNIA (Storage Networking Industry Association)	SMI-S (Storage Management Initiative Specification)	http://www.snia.org
DMTF (Distributed Management Task Force)	CIM (Common Information Model)	http://www.dmtf.org
OASIS (Organization for the Advancement of Structured Information Standards)	Several XML standards	http://www.oasis-open.org

continues

Table 6-6 *IPv6 in Other Standards (Continued)*

Organization	Standard	Website
IEEE	Several standards and specifications	http://www.ieee.org
W3C (World Wide Web Consortium)	URL, URI, and several other specifications	http://www.w3.org
DSL Forum	Several standards and specifications	http://www.dslforum.org
CableLabs	DOCSIS 3.0 and other specifications	http://www.cablelabs.org/

Summary

There are many documents, training modules, and books that present the technical aspects of IPv6 integration and its planning in great detail. Two of the resources we recommend are

- *Deploying IPv6 Networks*, by Ciprian Popoviciu, Eric Levy-Abegnoli, and Patrick Grossetete (Cisco Press, 2006)
- *6NET: An IPv6 Deployment Guide*, edited by Martin Dunmore (Lancaster University, 2005), available at http://www.6net.org/book/deployment-guide.pdf

Because this book is intended for decision makers, not technicians, this chapter focused on the nontechnical aspects of IPv6 planning, which are just as important to the success of a deployment as are the technical aspects. Table 6-7 concludes the chapter with a checklist that will help you start the planning process, organize it, and track it to its completion.

The integration of IPv6 is a multifaceted, strategic project requiring commitment at all levels of an organization. The early, comprehensive planning of the project is essential in the cost-effective delivery of IPv6 capabilities in time to meet the market needs. Regardless of whether the IPv6 deployment is imminent or not yet under consideration, it is never too soon to start planning for it.

Table 6-7 *IPv6 Planning Process Checklist (to be completed by reader)*

Action	Owner	Milestones	Status
IPv6 strategy definition			
Project scope definition			
Stakeholders, gatekeepers, and messaging			
IT environment assessment			
Policy updates			
Purchasing			
Development			
Security			
Entrance/acceptance			
Training			
Deployment planning			