IBM Data Center Networking
Planning for Virtualization and Cloud Computing

- Drivers for change in the data center
- IBM systems management networking capabilities
- The new data center design landscape

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Preface

The enterprise data center has evolved dramatically in recent years. It has moved from a model that placed multiple data centers closer to users to a more centralized dynamic model. The factors influencing this evolution are varied but can mostly be attributed to regulatory, service level improvement, cost savings, and manageability. Multiple legal issues regarding the security of data housed in the data center have placed security requirements at the forefront of data center architecture. As the cost to operate data centers has increased, architectures have moved towards consolidation of servers and applications in order to better utilize assets and reduce “server sprawl.” The more diverse and distributed the data center environment becomes, the more manageability becomes an issue. These factors have led to a trend of data center consolidation and resources on demand using technologies such as virtualization, higher WAN bandwidth technologies, and newer management technologies.

The intended audience of this book is network architects and network administrators.

The network has been widely viewed as the “plumbing” of the system. It has been architected without much if any consideration for the type of device at the end point. The usual consideration for the end-point requirements consisted of speed, duplex, and possibly some traffic engineering technology. There have been well-documented designs that allowed redundancy and availability of access ports that were considered interchangeable at best and indistinguishable at worst.

With the rise of highly virtualized environments and the drive towards dynamic infrastructures and cloud computing, the network can no longer remain just plumbing. It must be designed to become dynamic itself. It will have to provide the ability to interconnect both the physical and virtual infrastructure of the new enterprise data center and provide for cutting edge features such as workload mobility that will drive enterprise IT architecture for years to come.

In this IBM® Redbooks® publication we discuss the following topics:

- The current state of the data center network
- The business drivers making the case for change
- The unique capabilities and network requirements of system platforms
- The impact of server and storage consolidation on the data center network

- The functional overview of the main data center network virtualization and consolidation technologies
- The new data center network design landscape

The team who wrote this book

This book was produced by a team of specialists from around the world working at the International Technical Support Organization, Poughkeepsie Center.

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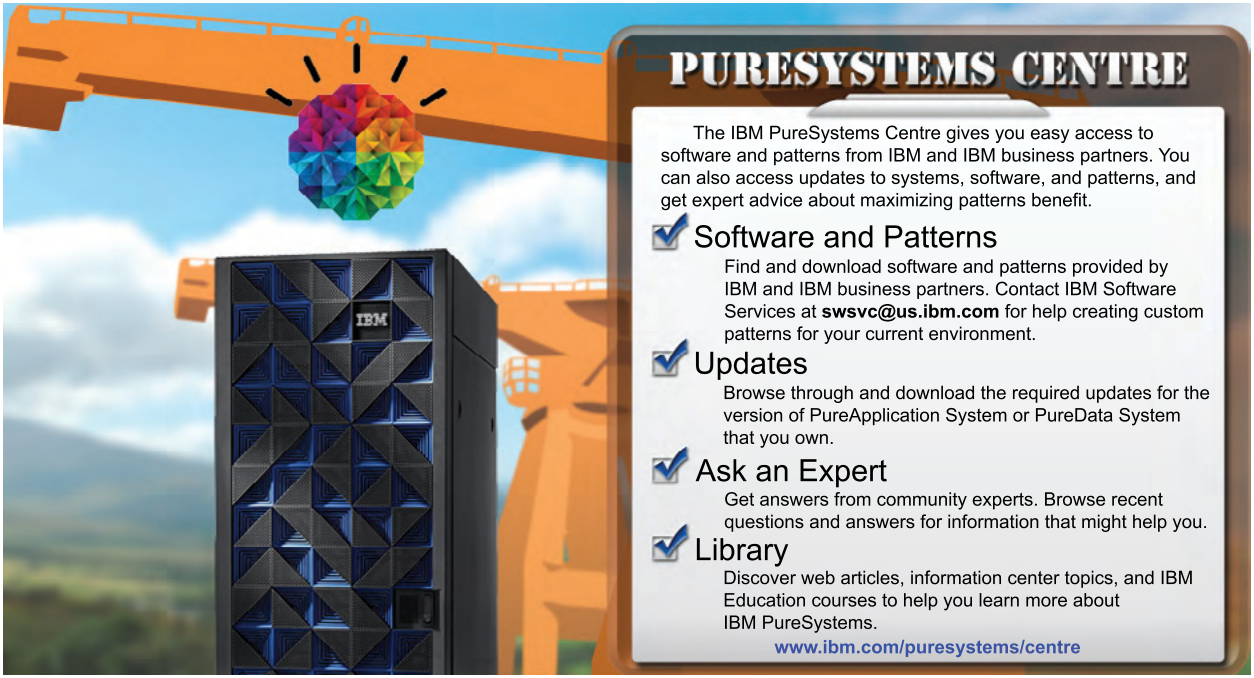
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Drivers for a dynamic infrastructure

Globalization and knowledge-based economies are forcing companies to embrace new business models and emerging technologies to stay competitive. The global integration is changing the corporate model and the nature of work itself. The reality of global integration can be seen, for example, by:

- Tight credit markets and limited access to capital
- Economic difficulties and uncertainty about the future
- Energy shortfalls and erratic commodity prices
- Information explosion and risk and opportunity growth
- Emerging economies
- New client demands and business models

Most IT infrastructures were not built to support the explosive growth in computing capacity and information that we see today. Many data centers have become highly distributed and somewhat fragmented. As a result, they are limited in their ability to change quickly and support the integration of new types of technologies or to easily scale to power the business as needed.

A more integrated IT approach is needed. IT service delivery needs to be changed to help move beyond today's operational challenges to a data center

model that is more efficient, service-oriented, and responsive to business needs—a model with improved levels of economies, rapid service delivery, and one that can provide tighter alignment with business goals.

IBM uses an evolutionary approach for efficient IT delivery that helps to drive business innovation. This approach allows organizations to be better positioned to adopt integrated new technologies, such as virtualization and cloud computing, to help deliver dynamic and seamless access to IT services and resources. As a result, IT departments will spend less time fixing IT problems and more time solving real business challenges.

With this approach to efficient IT service delivery, IBM captures an end-to-end view of the IT data center and its key components. The strategy for planning and building the dynamic infrastructure integrates the following elements:

- Highly virtualized resources
- Efficient, green, and optimized infrastructures and facilities
- Business-driven service management
- Business resiliency and security
- Information infrastructure

In this chapter, we examine the operational challenges leading to an approach to implement a dynamic infrastructure.

1.1 Key operational challenges

The delivery of business operations impacts IT in terms of application services and infrastructure. Business drivers also impose key requirements for data center networking:

- Support cost-saving technologies such as consolidation and virtualization with network virtualization
- Provide for rapid deployment of networking services
- Support mobile and pervasive access to corporate resources
- Align network security with IT security based on enterprise policies and legal issues
- Develop enterprise-grade network design to meet energy resource requirements
- Deliver a highly available and resilient networking infrastructure
- Provide scalability to support applications' need to access services on demand
- Align network management with business-driven IT Service Management in terms of processes, organization, Service Level Agreements, and tools

When equipped with a highly efficient, shared, and dynamic infrastructure, along with the tools needed to free up resources from traditional operational demands, IT can more efficiently respond to new business needs. As a result, organizations can focus on innovation and on aligning resources to broader strategic priorities. Decisions can be based on real-time information. Far from the "break or fix" mentality gripping many data centers today, this new environment creates an infrastructure that provides automated, process-driven service delivery and is economical, integrated, agile, and responsive.

IBM has taken a holistic approach to the transformation of IT and developed a vision and strategy for the future of enterprise computing based on leading practices and technologies. This approach enables businesses to better manage costs, improve operational performance and resiliency, and quickly respond to business needs. Its goal is to deliver the following benefits:

- Improved IT efficiency

  A dynamic infrastructure helps enterprises to transcend traditional operational issues and achieve new levels of efficiency, flexibility, and responsiveness. Virtualization can uncouple applications and business services from the underlying IT resources to improve portability. It also exploits highly optimized systems and networks to improve efficiency and reduce overall cost.

- Rapid service deployment

  The ability to deliver quality service is critical to businesses of all sizes. Service management enables visibility, control, and automation to deliver quality service at any scale. Maintaining stakeholder satisfaction through cost efficiency and rapid return on investment depends upon the ability to see the business (visibility), manage the business (control), and leverage automation (automate) to drive efficiency and operational agility.

- High responsiveness and business goal-driven infrastructure

  A highly efficient, shared infrastructure can help businesses respond quickly to evolving demands. It creates opportunities to make sound business decisions based on information obtained in real time. Alignment with a service-oriented approach to IT delivery provides the framework to free up resources from more traditional operational demands and to focus them on real-time integration of transactions, information, and business analytics.

IT professionals have continued to express concerns about the magnitude of the operational issues they face. These operational issues are described in the following sections.

1.1.1 Costs and service delivery

The daily expense of managing systems and networks is increasing, along with the cost and availability of skilled labor. Meanwhile, there is an explosion in the volume of data and information that must be managed, stored and shared. These pressing issues result in growing difficulty for IT departments to deploy new applications and services. Here are some facts to consider:

- Server management and administration costs grew four-fold between 1996 and 2008[1]
- Data volumes and network bandwidth consumed are doubling every 18 months, with devices accessing data over networks doubling every 2.5 years.
- 37% of data is expired or inactive.[2]

[1] Virtualization 2.0: The Next Phase in Customer Adoption. Doc. 204904 IDC, Dec. 2006 - from the IBM's Vision for the New Enterprise Data Center white paper
http://www-05.ibm.com/innovation/nl/shapeyourfuture/pdf/New_Enterprise_Data_Center.pdf

[2] IBM Information Infrastructure Newsletter, March 2009
http://www-05.ibm.com/il/systems/storage/pdf/information_infastructure_custnews1Q.pdf

1.1.2 Energy efficiency

The larger a company grows, the greater its need for power and cooling. But with power at a premium—and in some areas, capped—organizations are forced to become more energy efficient.

These trends are forcing technology organizations to control costs while developing a flexible foundation from which to scale. In fact, power and cooling costs grew eight-fold between 1996 and 2008[3].

1.1.3 Business resiliency and security

Global expansion has increased the need for tighter security measures. Users require real-time access to confidential, critical data. Enterprise risk management is now being integrated into corporate ratings. At the same time, companies are demanding that users have instantaneous access to this information, putting extra—and often, conflicting—pressure on the enterprise to be available, secure, and resilient.

Consider some facts:

- The average US legal discovery request can cost organizations from $150,000 to $250,000.[4]
- Downtime costs can amount to up to 16% of revenue in some industries[4].
- 84% of security breaches come from internal sources[4].

1.1.4 Changing applications and business models

A major shift has taken place in the way people connect, not only to each other but also to information, services, and products. The actions and movements of people, processes, and objects with embedded technology are creating vast amounts of data, which consumers use to make more informed decisions and drive action.

- As of June, 2010, almost two billion people are Internet users[5].
- Connected objects, such as cars, appliances, cameras, roadways, and pipelines will reach one trillion[6].

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[3] Virtualization 2.0: The Next Phase in Customer Adoption. Doc. 204904 IDC, Dec. 2006 - from the IBM's Vision for the New Enterprise Data Center white paper
http://www-05.ibm.com/innovation/nl/shapeyourfuture/pdf/New_Enterprise_Data_Center.pdf

[4] CIO Magazine, Survey 2007 as cited in
ftp://public.dhe.ibm.com/software/uk/itsolutions/optimiseit/energy-efficiency-solutions/1-new-enterprise-data-centre-ibm-s-vision-nedc.pdf

[5] http://www.internetworldstats.com/stats.htm

1.1.5 Harnessing new technologies to support the business

If an IT organization spends most of its time mired in day-to-day operations, it is difficult to evaluate and leverage new technologies that could streamline IT operations and help keep the company competitive and profitable. As noted in "The Enterprise of the Future: Immplications for the CEO"[7] which is a paper based on a 2008 IBM CEO Study[8], the design of the IT environment needs to do the following::

- Provide a flexible, resilient, highly scalable IT infrastructure
- Enable collaboration and help turn information into business insight
- Facilitate global integration with a shared service model
- Support evolving business models and rapid integration of acquisitions and mergers
- Provide support for broad company-wide "green" initiatives

Increasing speed and availability of network bandwidth is creating new opportunities to deliver services across the web and integrate distributed IT resources. Easier access to trusted information and real-time data and analytics will soon become basic expectations.

Further, the proliferation of data sources, RFID and mobile devices, unified communications, cloud computing, SOA, Web 2.0 and technologies such as mashups and XML create opportunities for new types of business solutions.

Ultimately, all of these innovations have a tremendous effect on improving communication and service, reducing barriers for market entry, and on how organizations do business.

1.1.6 Evolving business models

The Internet has gone beyond a research, entertainment, or commerce platform. It is now a platform for collaboration and networking, and has given rise to means of communication that we would not have thought possible just a few years ago. For example:

- Google's implementation of their MapReduce method is an effective way to support dynamic infrastructures.

[6] http://wwic2008.cs.tut.fi/1-Internet_of_Smart_Things.pdf
[7] ftp://public.dhe.ibm.com/common/ssi/ecm/en/ciw03040usen/CIW03040USEN.PDF
[8] http://cssp.us/pdf/Global%20CEO%20Study%20The%20Enterprise%20of%20the%20Future.pdf

- The delivery of standardized applications via the Internet, such as:

  http://SalesForce.com

  is bringing a new model to the market.

Furthermore, mobile devices now give us the ability to transport information, or access it online, nearly anywhere. Today, the people at the heart of this technology acceleration, Generation Y, cannot imagine a world without the Internet. They are the ones entering the workforce in droves, and they are a highly attractive and sought-after consumer segment. Because of this, business models are no longer limited to business-to-business or business-to-consumer. Instead, these new generations of technology—and people—have created a bidirectional business model that spreads influential content from consumer-to-consumer to communities-to-business.

Today, the power of information, and the sharing of that information, rests firmly in the hands of the user while real-time data tracking and integration are becoming the norm.

1.2 Cloud computing can change how IT supports business

Information technology (IT) is at a breaking point, and there is a critical need to improve IT's impact on the business.[9]

Consider the following:

- As much as 85% of computing capacity sits idle in distributed computing environments.
- Seventy percent of IT budgets is typically spent on maintaining current IT infrastructures, and only 30% is typically spent on new capabilities.
- Over 30% of consumers notified of a security breach will terminate their relationship with the company that contributed to the breach.

Clearly, infrastructures need to be more dynamic to free up budgets for new investments and accelerate deployment of superior capabilities being demanded by the business. Nearly all CEOs are adapting business models; cloud adoption can support these changing business dynamics.

[9] This section is sourced from “Capturing the Potential of Cloud - How cloud drives value in enterprise IT strategy”, IBM Global Business Services® White Paper. Document #GBW03097-USEN-00, September, 2009. Available at:
ftp://submit.boulder.ibm.com/sales/ssi/sa/wh/n/gbw03097usen/GBW03097USEN.PDF

Some are calling cloud computing the next big paradigm shift for technology. As with any major technology transformation, there are many definitions of cloud computing, each with their own nuances and subtleties. In very simple terms, cloud computing is a new consumption and delivery model for information technology (IT) and business services and is characterized by:

- On-demand self-service
- Ubiquitous network access
- Location-independent resource pooling
- Rapid elasticity and provisioning
- Pay-per-use

Cloud has evolved from on demand and grid computing, while building on significant advances in virtualization, networking, provisioning, and multitenant architectures. As with any new technology, the exciting impact comes from enabling new service consumption and delivery models that support business model innovation.

1.2.1 The spectrum of cloud solutions

Even within the cloud computing space there is a spectrum of offering types. There are five commonly used categories:

- Storage as a Service - SaaS

  Provisioning of database-like services, billed on a utility computing basis, for example, per gigabyte per month.

- Infrastructure as a Service - IaaS

  Provisioning of hardware or virtual computers where the client has control over the OS, therefore allowing the execution of arbitrary software.

- Platform as a Service - PaaS

  Provisioning of hardware and OS, frameworks and databases, for which developers write custom applications. There will be restrictions on the type of software they can write, offset by built-in application scalability.

- Software as a Service - SaaS

  Provisioning of hardware, OS, and special-purpose software made available through the Internet.

- Desktop as a Service - DaaS

  Provisioning of the desktop environment, either within a browser or as a Terminal Server.

Figure 1-1 [10] demonstrates these five layers of cloud offerings.

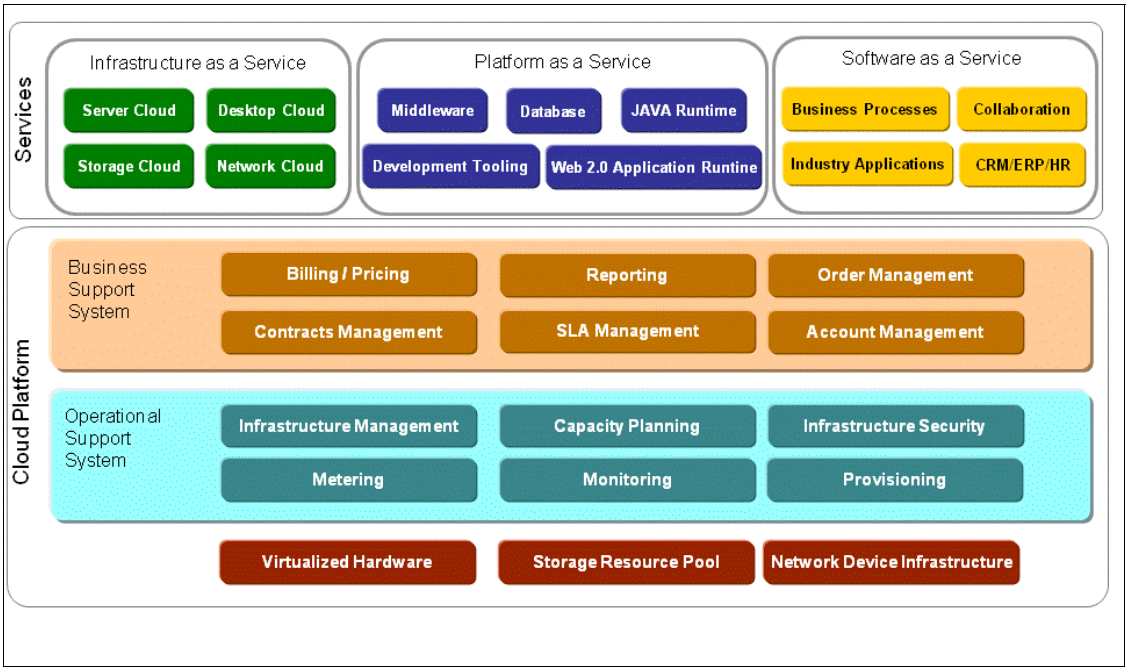

Figure 1-1 Simplified version of cloud offerings

The distinction between the five categories of cloud offering is not necessarily clear-cut. In particular, the transition from Infrastructure as a Service to Platform as a Service is a very gradual one, as shown in Figure 1-2 on page 10.

[10] Youseff, Lamia: Toward a Unified Ontology of Cloud Computing, November 2008, Available from: http://www.cs.ucsb.edu/~lyouseff/CCOntology/CloudOntology.pdf

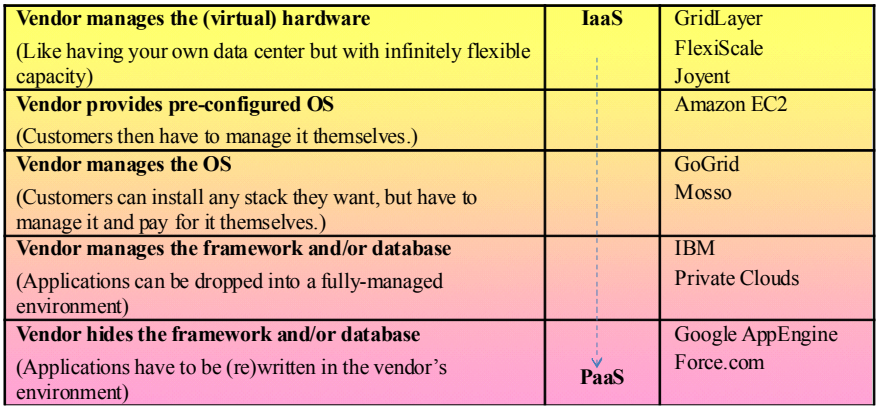

Figure 1-2 The gradual change from Iaas to Paas

1.3 Benefits and challenges of cloud computing

SaaS, PaaS, and IaaS suit different target audiences:

- SaaS is intended to simplify the provisioning of specific business services.
- PaaS provides a software development environment that enables rapid deployment of new applications.
- IaaS provides a managed environment into which existing applications and services can be migrated to reduce operational costs.

Table 1-1 on page 11 lists the benefits and challenges of SaaS, PaaS, and IaaS.

Table 1-1 Benefits and challenges of SaaS, PaaS, and IaaS

	Benefits	Challenges
SaaS	► SaaS saves costs by: – Removing the effort of development, maintenance, and delivery of software – Eliminating up-front software licensing and infrastructure costs – Reducing ongoing operational costs for support, maintenance and administration ► Provided extensive customization is not required, the time to build and deploy a new service is much shorter than for traditional software development. ► By transferring the management and software support to a vendor, internal IT staff can focus more on higher-value activities.	► Applications requiring extensive customization are not good candidates for SaaS. Typically this will include most complex core business applications. ► Moving applications to the Internet cloud might require upgrades to the local network infrastructure to handle an increase in network bandwidth usage. ► Normally only one version of the software platform will be provided. Therefore, all clients are obliged to upgrade to the latest software versions on the vendor's schedule. This could introduce compatibility problems between different vendor offerings.
PaaS	► PaaS saves costs by: – Reducing up-front software licensing and infrastructure costs – Reducing ongoing operational costs for development, test and hosting environments. ► PaaS significantly improves development productivity by removing the challenges of integration with services such as database, middleware, web frameworks, security, and virtualization. ► Software development and delivery times are shortened because software development and testing are performed on a single PaaS platform. There is no need to maintain separate development and test environments. ► PaaS fosters collaboration among developers and also simplifies software project management. This is especially beneficial to enterprises that have outsourced their software development.	► Tight binding of the applications with the platform makes portability across vendors extremely difficult. ► PaaS in general is still maturing, and the full benefits of componentization of, and collaboration between, services are still to be demonstrated. ► PaaS offerings lack the functionality needed for converting legacy applications into full-fledged cloud services.

	Benefits	Challenges
IaaS	► IaaS saves costs by: – Eliminating the need to over-provision computing resources to be able to handle peaks in demand. Resources dynamically scale up and down as required. – Reducing capital expenditure on infrastructure, and ongoing operational costs for support, maintenance, and administration. Organizations can massively increase their data center resources without significantly increasing the number of people needed to support them. ► The time required to provision new infrastructure resources is reduced from typically months to just minutes—the time required to add the requirements to an online shopping cart, submit them and have them approved. ► IaaS platforms are generally open platforms, supporting a wide range of operating systems and frameworks. This minimizes the risk of vendor lock-in.	► Infrastructure resources are leased on a pay-as-you-go basis, according to the hours of usage. Applications that need to run 24x7 may not be cost-effective. ► To benefit from the dynamic scaling capabilities, applications have to be designed to scale and execute on the vendor's infrastructure. ► There can be integration challenges with third-party software packages. This should improve over time, however, as and when ISVs adopt cloud licensing models and offer standardized APIs to their products.

1.4 Perceived barriers to cloud computing

IT organizations have identified four major barriers to large-scale adoption of cloud services:

► Security, particularly data security

Interestingly, the security concerns in a cloud environment are no different from those in a traditional data center and network. However, since most of the information exchange between the organization and the cloud service provider is done over the web or a shared network, and because IT security is handled entirely by an external entity, the overall security risks are perceived as higher for cloud services.

Some additional factors cited as contributing to this perception:

– Limited knowledge of the physical location of stored data

– A belief that multitenant platforms are inherently less secure than single-tenant platforms

– Use of virtualization as the underlying technology, where virtualization is seen as a relatively new technology

- Limited capabilities for monitoring access to applications hosted in the cloud

- Governance and regulatory compliance

  Large enterprises are still trying to sort out the appropriate data governance model for cloud services, and ensuring data privacy. This is particularly significant when there is a regulatory compliance requirement such as SOX or the European Data Protection Laws.

- Service level agreements and quality of service

  Quality of service (availability, reliability, and performance) is still cited as a major concern for large organizations:

  - Not all cloud service providers have well-defined SLAs, or SLAs that meet stricter corporate standards. Recovery times may be stated as “as soon as possible” rather than a guaranteed number of hours. Corrective measures specified in the cloud provider's SLAs are often fairly minimal and do not cover the potential consequent losses to the client's business in the event of an outage.
  - Inability to influence the SLA contracts. From the cloud service provider's point of view it is impractical to tailor individual SLAs for every client they support.
  - The risk of poor performance is perceived higher for a complex cloud-delivered application than for a relatively simpler on-site service delivery model. Overall performance of a cloud service is dependent on the performance of components outside the direct control of both the client and the cloud service provider, such as the network connection.

1. Integration and interoperability

   Identifying and migrating appropriate applications to the cloud is made complicated by the interdependencies typically associated with business applications. Integration and interoperability issues include:

   - A lack of standard interfaces or APIs for integrating legacy applications with cloud services. This is worse if services from multiple vendors are involved.
   - Software dependencies that must also reside in the cloud for performance reasons, but which may not be ready for licensing on the cloud.
   - Interoperability issues between cloud providers. There are worries about how disparate applications on multiple platforms, deployed in geographically dispersed locations, can interact flawlessly and can provide the expected levels of service.

Public clouds versus private clouds

A public cloud:

- Is a shared cloud computing infrastructure that anyone can access.
- Provides hardware and virtualization layers that are owned by the vendor and are shared between all clients.
- Presents the illusion of infinitely elastic resources.
- Is connected to the public Internet.

A private cloud:

- Is a cloud computing infrastructure owned by a single party.
- Provides hardware and virtualization layers that are owned by, or reserved for, the client.
- Presents an elastic but finite resource.
- May or may not be connected to the public Internet.

While very similar solutions from a technical point of view, there are significant differences in the advantages and disadvantages that result from the two models. Table 1-2 compares the major cloud computing features for the two solutions, categorizing them as:

✓✓ - a major advantage

✓- an advantage

✖ - a disadvantage

✖✖ - a major disadvantage

Table 1-2 Comparison of major cloud computing features

Feature	Public cloud	Private cloud
Initial investment	✓✓- No up-front capital investment in infrastructure.	✖✖- The infrastructure has to be provisioned and paid for up front (however, may leverage existing resources - sunk costs).
Consumption-based pricing	✓✓- The client pays for resources as used, allowing for capacity fluctuations over time.	✓✓- The client pays for resources as used, allowing for capacity fluctuations over time.
Provisioning	✓✓- Simple web interface for self-service provisioning of infrastructure capacity.	✓- Self-service provisioning of infrastructure capacity only possible up to a point. Standard capacity planning and purchasing processes required for major increases.

Feature	Public cloud	Private cloud
Economies of scale	✓✓- Potentially significant cost savings are possible from providers' economies of scale.	✓- For a large enterprise-wide solution, some cost savings are possible from providers' economies of scale.
Cloud operating costs	✓✓- Operating costs for the cloud are absorbed in the usage-based pricing.	✗✗- The client maintains ongoing operating costs for the cloud.
Platform maintenance	✗✗- Separate provider has to be found (and paid for) to maintain the computing stack. (May be part of the client's own organization or outsourcing provider, or may be an independent company such as RightScale.)	✓- Cloud vendor may offer a fully-managed service (for a price).
SLAs	✗✗- The client has no say in SLAs or contractual terms and conditions.	✓✓- SLAs and contractual terms and conditions are negotiable between client and the cloud vendor to meet specific requirements.
Service Level Commitment	✓- Vendors are motivated to deliver to contract.	✗- Users may not get service level desired
Data Security	✗- Sensitive data is shared beyond the corporate firewall.	✓✓- All data and secure information remains behind the corporate firewall.
Geographic locality	✗- Distance may pose challenges with access performance and user application content.	✓- The option exists for close proximity to non-cloud data center resources or to offices if required for performance reasons.
Platform choice	✗✗- Limited choices: Support for operating system and application stacks may not address the needs of the client.	✓✓- Private clouds can be designed for specific operating systems, applications and use cases unique to the client.

There is no clear "right answer", and the choice of cloud model will depend on the application requirements. For example, a public cloud could be ideally suited for development and testing environments, where the ability to provision and decommission capacity at short notice is the primary consideration, while the requirements on SLAs are not particularly strict. Conversely, a private cloud could be more suitable for a production application where the capacity fluctuations are well-understood, but security concerns are high.

Many of IBM's largest clients are looking at the introduction of Web 2.0 applications and cloud computing style data centers. Numerous newer

Web 2.0-enabled data centers are starting to expand and while they have some key strengths, such as scalability and service delivery, they are also facing operational challenges similar to traditional data centers.

The infrastructures that are exploiting some of the early cloud IT models for either acquiring or delivering services, or both, can be very nimble and scale very quickly. As a style of computing in which IT-enabled capabilities are delivered as a service to external clients using Internet technologies—popularized by such companies as Google and SalesForce.com—cloud computing can enable large, traditional-style enterprises to start delivering IT as a service to any user, at any time, in a highly responsive way. Yet, data centers using these new models are facing familiar issues of resiliency and security as the need increases for consistent levels of service.

1.5 Implications for today's CIO

CIOs who take a transformational approach to the data center can point to better alignment with business values through clients who are satisfied, systems that are meeting key Service Level Agreements, and IT that is driving business innovation. The open, scalable, and flexible nature of the new dynamic infrastructure enables collaboration and global integration, while supporting continually changing business models.

The solution to these challenges will not come from today's distributed computing models, but from more integrated and cost-efficient approaches to managing technology and aligning it with the priorities of organizations and users. To that end, we see an evolutionary computing model emerging, one that takes into account and supports the interconnected natures of the following:

- The maturing role of the mobile web
- The rise of social networking
- Globalization and the availability of global resources
- The onset of real-time data streaming and access to information

1.6 Dynamic infrastructure business goals

Dynamic infrastructure may help to reduce cost, improve service and manage risk.

1.6.1 Reduce cost

In conversations with numerous IT executives and professionals over the last few years, a recurring theme has surfaced: continued concerns about the magnitude of the operational issues they face, including server sprawl, virtualization management, and the increasing cost of space, power, and labor.

The combination of these issues results in increasing difficulty to deploy new applications and services. The top priority for most CIOs is not just to drive down overall costs, but to make better investments overall. This requires not just incremental improvements in savings or cost reductions, but dramatic improvements, brought about by leveraging consolidation and virtualization with optimized systems and networks across all system resources in the data center. By breaking down individual silos of similar resources and deploying end-to-end systems and network management tools, organizations can help simplify the management of the IT infrastructure, improve utilization, and reduce costs.

Leveraging alternative service delivery models such as cloud computing, IT outsourcing—without the investment and skills needed to build the infrastructure in house—can also complement this approach.

In addition to energy efficiency and enhancements in both systems and service management, this simplification of the data center helps make information more readily available for business applications regardless of the source or the changes to the physical infrastructure, and be more flexible and responsive to rapidly changing business demands.

Cloud computing brings a new paradigm to the cost equation, as well. This approach of applying engineering discipline and mainframe-style security and control to an Internet-inspired architecture can bring in improved levels of economics through virtualization and standardization. Virtualization provides the ability to pool the IT resources to reduce the capital expense of hardware, software, and facilities. Standardization, with common software stacks and operational policies, helps to reduce operating expenses, such as labor and downtime—which is far and away the fastest-growing piece of the IT cost.

While these technologies have improved the way we do business, they can put a tremendous strain on data centers and IT operations. IT professionals must balance the challenges associated with managing data centers as they increase in cost and complexity against the need to be highly responsive to ongoing demands from the business.

1.6.2 Improve service

To succeed in today's fast-paced business landscape, organizations must transform their service delivery models to achieve superior, differentiated delivery of goods and services. Smarter service delivery requires comprehensive visibility into the full breadth of business and IT assets that support services. It also requires effective control over those assets, as well as the business processes they enable, and extensive automation of these processes so that services can be delivered more reliably and economically.

An effective service delivery model is optimized and aligned to meet the needs of both the internal business and external consumers of goods and services. As the infrastructure becomes more dynamic and flexible, integrated service management takes on a primary role to help organizations do the following:

- Identify new opportunities for substantial cost efficiencies
- Measurably improve service quality and reliability
- Discover and respond quickly to new business opportunities
- Manage complexity and change, improve security and compliance, and deliver more value from all business assets

To become more dynamic and service-aligned, organizations must take a broad view of their infrastructure that encompasses traditional IT assets, physical assets, and emerging “smart” assets that cut across the boundaries that once divided the IT and operational spheres. In an effective service delivery model, all these assets, plus the people who support them, are integrated, optimized, and managed holistically.

The increasing digital instrumentation of once “dumb” physical, operational, and mobile assets presents exciting opportunities for organizations seeking to deliver differentiated service. More than ever before, it is possible for organizations to see, control, and automate the contributions of individual assets towards complex processes and services. From the data center to the plant floor to the delivery fleet, “smart” organizations are finding ways to leverage their dynamic infrastructures in support of accelerated, differentiated, and cost-effective service delivery.

1.6.3 Manage risk

Enterprises of all sizes and industries are seeing that global expansion, emerging technologies and the rising volume and sophistication of new threats have increased the need for improved security and resiliency measures. Users require real-time access to confidential, critical data. Enterprise risk management is now being integrated into corporate ratings delivered by such organizations as Fitch, Moody’s and Standard & Poor’s. At the same time,

companies are demanding that both internal and external users have instantaneous access to this information, putting extra—and often conflicting—pressure on the enterprise for improved availability, security, and resilience in the evolving IT environment.

By enhancing security and resiliency, IT becomes more responsive and better prepared to meet the needs of the business. Some of these critical areas include:

- Infrastructure security and resiliency - Protecting against evolving threats while enabling accelerated innovation, agility, and reduced operational costs through improved security, disaster recovery, and continuity efforts.
- Information and data protection - Ensuring that data is accessed by only authorized users, remains available and accessible in the event of a disruption, and that it is protected both at rest and in-flight.
- Regulatory compliance - Planning for and responding to regulatory requirements associated with security and business resiliency, such as The Health Insurance Portability and Accountability Act (HIPAA), Sarbanes-Oxley (SOX), and Payment Card Industry Standards (PCI).

1.7 Enabling the dynamic infrastructure

A dynamic infrastructure in this digitally-connected world helps support the convergence of business and IT needs and assets, creating integrated “smart” assets. This converged, dynamic infrastructure must be a cost-effective, highly scalable, secure and resilient service delivery model that enables collaboration and accelerates innovation. The dynamic infrastructure must flex and adapt with the business. By design, a dynamic infrastructure is service-oriented and focused on supporting and enabling the users in a highly responsive way.

One implementation of a dynamic infrastructure is cloud computing. A dynamic infrastructure conditions the IT environment for a cloud execution model.

Cloud resources can be accessed through a variety of methods, and can be rapidly scaled up and scaled down in a secure way to deliver a high quality of service. As discussed in “Public clouds versus private clouds” on page 14, clouds can be created for internal (private) or external (public) use but always with scalability, elasticity and share-ability of the application deployment and management environment in mind. Users can gain access to their applications from anywhere through their connected devices.

With regards to infrastructures, the good news is that there is more than one “right” answer. The correct solution is to pull the best from existing infrastructure designs and harness new technologies, solutions and deployment options that

will free up IT to help run the business—not just support it. Combining the “old” best practices (learned from years of managing high-volume, information-intense data centers) with the “new” best practices enabled by technologies such as virtualization and cloud computing, or pairing one’s own IT resources with strategic outsourcing such as managed services from IBM, can assist clients in creating a more dynamic infrastructure.

The key initiatives for implementing a dynamic infrastructure are:

Virtualization Breaking out of the barriers of physical devices in a data center, such as servers, storage, networks, data, and applications, giving clients improved TCO, resiliency and flexibility for a Dynamic Infrastructure®.

Energy efficiency Optimizing the energy efficiency of the IT infrastructure to reduce costs, resolve space, power, and cooling constraints, and achieve green strategy objectives.

Service management Achieving integrated visibility, control, and automation across all of the business and IT infrastructure components that support differentiated service delivery and accelerated business growth. Service management includes all aspects of managing complex service environments by controlling both physical and logical resources, targeting Service Level Agreements agreed with the users of any specific service.

Asset management Improving asset reliability, availability, and uptime that underpin quality delivery of service according to the priorities of the business, while also maximizing the return on lifetime asset investment along with inventory optimization, labor efficiency, and mitigating the risk of equipment failures that jeopardize the environment and the health and safety of people.

Security A new approach to managing risk, providing a full range of security capabilities to organizations, processes, and information as the IT and business infrastructure become more interconnected.

Business resiliency Providing the ability to rapidly adapt and respond to risks, as well as opportunities, in order to maintain continuous business operations, reduce operational costs, enable growth and be a more trusted partner.

Information infrastructure A comprehensive approach to a resilient infrastructure for securely storing and managing information and mitigating business risks.

1.8 The shift in the data center network architectural thinking

In order to enable a dynamic infrastructure capable of handling the new requirements that have been presented in the previous section, a radical shift in how the data center network is designed is required.

The figures here show the comparison between the traditional thinking and the new thinking that enables this change of paradigm.

Figure 1-3 illustrates a traditional, multitier, physical server-oriented, data center infrastructure.

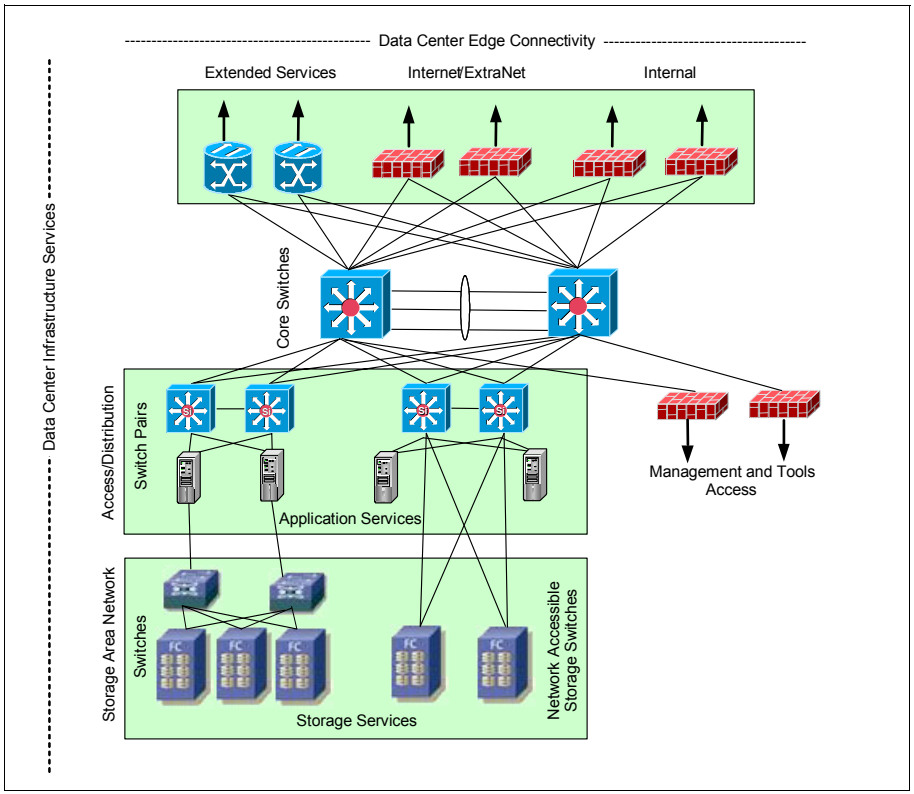

Figure 1-3 Traditional multitier data center infrastructure

Figure 1-4 illustrates a logical architectural overview of a virtualized data center network that supports server and storage consolidation and virtualization.

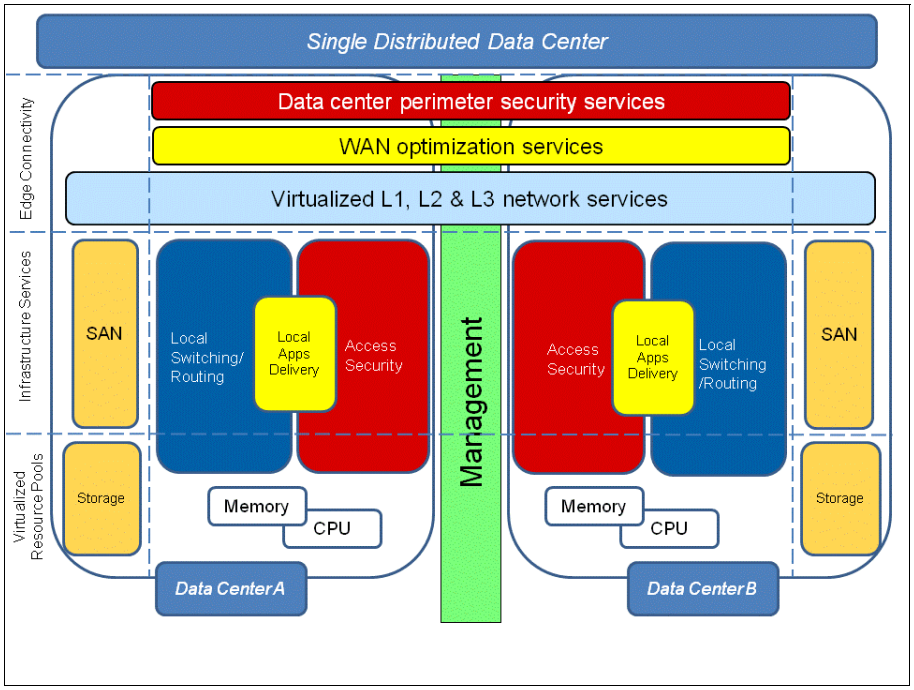

Figure 1-4 Virtualized data center network architectural overview

Consolidation began as a trend towards centralizing all the scattered IT assets of an enterprise for better cost control, operational optimization, and efficiency. Virtualization introduced an abstraction layer between hardware and software, allowing enterprises to consolidate even further—getting the most out of each physical server platform in the data center by running multiple virtual servers on it.

The leading edge of virtualization is beginning to enable dramatic shifts in the way the data center infrastructures are designed, managed, sourced, and delivered.

The emerging trend toward dynamic infrastructures, such as cloud, call for elastic scaling and automated provisioning; attributes that drive new and challenging requirements for the data center network.

By comparing the two diagrams we can highlight some important trends that impact the data center network architects and managers and that are described in detail throughout this document:

- The virtual machine is the new IT building block inside the data center. The physical server platform is no longer the basic component but instead is made up of several logical resources that are aggregated in virtual resource pools.
- Network architects can no longer stop their design at the NIC level, but need to take into account the server platforms' network-specific features and requirements, such as vSwitches. These will be presented in detail in Chapter 2, "Servers, storage, and software components" on page 31.
- The virtualization technologies that are available today (for servers, storage, and networks) decouple the logical function layer from the physical implementation layer so that physical connectivity becomes less meanigful than in the past. A deeper understanding of the rest of the infrastructure becomes paramount for network architects and managers to understand for a proper data center network design. The network itself can be virtualized; these technologies are described in Chapter 3, "Data center network functional components" on page 149.
- The architecture view is moving from physical to logical, focused on functions and how they can be deployed rather than on appliances and where they should be placed.
- Infrastructure management integration becomes more important in this environment because the inter-relations between appliances and functions are more difficult to control and manage. Without integrated tools that simplify the DC operations, managing the infrastructure box-by-box becomes cumbersome and more difficult. IBM software technologies that can be leveraged in order to achieve this goal are presented in Chapter 2, "Servers, storage, and software components" on page 31.
- The shift to "logical" applies also when interconnecting distributed data centers. In order to achieve high availability and maximize resource utilization, it is key to have all the available data centers in an active state. In order to do this, from a network standpoint, the network core must be able to offer layer 1 virtualization services (lamda on fiber connections), layer 2 virtualization services (for example VPLS connectivity to enable VM mobility) together with the usual layer 3 services leveraging proven technologies such as MPLS.

1.8.1 Networking nonfunctional requirements

The nonfunctional requirements (NFRs) of a network infrastructure are the quality requirements or constraints of the system that must be satisfied. These requirements address major operational and functional areas of the system in order to ensure its robustness. The infrastructure virtualization paradigm shift does not change the number of NFRs, but it does affect their priorities, the way they are met, and the inter-relations.

This section discusses each of the NFRs of an IT network system.

Availability

Availability means that data or information is accessible and usable upon demand by an authorized person. Network availability is affected by failure of a component such as a link.

Two factors that allow improved availability are redundancy of components and convergence in case of a failure.

- Redundancy - Redundant data centers involve complex solution sets depending on a client's requirements for backup and recovery, resilience, and disaster recovery.
- Convergence - Convergence is the time required for a redundant network to recover from a failure and resume traffic forwarding. Data center environments typically include strict uptime requirements and therefore need fast convergence.

Backup and recovery

Although the ability to recover from a server or storage device failure is beyond the scope of network architecture NFRs, potential failures such as the failure of a server network interface card (NIC) have to be taken into consideration. If the server has a redundant NIC, then the network must be capable of redirecting traffic to the secondary network as needed.

As to network devices, the backup and recovery ability typically requires the use of diverse routes and redundant power supplies and modules. It also requires defined processes and procedures for ensuring that current backups exist in case of firmware and configuration failures.

Capacity estimates and planning

Network capacity is defined in two dimensions, vertical and horizontal capacity:

- Vertical capacity relates to the forwarding and processing capacity—in this case, a matrix such as bandwidth, packet rate, concurrent sessions, and so on.
- Horizontal capacity involves the breadth and reach of the network—in this case, a matrix such as server port counts, external connectivity bandwidth, and so on.

Configuration management

Configuration management covers the identification, recording, and reporting of IT/network components, including their versions, constituent components, states and relationships to other network components. Configuration Items (CIs) that

should be under the control of configuration management include network hardware, network software, services, and associated documentation.

It also includes activities associated with change management policies and procedures, administration, and implementation of new installations and equipment moves, additions, or changes.

The goal of configuration management is to ensure that a current backup of each network device's configuration exists in a format that can be quickly restored in case of failure.

Also, a trail of the changes that have been made to the different components is needed for auditing purposes.

Disaster recovery

The requirement for disaster recovery is the ability to resume functional operations following a catastrophic failure. The definition of functional operations depends upon the depth and scope of an enterprise's operational requirements and its business continuity and recovery plans.

Multidata center environments that provide a hot standby solution is one example of a disaster recovery plan.

Environment

There are environmental factors such as availability of power or air conditioning and maximum floor loading that influence the average data center today. The network architecture must take these factors into consideration.

Extensibility and flexibility

The network architecture must allow the infrastructure to expand as needed to accommodate new services and applications.

Failure management

All failures must be documented and tracked. The root cause of failures must be systematically determined and proactive measures taken to prevent a repeat of the failure. Failure management processes and procedures will be fully documented in a well-architected data center environment.

Performance

Network performance is usually defined by the following terms:

- Capacity

  Capacity refers to the amount of data that can be carried on the network at any time. A network architecture should take into account anticipated minimum, average, and peak utilization of traffic patterns.

- Throughput

  Throughput is related to capacity, but focuses on the speed of data transfer between session pairs versus the utilization of links.

- Delay

  Delay, also known as “lag” or “latency,” is defined as a measurement of end-to-end propagation times. This requirement is primarily related to isochronous traffic, such as voice and video services.

- Jitter

  Jitter is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes. It is most typically associated with telephony and video-based traffic.

- Quality of Service

  Quality of Service (QoS) requirements include the separation of traffic into predefined priorities. QoS helps to arbitrate temporary resource contention. It also provides an adequate service level for business-critical administrative functions, as well as for delay-sensitive applications such as voice, video, and high-volume research applications.

Reliability

Reliabilty is the ability of a system to perform a given function, under given conditions, for a given time interval.

There is a difference between availability and reliability. A system can be unavailable but not considered as unreliable because this system is not in use at the given time. An example is a maintenance window where the system is shut down for an upgrade and restarted. During this window, we know the system is not available, but the reliability is not affected. Since today’s data center houses critical applications and services for the enterprise, outages are becoming less and less tolerable. Reliability is expressed in terms of the percentage of time a network is available, as shown in Table 1-3 on page 27.

Table 1-3 Reliability

	Total downtime (HH:MM:SS)		
Availability	**per day**	**per month**	**per year**
99.9999%	00:00:00.08	00:00:02.7	00:00:32
99.999%	00:00:00.4	00:00.26	00:05:15
99.99%	00:00:08	00:04:22	00:52:35
99.9%	00:01:26	00:43:49	08:45:56
99%	00:14:23	07:18:17	87:39:29

Very few enterprises can afford a 99.9999% level of reliability, because it is usually too costly. Instead, many moderate-sized businesses opt for a 99.99% or 99.9% level of reliability.

Scalability

In networking terms, scalability is the ability of the network to grow incrementally in a controlled manner.

For enterprises that are constantly adding new servers and sites, architects may want to specify something more flexible, such as a modular-based system. Constraints that may affect scalability, such as defining spanning trees across multiple switching domains or additional IP addressing segments to accommodate the delineation between various server functions, must be considered.

Security

Security in a network is the definition of permission to access devices, services, or data within the network. The following components of a security system will be considered:

- Security policy

  Security policies define how, where, and when a network can be accessed. An enterprise normally develops security policies related to networking as a requirement. The policies will also include the management of logging, monitoring, and audit events and records.

- Network segmentation

  Network segmentation divides a network into multiple zones. Common zones include various degrees of trusted and semi-trusted regions of the network.

- Firewalls and inter-zone connectivity

  Security zones are typically connected with some form of security boundary, often firewalls or access control lists. This may take the form of either physical or logical segmentation.

- Access controls

  Access controls are used to secure network access. All access to network devices will be via user-specific login credentials; there must be no anonymous or generic logins.

- Security monitoring

  To secure a data center network, a variety of mechanisms are available including IDS, IPS, content scanners, and so on. The depth and breadth of monitoring will depend upon both the client's requirements as well as legal and regulatory compliance mandates.

- External regulations

  External regulations often play a role in network architecture and design due to compliance policies such as Sarbanes-Oxley (SOX), Payment Card Industry Standards (PCI), the Health Insurance Portability and Accountability Act (HIPAA); and a variety of other industry and non-industry-specific regulatory compliance requirements.

Serviceability

Serviceability refers to the ability to service the equipment. Several factors can influence serviceability, such as modular or fixed configurations or requirements of regular maintenance.

Service Level Agreement

A Service Level Agreement (SLA) is an agreement or commitment by a service provider to provide reliable, high-quality service to its clients. An SLA is dependent on accurate baselines and performance measurements. Baselines provide the standard for collecting service-level data, which is used to verify whether or not negotiated service levels are being met.

Service level agreements can apply to all parts of the data center, including the network. In the network, SLAs are supported by various means such as QoS and configuration management, and availability. IT can also negotiate Operational Level Agreements (OLAs) with the Business Units in order to guarantee and end-to-end service level to the final users.

Standards

Network standards are key to the ongoing viability of any network infrastructure. They define such standards as:

- Infrastructure naming
- Port assignment
- Server attachment
- Protocol, ratified for example by IEEE and IETF
- IP addressing

System management

Network management must facilitate key management processes, including:

- Network Discovery and Topology Visualization

  This includes the discovery of network devices, network topology, and the presentation of graphical data in an easily understood format.

- Availability management

  This provides for the monitoring of network device connectivity.

- Event management

  This provides for the receipt, analysis, and correlation of network events.

- Asset management

  This facilitates the discovery, reporting, and maintenance of the network hardware infrastructure.

- Performance management

  This provides for monitoring and reporting network traffic levels and device utilization.

- Incident management

  The goal of incident management is to recover standard service operation as quickly as possible. The incident management process is used by many functional groups to manage an individual incident. The process includes minimizing the impact of incidents affecting the availability and/or performance, which is accomplished through analysis, tracking, and solving of incidents that have impact on managed IT resources.

- Problem management

  This includes identifying problems through analysis of incidents that have the same symptoms, then finding the root cause and fixing it in order to prevent malfunction reoccurrence.

- User and accounting management

  This is responsible for ensuring that only those authorized can access the needed resources.

- Security management

  This provides secure connections to managed devices and management of security provisions in device configurations.

2

Servers, storage, and software components

New economic trends necessitate cost-saving approaches, such as consolidation and virtualization. Our focus in this chapter is on the networking features and impacts of server and storage platforms on the network, while the next chapter focuses on key data center networking considerations. This chapter offers examples of those platforms, the related technologies, and analyzes the software stack that is capable of managing the consolidated and virtualized building blocks.

This chapter contains the following sections:

- Section 2.1 briefly describes what technologies underlie the concepts of server, storage, and network virtualization.
- Section 2.2 describes the IBM System z® server platform, the network features it utilizes, and the data center network impact of consolidating workloads on this platform.
- Section 2.3 describes the IBM Power Systems™ server platforms, the network features it utilizes, and the data center network impact of consolidating workloads on this platform.
- Section 2.4 describes IBM System x® and BladeCenter®,the network features utilized, and the data center network impact of consolidating workloads on these platforms.

- Section 2.5 describes the main x86 virtualization technologies available on the market today, together with the main network virtualization features.
- Section 2.6 briefly describes the IBM Storage platforms portfolio and the main consolidation and virtualization technologies.
- Section 2.7 presents the main IBM Software products for the management and provisioning of the virtualized data center, from a networking point of view.
- Section 2.8 describes the main IBM Integrated Data Center Solutions: iDataPlex™ and Cloudburst, highlighting the networking options that are available today.

2.1 Virtualization

Virtualization refers to the abstraction of logical resources away from their underlying physical resources to improve agility and flexibility, reduce costs, and thus enhance business value. Virtualization allows a set of underutilized physical infrastructure components to be consolidated into a smaller number of better utilized devices, contributing to significant cost savings.

- Server virtualization

  A physical server is abstracted to provide, or host, multiple virtual servers or multiple operating systems on a single platform.

- Storage virtualization

  The storage devices used by servers are presented in the form of abstracted devices, partitioned and dedicated to servers as needed, independent of the actual structure of the physical devices.

- Network virtualization (will be described in more detail in Chapter 3, “Data center network functional components” on page 149).

  Network devices such as switches, routers, links and network interface cards (NICs) are abstracted to provide many virtualized network resources on few physical resources, or combine many physical resources into few virtual resources.

2.1.1 Server virtualization techniques

Server virtualization is a method of abstracting the operating system from the hardware platform. This allows multiple operating systems or multiple instances of the same operating system to coexist on one or more processors. A hypervisor or virtual machine monitor (VMM) is inserted between the operating system and the hardware to achieve this separation. These operating systems are called “guests” or “guest OSs.” The hypervisor provides hardware emulation to the guest operating systems. It also manages allocation of hardware resources between operating systems.

Currently there are three common types of hypervisors: type 1, type 2, and containers, as explained here:

Type 1 - Virtualization code that runs directly on the system hardware that creates fully emulated instances of the hardware on which it is executed. Also known as “full,” “native,” or “bare metal.”

Type 2 - Virtualization code that runs as an application within a traditional operating system environment that creates fully emulated instances of the

hardware made available to it by the traditional operating system on which it is executed. These are also known as “hosted” hypervisors.

Containers - Virtualization code that runs as an application within a traditional operating system that creates encapsulated, isolated virtual instances that are pointers to the underlying host operating system on which they are executed. This is also known as “operating system virtualization.”

Figure 2-1 depicts the three hypervisor types.

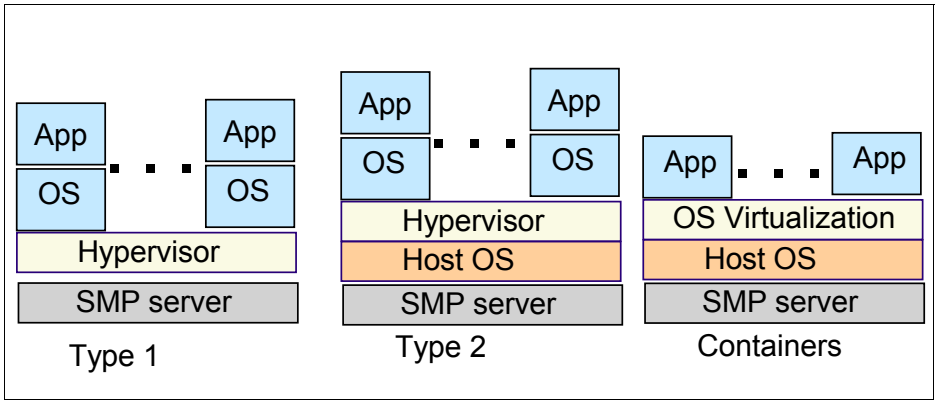

Figure 2-1 Hypervisor types

Type 1 or bare metal hypervisors are the most common in the market today, and they can be further classified into three main subtypes:

- Standalone (for example, VMware ESX and vSphere)
- Hybrid (for example, Hyper-V or XenServer)
- Mixed (Kernel Virtual Machine)

Type 1 standalone

In a standalone hypervisor, all hardware virtualization and virtual machine monitor (VMM) functions are provided by a single, tightly integrated set of code. This architecture is synonymous with the construct of VMware vSphere and previous generations of the ESX hypervisor. Figure 2-2 on page 35 shows a sample diagram of the architectural overview of VMware vSphere 4.0 (also referred to as ESX 4).

Contrary to common belief, VMware is *not* a Linux®-based hypervisor. Rather, ESX is comprised of a strictly proprietary, highly sophisticated operating system called VMkernel, providing all virtual machine monitor and hardware virtualization functions. The full version of ESX does provide a Linux-based service console (shown to the left of the diagram). As described in the VMware

section of this document, ESXi (the embedded version of the hypervisor) does not contain this service console instance.

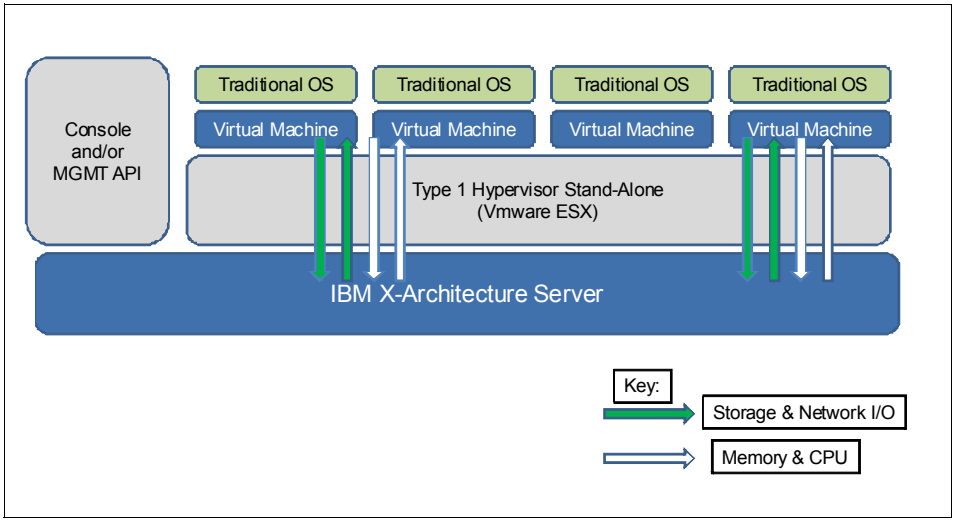

Figure 2-2 Example of Type 1 standalone hypervisor architecture

Type 1 Hybrid

The hybrid type 1 architecture includes a split software model where a “thin” hypervisor provides hardware virtualization in conjunction with a parent partition (privileged virtual machine) which provides virtual machine monitor (VMM) functionality. This model is associated primarily with Microsoft® Hyper-V and Xen-based hypervisors.The parent partition, also called “Domain 0” (Dom0), is typically a virtual machine that runs a full version of the native operating system with root authority. For example, Dom0 for Xen-enabled and executed within Novell SUSE Linux Enterprise Server (SLES) would execute as a full instance of SLES, providing the management layer of VM creation, modification, deletion, and other similar configuration tasks. At system boot, the Xen-enabled kernel loads initially, followed by the parent partition, which runs with VMM privileges, serves as the interface for VM management, and manages the I/O stack.

Similar to VMware, all hybrid products available today provide paravirtualized drivers for guests, enabling improved performance to network and I/O resources. Guests not implementing paravirtualized drivers must traverse the I/O stack in the parent partition, degrading guest performance. Operating system (OS) paravirtualization is becoming increasingly common to achieve optimal guest performance and improved interoperability across hypervisors. For example, Microsoft Hyper-V/Windows® Server 2008 R2 provides full OS paravirtualization

support (also known as “Enlightened” guest support) for Windows Server 2008 and SUSE Enterprise Linux guests; see Figure 2-3.

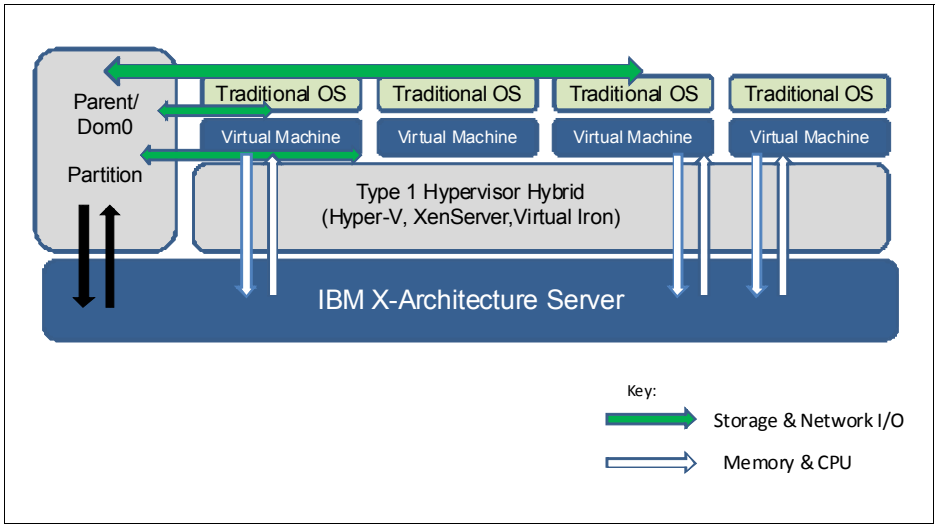

Figure 2-3 Type 1 Hybrid hypervisor architecture

Type 1 mixed

The Linux-based Kernel Virtual Machine (KVM) hypervisor model provides a unique approach to Type 1 architecture. Rather than executing a proprietary hypervisor on bare-metal, the KVM approach leverages open-source Linux (including RHEL, SUSE, Ubuntu, and so on) as the base operating system and provides a kernel-integrated module (named KVM) that provides hardware virtualization.

The KVM module is executed in user mode (unlike standalone and hybrid hypervisors, which run in kernel or root mode), but it enables virtual machines to execute with kernel-level authority using a new instruction execution context called Guest Mode; see Figure 2-4 on page 37.

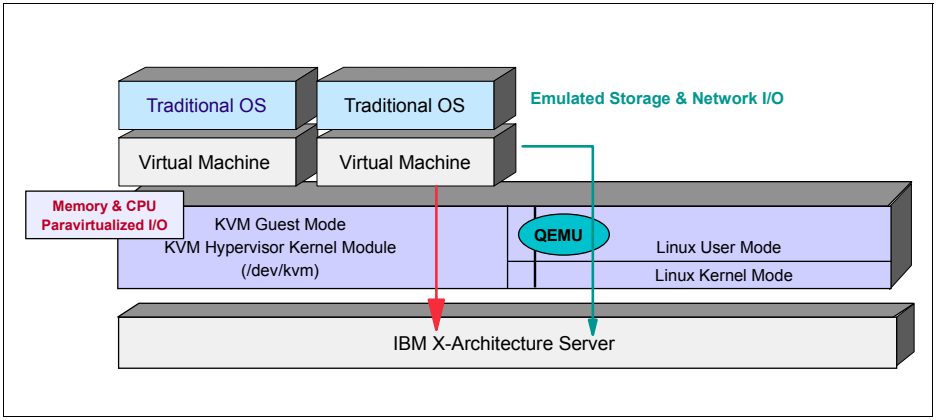

Figure 2-4 Operating system-level virtualization

Virtualization is a critical part of the data center. It offers the capability to balance loads, provide better availability, reduce power and cooling requirements, and allow resources to be managed fluidly.

For more detailed information, see *IBM Systems Virtualization: Servers, Storage, and Software*, REDP-4396.

2.1.2 Storage virtualization

Only a high-level view of storage virtualization is presented in this document.

Currently, storage is virtualized by partitioning the SAN into separate partitions called Logical Unit Numbers (LUNs), as shown in Figure 2-5 on page 38. Each LUN can only be connected to one server at a time.

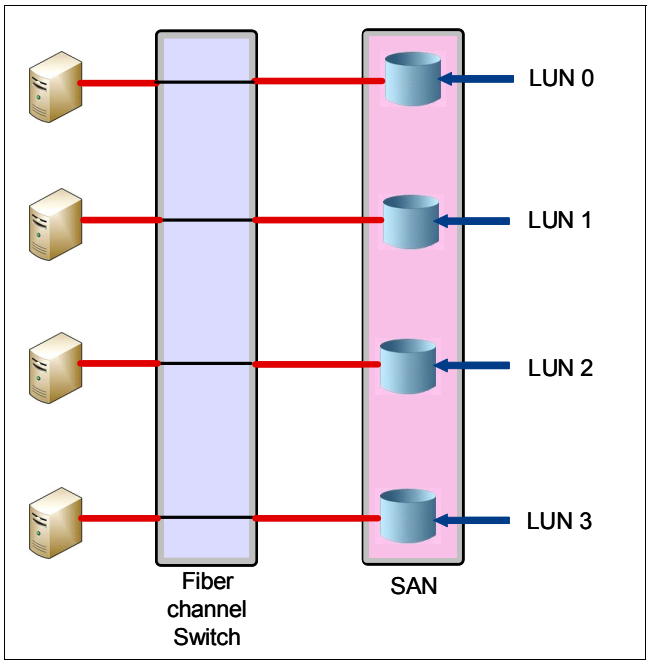

Figure 2-5 Storage virtualization overview

This SAN is connected to the server through a Fibre Channel connection switch.

The advantages of SAN virtualization are:

- Provides centralized stored data.
- Eases backup of stored data.
- Has the ability to remap a LUN to a different server in case of server failure.
- Makes storage appear local to servers and to users.
- Improves utilization and reduces storage growth.
- Reduces power and cooling requirements.

See 2.6 “Storage virtualization” on page 104 for more details.

2.2 The System z platform

System z is the IBM platform designed to provide the most reliable environment for high-value critical enterprise applications, with the goal of reaching *near-zero*

service downtime. The System z platform is commonly referred to as a mainframe.

The newest zEnterprise System consists of the IBM zEnterprise 196 central processor complex, IBM zEnterprise Unified Resource Manager, and IBM zEnterprise BladeCenter Extension. The z196 is designed with improved scalability, performance, security, resiliency, availability, and virtualization. The z196 Model M80 provides up to 1.6 times the total system capacity of the z10™ EC Model E64, and all z196 models provide up to twice the available memory of the z10 EC. The zBX infrastructure works with the z196 to enhance System z virtualization and management through an integrated hardware platform that spans mainframe and POWER7™ technologies. Through the Unified Resource Manager, the zEnterprise System is managed as a single pool of resources, integrating system and workload management across the environment.

The following sections contain network-related information about the System z architecture in general. The zEnterpise, however, introduces some new network-specific functions. In fact, the most significant change is that other kinds of servers can now be “plugged into” the mainframe to create an “Ensemble Network” where security exposures are minimized and the data center can be managed as if it were a single pool of virtualized resources.

For more information on zEnterprise networking, refer to this site:

http://www.ibm.com/systems/z/faqs

2.2.1 Introduction to the System z architecture

The System z architecture was designed with the concept of *sharing*. Sharing starts in the hardware components and ends with the data that is being used by the platform. The ability to share everything is based on one of the major strengths of the System z mainframe: virtualization.

As it is commonly used in computing systems, virtualization refers to the technique of hiding the physical characteristics of the computing resources from users of those resources. Virtualizing the System z environment involves creating virtual systems (logical partitions and virtual machines), and assigning virtual resources (such as processors, memory, and I/O channels) to them. Resources can be dynamically added or removed from these logical partitions through operator commands.

For more information about the System z architecture, refer to the IBM zEnterprise System Technical Guide at:

http://www.redbooks.ibm.com/abstracts/sg247833.html?Open

2.2.2 Mainframe virtualization technologies

The virtualization capabilities of the IBM mainframe represent some of the most mature and sophisticated virtualization technologies in the industry today. For example, a single IBM System z mainframe can scale up to millions of transactions per day or scale out to manage tens to hundreds of virtual servers. It can also redistribute system resources dynamically to manage varying server demands on the system resources automatically.

The major virtualization technologies available on IBM System z are:

- PR/SM™ and logical partitioning
- Address spaces within LPARS
- HiperSockets™
- Channel Subsystem (CSS)
- z/OS® Workload Manager
- Intelligent Resource Director
- System z Parallel Sysplex®
- Geographically Dispersed Parallel Sysplex™ (GDPS®)
- Capacity Upgrade on Demand
- z/OS Capacity Provisioning

PR/SM and logical partitioning

Processor Resource/Systems Manager™ (PR/SM) is a hypervisor integrated with all System z elements that maps physical resources into virtual resources so that many logical partitions can share the physical resources.

PR/SM provides the logical partitioning function of the central processor complex (CPC). It provides isolation between partitions, which enables installations to separate users into distinct processing images, or to restrict access to certain workloads where different security clearances are required.

Each logical partition operates as an independent server running its own operating environment. On the latest System z models, up to 60 logical partitions running z/OS, z/VM®, z/VSE™, z/TPF, and Linux on System z operating systems can be defined. PR/SM enables each logical partition to have dedicated or shared processors and I/O channels, and dedicated memory (which can be dynamically reconfigured as needed).

There are two types of partitions, dedicated and shared:

- A *dedicated* partition runs on the same dedicated physical processors at all times, which means the processors are not available for use by other partitions even if the operating system running on that partition has no work to do. This eliminates the need for PR/SM to get involved with swapping out one guest and dispatching another.
- *Shared* partitions, alternatively, can run on all remaining processors (those that are not being used by dedicated partitions). This allows idle systems to be replaced by systems with real work to do at the expense of PR/SM overhead incurred by the dispatching of the operating systems. In contrast with dedicated partitions, shared partitions provide increased processor utilization, but at the potential expense of performance for a single operating system.

PR/SM transforms physical resources into virtual resources so that several logical partitions can share the same physical resources. Figure 2-6 illustrates the PR/SM and LPAR concepts.

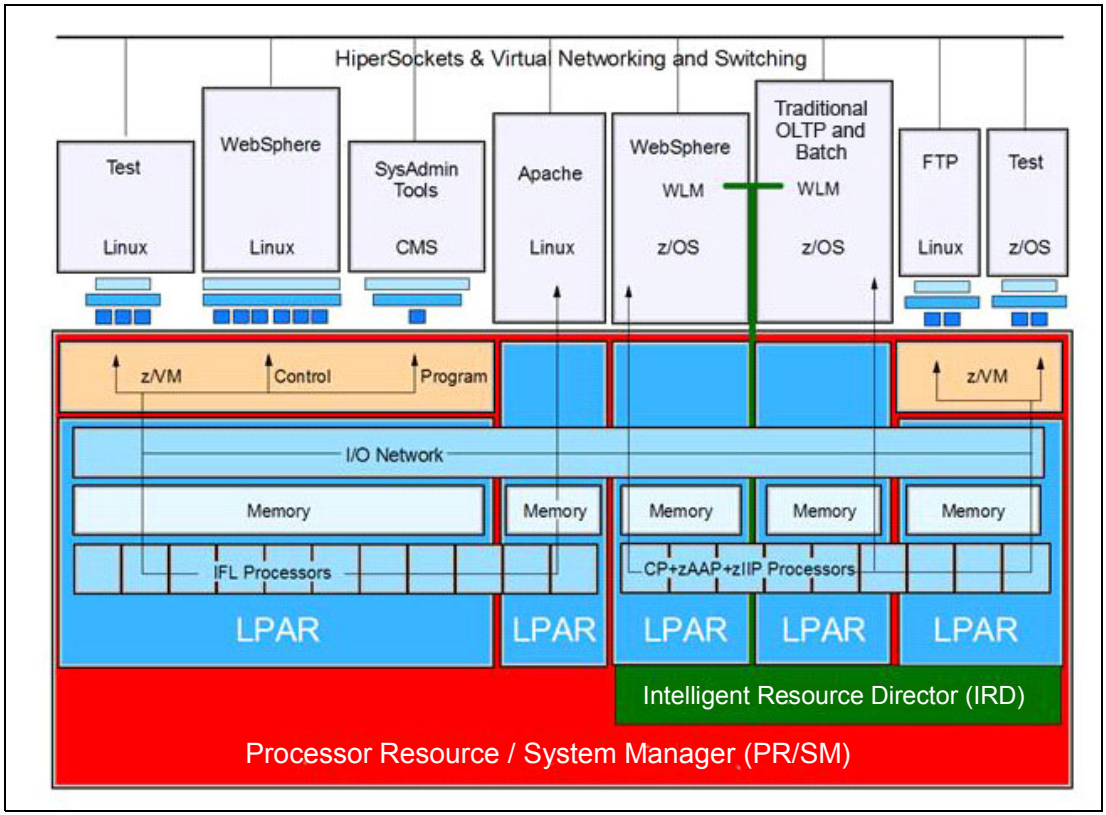

Figure 2-6 PR/SM and LPAR concepts

For a better understanding of the above IBM System z functionalities, we will now briefly describe the most important network-related topics in more detail.

Channel Sub System (CSS)

The role of the Channel Sub System (CSS) is to control communication of internal and external channels, and control units and devices. The configuration definitions of the CSS specify the operating environment for the correct execution of all system I/O operations. The CSS provides the server communications to external devices through channel connections. The channels permit transfer of data between main storage and I/O devices or other servers under the control of a channel program. The CSS allows channel I/O operations to continue independently of other operations in the central processors (CPs).

The building blocks that make up a CSS are shown in Figure 2-7.

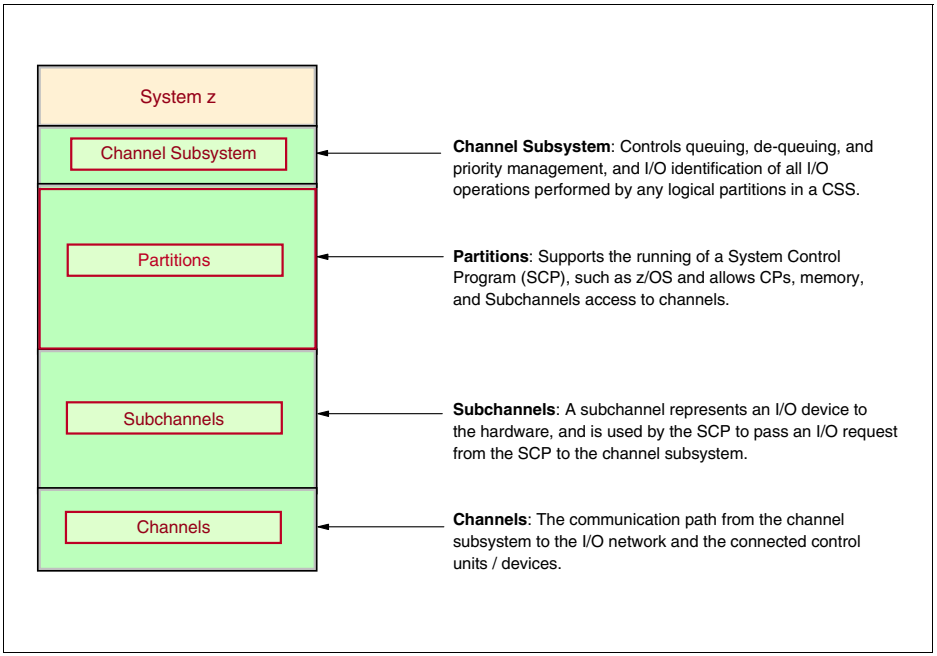

Figure 2-7 Channel Sub System

One of the major functions is the Multiple Image Facility (MIF). MIF capability enables logical partitions to share channel paths, such as ESCON®, FICON®, and Coupling Facility sender channel paths, between logical partitions within a processor complex. If a processor complex has MIF capability, and is running in LPAR mode, all logical partitions can access the same shared channel paths, thereby reducing the number of required physical connections. In contrast, if a

processor complex does not have MIF capability, all logical partitions must use separate channel paths to share I/O devices.

For more information about CSS, refer to section 2.1 in *IBM System z Connectivity Handbook*, SG24-5444, which can be found at:

http://www.redbooks.ibm.com/abstracts/sg245444.html?Open

HiperSockets

HiperSockets provides the fastest TCP/IP communication between consolidated Linux, z/VM, z/VSE, and z/OS virtual servers on a System z server. HiperSockets provides internal "virtual" LANs, which act like TCP/IP networks in the System z server. It eliminates the need for any physical cabling or external networking connection between these virtual servers. Figure 2-8 shows an example of HiperSockets connectivity with multiple LPs and virtual servers.

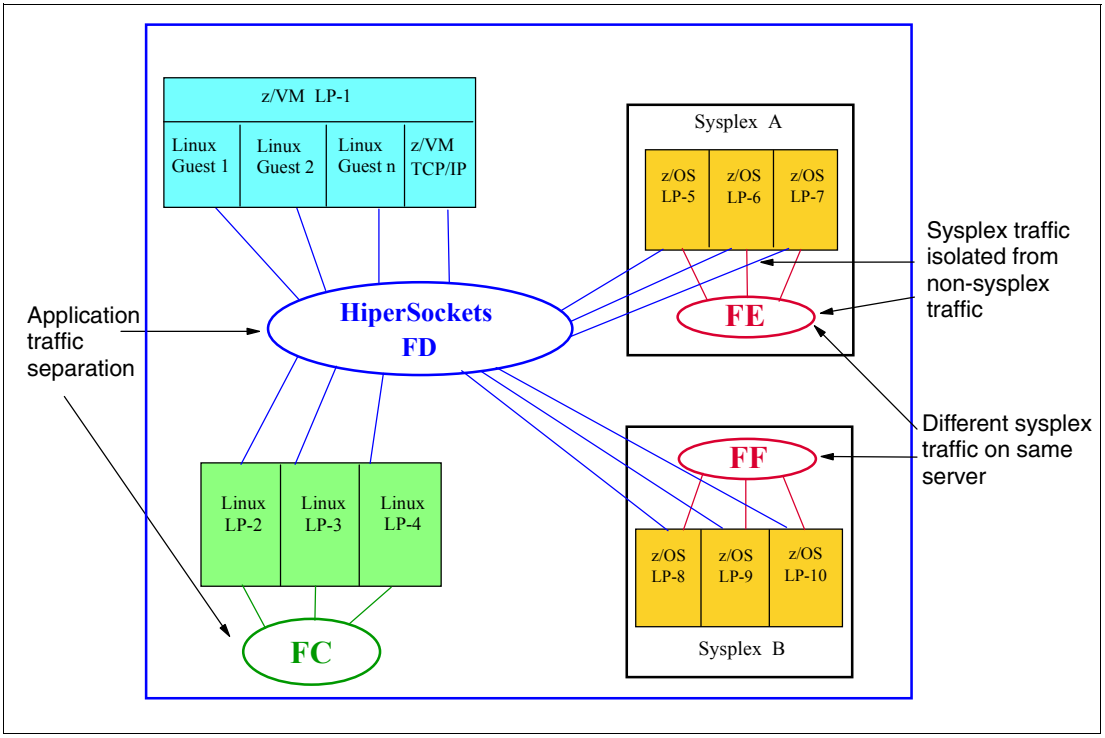

Figure 2-8 HiperSockets connectivity

HiperSockets is implemented in the Licensed Internal Code (LIC) of a System z, with the communication path being in system memory. HiperSockets uses internal Queued Direct Input/Output (iQDIO) at memory speed to transfer

information between the virtual servers. This iQDIO is an integrated function on the System z servers that provides users with attachment to high-speed “logical” LANs with minimal system and network overhead.

Since HiperSockets does not use an external network, it can free up system and network resources, eliminating attachment costs while improving availability and performance. And also, because HiperSockets has no external components, it provides a very secure connection.

Intelligent Resource Director

Intelligent Resource Director (IRD) is a feature that extends the concept of goal-oriented resource management by allowing grouping system images that are resident on the same System z running in LPAR mode, and in the same Parallel Sysplex, into an LPAR cluster. This gives Workload Manager (WLM) the ability to manage resources, both processor and I/O, not just in one single image, but across the entire cluster of system images.

WLM is responsible for enabling business-goal policies to be met for the set of applications and workloads. IRD implements the adjustments that WLM recommends to local sysplex images by dynamically taking the hardware (processor and channels) to the LPAR where it is most needed.

IRD addresses three separate but mutually supportive functions:

- LPAR processor management

  The goal of LPAR processor management is to help simplify the configuration task by automatically managing physical processor resources to allow high utilization of physical processor capacity, while allowing performance objectives to be met at times of peak demands. IRD LPAR processor management extends WLM goal-oriented resource management to allow for dynamic adjustment of logical partition processor weight. This function moves processor to the partition with the most deserving workload, based on the WLM policy, and enables the system to adapt to changes in the workload mix.

- Channel Subsystem Priority Queuing

  z/OS in WLM uses this new function to dynamically manage the channel subsystem priority of I/O operations for given workloads based on the performance goals for these workloads as specified in the WLM policy. In addition, because Channel Subsystem I/O Priority Queuing works at the channel subsystem level, and therefore affects every I/O request (for every device, from every LPAR) on the machine, a single channel subsystem I/O priority can be specified, used for all I/O requests from systems that do not actively exploit Channel Subsystem I/O Priority Queuing.

- Dynamic channel path management (DCM)

  Dynamic channel path management is designed to dynamically adjust the channel configuration in response to shifting workload patterns. It is a function in IRD, together with WLM LPAR processor management and Channel Subsystem I/O Priority Queuing.

  DCM can improve performance by dynamically moving the available channel bandwidth to where it is most needed. Prior to DCM, the available channels had to be manually balanced across the I/O devices, trying to provide sufficient paths to handle the average load on every controller. This means that at any one time, some controllers probably have more I/O paths available than they need, while other controllers possibly have too few.

System z Parallel Sysplex

While System z hardware, operating systems, and middleware have long supported multiple applications on a single server, Parallel Sysplex clustering allows multiple applications to communicate across servers—and it can even support one large application spanning multiple servers, resulting in optimal availability for that application.

With Parallel Sysplex clustering and its ability to support data sharing across servers, IT architects can design and develop applications that have one integrated view of a shared data store. This eliminates the need to partition databases, which in non-System z environments typically creates workload skews requiring lengthy and disruptive database repartitioning. Also, ensuring data integrity with non-System z partitioned databases often requires application-level locking, which in high-volume transaction environments could lead to service level agreements not being met.

For more information on System z Parallel Sysplex, refer to *IBM z/OS Parallel Sysplex Operational Scenarios*, SG24-2079, which can be found here:

http://www.redbooks.ibm.com/abstracts/sg242079.html?Open

2.2.3 Linux on System z

With the ability to run Linux on System z, IT departments can simplify their processes by consolidating their multiple server farms down to a single System z running z/VM and Linux on System z. This can lead to both hardware savings and power savings, and could also simplify the management of the infrastructure.

Using virtualization, bringing up Linux systems takes a matter of minutes rather than days waiting for new hardware and the installation process to complete.

Because each Linux image is running in its own virtual system, the Linux images do not affect the other systems around them.

By consolidating Linux servers onto one platform, hundreds or thousands of Linux instances on a single server require less energy, cooling, and floor space.

Linux on System z is able to run in three modes: basic, LPAR, and z/VM guest. The most common way to consolidate distributed applications is to a single image of Linux running in one of the other two modes, shown in Figure 2-9, depending on application footprints and resource usage.

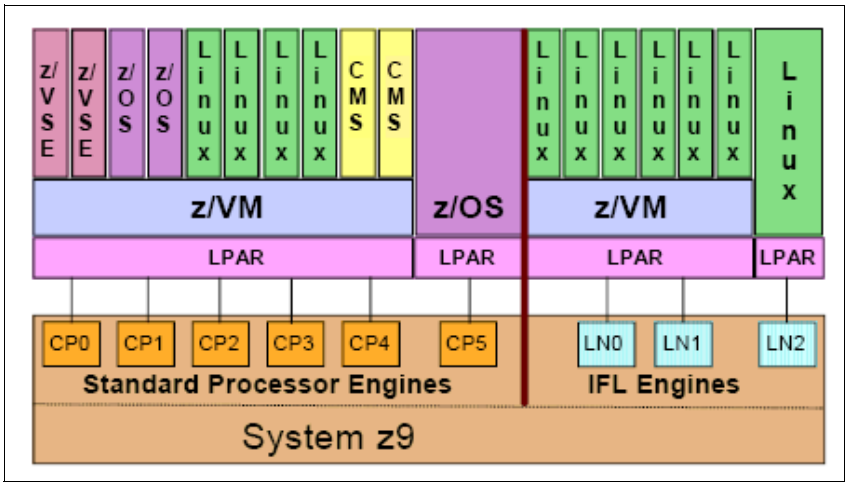

Figure 2-9 Linux on System z

Virtually any application that is portable to Linux can be consolidated to Linux on System z.

Integrated Facility for Linux

The Integrated Facility for Linux (IFL) is a central processor (CP) that is dedicated to Linux workloads. IFLs are managed by PR/SM in logical partitions with dedicated or shared processors. The implementation of an IFL requires a logical partition (LPAR) definition, following the normal LPAR activation procedure. An LPAR defined with an IFL cannot be shared with a general purpose processor. IFLs are supported by z/VM, the Linux operating system and Linux applications, and cannot run other IBM operating systems.

A Linux workload on the IFL does not result in any increased IBM software charges for the traditional System z operating systems and middleware.

For more information on Linux on System z, refer to *z/VM and Linux Operations for z/OS System Programmers*, which can be found here:

http://www.redbooks.ibm.com/abstracts/sg247603.html?Open

2.2.4 z/VM

z/VM is key to the software side of virtualization on the mainframe. It provides each user with an individual working environment known as a virtual machine (VM). The virtual machine uses virtualization to simulate the existence of a real machine by sharing resources of a real machine, which include processors, storage, memory, and input/output (I/O) resources.

Operating systems and application programs can run in virtual machines as guests. For example, multiple Linux and z/OS images can run on the same z/VM system that is also supporting various applications and users. As a result, development, testing, and production environments can share a single physical platform.

Figure 2-10 on page 48 shows an example of a configuration of an LPAR with z/VM. A first-level z/VM means that it is the base operating system that is installed directly on top of the real hardware. A second-level system is a user brought up in z/VM where an operating system can be executed upon the first-level z/VM.

In other words, a first-level z/VM operating system sits directly on the hardware, but the guests of this first-level z/VM system are virtualized. By virtualizing the hardware from the first level, as many guests as needed can be created with a small amount of actual real hardware.

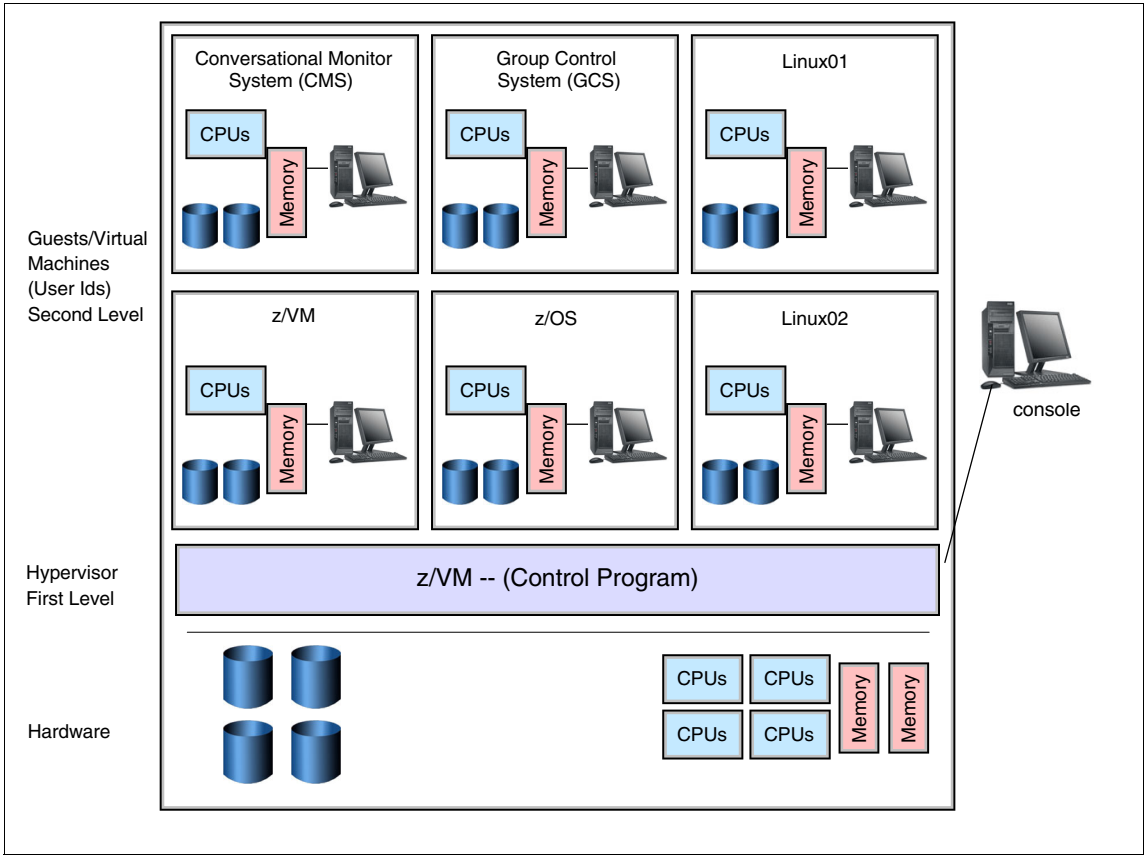

Figure 2-10 Sample configuration of an LPAR

z/VM consists of many components and facilities that bring the reliability, availability, scalability, security, and serviceability characteristics of System z servers, such as:

- TCP/IP for z/VM brings the power and resources of the mainframe server to the Internet. Using the TCP/IP protocol suite of TCP/IP for z/VM, multiple vendor networking environments can be reached from the z/VM system. Applications can be shared transparently across z/VM, Linux, and other environments. Users can send messages, transfer files, share printers, and access remote resources with a broad range of systems from multiple vendors.
- Open Systems Adapter-Express (OSA-Express), Open Systems Adapter Express2 (OSA-Express2), and Open Systems Adapter Express3 (OSA-Express3) are integrated hardware features that enable the System z

platform to provide industry-standard connectivity directly to clients on local area networks (LANs) and wide area networks (WANs).

- The Resource Access Control Facility (RACF®) Security Server for z/VM is a security tool that works together with existing functions in the z/VM base system to provide improved data security for an installation. RACF protects information by controlling access to it. RACF also controls what can be done on the operating system and protects the resources. It provides this security by identifying and verifying users, authorizing users to access protected resources, and recording and reporting access attempts.

Contrasted with a discrete server implementation, z/VM-based System z solutions are designed to provide significant savings, which can help lower total cost of ownership (TCO) for deploying new business and enterprise application workloads on a mainframe.

How z/VM virtualization works

The heart of z/VM is a multi-programming, multi-processing operating system kernel known as the Control Program (CP). One CP is the component of z/VM that creates and dispatches virtual machines on the real System z hardware.

CP supports hundreds of commands, including the configuration of the virtual machine, and lets users change virtual machine configurations nearly at will.

z/VM virtualization covers processors, memory, and I/O devices:

- Virtualization of processors

  Because the z/Architecture® defines that a System z data processing system can house 1 to 64 processors, each virtual machine z/VM creates can have 1 to 64 virtual processors. z/VM provides control over processor resources by letting a system administrator assign a share value to each virtual machine.

  z/VM also lets the system administrator define a maximum share value to prevent a guest from excessively consuming processor resource. The z/VM system administrator or system operator can adjust share settings while virtual machines are running.

- Virtualization of memory

  z/VM lets virtual machines share memory, which helps reduce memory requirements. All guest memory is virtual. CP overcommits physical memory by keeping resident only those guest pages that appear to have been needed in the recent past. When physical memory is scarce, CP moves stagnant guest pages first to expanded storage (a high-speed page storage buffer) and eventually to disk. CP brings these pages back to memory if the guest ever needs them again.

- Virtualization of I/O devices

  z/VM uses various methods to provide devices to virtual machines. CP can dedicate, or attach, a real device to a virtual machine. This gives the virtual machine exclusive use of the entire real device. CP can also virtualize a device, which means it gives a guest a portion of a real device. This can be a portion in time, such as of a processor, or a portion of the device's storage capacity, such as of a disk drive.

  Network connectivity is an important concern in many environments. z/VM meets customers' network needs by offering several networking options. The Control Program can dedicate network devices to virtual machines. The dedicated device can be a channel-to-channel adapter, an IBM Open Systems Adapter (OSA) that provides Ethernet connectivity, or a HiperSockets device, a kind of network adapter that connects one LPAR to another. z/VM also has its own TCP/IP stack, which guests can use as though it were an IP router.

  A common network option used today is the virtual switch. Here, CP equips each virtual machine with a simulated IBM OSA and connects all those simulated OSAs to a simulated LAN segment called a guest LAN. Also connected to the guest LAN is a real OSA that CP manages. With this configuration established, CP can provide packet- or frame-switching functions for the guests, just as a real switch would in a real external network. In this way, the guest LAN becomes an extension of a real external LAN segment.

z/VM virtual switch

The z/VM virtual switch is built on guest LAN technology and consists of a network of virtual adapters that can be used to interconnect guest systems. The virtual switch can also be associated with one or more OSA ports. This capability allows access to external LAN segments without requiring an intermediate router between the external LAN and the internal z/VM guest LAN.

The virtual switch can operate at Layer 2 (data link layer) or Layer 3 (network layer) of the OSI model and bridges real hardware and virtualized LANs, using virtual QDIO adapters.

External LAN connectivity is achieved through OSA Ethernet features configured in QDIO mode. Like the OSA Ethernet features, the virtual switch supports the transport of Layer 2 (Ethernet frames) and Layer 3 (IP packets) traffic.

By default, the virtual switch operates in IP mode (Layer 3) and data is transported in IP packets. Each guest system is identified by one or more IP addresses for the delivery of IP packets. All outbound traffic destined for the physical portion of the LAN segment is encapsulated in Ethernet frames, with the MAC address of the OSA port as the source MAC address. With inbound traffic,

the OSA port strips the Ethernet frame and forwards the IP packets to the virtual switch for delivery to the guest system based on the destination IP address in each IP packet.

When operating in Ethernet mode (Layer 2), the virtual switch uses a unique MAC address for forwarding frames to each connecting guest system. Data is transported and delivered in Ethernet frames. This provides the ability to transport both TCP/IP and non-TCP/IP based application data through the virtual switch. The address-resolution process allows each guest system's MAC address to become known to hosts residing on the physical side of the LAN segment through an attached OSA port. All inbound or outbound frames passing through the OSA port have the guest system's corresponding MAC address as the destination or source address.

The switching logic resides in the z/VM Control Program (CP), which owns the OSA port connection and performs all data transfers between guest systems connected to the virtual switch and the OSA port; see Figure 2-11.

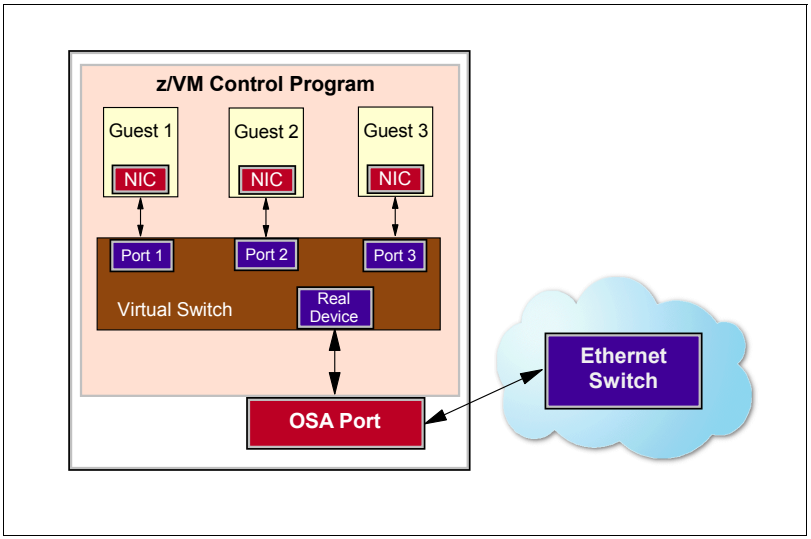

Figure 2-11 Data transfers between guest systems

2.2.5 System z network connectivity

IBM System z servers provide a wide range of interface options for connecting the system to an IP network or to another IP host. The System z interface description is listed in Table 2-1 on page 52.

Table 2-1 System z network interfaces

Interface type	Attachment type	Protocol type	Description
Common link access to workstation (CLAW)	IBM System p® Channel-attached routers	Point-to-point Point-to-Multipoint	Provides access from IBM System p server directly to a TCP/IP stack over a channel. Can also be used to provide connectivity to other vendor platforms.
Channel-to-channel (CTC)	FICON/ESCON channel	Point-to-point	Provides access to TCP/IP hosts by way of a CTC connection established over a FICON or ESCON channel.
HYPERchannel	Series A devices	Point-to-Multipoint	Provides access to TCP/IP hosts by way of a series A devices and series DX devices that function as series A devices.
LAN Channel Station (LCS)	OSA-Express: ► 1000BASE-T ► Fast Ethernet ► Token Ring ► ATM Native and LAN Emulation	LAN: ► IEEE802.3 ► IEEE802.3 ► IEEE802.5 ► ATM network	A variety of channel adapters support a protocol called the LCS. The most common are OSA-Express features.
MultiPath Channel IP Assist (MPCIPA)	HiperSockets[a] OSA-Express: ► 10 Gigabit Ethernet ► Gigabit Ethernet ► 1000BASE-T ► Fast Ethernet ► Token Ring ► ATM LAN Emulation	Internal LAN LAN: ► IEEE802.3 ► IEEE802.3 ► IEEE802.3 ► IEEE802.3 ► IEEE802.5 ► ATM network	Provides access to TCP/IP hosts, using OSA-Express in Queued Direct I/O (QDIO) mode and HiperSockets using the internal Queued Direct I/O (iQDIO).
MultiPath Channel Point-to-Point (MPCPTP)	IUTSAMEH (XCF link)	Point-to-point	Provides access to directly connect z/OS hosts or z/OS LPARs, or by configuring it to utilize Coupling Facility links (if it is part of a sysplex).
SAMEHOST (Data Link Control)	SNALINK LU0 SNALINK LU6.2 X25NPSI	Point-to-point Point-to-point X.25 network	Enables communication between CS for z/OS IP and other servers running on the same MVS™ image.

a. Can also be used in conjunction with DYNAMICXCF

Here, some further considerations about the network features of the OSA, Hipersocket and Dynamic Cross-System Coupling Facility interfaces are provided.

The following interfaces are supported by System z hardware and z/OS Communications Server. They deliver the best throughput and performance, as well as offer the most flexibility and highest levels of availability. These interfaces include:

- OSA-Express

  OSA-Express utilizes a direct memory access (DMA) protocol to transfer the data to and from the TCP/IP stack. It also provides the offloading of IP processing from the host. The OSA-Express Ethernet features support IEEE standards 802.1p/q (priority tagging and VLAN identifier tagging). OSA-Express also provides primary (PRIRouter) and secondary (SECRouter) router support. This function enables a single TCP/IP stack, on a per-protocol (IPv4 and IPv6) basis, to register and act as a router stack based on a given OSA-Express port. Secondary routers can also be configured to provide for conditions in which the primary router becomes unavailable and the secondary router takes over for the primary router.

- HiperSockets

  As described in “HiperSockets” on page 43, HiperSockets provides high-speed LPAR-to-LPAR communications within the same server (through memory). It also provides secure data flows between LPARs and high availability, if there is no network attachment dependency or exposure to adapter failures.

  HiperSockets connection supports VLAN tagging. This allows to split the internal LAN represented by a single HiperSockets CHPID into multiple virtual LANs, providing isolation for security or administrative purposes. Only stacks attached to the same HiperSockets VLAN can communicate with each other. Stacks attached to a different HiperSockets VLAN on the same CHPID cannot use the HiperSockets path to communicate with the stacks on a different VLAN.

  When the TCP/IP stack is configured with HiperSockets Accelerator, it allows IP packets received from HiperSockets to be forwarded to an OSA-Express port (or vice versa) without the need for those IP packets to be processed by the TCP/IP stack.

- Dynamic Cross-System Coupling Facility (dynamic XCF)

  Cross-System Coupling Facility (XCF) allows communication between multiple Communications Servers (CSs) for z/OS IP stacks in a Parallel Sysplex. The XCF connectivity to other TCP/IP stacks can be defined individually, or using the dynamic XCF definition facility. Dynamic XCF significantly reduces the number of definitions needed whenever a new

system joins the sysplex or when a new TCP/IP stack needs to be started up. These changes become more numerous as the number of stacks and systems in the sysplex grows. This could lead to configuration errors. With dynamic XCF, the definitions of the existing stacks do not need to be changed in order to accommodate the new stack.

Design considerations

To design connectivity in a z/OS environment, the following considerations should be taken into account:

- As a server environment, network connectivity to the external corporate network should be carefully designed to provide a high-availability environment, avoiding single points of failure.
- If a z/OS LPAR is seen as a standalone server environment on the corporate network, it should be designed as an end point.

If a z/OS LPAR will be used as a front-end concentrator (for example, making use of HiperSockets Accelerator), it should be designed as an intermediate network or node.

Although there are specialized cases where multiple stacks per LPAR can provide value, in general we recommend implementing only one TCP/IP stack per LPAR. The reasons for this recommendation are as follows:

- A TCP/IP stack is capable of exploiting all available resources defined to the LPAR in which it is running. Therefore, starting multiple stacks will not yield any increase in throughput.
- When running multiple TCP/IP stacks, additional system resources, such as memory, CPU cycles, and storage, are required.
- Multiple TCP/IP stacks add a significant level of complexity to TCP/IP system administration tasks.

One example where multiple stacks can have value is when an LPAR needs to be connected to multiple isolated security zones in such a way that there is no network level connectivity between the security zones. In this case, a TCP/IP stack per security zone can be used to provide that level of isolation, without any network connectivity between the stacks.

2.2.6 z/OS Communications Server for IP

z/OS Communications Server provides the industry-standard TCP/IP protocol suite, allowing z/OS environments to share data and computing resources with other TCP/IP computing environments, when authorized. CS for z/OS IP enables

anyone in a non-z/OS TCP/IP environment to access the z/OS Communications Server, and perform tasks and functions provided by the TCP/IP protocol suite.

Routing support

z/OS Communications Server supports static routing and two different types of dynamic routing: Open Shortest Path First (OSPF) and Routing Information Protocol (RIP). z/OS Communications Server also supports policy-based routing, which determines the destination based on a defined policy. Traffic descriptors such as TCP/UDP port numbers, application name, and source IP addresses can be used to define the policy to enable optimized route selection.

Virtual Medium Access Control support

Virtual Medium Access Control (VMAC) support enables an OSA interface to have not only a physical MAC address, but also distinct virtual MAC addresses for each device or interface in a stack.

Prior to the introduction of the *virtual* MAC function, an OSA interface only had one MAC address. This restriction caused problems when using load balancing technologies in conjunction with TCP/IP stacks that share OSA interfaces.

The single MAC address of the OSA also causes a problem when using TCP/IP stacks as a forwarding router for packets destined for unregistered IP addresses.

With the use of the VMAC function, packets destined for a TCP/IP stack are identified by an assigned VMAC address and packets sent to the LAN from the stack use the VMAC address as the source MAC address. This means that all IP addresses associated with a TCP/IP stack are accessible through their own VMAC address, instead of sharing a single physical MAC address of an OSA interface.

Fundamental technologies for z/OS TCP/IP availability

TCP/IP availability is supported as follows:

- Virtual IP Addressing (VIPA)

  VIPA provides physical interface independence for the TCP/IP stack (the part of a z/OS Communications Server software that provides TCP/IP protocol support) and applications so that interface failures will not impact application availability.

  - Static VIPA

    A *static* VIPA is an IP address that is associated with a particular TCP/IP stack. Using either ARP takeover or a dynamic routing protocol (such as OSPF), static VIPAs can enable mainframe application communications to

continue unaffected by network interface failures. As long as a single network interface is operational on a host, communication with applications on the host will persist.

- Dynamic VIPA (DVIPA)

  Dynamic VIPAs (DVIPAs) can be defined on multiple stacks and moved from one TCP/IP stack in the sysplex to another automatically. One stack is defined as the primary or owning stack, and the others are defined as backup stacks. Only the primary stack is made known to the IP network.

  TCP/IP stacks in a sysplex exchange information about DVIPAs and their existence and current location, and the stacks are continuously aware of whether the partner stacks are still functioning.

  If the owning stack leaves the XCF group (resulting from some sort of failure, for example), then one of the backup stacks automatically takes its place and assumes ownership of the DVIPA. The network simply sees a change in the routing tables (or in the adapter that responds to ARP requests).

- Address Resolution Protocol takeover

  Address Resolution Protocol (ARP) enables the system to transparently exploit redundant physical interfaces without implementing a dynamic routing protocol in the mainframe. ARP takeover is a function that allows traffic to be redirected from a failing OSA connection to another OSA connection. If an OSA port fails while there is a backup OSA port available on the same subnetwork, then TCP/IP informs the backup adapter as to which IP addresses (real and VIPA) to take over, and network connections are maintained. After it is set up correctly, the fault tolerance provided by the ARP takeover function is automatic.

- Dynamic routing

  Dynamic routing leverages network-based routing protocols (such as OSPF) in the mainframe environment to exploit redundant network connectivity for higher availability (when used in conjunction with VIPA).

- Internal application workload balancing

  - Sysplex Distributor (SD)

    The application workload balancing decision-maker provided with the Communications Server is the Sysplex Distributor (SD). The design of the SD provides an advisory mechanism that checks the availability of applications running on different z/OS servers in the same sysplex, and then selects the best-suited target server for a new connection request.

    The Sysplex Distributor bases its selections on real-time information from sources such as Workload Manager (WLM) and QoS data from the Service Policy Agent. Sysplex Distributor also measures the

responsiveness of target servers in accepting new TCP connection setup requests, favoring those servers that are more successfully accepting new requests.

Internal workload balancing within the sysplex ensures that a group or cluster of application server instances can maintain optimum performance by serving client requests simultaneously. High availability considerations suggest at least two application server instances should exist, both providing the same services to their clients. If one application instance fails, the other carries on providing service. Multiple application instances minimize the number of users affected by the failure of a single application server instance. Thus, load balancing and availability are closely linked.

– Portsharing

In order for a TCP server application to support a large number of client connections on a single system, it might be necessary to run more than one instance of the server application. Portsharing is a method to distribute workload for IP applications in a z/OS LPAR. TCP/IP allows multiple listeners to listen on the same combination of port and interface. Workload destined for this application can be distributed among the group of servers that listen on the same port.

- External application workload balancing

With external application workload distribution, decisions for load balancing are made by external devices. Such devices typically have very robust capabilities and are often part of a suite of networking components.

From a z/OS viewpoint, there are two types of external load balancers available today. One type bases decisions completely on parameters in the external mechanism, while the other type uses sysplex awareness matrixes for each application and each z/OS system as part of the decision process through the Load Balancing Advisor (LBA) function. Which technique is best depends on many factors, but the best method usually involves knowledge of the health and status of the application instances and the z/OS systems.

- z/OS Parallel Sysplex

z/OS Parallel Sysplex combines parallel processing with data sharing across multiple systems to harness the power of plural z/OS mainframe systems, yet make these systems behave like a single, logical computing facility. This combination gives the z/OS Parallel Sysplex unique availability and scalability capabilities.

Security and network management

- RACF

  RACF has evolved over more than 30 years to provide protection for a variety of resources, features, facilities, programs, and commands on the z/OS platform. The RACF concept is very simple: it keeps a record of all the resources that it protects in the RACF database.

  A *resource* can be a data set, a program, and even a subnetwork. RACF can, for example, set permissions for file patterns even for files that do not yet exist. Those permissions are then used if the file (or other object) is created at a later time. In other words, RACF establishes security policies rather than just permission records.

  RACF initially identifies and authenticates users through a user ID and password when they log on to the system. When a user tries to access a resource, RACF checks its database. Then, based upon the information that it finds in the database, RACF either allows or denies the access request.

- Network Security

  Network Security protects sensitive data and the operation of the TCP/IP stack on z/OS, by using the following:

  – IPsec/VPN functions that enable the secure transfer of data over a network using standards for encryption, authentication, and data integrity.

  – Intrusion Detection Services (IDS), which evaluates the stack for attacks that would undermine the integrity of its operation. Events to examine and actions to take (such as logging) at event occurrence are defined by the IDS policy.

  – Application Transparent Transport Layer (AT-TLS) and Transport Layer Security (TLS) enablement ensure that data is protected as it flows across the network.

- Network Management

  Network Management support collects network topology, status, and performance information and makes it available to network management tools, including the following:

  – Local management applications that can access management data through a specialized high-performing network management programming interface that is known as NMI.

  – Support of remote management applications with the SNMP protocol. CS z/OS Communications Server supports the latest SNMP standard, SNMPv3. z/OSCommunications Server also supports standard TCP/IP-based Management Information Base (MIB) data.

– Additional MIB support is also provided by enterprise-specific MIB, which supports management data for Communications Server TCP/IP stack-specific functions.

2.3 Power Systems

PowerVM™ on POWER® Systems offers industry-leading virtualization capabilities for AIX® (the IBM UNIX®-based operating system) and Linux. With the Standard Edition of PowerVM, micro-partitioning enables businesses to increase the utilization of their servers, with server definitions (such as processor resources, memory allocation, and so on) down to 1/10th of a processor and the ability to allow server size to flex with demand. In addition, with PowerVM-SE, there is the Virtual I/O Server, which allows the sharing of expensive disk and network resources while minimizing management and maintenance costs. Figure 2-12 highlights the breadth of the POWER Systems portfolio, which was refreshed in 2010 with the launch of the new POWER 7 line.

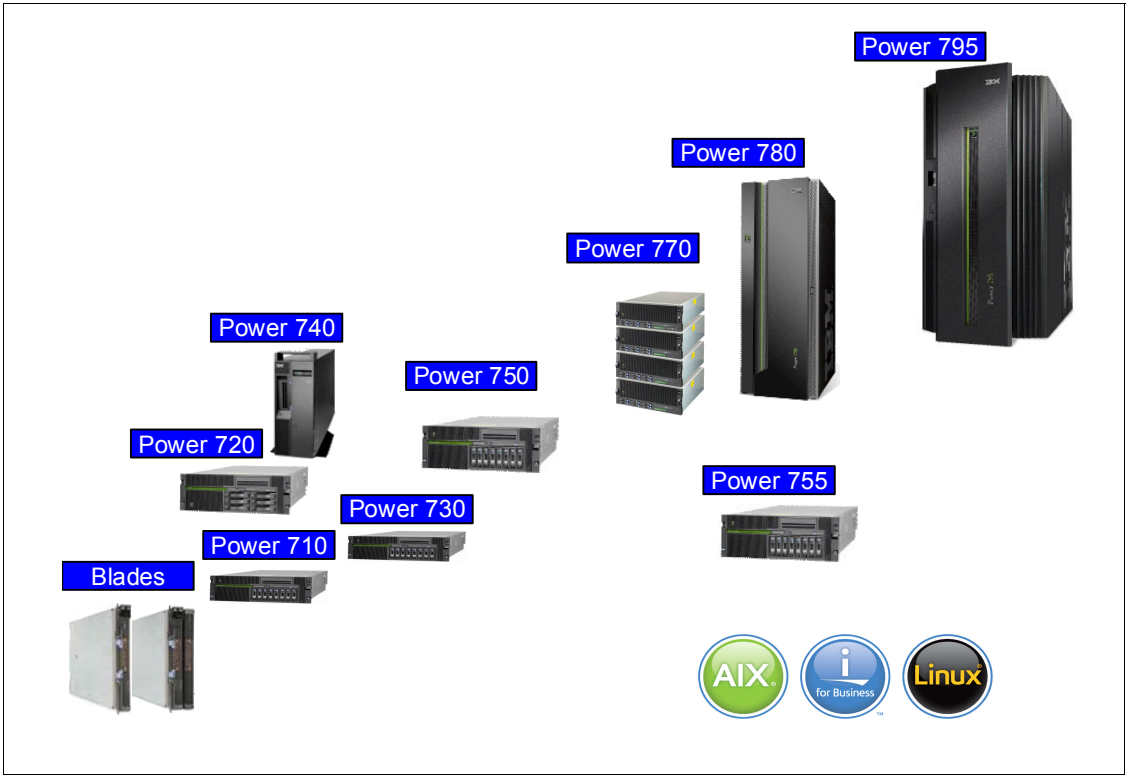

Figure 2-12 POWER 7 Systems Portfolio

2.3.1 PowerVM

The PowerVM platform is the family of technologies, capabilities, and offerings that delivers industry-leading virtualization on the IBM Power Systems. It is the new umbrella branding term for Power Systems Virtualization (Logical Partitioning, Micro-Partitioning™, Power Hypervisor, Virtual I/O Server, Live Partition Mobility, Workload Partitions, and so on). As with Advanced Power Virtualization in the past, PowerVM is a combination of hardware enablement and value-added software.

2.3.2 PowerVM Editions

PowerVM Editions are optional hardware features available on IBM System p servers based on POWER5™, POWER6®, or POWER7 processors.

There are three versions of PowerVM, suited for different purposes:

- PowerVM Express Edition

  This edition is intended for evaluations, pilots, proof of concepts, generally in single-server projects.

- PowerVM Standard Edition

  This edition is intended for production deployments and server consolidation.

- PowerVM Enterprise Edition

  The Enterprise Edition is suitable for large server deployments such as multiserver deployments and cloud infrastructure.

The PowerVM Express Edition is available on the POWER6 technology-based System p550 and System p520 Express servers, or the POWER7 technology-based System p750 Express servers, and includes the following:

- Up to three partitions per server
- Shared dedicated capacity
- PowerVM Lx86, which enables x86-based Linux applications to run on these servers
- The Virtual I/O Server
- Integrated Virtualization Manager
- Power Hypervisor

The PowerVM Standard Edition supports POWER5-based systems, allows a greater number of LPARs, and adds Multiple Shared Processor pools for POWER6-based and POWER7-based systems.

The PowerVM Enterprise Edition is only available on the new POWER6-based and POWER7-based systems, and adds PowerVM Live Partition Mobility to the suite of functions.

It is possible to upgrade from the Express Edition to the Standard or Enterprise Edition, and from Standard to Enterprise Editions.

Table 2-2 lists the versions of PowerVM that are available on each model of POWER7 processor technology-based servers.

Table 2-2 Availability of PowerVM per POWER7 processor technology-based server model

PowerVM Editions	Express	Standard	Enterprise
IBM Power 750	#7793	#7794	#7795
IBM Power 755	No	No	No
IBM Power 770	No	#7942	#7995
IBM Power 780	No	#7942	#7995

It is possible to upgrade from the Express Edition to the Standard or Enterprise Edition, and from Standard to Enterprise Editions. Table 2-3 outlines the functional elements of the three PowerVM editions.

Table 2-3 PowerVM capabilities

PowerVM Editions	Express	Standard	Enterprise
Micro-partitions	Yes	Yes	Yes
Maximum LPARs	1+2 per server	10/core	10/core
Management	VMcontrol IVM	VMcontrol IVM, HMC	VMcontrol IVM, HMC
Virtual IO Server	Yes	Yes	Yes
NPIV	Yes	Yes	Yes

2.3.3 POWER Hypervisor

POWER Hypervisor™ is the foundation for virtualization on IBM System p servers, allowing the hardware to be divided into multiple partitions, and ensuring isolation between them.

Always active on POWER5-, POWER6-, and POWER7-based servers, POWER Hypervisor is responsible for dispatching the logical partition workload across the

shared physical processors. It also enforces partition security, and can provide inter-partition communication that enables the Virtual I/O Server's virtual SCSI and virtual Ethernet functions.

Combined with features designed into the IBM POWER processors, the POWER Hypervisor delivers functions that enable capabilities including dedicated processor partitions, Micro-Partitioning, virtual processors, IEEE VLAN compatible virtual switch, virtual Ethernet adapters, virtual SCSI adapters, and virtual consoles.

The POWER Hypervisor is a firmware layer sitting between the hosted operating systems and the server hardware, as shown in Figure 2-13 on page 63. The POWER Hypervisor has no specific or dedicated processor resources assigned to it.

The POWER Hypervisor also performs the following tasks:

- Enforces partition integrity by providing a security layer between logical partitions.
- Provides an abstraction layer between the physical hardware resources and the logical partitions using them. It controls the dispatch of virtual processors to physical processors, and saves and restores all processor state information during virtual processor context switch.
- Controls hardware I/O interrupts and management facilities for partitions.

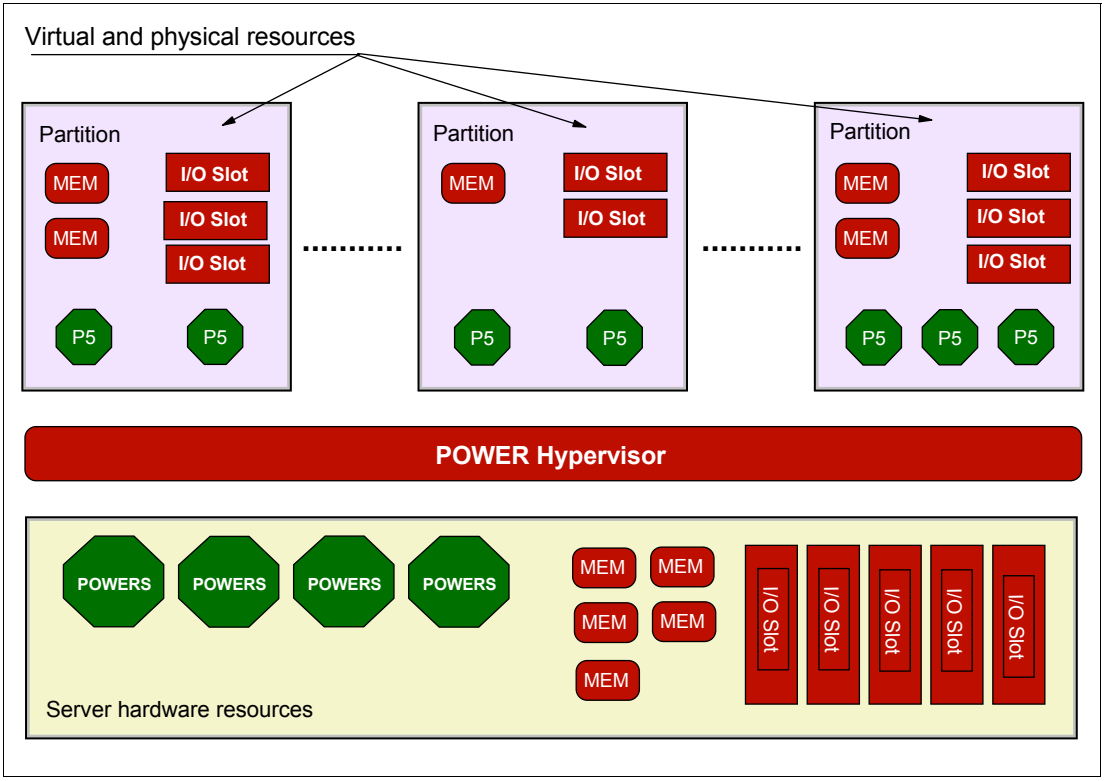

Figure 2-13 The POWER Hypervisor abstracts the physical server hardware

The POWER Hypervisor firmware and the hosted operating systems communicate with each other through POWER Hypervisor calls. Through Micro-Partitioning, the POWER Hypervisor allows multiple instances of operating systems to run on POWER5-based, POWER6- and POWER7-based servers concurrently.

A logical partition can be regarded as a logical server. It is capable of booting an operating system and running a workload. Logical partitions (LPARs) and virtualization increase utilization of system resources and add a new level of configuration possibilities.

This IBM Power 750 system can be configured with up to 32 cores, and the IBM Power 770 and 780 servers up to 64 cores. At the time of writing, these systems can support:

- Up to 32 and 64 dedicated partitions, respectively
- Up to 160 micro-partitions

It is important to point out that the maximums stated are supported by the hardware, but the practical limits depend on the application workload demands.

2.3.4 Live Partition Mobility

Live Partition Mobility, licensed through PowerVM Enterprise Edition, is a feature that relies on a number of components, including:

- POWER Hypervisor
- Virtual I/O Server (or IVM)
- Hardware Management Console (or IVM)

Live Partition Mobility makes it possible to move running AIX or Linux partitions from one physical POWER6 and POWER7 server to another without disruption. The movement of the partition includes everything that partition is running, that is, all hosted applications. Some possible uses and their advantages are:

- Moving partitions from a server to allow planned maintenance of the server without disruption to the service and users
- Moving heavily used partitions to larger machines without interruption to the service and users
- Moving partitions to appropriate servers depending on workload demands; adjusting the utilization of the server-estate to maintain an optimal level of service to users at optimal cost
- Consolidation of underutilized partitions out-of-hours to enable unused servers to be shut down, saving power and cooling expenditure

A partition migration operation can occur either when a partition is powered off (inactive), or when a partition is providing service (active).

During an active partition migration, there is no disruption of system operation or user service.

For more information on Live Partition Mobility, see *PowerVM Virtualization on IBM System p: Introduction and Configuration Fourth Edition*, SG24-7940.

We now focus on the network-specific characteristics of the POWER platform.

2.3.5 Virtual I/O Server

As part of PowerVM there is an appliance server with which physical resources can be associated and that allows to share these resources among a group of

logical partitions. The Virtual I/O Server can use both virtualized storage and network adapters, making use of the virtual SCSI and virtual Ethernet facilities.

For storage virtualization, the following backing devices can be used:

- Direct-attached entire disks from the Virtual I/O Server
- SAN disks attached to the Virtual I/O Server
- Logical volumes defined on either of the previous disks
- File-backed storage, with the files residing on either of the first two disks
- Optical storage devices

For virtual Ethernet we can define Shared Ethernet Adapters on the Virtual I/O Server, bridging network traffic from the virtual Ethernet networks out to physical Ethernet networks.

The Virtual I/O Server technology facilitates the consolidation of LAN and disk I/O resources and minimizes the number of physical adapters that are required, while meeting the non-functional requirements of the server. To understand the support for storage devices, refer to the website at:

http://www14.software.ibm.com/webapp/set2/sas/f/vios/documentation/datasheet.html

Virtual I/O Server can run in either a dedicated processor partition or a micro-partition. For the configurations for Virtual I/O Server and associated I/O subsystems, refer to *Advanced POWER Virtualization on IBM System p: Virtual I/O Server Deployment Examples*, REDP-4224.

2.3.6 Virtual Ethernet

The virtual Ethernet function is provided by the POWER Hypervisor. The POWER Hypervisor implements the Ethernet transport mechanism as well as an Ethernet switch that supports VLAN capability. Virtual LAN allows secure communication between logical partitions without the need for a physical I/O adapter or cabling. The ability to securely share Ethernet bandwidth across multiple partitions increases hardware utilization.

2.3.7 Virtual Ethernet switch

POWER Hypervisor implements a virtual Ethernet switch to deal with traffic from virtual Ethernet adapters. Every virtual Ethernet adapter has a corresponding virtual switch port on the virtual Ethernet switch. The virtual Ethernet switch uses Virtual LANs (VLANs) to segregate traffic; the switch is consistent with the IEEE 802.1q frame format.

The virtual Ethernet switch is not fully compliant with the 802.1q specification since it does not support spanning-tree algorithms and will not participate in spanning-tree calculations. The hypervisor knows the MAC addresses of all virtual Ethernet adapters and thus can switch datagrams between the virtual Ethernet adapters if the adapters belong to the same VLAN.

In Figure 2-14, packets can be exchanged between Partition 1 and Partition 2. Partition 2 and Partition 3 can also exchange packets. But Partition 1 and Partition 3 cannot exchange packets at the virtual Ethernet switch.

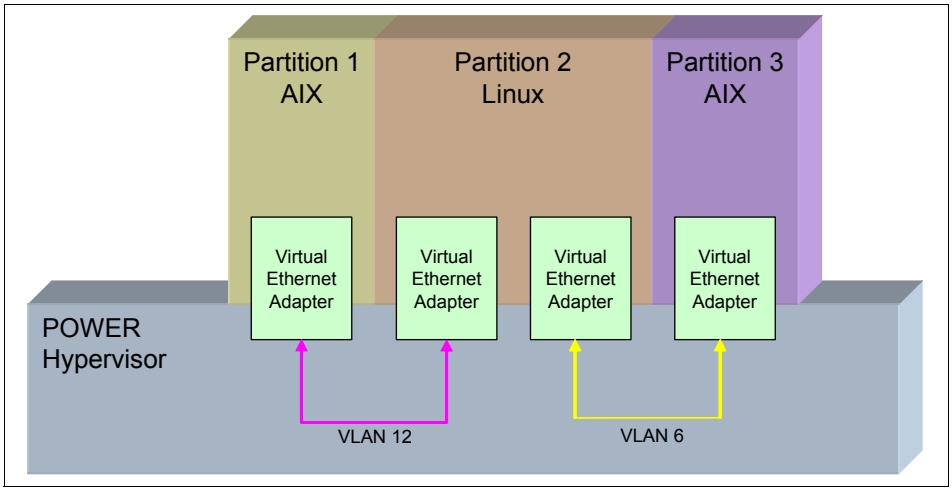

Figure 2-14 Packet exchange

By default, POWER Hypervisor has only one virtual switch but it can be changed to support up to 16 virtual Ethernet switches per system. Currently, the number of switches must be changed through the Advanced System Management (ASM) interface. The same VLANs can be used on different virtual switches and traffic will still be separated by the POWER Hypervisor.

Benefits of the virtual Ethernet switch concept are:

- Partitions “think” they have a dedicated Ethernet adapter.
- For pure inter-partition communication, no physical Ethernet adapters are needed.
- Currently AIX-to-AIX communication over Virtual Ethernet 64 KB MTU is possible as long as there are no non-AIX LPARs in the system. In the presence of other Linux or i5OS LPARs, the MTU must be capped at 9 KB to allow for interoperability.
- Several VLANs may be defined on one virtual Ethernet adapter, one native VLAN (without a 802.1q tag), and up to 20 tagged VLANs.

SEA is the component that provides connectivity to an external Ethernet switch, bridging network traffic from the virtual Ethernet adapters out to physical Ethernet networks. In 2.3.8 “External connectivity” on page 67 we discuss SEA architecture in detail and how external Ethernet switches can be connected.

All virtual Ethernet adapters in a Shared Ethernet Adapter (SEA) must belong to the same virtual switch, or SEA creation will fail.

2.3.8 External connectivity

To provide access for users to the POWER System, the virtual Ethernet switch needs to be connected to an external Ethernet switch. This is done through the SEA, which provides bridging functionality between the virtual network and one or several physical adapters; see Figure 2-15.

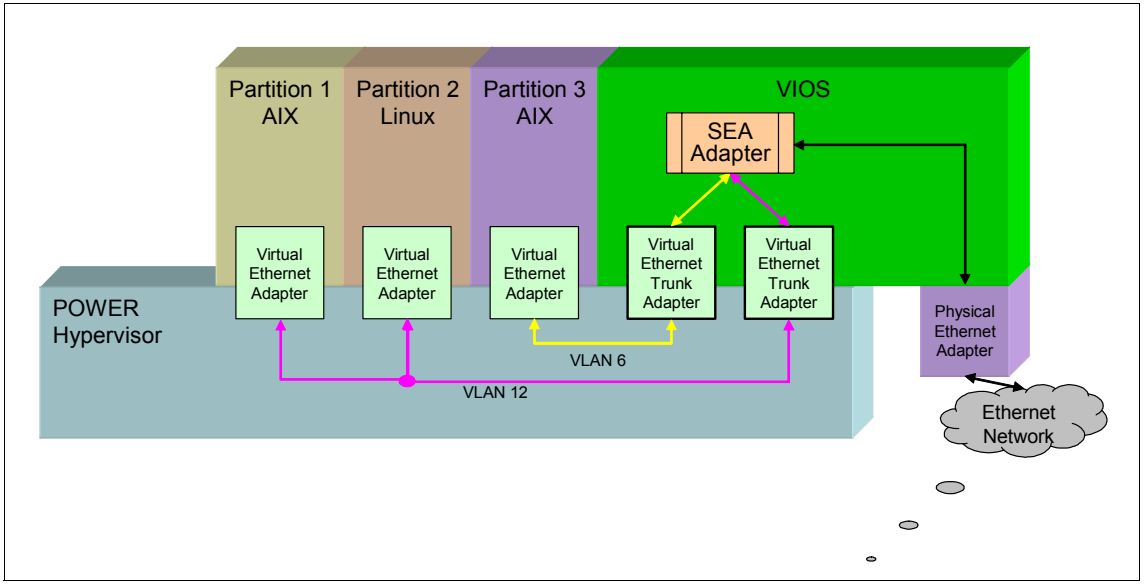

Figure 2-15 The Shared Ethernet Adapter

SEA provides the following functions:

- Datagrams from the virtual network can be sent on a physical network, and vice versa.
- One or more physical adapters can be shared by multiple virtual Ethernet adapters.
- Virtual Ethernet MAC is visible to outside systems.
- Broadcast and multicast datagrams are bridged.

- Both VLAN-tagged and untagged datagrams are bridged.

SEA has the following characteristics:

- A Physical Ethernet adapter will not receive datagrams not addressed to itself. SEA puts the physical adapter in “promiscuous mode,” where it receives all packets seen on the wire.
- POWER Hypervisor will not give datagrams to a virtual Ethernet if they are not addressed to its MAC address. Virtual Ethernet adapters that belong to the SEA must be created as “trunk” adapters: when the hypervisor sees a datagram destined for a MAC address it does not know about, it gives it to the trunk adapter.
- SEA does IPv4 fragmentation when a physical adapter’s MTU is smaller than the size of a datagram.
- If the VIOS fails (crashes, hangs, or is rebooted), all communication between the virtual and the physical networks ceases. SEA can be placed in a redundant failover mode.

To avoid single points of failure, the SEA can be configured in *redundant failover mode*; see Figure 2-16. This mode is desirable when the external Ethernet network can provide high availability. Also, more than one physical adapter is needed at the POWER System.

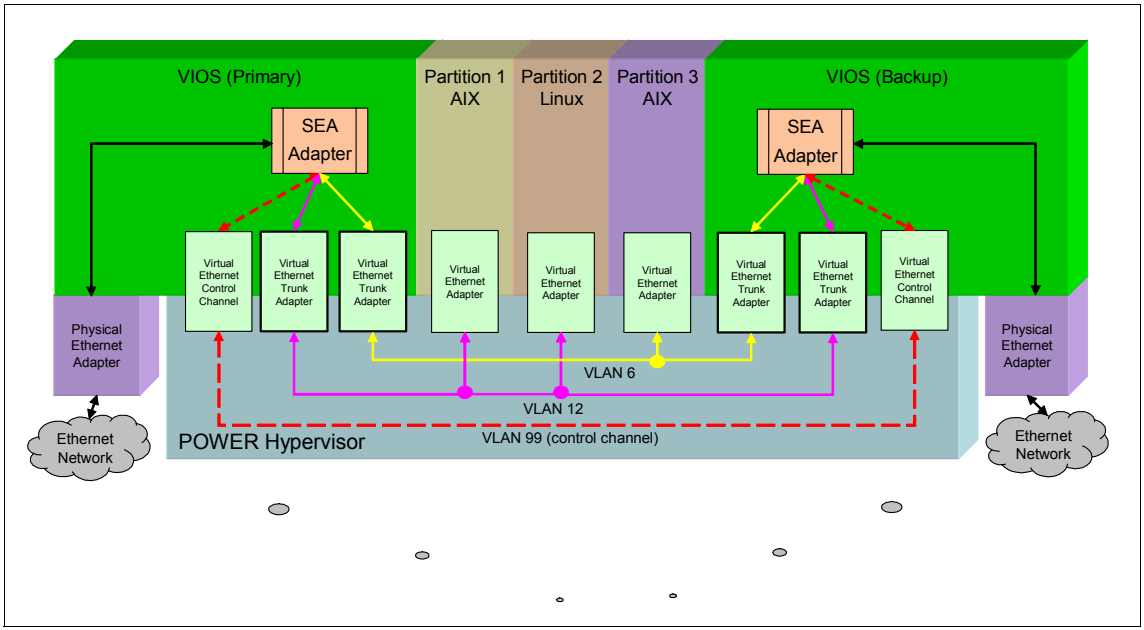

Figure 2-16 SEA in redundant failover mode

Primary and backup SEAs communicate through a control channel on a dedicated VLAN visible only internally to the POWER Hypervisor. A proprietary protocol is used between SEAs to determine which is the primary and which is the backup.

One backup SEA may be configured for each primary SEA. The backup SEA is idle until a failure occurs on the primary SEA; failover occurs transparently to client LPARs.

Failure may be due to:

- Physical adapter failure
- VIOS crash or hang or reboot
- Inability to ping a remote host (optionally)

Each SEA in a failover domain has a different priority. A lower priority means that an SEA is favored to be the primary. All virtual Ethernet adapters on an SEA must have the same priority. Virtual Ethernet adapters of primary and backup SEAs must belong to the same virtual switch.

SEAs also support EtherChannel (Cisco proprietary) and IEEE 802.3ad solutions, that is, several Ethernet adapters are aggregated to form one virtual adapter. The adapter aggregation is useful to address increased bandwidth demands between the server and network, or to improve resilience with the adjacent Ethernet network—especially when a Multichassis EtherChannel solution is implemented in the Ethernet network.

SEA supports four hash modes for EtherChannel and IEEE 802.3ad to distribute the outgoing traffic:

- Default mode - The adapter selection algorithm uses the last byte of the destination IP address (for TCP/IP traffic) or MAC address (for ARP and other non-IP traffic). This mode is typically the best initial choice for a server with a large number of clients.
- Src_dst_port - The outgoing adapter path is selected through an algorithm using the combined source and destination TCP or UDP port values: Average the TCP/IP address suffix values in the Local and Foreign columns shown by the **`netstat -an`** command.

  Since each connection has a unique TCP or UDP port, the three port-based hash modes provide additional adapter distribution flexibility when there are several separate TCP or UDP connections between an IP address pair. Src_dst_port hash mode is recommended when possible.
- src_port - The adapter selection algorithm uses the source TCP or UDP port value. In **`netstat -an`** command output, the port is the TCP/IP address suffix value in the Local column.

- Dst_prt - The outgoing adapter path is selected through an algorithm using the destination system port value. In **`netstat -an`** command output, the TCP/IP address suffix in the Foreign column is the TCP or UDP destination port value.

SEA supports a fifth hash mode, but it is only available in EtherChannel mode. When used, the outgoing datagrams are scheduled in a round-robin fashion, that is, outgoing traffic is spread evenly across all adapter ports. This mode is the typical choice for two hosts connected back-to-back (that is, without an intervening switch).

AIX supports a backup adapter capability for EtherChannel and 802.3ad. Network Interface Backup (NIB) is possible with two adapters (primary and backup).

2.3.9 IPv4 routing features

POWER System supports both static and dynamic routing protocols. Static IP routes can be added or deleted using the **`route`** command. AIX ships routed and gated, which implement IP routing protocols (RIP, OSPF, and BGP) and can update the routing table of the kernel. By default, IP routing is off but can be turned on.

AIX also supports IP Multipath Routing, that is, multiple routes can be specified to the same destination (host or net routes), thus achieving load balancing.

If the upstream IP network does not support First Hop Redundancy Protocol (FHRP)—such as Virtual Router Redundancy Protocol (VRRP), Hot Standby Router Protocol (HSRP), or Gateway Load Balancing Protocol (GLBP)—POWER System can use a Dead Gateway Detection (DGD) mechanism: If DGD detects that the gateway is down, DGD allows an alternative route to be selected. Using DGD in conjunction with IP multipathing, the platform can provide IP level load balancing and failover. DGD uses ICMP and TCP mechanisms to detect gateway failures. HSRP and GLBP are Cisco proprietary protocols.

AIX supports Virtual IP Address (VIPA) interfaces (vi0, vi1, and so on) that can be associated with multiple underlying interfaces. The use of a VIPA enables applications to bind to a single IP address. This feature can be used as failover and load balancing in conjunction with multipath routing and DGD.

Considerations

The following could be reasons for not using routing features at the server level:

- Troubleshooting and modifications of routing issues are more complex because the routing domain is spread over several administrators and thus will increase operational expenses.
- Routed and gated are not as advanced as commercial routing solutions. For example, IP fast rerouting mechanisms are not implemented in gated and routed.

An FHRP solution could be implemented in the Ethernet network devices so that servers do not participate in the routing domain at all, when possible. When a FHRP schema is implemented in the network, the server will have only a default gateway parameter configured—no other routing features are implemented at the server.

In POWER5, POWER6, and POWER7 machines, all resources are controlled by the POWER Hypervisor. The POWER Hypervisor ensures that any partition attempting to access resources within the system has permission to do so.

PowerVM has introduced technologies that allow partitions to securely communicate within a physical system. To maintain complete isolation of partition resources, the POWER Hypervisor enforces communications standards, as normally applied to external infrastructure communications. For example, the virtual Ethernet implementation is based on the IEEE 802.1q standard.

The IBM System p partition architecture, AIX, and the Virtual I/O Server have been security certified to the EAL4+ level. For more information, see:

`http://www-03.ibm.com/systems/p/os/aix/certifications/index.html`

More information about this section can be found in *PowerVM Virtualization on IBM System p: Introduction and Configuration Fourth Edition*, SG24-7940, and *IBM Power 770 and 780 Technical Overview and Introduction*, REDP-4639.

2.4 System x and BladeCenter virtualization

IBM offers a complete and robust portfolio built from client requirements across the industries. In System x and BladeCenter, enterprise-level technology standards are implemented. The products span a portfolio for any environment (small, medium, and enterprise) by covering a full range of servers from tower or rack servers designed to run single applications that can be implemented by itself or in extremely large installations to high-performance, enterprise servers and clusters and iDataPlex for HPC and cloud computing.

These products use Intel®-based chipsets. Both Intel and AMD have developed hardware technology that allows guest operating systems to run reliably and securely in this virtual environment.

x86 technology is probably the most widely used today. IBM System x servers support both Intel and AMD hardware virtualization assistance. System x servers are built with the IBM X-Architecture® blueprint, which melds industry standards and innovative IBM technology. Some models even include VMware embedded in hardware to minimize deployment time and improve performance.

IBM System x and BladeCenter are now part of the IBM CloudBurst™ offering (see 2.8.2, “CloudBurst”), so these platforms are also available as integrated modules for a cloud data center.

2.4.1 Benefits of virtualization

The System x and BladeCenter portfolio is designed to deliver the benefits of a dynamic infrastructure. X-Architecture servers and tools such as Systems Director reduce costs by delivering lower operating expenses and increased utilization. X-Architecture builds resilient systems and offers management tools to simplify infrastructure management. Especially in the small and medium market, where clients often have limited rack space and facilities resources, x86 and BladeCenter virtualization allows them to consolidate multiple servers into one (System x or BladeCenter) platform.

The following are some important benefits of virtualization that can be achieved with System x and BladeCenter:

- Optimize and lower the costs (CAPEX and OPEX) due to:
  - A higher degree of server utilization
  - Reduced power and cooling costs
  - Simpler, more comprehensive server management
  - Reliability and availability to minimize downtime
- IBM x3850 M2 and x3950 M2 servers deliver consolidation and virtualization capabilities, such as:
  - IBM X-Architecture and eX4 chipsets are designed for virtualization.
  - Scales easily from 4 to 16 sockets.
- IBM BladeCenter provides end-to-end blade platform for virtualization of client, server, I/O, networking, and storage.
- IBM Systems Director enables new and innovative ways to manage IBM Systems across a multisystem environment, improving service with integrated

systems management by streamlining the way physical and virtual systems are managed.

  - Unifies the management of physical and virtual IBM systems, delivering a consistent look and feel for common management tasks.
  - Multisystem support for IBM Power Systems, System x, BladeCenter, System z, and Storage Systems.
  - Reduced training cost by means of a consistent and unified platform management foundation and interface.

- Full integration of Virtualization Manager into IBM Systems Director 6.1 base functionality:
  - Consolidate management for different virtualized environments and tools includes VMware ESX, Microsoft Virtual Server and Xen virtualization, as well as Power Systems Hardware Management Console (HMC) and Integrated Virtualization Manager (IVM).
  - Track alerts and system status for virtual resources and their resources to easily diagnose problems affecting virtual resources.
  - Perform lifecycle management tasks, such as creating additional virtual servers, editing virtual server resources, or relocating virtual servers to alternate physical hosts.
  - Get quick access to native virtualization management tools through launch-in-context.
  - Create automation plans based on events and actions from virtual and physical resources, such as relocating a virtual server.
- IBM System Director integration with VMware Virtual Center
  - VMware VirtualCenter client is installed on the management console and VMware VirtualCenter server is installed on a physical system with:
    - IBM Systems Director Agent
    - Virtualization Manager Agent for VMware VirtualCenter
  - Drive VMware VMotion using physical hardware status information through automated policies.

2.4.2 Hardware support for full virtualization

For industry standard x86 systems, virtualization approaches use either a hosted or a hypervisor architecture. A hosted architecture installs and runs the virtualization layer as an application on top of an operating system and supports the broadest range of hardware configurations.

In contrast, a hypervisor (bare-metal) architecture installs the virtualization layer directly on a clean x86-based system. Since it has direct access to the hardware resources rather than going through an operating system, theoretically a hypervisor is more efficient than a hosted architecture and delivers greater scalability, robustness and performance. ESX Server, for example, employs a hypervisor architecture on certified hardware for data center class performance; the hypervisor runs directly on the hardware.

The functionality of the hypervisor varies greatly based on architecture and implementation. Each virtual machine monitor (VMM) running on the hypervisor implements the virtual machine hardware abstraction and is responsible for running a guest operating system. Each VMM has to partition and share the processor, memory, and I/O devices to successfully virtualize the system.

Hardware support for virtualization on x86 systems is provided by Intel or AMD. In the past, limitations of the x86 architecture have posed some issues with virtualization. Both Intel and AMD have made improvements that overcome many of these limitations. VMware is currently utilizing all of these x86 virtualization techniques. Virtualization for the x86 architecture is essentially full virtualization architecture with hardware-assisted technology to overcome some of the limitations of full virtualization.

2.4.3 IBM BladeCenter

IBM BladeCenter technology places physical “server blades” in a chassis design with “service blades” such as connectivity services. This architecture allows both physical and virtual separation of operating systems. It provides a reduced footprint in the data center. Additionally, a hypervisor such as VMware or KVM can provide further virtualization on each blade.

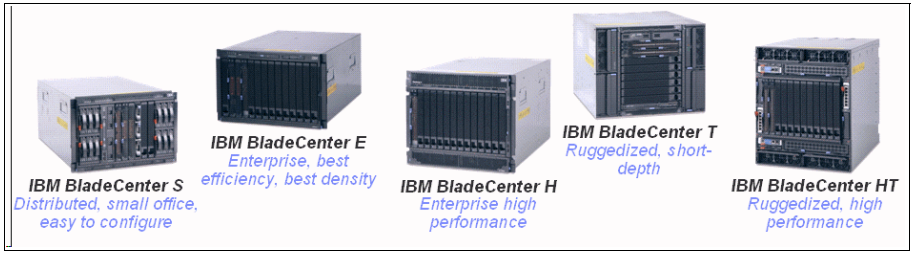

Figure 2-17 IBM BladeCenter portfolio

The combined characteristics of extremely compact, mature, manageable, flexible, green, open, and scalable make the IBM BladeCenter family of products a very attractive solution for server virtualization and consolidation initiatives. For

more information about the IBM BladeCenter, refer to the IBM BladeCenter Products and Technology Redbooks publication, which can be found here:

http://www.redbooks.ibm.com/abstracts/sg247523.html?Open

The IBM blade technologies cover a very broad spectrum in the market by including Intel, AMD, POWER servers, and Cell BE blades. This allows great flexibility for using disparate workloads.

The IBM BladeCenter chassis portfolio (shown in Figure 2-17 on page 74) is designed for different customer needs:

- BladeCenter S - For SMBs or remote locations
- BladeCenter E - High density and energy efficiency for the enterprise
- BladeCenter H - For commercial applications, high-performance computing (HPC), technical clusters, and virtualized enterprise solutions needing high throughput
- BladeCenter HT - For telecommunications and rugged environments that require high performance and flexible I/O
- BladeCenter T - For telecommunications and rugged environments such as military, manufacturing, or medical

The IBM BladeCenter network hardware supports 1 Gbps and 10 Gbps native Ethernet or the new converged enhanced Ethernet. Blade servers can have several 10 Gbps converged network adapters or just 1-Gbps Ethernet adapters.

Switches can be from several vendors such as BNT, Brocade or Cisco and can also be legacy Ethernet (1 or 10 Gbps) or 10-Gbps FCoE switches with up to 10 10-Gbps uplink ports each. Each H chassis, for example, can have up to four switches, which represents up to 400 Gbps full-duplex.

All this hardware is standards-based, so standard switches (IBM, Juniper, Brocade, or Cisco) can be used for connecting the BladeCenter switches, thereby eliminating the need to buy special proprietary switches.

IBM BladeCenter also has the following storage options available, external or internal, including internal Solid® State Drives:

- External storage: NAS, FC SAN, iSCSI SAN, SAS SAN
- Internal storage: Solid state (SSD), Flash, SAS, SATA

Characteristics of Solid State Drives include:

- More than twice the MTBF of conventional drives.
- Optimized for disk mirroring.
- Reduced power consumption compared to conventional drives.
- Despite smaller capacity, the performance advantage is significant and solves some previous speed bottlenecks.

IBM also supports RAID 5 and battery-backed cache configurations through the use of an optional ServeRAID-MR10e controller.

Hardware address virtualization: BladeCenter Open Fabric manager

The BladeCenter Open Fabric enables virtualization of hardware addresses across the BladeCenter and can manage up to 100 chassis or 1400 blades. Both Ethernet NICs and MAC addresses can be assigned dynamically. For Fiber Channel SAN, the world-wide name (WWN) can be assigned dynamically. This technology enables these critical addresses to follow the virtual machine when that machine is reprovisioned on another physical device.

The server can also be booted from the SAN, which further virtualizes the operating system from the physical device.

Blade Open Fabric Manager (BOFM) is also useful when replacing failed blades. After replacement the switch tables are unchanged and any other configuration depending on the MAC address or the WW name is unaffected. In addition, installations can be preconfigured before plugging in the first blade.

Hardware virtualization: Virtual Fabric

The Virtual Fabric for IBM BladeCenter is a fast, flexible, and reliable I/O solution that helps virtualize I/O. This new and innovative fabric can be multiple fabrics by port at the same time. To use Virtual Fabric, a virtual fabric adapter is needed in the blade and a Virtual fabric-enabled switch is needed in the BladeCenter.

By using the Virtual Fabric solution, the number of ports on the Virtual Fabric adapter can quadruple, while at the same time reducing switch modules by up to 75%. Characteristics that are leveraged by this technology include:

- Multiple virtual ports and protocols (Ethernet, FCoE, and iSCSI) from a single physical port.
- Up to 8 virtual NICs or mix of vNICs and vCNA per adapter.
- Each virtual port operates anywhere between 100 Mb to 10 Gb and can run as Ethernet, FCoE, or iSCSI.
- Shared bandwidth across multiple applications.
- Support of vendor-branded switches.

For more information about the Virtual Fabric, refer to *IBM BladeCenter Virtual Fabric Solutions*, REDP-4673, which can be found here:

`http://www.redbooks.ibm.com/abstracts/redp4673.html?Open`

2.5 Other x86 virtualization software offerings

Today, IBM server virtualization technologies are at the forefront of helping businesses with consolidation, cost management, and business resiliency.

Virtualization was first introduced by IBM in the 1960s to allow the partitioning of large mainframe environments. IBM has continued to innovate around server virtualization and has extended it from the mainframe to the IBM Power Systems, IBM System p, and IBM System i product lines. In the industry-standard environment, VMware, Microsoft Hyper-V, and Xen offerings are for IBM System x and IBM BladeCenter systems.

With server virtualization, multiple virtual machines (VMs) can be created on a single physical server. Each VM has its own set of virtual hardware on which the guest operating systems and applications are loaded. There are several types of virtualization techniques to help position the relative strengths of each and relate them to the systems virtualization offerings from IBM.

In the x86 server environment, virtualization has become the standard. First by consolidating the number of underutilized physical servers into virtual machines that are placed onto a smaller number of more powerful servers, resulting in cost reduction in the number of physical servers and environmental usage (electrical power, air conditioning and computer room floor space). Secondly, by encapsulating the x86 server into a single logical file, it becomes easier to move this server from one site to another site for disaster recovery purposes. Besides the x86 servers being virtualized, the next virtualization environment being undertaken is the desktops.

There has been significant work to introduce virtualization to Linux in the x86 markets using hypervisor technology. Advantages to Linux-based hypervisor include:

- The hypervisor has the advantage of contributions from the entire open source communities, not just related to one vendor (Open Sources Solutions).
- Currently Linux supports a very large base of hardware platforms, so it is not limited to just the platforms certified by a single vendor. Also, as new technologies are developed, a Linux-based hypervisor can take advantage of these technologies, such as iSCSI, InfiniBand, 10 Gig Ethernet, and so forth.

The rise of Linux in the IT world, from an interesting academic exercise to a popular platform for hosting enterprise applications, is changing the way enterprises think about their computing models.

2.5.1 Xen

Xen originated as a research project at the University of Cambridge, led by Ian Pratt, founder of XenSource, Inc., and developed collaboratively by the Xen community spearheaded by XenSource and engineers at over 20 of the most innovative data center solution vendors, with IBM second only to Citrix as the most active contributor. The first public release of Xen was made available in 2003. XenSource, Inc. was acquired by Citrix Systems in October 2007. XenSource's products have subsequently been renamed under the Citrix brand: XenExpress was renamed XenServer Express Edition and XenServer OEM Edition (embedded hypervisor), XenServer was renamed XenServer Standard Edition, and XenEnterprise was renamed XenServer Enterprise Edition. The Xen project website has been moved to:

http://xen.org

Although Xen was owned by XenSource, the nature of Open Source software ensures that there are multiple forks and distributions, many released by other vendors, apart from Citrix. In fact Virtual Iron, OracleVM, and Sun xVM are all based on Xen. Red Hat Inc. includes the Xen hypervisor as part of Red Hat Enterprise Linux (RHEL) software.[1] At the time of writing, Xen Server v5.5 is the most widely supported version.

Xen is a Type 1 *hybrid hypervisor*. It uses both paravirtualization and full virtualization with device emulation (QEMU[2]) and/or hardware assistance. With paravirtualization, the guest's operating system (Solaris, SLES, RHEL, or FreeBSD) has to be modified to run on Xen. Together with QEMU, it can also provide support for the Windows operating system, which cannot be modified by third parties to support paravirtualization techniques. Figure 2-18 on page 79 displays an overview of Xen.

Xen allows paravirtual guests to have direct access to I/O hardware. The scheduler is optimized to support virtual machine guests. I/O overhead is reduced in Xen, as compared to full virtualization techniques.

On the other hand, hardware assistance technology processes today offer better performance than paravirtualization. Since the release of Xen Server 3.0, hardware-assisted virtualization has been supported through the use of the Intel VTx and AMD AMD-V, integrated into modern x86/x64 processors.

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[1] Red Hat is taking two directions. Although its current portfolio is built around the Xen hypervisor, it seems RH's strategic route will be KVM. Actually, Red Hat is supporting both the paravirtualized version and the full virtualized version. The latest requires hardware support (Intel VT-x or AMD Pacifica).

[2] QEMU is a community-driven project and all Open Source hypervisors exploit it. It can emulate nine target architectures on 13 host architectures and provide full system emulation supporting more than 200 devices.

Windows hosted on XenServer products is supported by Microsoft; the collaboration between Microsoft and Citrix is focused on driving industry standards within virtualization. This extends to interoperability between Microsoft and Xen guests, allowing the optional Citrix Essentials package to enable dynamic virtual machine migration between Microsoft Hyper-V and Citrix XenServer.

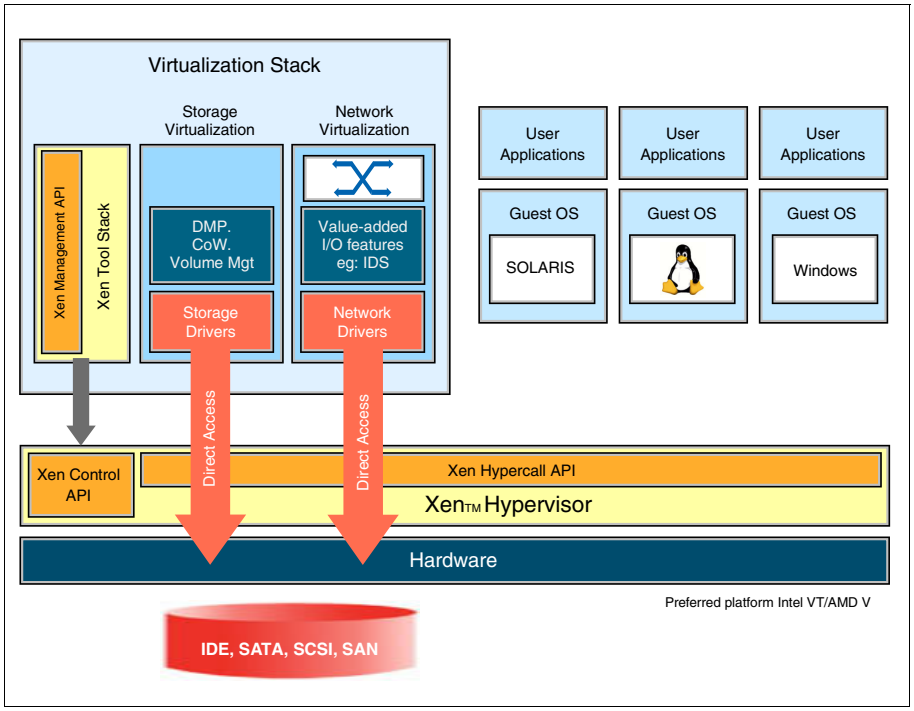

Figure 2-18 Xen overview

From a network perspective, Xen requires an extended Layer 2 topology to allow virtual machine mobility (XenMotion). When the movement has occurred, the switching infrastructure expects the VM's MAC to be reachable through a specific interface, which has now changed.

To update the external devices, the destination host sends a gratuitous ARP packet as the last step of the migration. Spanning tree protocol should not be a problem because loops are automatically prevented inside the hypervisor. Citrix Xen Server 5.5 supports up to 6 physical Ethernet NICs per physical server. Physical NICs can be bonded in XenServer so that they could act like one.

Citrix XenServer v5.5 runs the Xen 3.3 kernel. The Xen 4.0 kernel is expected to incorporate networking-related features such as VLAN tagging per NIC in the VM Configuration File and a Virtual Ethernet Switch.

Currently, XenServer uses virtual Ethernet bridging to allow VMs to communicate among each other and to share a physical NIC among many virtual NICs, assigned to the running VMs. MAC address assignments can be randomly assigned or allocated by the administrator. On the internal network, the bridge will be allocated a unicast MAC address, which is FE:FF:FF:FF:FF:FF, while on the external network the bridge will share the MAC address of the physical NIC. Ethernet frames coming from the outside to a specific VM arrive properly because the NIC has to be set in promiscuous mode. When VLANs are enabled (the link to the physical access layer is a trunk), every distinct VLAN will have its own bridge.

Security is provided basically by keeping the guest operating systems separated. Note the following considerations:

- It is critical to partition the memory for each guest operating system so that each VM has its dedicated memory. The VM monitor keeps all guests in their dedicated memory sandbox.
- Assure that there is no memory sharing when partitioning I/O devices are to be shared across different guests.
- Set the appropriate privilege hierarchy. Only the root user can start and stop guests and run management tasks and scheduling priority.
- Partitioning should prevent denial of service (DoS) attacks if, for example, there is a bug in a guest. The VM monitor needs to make sure that this will not affect the other guests.

From a management perspective, Xen has its own kernel, so it uses a separate VM monitor. Being a root user is not needed to monitor a guest to see how it is performing. Xen is the first thing that comes up in the machine. Then Xen loads its first Linux operating system (Domain 0).

IBM supports both the management tools and the VM image packaging.

2.5.2 KVM

Kernel-based Virtual Machine (KVM) is a Linux kernel module that turns Linux into a hypervisor; this is known as *Linux-based virtualization*. It requires hardware virtualization assistance (Intel VT-x or AMD Pacifica). It consists of a loadable kernel module, kvm.ko. This module provides the core virtualization infrastructure and a processor-specific module, kvm-intel.ko or kvm-amd.ko.

KVM development, which has been carried out since 2006 by the start-up Qumranet, originated with the effort of trying to find an alternative to Xen that could overcome some limitations such as support for NUMA computing architectures. Originally, KVM was intended as a base technology for desktop virtualization and was never intended to be a stand-alone hypervisor. The KVM original patchset was submitted in October 2006. It has been included in the Linux kernel since then and Kumranet was acquired by Red Hat Inc. in September 2008. RHEV[3] from Red Hat incorporates KVM. For more information about this subject, visit the following site:

http://www.linux-kvm.org/

Without QEMU, KVM is not a hypervisor. With QEMU, KVM can run unmodified guest operating systems (Windows, FreeBSD, or Linux). The emulation has very good performance (near-native) because it is supported by the hardware.

KVM can run on any x86 platform with a Linux operating system running. The first step is to boot Linux. Then the virtual machines (VMs) are seen as Linux processes, which can be assigned with a different scheduling priority. Figure 2-19 on page 82 displays an overview of KVM.

KVM is not a hosted hypervisor. Instead, it uses the hardware to get control of the machine. No modifications to the Linux operating system are required (in upstream Linux). In fact, Linux provides essential services (hardware support, bootstrap memory management, process management and scheduling, and access control), and KVM becomes a loadable module. It is essentially a CPU/MMU driver.

Moreover, running under a Linux kernel allows for not only physical but also virtual memory paging and oversubscription. Recently (accepted for inclusion in the Linux kernel 2.6.32 release) the Kernel Samepage Merging (KSM) feature has been added. By looking for identical pages and merging them, this provides the memory overcommit capabilities to make efficient usage of the available physical memory and achieve more VMs per host and thus higher consolidation ratios.

KVM introduces a new instruction execution mode known as Guest Mode. Usually applications run in User Mode, and an application goes into Kernel Mode when certain system operations are needed, such as writing on the hard drive. KVM Guest Mode processes are run from the VMs. This allows the execution of the VMs to occur closer to the kernel, thereby avoiding User Mode context-switching.

[3] RHEV is short for Red Hat Enterprise Virtualization, which is a distribution from Red Hat that is comprised of two components: RHEV-H and RHEV-M. RHEV-H (or Red Hat Enterprise Virtualization Hypervisor) is based on the KVM open source hypervisor. RHEV-M is Red Hat Enterprise Virtualization Manager, an enterprise grade server management system.

A slightly modified QEMU is used for I/O. VirtIO is an API for Virtual I/O that implements network and block driver logic. The goal behind VirtIO is to provide a single driver abstraction layer for multiple hypervisors instead of maintaining several drivers for all the different hypervisors. In fact, VirtIO uses User Mode VirtIO drivers to emulate storage and network I/O to maximize performance. This approach is called paravirtualized I/O. The different instruction execution modes in KVM are highlighted in Figure 2-19.

To overcome the limits of the paravirtualized I/O approach, KVM can leverage hardware-assisted virtualization for PCI pass-through on Intel and AMD platforms and SR-IOV adapters for hypervisor-bypass, making it possible to obtain near-native I/O performance.

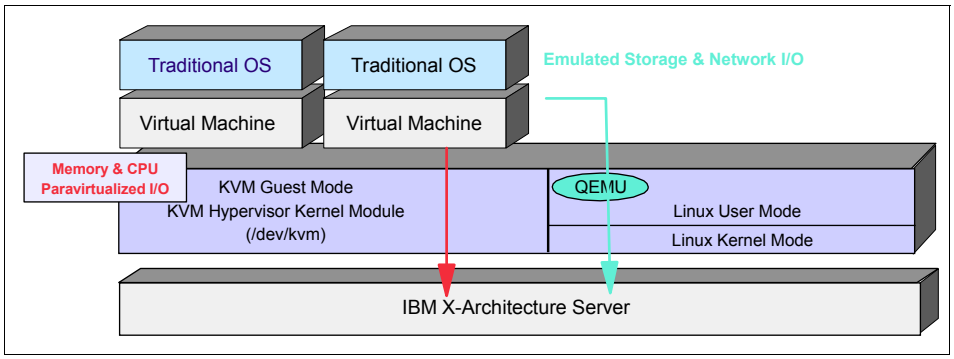

Figure 2-19 KVM overview

From a network perspective, KVM requires an extended Layer 2 topology to allow virtual machine mobility. Spanning tree protocol should not be a problem because loops are automatically prevented inside the hypervisors. Linux management tools can be used to manage KVM. KVM supports VLANs in the same way that the Linux kernel supports them.

These technologies reduce the overhead on the VM monitor through extended page table support. Moreover, KVM supports virtual machine mobility.

With regard to virtual networking (or guest networking), KVM internal network can be configured in different modes[4]:

- User Networking - The VM simply accesses the external network and the Internet.
- Private Virtual Bridge - A private network between two or more VMs that is not seen by the other VMs and the external network.

[4] Excerpt from http://www.linux-kvm.org/page/Networking

- Public Bridge - The same as Private Virtual Bridge, but with external connectivity.

KVM can also be seen as a virtualization driver, and in that sense it can add virtualization support of multiple computing architectures, and it is not confined only to the x86 space: IA64, S390, and Embedded PowerPC®.

IBM supports KVM in terms of management tools, VM image packaging, and hardware platforms (System x, BladeCenter, and System z).

KVM permits hybrid mode operation; regular Linux applications can run side-by-side with VMs, achieving a very high rate of hardware efficiency. Moreover, being based on Linux, KVM supports all the hardware that Linux supports. VM Storage access, for example, is performed through Linux.

KVM uses Linux and is a self-contained, non-intrusive patchset. IBM supports RHEL 5.4 with KVM in production environments today, and will continue to work with clients and others to enhance KVM over time.

2.5.3 VMware vSphere 4.1

VMware vSphere 4.1 is an infrastructure virtualization suite that provides enterprise clients with:

- Virtualization capabilities for x86 platforms using ESX or ESXi
- Management for this environment using vCenter
- Resource optimization using dynamic resource scheduler
- Application availability using high availability and fault tolerance
- Operational automation capabilities

The VMware vSphere component can be summarized in Figure 2-20 on page 84.

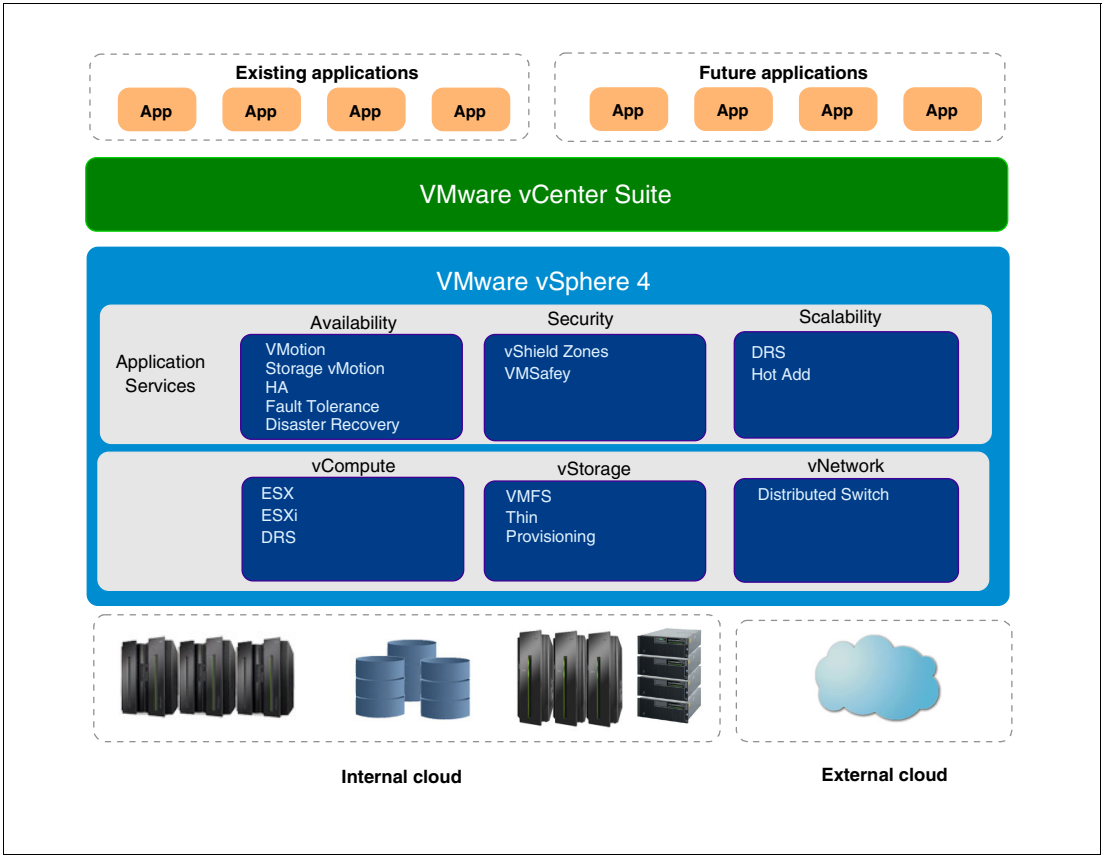

Figure 2-20 VMware vSphere Components

The vSphere 4 kernel has been developed for 64-bit processors. Also, vSphere utilizes the virtualization acceleration feature on microprocessors, such as Intel VT and AMD-V. This will enhance virtualization performance and scalability compared with ESX Version 3, which is built as 32 bit and software-based.

vSphere virtualizes and aggregates the underlying physical hardware resources across multiple x86 servers providing pools of virtual resources to the data center. vSphere is a hypervisor-based solution that is installed on the bare metal of the x86 server and creates an abstraction layer between the physical CPU, memory, storage, and network to the virtual machines. [5]

There are two types of vSphere software. The vSphere ESX software has a service console that is compatible with Red Hat Enterprise Linux (RHEL) 5.2.

[5] VMware, Introduction to VMware vSphere, EN-000102-00, http://www.vmware.com/pdf/vsphere4/r40/vsp_40_intro_vs.pdf

Third-party applications can be installed into the service console to provide additional management for the ESX server.

The other type is called ESXi; it does not have a service console. VMware has published a set of APIs that can be used by third parties to manage this environment. This environment is deemed more secure by not having this Linux environment to maintain. ESXi is maintained using the VMkernel interface.

Figure 2-4 on page 85 describes some of the performance and capacity enhancements of vSphere as it relates to virtual machines and the network.

Table 2-4 Performance and capacity enhancements of vSphere

Maximum	ESX 3.5	ESX 4.1
Number of processors per VM	4	8
Memory per VM	64 GB	255 GB
Network throughput per Host	9 Gbps	40 Gbps
IOPS per Host	100,000	200,000+

ESX overview

All virtual machines (VMs) run on top of the VMkernel and share the physical resources. VMs are connected to the internal networking layer and gain transparent access to the ESX server. With virtual networking, virtual machines can be networked in the same way as physical machines. Figure 2-21 on page 86 shows an overview of the ESX structure.

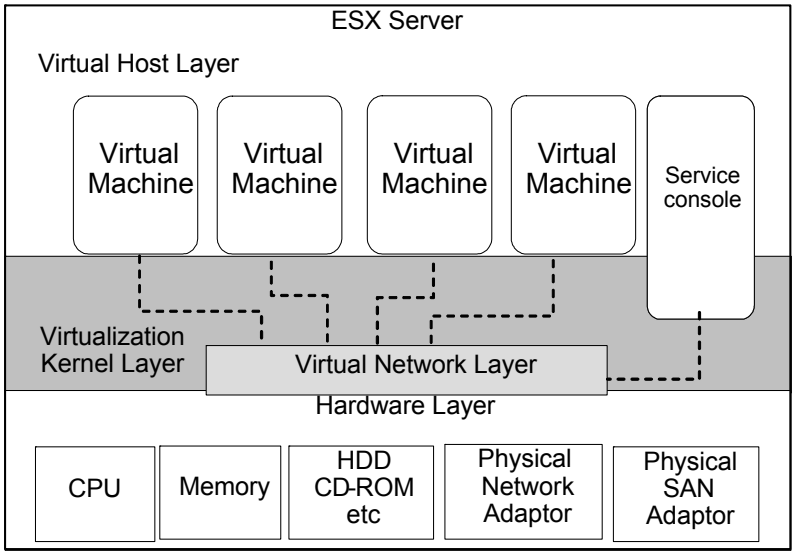

Figure 2-21 Overview of the ESX structure

vSphere vNetwork overview

ESX/ESXi (whenever ESX is referenced in this document, it includes ESXi) has its own internal networking layer, the virtual switch architecture, which mirrors that used in a physical environment.

There are similarities and differences between virtual switches and physical switches. There are two types of virtual switches: vNetwork Standard Switch (vSS) and the vNetwork Distributed Switch (vDS). The vSS is configured at the ESX host level, whereas the vDS is configured at the vCenter level and functions as a single virtual switch across the associated ESX hosts.

vNetwork Standard Switch overview

The vNetwork Standard Switch is referred to here as the vSwitch or virtual switch. The elements of a virtual switch are as follows:

- Virtual switch

  This is the internal switch inside the ESX server. You can configure up to 248 virtual switches per ESX server. A virtual switch has Layer 2 forwarding capability and has virtualized ports and uplink ports. Virtual switches combine the bandwidth of multiple network adapters and balance communication traffic between them. They can also be configured to handle physical NIC failover. There is no need for each VM to have its own failover configuration.

- Virtual NIC

  Virtual NIC, also called Virtual Ethernet Adapter, is a virtualized adapter that emulates Ethernet and is used by each VM. Virtual NIC has its own MAC address, which is transparent to the external network.

- Virtual switch port

  A virtual port corresponds to a physical port on a physical Ethernet switch. A virtual NIC connects to the port that you define on the virtual switch. The maximum number of virtual switch ports per ESX server is 4096. The maximum number of active ports per ESX server is 1016.

- Port group

  A port group specifies port configuration options such as bandwidth limitations and VLAN tagging policies for each member port. The maximum number of port groups per ESX server is 512.

- Uplink port

  Uplink ports are ports associated with physical adapters, providing a connection between a virtual network and a physical network.

- Physical NIC

  Physical NIC is a physical Ethernet adapter that is installed on the server. The maximum number of physical NICs per ESX server varies depending on the Ethernet adapter hardware.

Figure 2-22 on page 88 shows an overview of how ESX virtual network components relate to each other.

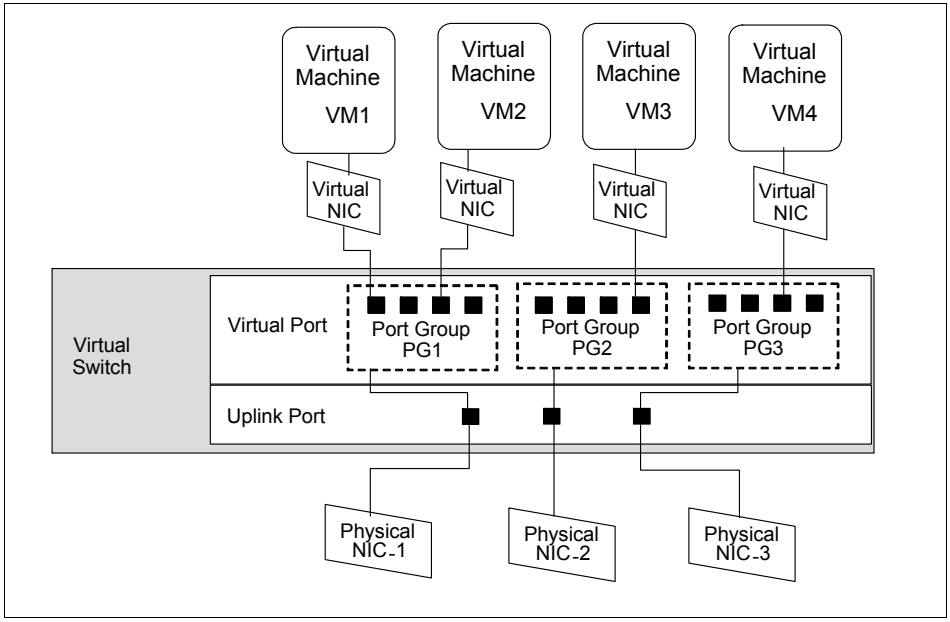

Figure 2-22 Relationship of VMware ESX virtual network components

Difference between a virtual switch and a physical switch

A virtual switch maintains a MAC address and port forwarding table, and forwards a frame to one or more ports for transmission, just as a physical switch does. A virtual switch does not have Layer 3 functionality.

A single-tier networking topology is enforced within the ESX server. In other words, there is no way to interconnect multiple virtual switches except through a virtual firewall or router. Thus, the ESX network cannot be configured to introduce loops. Because of this, the virtual switch on the ESX host does not support the Spanning Tree Protocol (STP).

No private VLANs are supported on a virtual switch. However, there is support on a virtual distributed switch.

VLAN tagging

802.1Q tagging is supported on a virtual switch. There are three types of configuration modes:

- Virtual switch tagging (VST)

  Define one port group on a virtual switch for each VLAN, then attach the virtual machine's virtual adapter to the port group instead of to the virtual switch directly. The virtual switch port group tags all outbound frames and

removes tags for all inbound frames. It also ensures that frames on one VLAN do not leak into a different VLAN. Use of this mode requires that the physical switch provide a trunk. This is the most typical configuration.

- Virtual machine guest tagging (VGT)

  Install an 802.1Q VLAN trunking driver inside the virtual machine, and tags will be preserved between the virtual machine networking stack and external switch when frames are passed from or to virtual switches.

- External switch tagging (EST)

  Use external switches for VLAN tagging. This is similar to a physical network, and a VLAN configuration is normally transparent to each individual physical server.

QoS

The virtual switch shapes traffic by establishing parameters for three outbound traffic characteristics: Average bandwidth, burst size, and peak bandwidth. You can set values for these characteristics for each port group. For the virtual Distributed Switch, the same traffic classifications can be placed on the inbound traffic.

High availability

In terms of networking, you can configure a single virtual switch to multiple physical Ethernet adapters using NIC teaming. A team can share the load of traffic between physical and virtual networks and provide passive failover in the event of a hardware failure or a network outage. You can set NIC teaming policies (virtual port ID, source MAC hash, or IP hash) at the port group level. High availability of VM is described later in this section.

Examples of virtual switch configuration

Figure 2-23 on page 90 shows an example of a virtual switch configuration of a server that has four physical NICs. VMware recommends that the ESX administration network and VMotion must be separated from other VMs. VMware recommends that dedicated 1-Gbps interfaces be assigned to VMotion. Physical NIC teaming can be configured on a virtual switch. Redundancy configuration on each VM is not required.

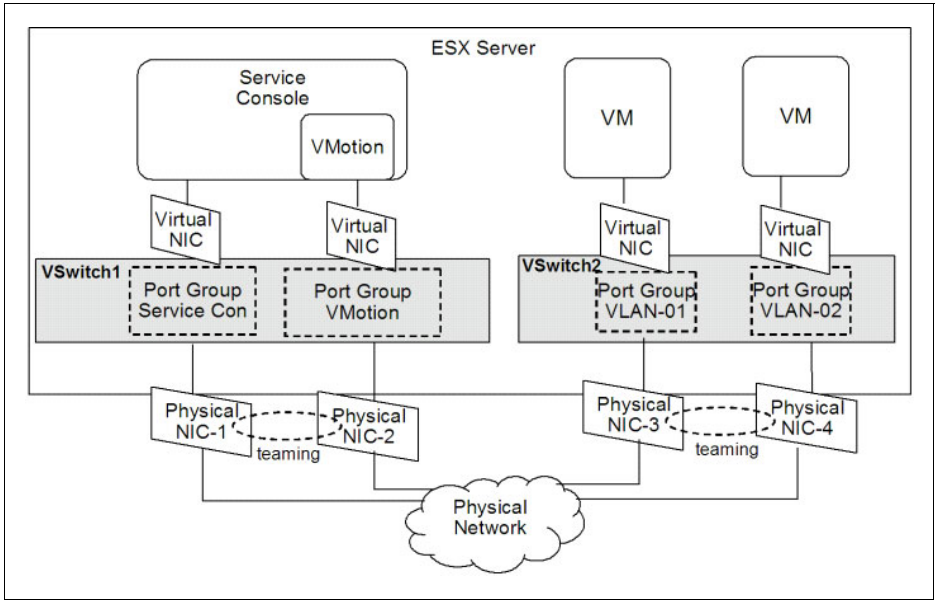

Figure 2-23 Virtual switch configuration of a server with four physical NICs

vNetwork Distributed Switch (vDS)

As discussed in "vSphere vNetwork overview" on page 86, vSphere has two types of virtual switches. The vNetwork Standard Switch (vSS) has already been discussed, and the new vNetwork Distributed Switch (vDS).

The distributed switch is an enhancement of the standard switch. In the distributed switch, the vCenter server stores the state of distributed virtual network ports in the vCenter database. Networking statistics and policies migrate with virtual machines when moved from host to host. With a vNetwork Standard Switch, when a vMotion is performed, the networking statistics are not kept with the virtual machine, they are reset to zero.

Figure 2-24 on page 91 shows an overview diagram of vDS. The vDS is really a vSS with additional enhancements. Virtual port groups are associated with a vDS and specify port configuration options for each member port. Distributed virtual port groups define how a connection is made through the vDS to the network. Configuration parameters are similar to those available with port groups on standard switches. The VLAN ID, traffic shaping parameters, port security, teaming, the load balancing configuration, and other settings are configured here.

Virtual uplinks provide a level of abstraction for the physical NICs (vmnics) on each host. NIC teaming, load balancing, and failover policies on the vDS and

virtual port Groups are applied to the uplinks and not the vmnics on individual hosts. Each vmnic on each host is mapped to virtual uplinks, permitting teaming and failover consistency, irrespective of vmnic assignments.

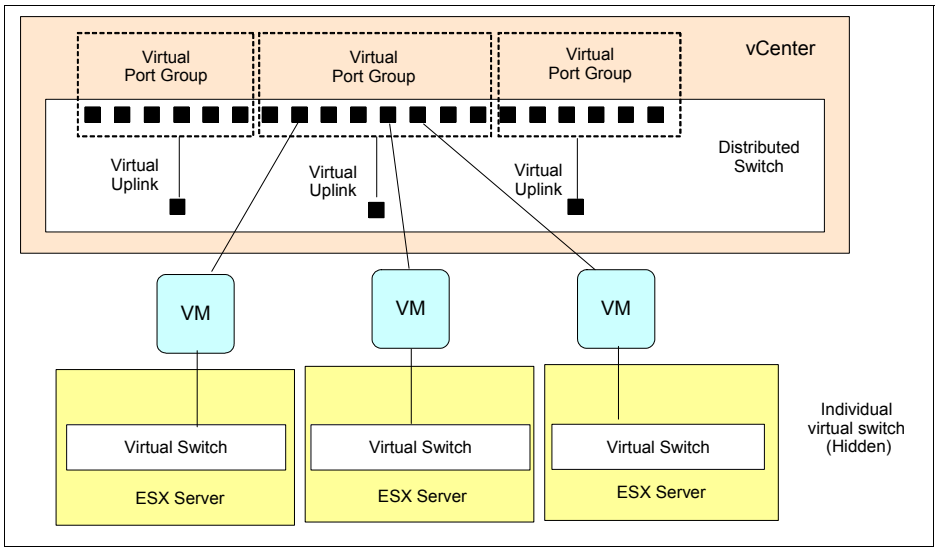

Figure 2-24 vDS overview

With vCenter management, the distributed switch is configured like a logical single switch that combines multiple virtual switches on different ESX servers. vDS does not provide switch-to-switch interconnection such as STP.

Access to corresponding VLANs should be prepared by physical network layers prior to configuring the vDS. Uplinks on each vDS should be in the same broadcast domain. Consider vDS as a template for the network configuration.

Other new features with vDS

The distributed switch enhances the standard switch. vDS provides bidirectional traffic shaping. The previous version and the standard switch can control outbound bandwidth only. The distributed switch also provides private VLANs, which isolates ports within the same VLAN.

IPv6 support for guest operating systems was introduced in VMware ESX 3.5. With vSphere, IPv6 support is extended to include the VMkernel and service console, allowing IP storage and other ESX services to communicate over IPv6.

Nexus 1000V

VMware provides the Software Development Kit (SDK) to third-party partners to create their own plug-in to distributed virtual switches. Nexus 1000V is one of the

third-party enhancements from Cisco. After 1000V is installed, it acts as substitution for the virtual Distributed Switch.

Note the following major differences:

- Switching function
  - Virtual port channel
  - Link Aggregation Control Protocol (LACP)
  - Load balancing algorithm enhancement, source and destination MAC address, IP address, IP port and hash
- Traffic control
  - DSCP and ToS marking
  - Service Class (CoS)
- Security
  - Access control list
  - DHCP snooping
  - Dynamic ARP inspection (DAI)
- Management
  - Same command line interface (CLI) as other Cisco devices
  - Port analyzer (SPAN and ERSPAN)
  - Netflow v9 support
  - RADIUS and TACCS support

Nexus 1000V has two major components: the Virtual Ethernet Module (VEM) running on each ESX hypervisor kernel, and, as in vDS, a Virtual Supervisor Module (VSM) managing multiple clustered VEMs as a single logical switch. VSM is an appliance that is integrated into vCenter management.

Cisco implements VN-Link on both Nexus 1000v and other Nexus hardware switch. VN-Link offloads switching function from the virtual switch. It defines association with virtual NIC and virtual port called VNtag ID. For more information about VN-Link, see:

`http://www.cisco.com/en/US/netsol/ns894/index.html`

Communications between VMs are processed on an external hardware switch even if those VMs are on the same segment on the same virtual switch. Currently, this function is Cisco proprietary; Nexus 1000v and Cisco Nexus 2000/4000/5000 are required. Cisco has proposed this technology to IEEE.

There are other, similar technologies. Virtual Ethernet Port Aggregator (VEPA) and Virtual Ethernet Bridging (VEB), which can offload switching function from a virtual switch, are also proposed to IEEE.

Security and management

VMware provides integrated management tools called the VMware vSphere vCenter management server. Using vCenter, you can provision virtual machines and monitor performance of physical servers and virtual machines. VMware vCenter is the administrative interface to configure the Dynamic Resource Scheduler (DRS) and High Availability (HA). The HA process itself is handled by ESX servers, independently from vCenter. In case of a vCenter failure, HA still functions. Within each cluster, up to five “masters” are elected to govern this.

Support for dynamic environments

There are a few unique VMware technologies to support dynamic environments. One of these is Dynamic Resource Scheduling (DRS). To understand DRS it is important to grasp the concepts of *clusters* and *resource pools*. The balancing of resources is handled by the DRS function. DRS leverages VMware VMotion technology.

Clusters and resource pools

A cluster is a set of loosely connected ESX hosts sharing the same resources (memory, processors, storage, and network). A resource pool is used to subdivide clusters into pools with different characteristics (for example, different service levels, production, or development, and so on). Figure 2-25 shows an overview of the concept of clusters and resource pools.

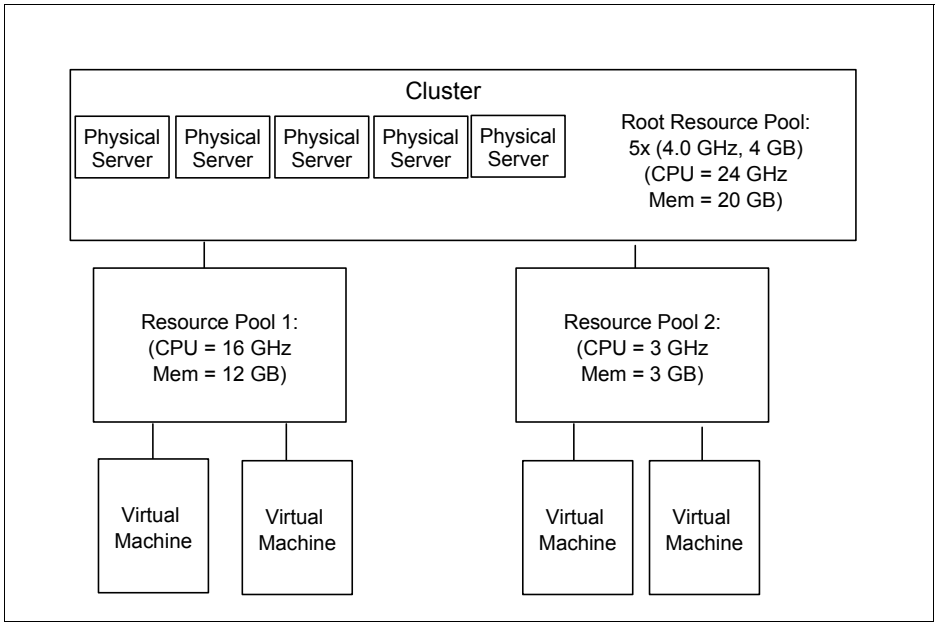

Figure 2-25 Clusters and resource pools

The VMware vCenter management server monitors the utilization of resources and balances computing resources across resource pools. Resource allocation is based on predefined rules. This capability is based on VMotion, which makes it possible to move an entire VM environment to another physical ESX server.

VMotion overview

This function moves a running VM from one physical server to another with minimum impact to users. Figure 2-26 shows an overview of VMotion.

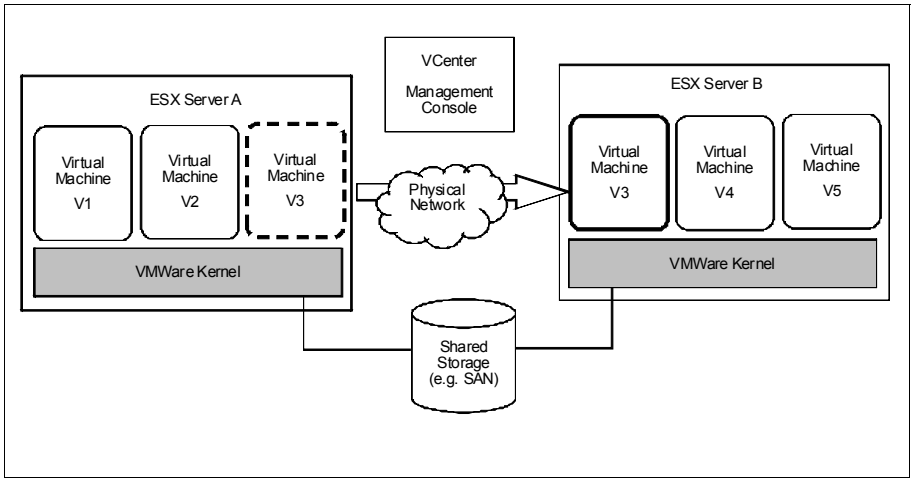

Figure 2-26 VMotion overview

In this overview, the ESX servers (ESX Server A and ESX Server B) share the storage (for example, the SAN or iSCSI volume). When VM3 is VMotion from ESX Server A, it is moved, which means the memory contents of the virtual machine are copied to ESX Server B. After the transfer is completed, VM3 is activated on ESX Server B. This technology provides for a dynamic infrastructure that includes features for:

- Dynamic resource optimization in the resource group
- High availability of VM
- Easy deployment of VM

VMotion only works in an L2 environment. In other words, source and target ESX servers should be located within the same broadcast domain.

VM Direct I/O

VMDirectPath is a new capability provided in vSphere for direct assignment of physical NIC/HBA to a VM as guest. VMDirectPath is designed for VMs that require the dedicated network bandwidth. But virtual machines that use Direct I/O cannot perform additional VM functions such as VMotion, fault tolerance, and suspend/resume. Note that this function requires specific network adapters listed on the compatibility list provided by VMware.

VMSafe and vShield zones

VMsafe is a set of security-oriented APIs created by VMware and introduced with the launch of vSphere 4. VMsafe enables third-party ISVs to develop products that closely integrate with vSphere to deliver new capabilities for securing the virtual environment. The three areas covered by VMsafe are memory, disk, and network.

In general, these APIs enable a security product to inspect and control certain aspects of VM access to memory, disk, and the network from “outside” VM, using the hypervisor to look inside a VM without actually loading any host agents. One of the examples of VMsafe implementation is VSS from IBM. Refer to the VSS section for details (3.4.6, “Virtual network security”).

vShield Zones is a new application service on vSphere. It is a virtual appliance that allows you to monitor and restrict inter-VM traffic within and between ESX hosts to provide security and compliance within shared resource pools. vShield Zones is configured like the L2 bridged firewall. It works between the virtual switch and VMs, monitors and controls network access, and isolates VMs grouped with clusters or VLANs. vShield Zones provides stateful inspection and logging functions such as a generic firewall, but the IDS/IPS function is not provided.

VMware Fault Tolerance

VMware Fault Tolerance (FT) creates a duplicate, secondary copy of the virtual machine on a different host. Record/Replay technology records all executions on the primary virtual machine and replays them on the secondary instance. FT ensures that the two copies stay synchronized and allows the workload to run on two different ESX/ESXi hosts simultaneously. To the external world, the virtual machines appear as one virtual machine. That is, they have one IP address and one MAC address, and you only manage the primary virtual machine.

Heartbeats and replay information allow the virtual machines to communicate continuously to monitor the status of their complementary virtual machine. If a failure is detected, FT creates a new copy of the virtual machine on another host in the cluster. If the failed virtual machine is the primary, the secondary takes over and a new secondary is established. If the secondary fails, another secondary is created to replace the one that was lost.

FT provides a higher level of business continuity than HA but requires more overhead and resources than HA. To preserve the state of VMs, dedicated physical NIC for Record/Replay and dedicated VMotion NIC are required in addition to the production network and the management network. Record/Replay and VMotion NIC require a minimum 1-Gbps bandwidth; however, more bandwidth (for example 10 Gbps) may be required, depending on the traffic.

Careful capacity planning and testing should be performed. At this time, only virtual machines with one virtual CPU are supported.

VMware vSphere 4.1 enhancements

VMware vSphere 4.1 includes the following set of enhancements. For more information, see:

http://www.vmware.com/support/vsphere4/doc/vsp_41_new_feat.html

Network I/O Control

Network I/O Control (NetIOC) is a new traffic-management feature of the vDS. NetIOC implements a software scheduler within the vDS to isolate and prioritize specific traffic types contending for bandwidth on the uplinks connecting ESX/ESXi 4.1 hosts with the physical network.

NetIOC is able to individually identify and prioritize the following traffic types leaving an ESX/ESXi host on a vDS-connected uplink:

- Virtual machine traffic
- Management traffic
- iSCSI
- NFS
- VMware Fault Tolerance (VFT) logging
- VMotion

NetIOC is particularly applicable to environments in which multiple traffic types are converged over a pair of 10GbE interfaces. If an interface is oversubscribed (that is, more than 10 Gbps is contending for a 10GbE interface), NetIOC is able to ensure each traffic type is given a selectable and configurable minimum level of service.

In Figure 2-27 on page 98, NetIOC is implemented on the vDS using shares and maximum limits. Shares are used to prioritize and schedule traffic for each physical NIC, and maximum limits on egress traffic are applied over a team of physical NICs. Limits are applied first and then shares.

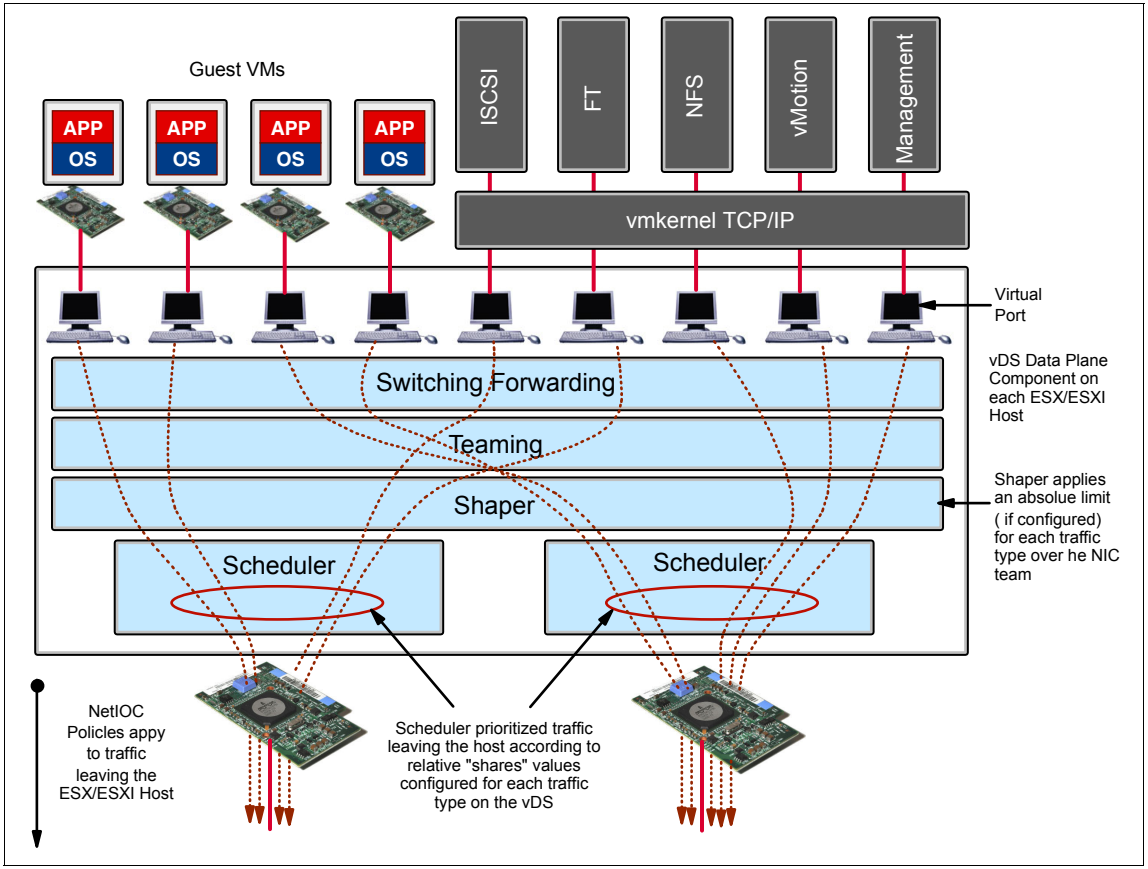

Figure 2-27 NetIOC flow diagram

Load Based Teaming

Load Based Teaming (LBT) is a new load balancing technique for the virtual Distributed Switch. It is not supported on the virtual Standard Switch.

LBT dynamically adjusts the mapping of virtual ports to physical NICs to best balance the network load entering or leaving the ESX/ESXi 4.1 host. When LBT detects an ingress or egress congestion condition on an uplink, signified by a mean utilization of 75% or more over a 30-second period, it will attempt to move one or more of the virtual ports to vmnic-mapped flows to lesser-used links within the team.

LBT is applied on virtual distributed port groups by selecting “Route based on physical NIC load.”

IPv6 enhancements

vSphere 4.1 is undergoing testing for U.S. NIST Host Profile compliance that includes requirements for IPsec and IKEv2 functionality (with the exception of MLDv2 plus PKI and DH-24 support within IKE).

In vSphere 4.1, IPv6 is supported for:

- Guest virtual machines
- ESX/ESXi management
- vSphere client
- vCenter Server
- vMotion
- IP storage (iSCSI, NFS) - experimental

Note: IPv6 is not supported for vSphere vCLI, VMware HA and VMware FT logging. IKEv2 is disabled by default.

Network scaling increases

Many of the networking maximums are increased in vSphere 4.1. Some of the notable increases are shown in Figure 2-5.

Table 2-5 Network scaling changes

	vSphere 4.0	vSphere 4.1
Hosts per vDS	64	350
Ports per vDS	4096	20,000
vDS per vCenter	16	32

VMware vCloud Director[6]

vCloud Director provides the interface, automation, and management features that allow enterprises and service providers to supply vSphere resources as a web-based service. The vCloud Director is based on technologies from VMware Lab Manager where catalog-based services are delivered to users.

The system administrator creates the organization and assigns resources. After the organization is created, the system administrator emails the organization's URL to the administrator assigned to the organization. Using the URL, the organization administrator logs in to the organization and sets it up, configures resource use, adds users, and selects organization-specific profiles and settings. Users create, use, and manage virtual machines and vApps.

[6] Taken from “Cloud Director Installation and Configuration Guide”, EN-000338-00 found at http://www.vmware.com/pdf/vcd_10_install.pdf

In a VMware vCloud Director cluster, the organization is linked with one or more vCenter servers and vShield Manager servers, and an arbitrary number of ESX/ESXi hosts. The vCloud Director cluster and its database manage access by cloud clients to vCenter resources (see Figure 2-28).

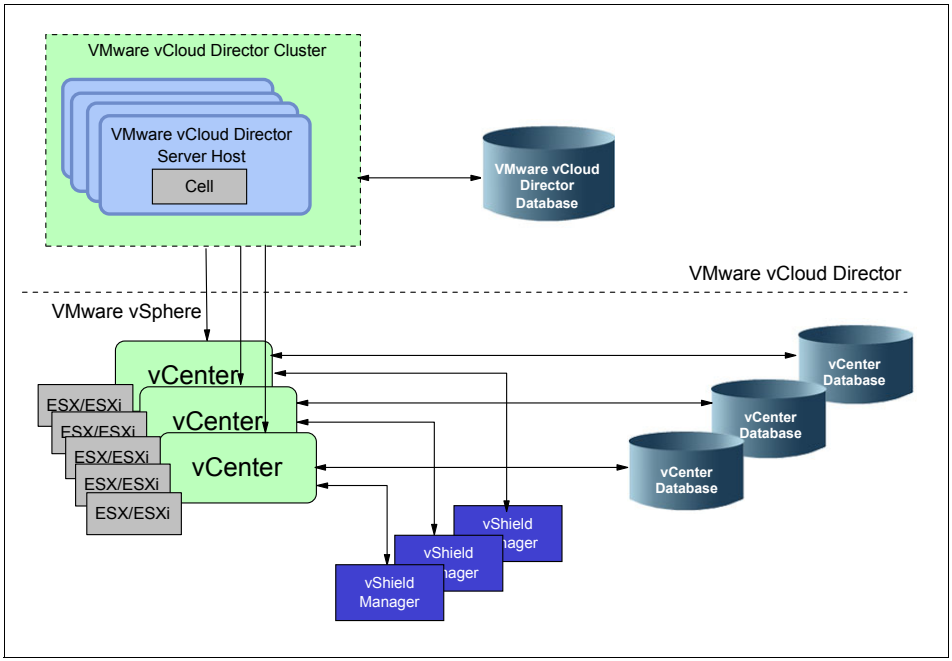

Figure 2-28 A simple cloud

Figure 2-28 shows a vCloud Director cluster comprised of four server hosts. Each host runs a group of services called a vCloud Director cell. All hosts in the cluster share a single database. The entire cluster is connected to three vCenter servers and the ESX/ESXi hosts that they manage. Each vCenter server is connected to a vShield Manager host, which provides network services to the cloud.

Table 2-6 provides information about the limits in a vCloud Director installation.

Table 2-6 Limits in a Cloud Director installation

Category	Maximum number
Virtual Machines	10,000
ESX/ESXi Hosts	1000
vCenter Servers	10

Category	Maximum number
Users	5000

The vCloud Director installation and configuration process creates the cells, connects them to the shared database, and establishes the first connections to a vCenter server, ESX/ESXi hosts, and vShield Manager. After installation and configuration is complete, a system administrator can connect additional vCenter servers, vShield Manager servers, and ESX/ESXi hosts to the Cloud Director cluster at any time.

vCloud Director includes three different techniques to isolate network pools:

- VLAN backed - A range of VLAN IDs and a vNetwork distributed switch are available in vSphere. The VLAN IDs must be valid IDs that are configured in the physical switch to which the ESX/ESXi servers are connected.
- vSphere port groups - Unlike other types of network pools, a network pool that is backed by port groups does not require a vNetwork distributed switch. This is the only type of network pool that works with Cisco Nexus 1000V virtual switches.
- vCloud Director Network Isolation (VCDNI) - An isolation-backed network pool does not require preexisting port groups in vSphere but needs a vSphere vNetwork distributed switch. It uses portgroups that are dynamically created. A cloud isolated network spans hosts and provides traffic isolation from other networks. This technique uses MAC-in-MAC encapsulation.

To learn more about the value of IBM System x, BladeCenter, and VMware, see *IBM Systems Virtualization: Servers, Storage, and Software*, REDP-4396.

2.5.4 Hyper-V R2

Windows Server 2008 R2 includes Hyper-V R2, which is a hypervisor-based architecture (“bare metal” hypervisor) that is a very thin software layer (less than 1 MB in space). It was released in the summer of 2008. The free, standalone version of Hyper-V (Microsoft Hyper-V Server 2008) was released in October. The two biggest concerns with Hyper-V have been addressed in the R2 release:

- It fully supports failover clustering.
- It now includes live migration, which is the ability to move a virtual machine from one physical host to another without service interruption.

Hyper-V is a Type 1 *hybrid* hypervisor; that is, a “thin” hypervisor provides hardware virtualization in conjunction with a parent partition (privileged virtual machine), which provides virtual machine monitor (VMM) functionality. It

leverages both paravirtualization and full virtualization because it is the hypervisor that mediates between the hardware and the unmodified operating systems. It can run only on 64-bit servers, but can host both 32-bit and 64-bit virtual machines.

It is capable of virtualizing multiple Windows and non-Windows operating systems (only SUSE Linux Enterprise Server 10 is officially certified for paravirtualization at this time) on a single server. It requires hardware-assisted virtualization (Intel VT or AMD Pacifica) and hardware Data Execution Prevention (DEP).

A primary virtual machine (parent partition) runs only Windows Server 2008 and the virtualization stack, and has direct access to the physical machine's hardware and I/O. The other VMs (children) do not have direct access to the hardware. Also, Hyper-V implements a virtual switch. The virtual switch is the only networking component that is bound to the physical network adapter. The parent partition and the child partitions use virtual network adapters (known as vNICs), which communicate with the virtual switch using Microsoft Virtual Network Switch Protocol. Multiple virtual switches can be implemented, originating different virtual networks.

There are three types of virtual networks in Hyper-V:

- External Virtual Network - The VMs can access the external network and the Internet. This must be tied to a specific physical network adapter.
- Internal Virtual Switch - This permits VM-to-VM communication but not external connectivity. It can also facilitate communications between the host operating system and the guests.
- Private Virtual Network - The same as an internal virtual switch, but they cannot access the host operating system.

VLAN IDs can be specified on each Virtual Network Virtual Switch except for the Private Network Virtual Switch.

Figure 2-29 on page 103 shows an overview of Hyper-V. The purple VMs are fully virtualized. The green VMs are paravirtualized (enlightened partitions). Paravirtualized drivers are available for guests; guests not implementing paravirtualized drivers must traverse the I/O stack in the parent partition, degrading guest performance. The VMbus is a logical channel that connects each VM, using the Virtualization Service Client (VSC) to the parent partition that runs the Virtualization Service Provider (VSP). The VSP handles the device access connections from the child partitions (VMs).

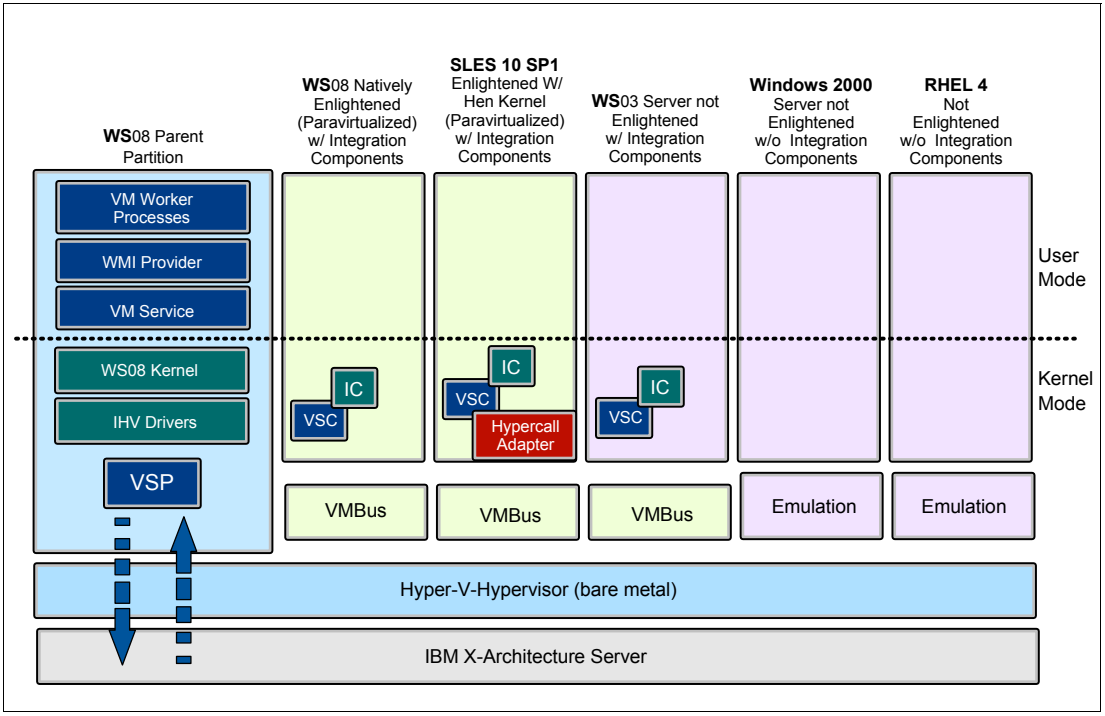

Figure 2-29 Hyper-V overview

At least one VLAN must be created to allow the VMs to communicate with the network (VLAN creation is supported by Hyper-V). The physical NIC is then configured to act as a virtual switch on the parent partition. Then the virtual NICs are configured for each child partition to communicate with the network using the virtual switch.

Each virtual NIC can be configured with either a static or dynamic MAC address. At this time NIC teaming is not supported. Spanning tree protocol should not be a problem because loops are prevented by the virtual switch itself.

If it is small or medium-sized, the entire environment can be managed by the Hyper-V Manager. In an enterprise scenario, Microsoft System Center Server Management Suite Enterprise (SMSE) is the recommended choice. In the future, this should also allow the management of Citrix XenServer and VMware ESX v3 hosts, apart from Hyper-V hosts.

One significant advantage of the Microsoft approach is that SMSE is not limited to managing virtual environments because it was designed to manage all systems, including physical and virtual.

For more information about implementing Hyper-V on System x, see "*Virtualization cookbook: Microsoft Hyper-V R2 on IBM System x*" at this link:

http://www-01.ibm.com/common/ssi/cgi-bin/ssialias?infotype=SA&subtype=WH&htmlfid=XSW03046USEN&appname=STG_BC_USEN_WH

2.6 Storage virtualization

Storage virtualization refers to the process of completely abstracting logical storage from physical storage. The physical storage resources are aggregated into storage pools, from which the logical storage is created. It presents to the user a logical space for data storage and transparently handles the process of mapping it to the actual physical location. This is currently implemented inside each modern disk array, using vendors' proprietary solution. However, the goal is to virtualize multiple disk arrays, made by different vendors, scattered over the network, into a single monolithic storage device, which can be managed uniformly.

The following are key storage and virtualization technologies from IBM, discussed further in this section:

- Storage Area Networks (SAN) and SAN Volume Controller (SVC)
- Virtualization Engine TS7520: virtualization for open systems
- Virtualization Engine TS7700: mainframe virtual tape
- XIV Enterprise Storage
- IBM Disk Systems
- Storwize V7000
- Network Attached Storage (NAS)
- N Series

Figure 2-30 on page 105 illustrates the IBM Storage Disk Systems portfolio, with the components that will be briefly described in the next sections.

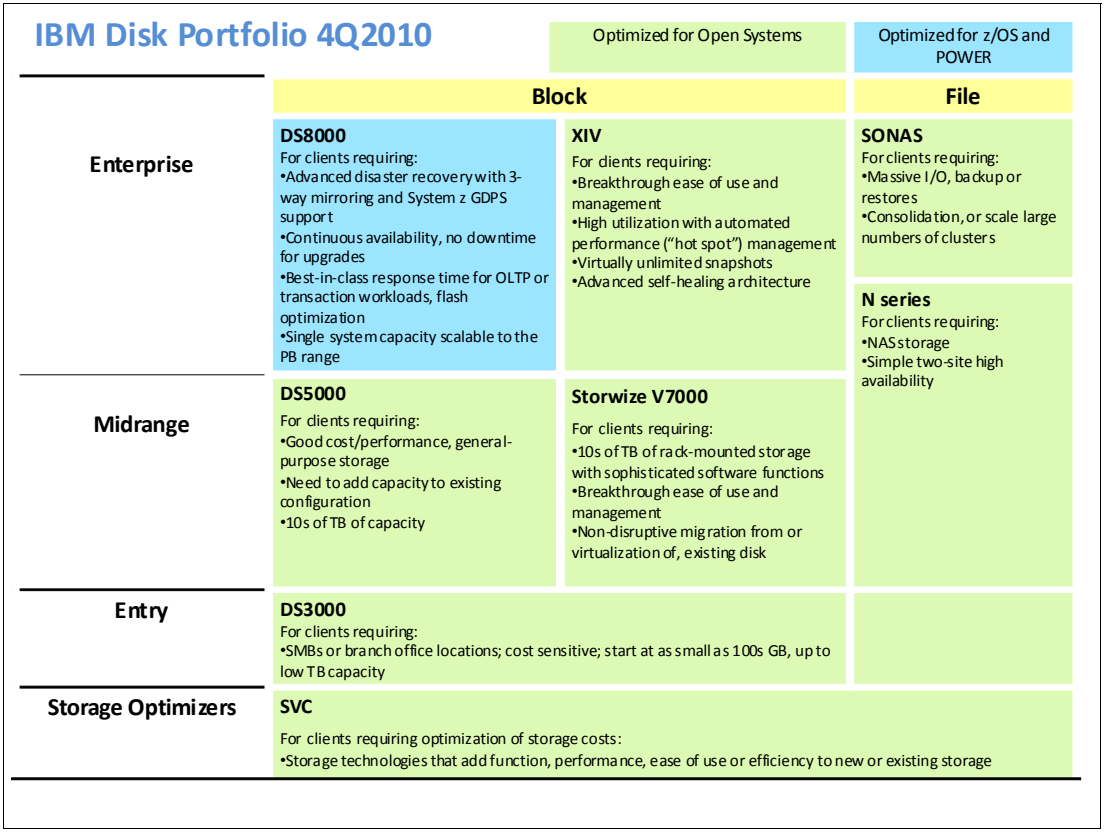

Figure 2-30 IBM Disk portfolio

For more information about IBM Storage Solutions, refer to *IBM System Storage Solutions Handbook*, SG24-5250, which can be found here:

http://www.redbooks.ibm.com/abstracts/sg245250.html?Open

2.6.1 Storage Area Networks (SAN) and SAN Volume Controller (SVC)

SAN-attached storage connects storage to servers with a Storage Area Network using ESCON or Fibre Channel technology. Storage area networks make it possible to share homogeneous storage resources across the enterprise. For many companies, however, information resources are spread over various locations and storage environments with products from different vendors. With this in mind, the best storage solution takes advantage of the existing investment and provides growth when it is needed.

For more detailed information about this subject, see “SAN Volume Controller” in *IBM Systems Virtualization: Servers, Storage, and Software*, REDP-4396, which can be found at:

http://www.redbooks.ibm.com/abstracts/redp4396.html?Open

As illustrated in Figure 2-31, a SAN has the following characteristics:

- Remote, shared storage access
- Private network for storage
- Storage protocols
- Centralized management

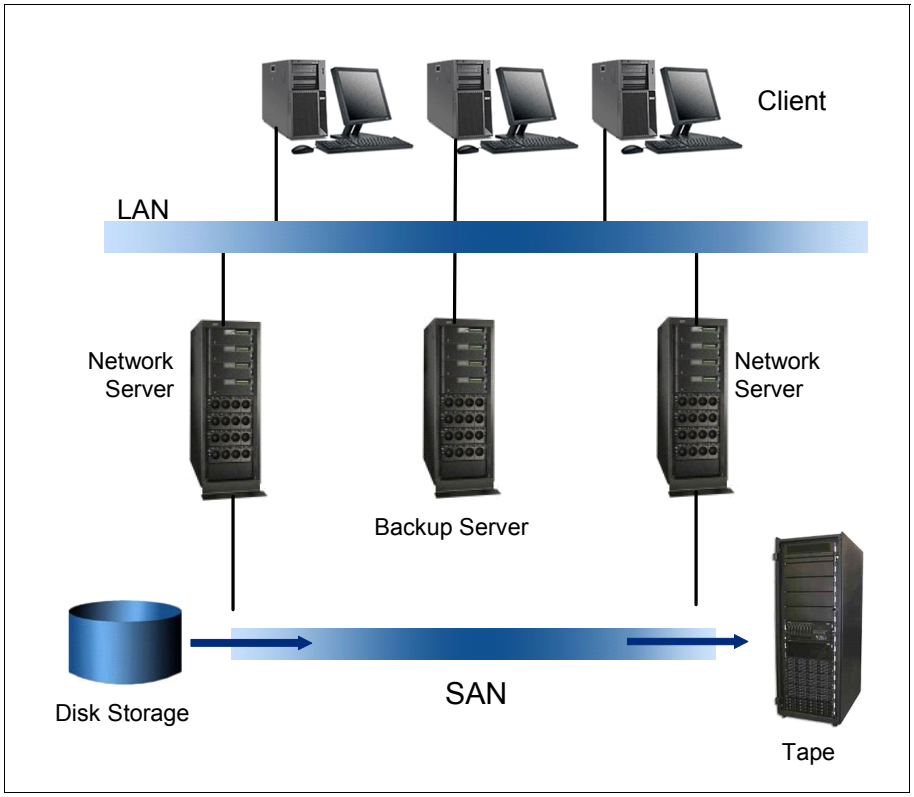

Figure 2-31 SAN high-level architecture overview

Based on virtualization technology, SAN Virtual Controller (SVC) supports a virtualized pool of storage from the storage systems attached to a SAN. This storage pool helps to tap unused storage capacity and make the business more efficient and resilient.

SVC helps to simplify storage management by presenting a single view of storage volumes. Similarly, SVC is an integrated solution supporting high performance and continuous availability in open system environments, as shown in Figure 2-32.

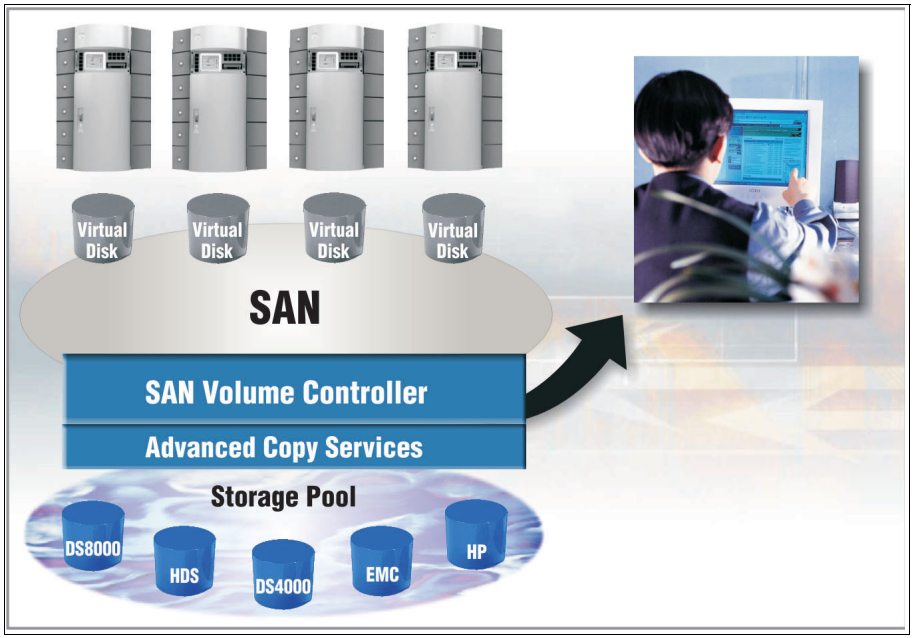

Figure 2-32 The SAN Volume Controller

The solution runs on clustered storage engines, based on System x servers and open standards-based technology. Industry-standard host bus adapters (HBAs) interface with the SAN fabric. SVC represents storage to applications as virtual disks, created from the pool of managed disks residing behind the storage engines. Storage administrators can scale performance by adding storage engines and capacity by adding disks to the managed storage pool.

The SAN Volume Controller allows to do the following:

- Manage storage volumes from the SANs
- Virtualize the capacity of multiple storage controllers
- Migrate data from one device to another without taking the storage offline
- Increase storage capacity utilization and uptime
- Virtualize and centralize management
- Support advanced copy services across all attached storage
- Use virtual disks and management

- Support local area network (LAN)-free and server-free backups
- Manage up to 8 petabytes (PBs) of total usable storage capacity
- Apply copy services across disparate storage devices within the network
- Respond with flexibility and speed
- Experience high availability in terms of SVC nodes, mirrors, and fault tolerance

SVC is designed to support the delivery of potential benefits to meet a client's business requirements. These benefits include, but are not limited to:

- Keeping applications running
  - Supporting continued access to data via data migration capabilities
  - Allocating more capacity to an application automatically
- Reducing cost and complexity
  - Saving costs of midrange storage while achieving the benefits of enterprise storage
  - Managing systems from different vendors and automation
  - Providing a single place to manage multiple, different systems
  - Providing a common set of functions
- Increasing staff productivity
  - Creating a virtualized pool of heterogeneous storage environments
  - Reducing administration efforts
  - Generating additional operational savings
- Utilizing storage assets more efficiently
  - Combining storage capacity from many disk arrays into a single storage resource
  - Centralizing storage management
  - Applying copy services and replication across disparate storage arrays

2.6.2 Virtualization Engine TS7520: virtualization for open systems

The IBM Virtualization Engine TS7520 combines hardware and software into an integrated tiered solution designed to provide tape virtualization for open systems servers connecting over Fibre Channel and iSCSI physical connections.

When combined with physical tape resources for longer-term data storage, the TS7520 Virtualization Engine is designed to provide an increased level of

operational simplicity and energy efficiency, support a low cost of ownership, and increase reliability to provide significant operational efficiencies.

For further details, see “Virtualization Engine TS7520: Virtualization for open systems” in *IBM Systems Virtualization: Servers, Storage, and Software*, REDP-4396, which can be found at:

http://www.redbooks.ibm.com/abstracts/redp4396.html?Open

2.6.3 Virtualization Engine TS7700: mainframe virtual tape

The IBM Virtualization Engine TS7700 is a mainframe virtual tape solution that is designed to optimize tape processing. Through the implementation of a fully integrated tiered storage hierarchy of disk and tape, the benefits of both technologies can be used to help enhance performance and provide the capacity needed for today’s tape processing requirements. Deploying this innovative subsystem can help reduce batch processing time, total cost of ownership, and management overhead.

For further details, see “Virtualization Engine TS7700: Mainframe virtual-tape” in *IBM Systems Virtualization: Servers, Storage, and Software*, REDP-4396, which can be found at:

http://www.redbooks.ibm.com/abstracts/redp4396.html?Open

2.6.4 XIV Enterprise Storage

The XIV® Storage System is designed to be a scalable enterprise storage system that is based upon a grid array of hardware components. It can attach to both Fibre Channel Protocol (FCP) and IP network Small Computer System Interface (iSCSI) capable hosts. This system is a good fit for enterprises that want to be able to grow capacity without managing multiple tiers of storage.

The XIV Storage System is well suited for mixed or random access workloads, such as the processing of transactions, video clips, images, and email; and industries such as telecommunications, media and entertainment, finance, and pharmaceutical; as well as new and emerging workload areas, such as Web 2.0. Storage virtualization is inherent to the basic principles of the XIV Storage System design: physical drives and their locations are completely hidden from the user, which dramatically simplifies storage configuration, letting the system lay out the user’s volume in an optimal way.

Here are some key properties of this solution:

- Massive parallelism and sophisticated distributed algorithms that yield superior power and value and very high scalability (both with a scale out and with a scale up model)
- Compatibility benefits due to the use of standard, off-the-shelf components. The system can leverage the newest hardware technologies without the need to deploy a whole new subsystem
- Maximized utilization of all disks, true distributed cache implementation coupled with more effective cache bandwidth, and practically zero overhead incurred by snapshots
- Distributed architecture, redundant components, self-monitoring and auto-recovery processes; ability to sustain failure of a complete disk module and three more disks with minimal performance degradation

For more information about IBM XIV Storage System, refer to *IBM XIV Storage System: Architecture, Implementation, and Usage*, SG24-7659, which can be found at:

http://www.redbooks.ibm.com/abstracts/sg247659.html?Open

2.6.5 IBM Disk Systems

The IBM Disk Systems portfolio is vast and covers entry disk storage systems (EXP3000, DS3400, DS3300, and DS3200) mid-range systems (DS4700 Express, DS5000 Series, and DS5020 Express) and high-end, enterprise-class systems (DS6000™ and DS8000®). They support iSCSI and Fibre Channel interfaces to Fibre Channel or SATA physical storage, depending on the specific model. High-end systems may also contain dedicated Gigabit Ethernet switches to connect the disk enclosure and the processor complexes.

For more information about IBM Disk Systems Solutions, refer to *IBM System Storage Solutions Handbook*, SG24-5250, which can be found at:

http://www.redbooks.ibm.com/abstracts/sg245250.html?Open

2.6.6 Storwize V7000

IBM Storwize V7000 is a new storage offering that delivers essential storage efficiency technologies and exceptional ease of use and performance—all integrated into a compact, modular design. The functions it provides are:

- Easy to use GUI, similar to XIV
- Smart placement of data (EasyTier)

- Management integration with IBM Systems Director
- Fibre Channel or iSCSI interfaces

2.6.7 Network Attached Storage

Advanced features generally found in high-end products such as external storage virtualization are based on SVC technology, thin provisioning, robust data protection, SSD support and non-disruptive data migration.

Network Attached Storage (NAS) uses IP networks to connect servers with storage. Servers access the storage using specialized file access and file sharing protocols. NAS products provide an ideal choice for a shared file environment among many servers, especially among heterogeneous servers.

IBM also developed a cutting edge solution for distributed NAS called Scale Out NAS (SoNAS). For more information about SoNAS, refer to *IBM Scale Out Network Attached Storage Architecture and Implementation*, SG24-7875, which can be found at:

http://www.redbooks.ibm.com/redpieces/abstracts/sg247875.html?Open

Network Attached Storage, illustrated in Figure 2-33, has the following characteristics:

- Uses remote, shared file access
- Shares user networks
- Uses Network protocols
- Uses distributed management

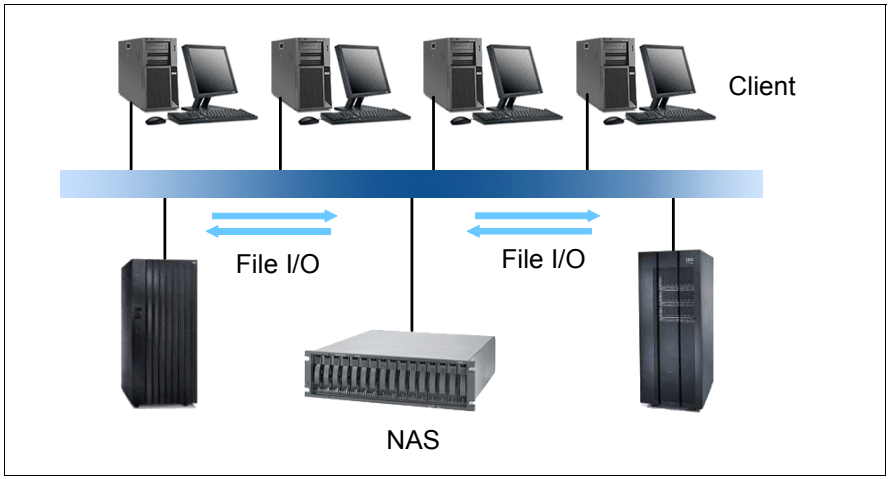

Figure 2-33 Network Attached Storage overview

2.6.8 N Series

The IBM System Storage® N Series provides a range of reliable, scalable storage solutions for a variety of storage requirements. These capabilities are achieved by using network access protocols such as Network File System (NFS), Common Internet File System (CIFS), HTTP, iSCSI, and FCoE as well as storage area network technologies such as Fibre Channel (FC), SAS, and SATA, utilizing built-in Redundant Array of Inexpensive Disks (RAID) technologies.

The N series is a specialized, thin server storage system with a customized operating system, similar to a stripped-down UNIX kernel, hereafter referred to as Data ONTAP®.

The IBM System Storage N series Gateways, an evolution of the N5000 series product line, is a network-based virtualization solution that virtualizes tiered, heterogeneous storage arrays, allowing clients to utilize the dynamic virtualization capabilities available in Data ONTAP across multiple tiers of IBM and vendor-acquired storage.

For more information about N Series Storage Systems, refer to *IBM System Storage N Series Hardware Guide*, SG24-7840, which can be found here:

http://www.redbooks.ibm.com/abstracts/sg247840.html?Open

2.7 Virtualized infrastructure management

Specific IBM tools are available that provide the capability to manage today's virtualized infrastructure. These tools, at the higher level, are focused on service management and the need to align the IT infrastructure with the business objectives and SLAs. This is done by gathering event information from diverse sources using specific tools focused on:

- Systems - primarily IBM Systems Director
- Storage - primarily IBM TotalStorage® Productivity Center
- Networks - primarily IBM Tivoli® Network Manager

IBM IT management solutions deliver operational management products to visualize, control, and automate the management of the virtual environment. Together these technologies and products allow the business to increase workload velocity and utilization, respond to changing market conditions faster, and adapt to client requirements.

Managing virtualized environments creates new and unique requirements. The ability to take a virtual machine and resize the memory or processor power

dynamically brings new capabilities to the business that can be exploited to deliver higher efficiencies.

The ability to move virtual machines from physical host to physical host while the virtual machines remain operational is another compelling capability. One of the key values that IBM systems management software can provide is to mask the complexities that are introduced by virtualization.

Businesses are embracing virtualization because it brings value and enhances capabilities for business continuity and disaster recovery. The ability to use business policy-based process automation for orchestrating, provisioning, workload, and service level management in line with business goals will drive higher levels of virtualization adaptation.

In dynamic infrastructure and cloud computing environments, the support of automated provisioning of servers, storage and network is a key enabler to support services in a highly-virtualized infrastructure. Managed provisioning is the interlock between the service management supported by Tivoli's Service Automation Manager and the resources management supported by single platform applications (such as Systems Director or Tivoli Network Manager).

Figure 2-34 on page 114 illustrates the solution overview of a service-oriented architecture to deploy provisioning services to the virtualized managed nodes at the resources level. The solution is comprised of the following elements:

- Self-service provisioning of virtualized network, storage, and server resources
- User-initiated scheduling and reservation through a service catalog model
- Self-service provisioning of a preconfigured application
- Customized deployment workflows implementing client-specific processes and enforcing specific policies
- Integrated Service Management of the Provisioning Environment

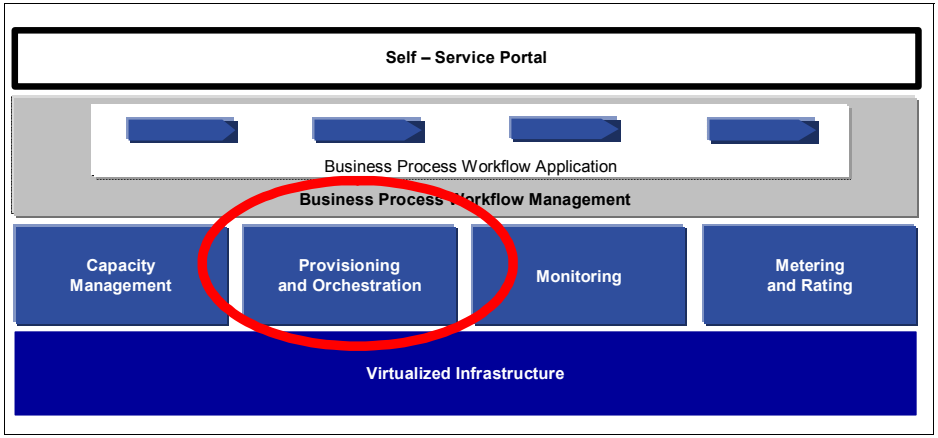

Figure 2-34 Provisioning solution overview

2.7.1 IT Service Management

Today, network and IT operations are under tremendous pressure to deliver next-generation services more quickly than ever before. At the same time, lines of business (LOBs) and clients demand more services and service level agreements (SLAs) to ensure that they receive the service quality that they expect. These challenges are further compounded by increased regulatory and audit requirements that often require budget and labor shifts from more strategic growth initiatives.

IBM Tivoli enables clients to take a more comprehensive approach to aligning operations and processes with their organization's business needs—an approach that leverages best practices such as those of the IT Infrastructure Library® (ITIL®) and the NGOSS Business Process Framework of the TMForum enhanced Telecom Operations Map (eTOM). IBM calls this approach IBM Service Management. The reference model is illustrated in Figure 2-35 on page 115.

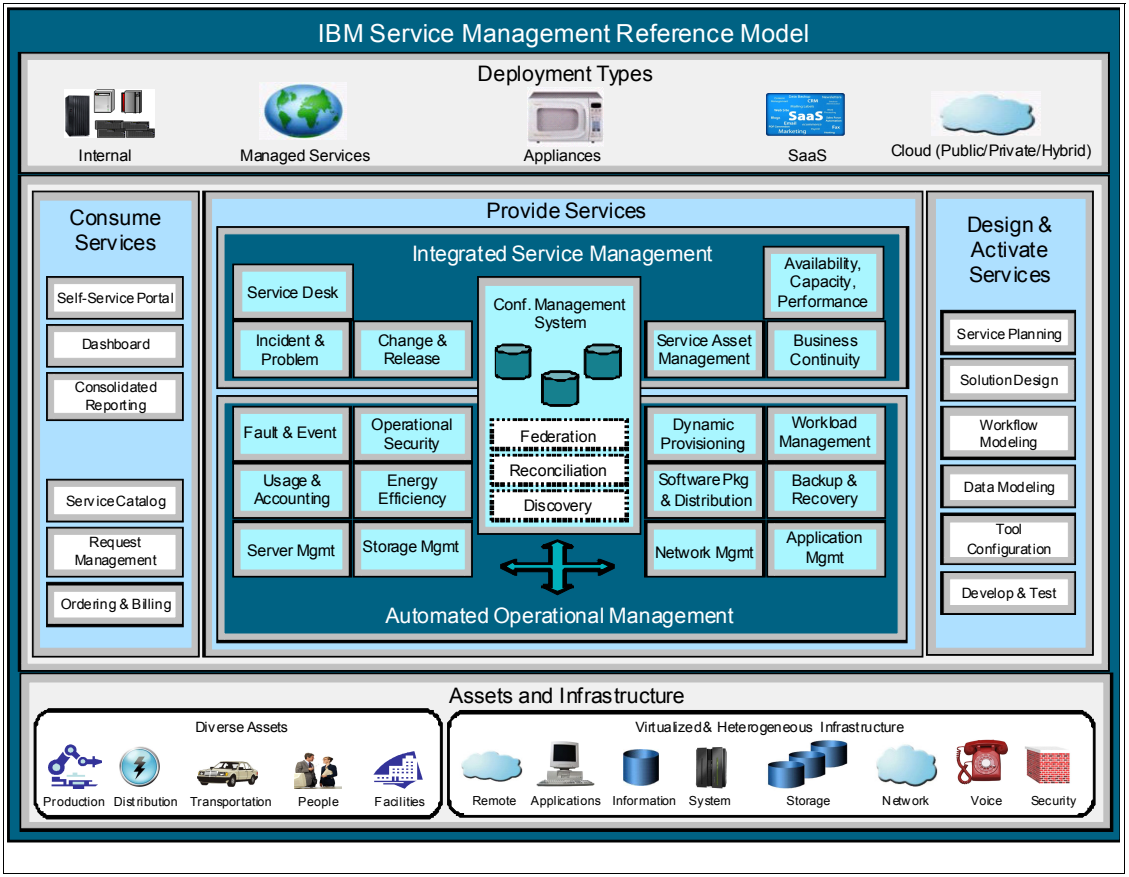

Figure 2-35 IBM Service Management reference model

IBM Service Management offerings provide a complete solution, automating the full life cycle of service requests, incidents, and trouble tickets from their creation through to the environmental changes that they produce.

IBM Service Management products are integrated to capture incoming requests, incidents, and problems; route them to the correct decision-makers; and expedite resolution with enterprise-strength server and desktop provisioning tools. They do this while keeping an accurate record of all the configuration items in a federated management database and a real-time picture of the deployed infrastructure, thus matching hardware and software services with the business needs that they fulfill.

By automating change, configuration, provisioning, release, and asset management tasks, IBM Service Management software helps to reduce cost and avoid errors.

Figure 2-36 shows a view of the overall architecture of IBM Service Management (ISM). It is based on the Tivoli Process Automation Engine (TPAe), which provides a common runtime and infrastructure (shown in green) for the various ISM components. TPAe provides a process runtime, as well as a common user interface and configuration services that can be leveraged by other components.

On top of TPAe, Process Management Products (PMPs) can be deployed. The PMPs provide implementation of processes around the ITSM service life cycle. The Change Management PMP, for example, provides a good practices framework for implementing the change management process according to ITSM and ITIL.

IT management products that are outside the scope of TPAe, so-called Operational Management Products (OMPs), are accessible by means of Integration Modules, so their functionality can be used by PMPs inside TPAe.

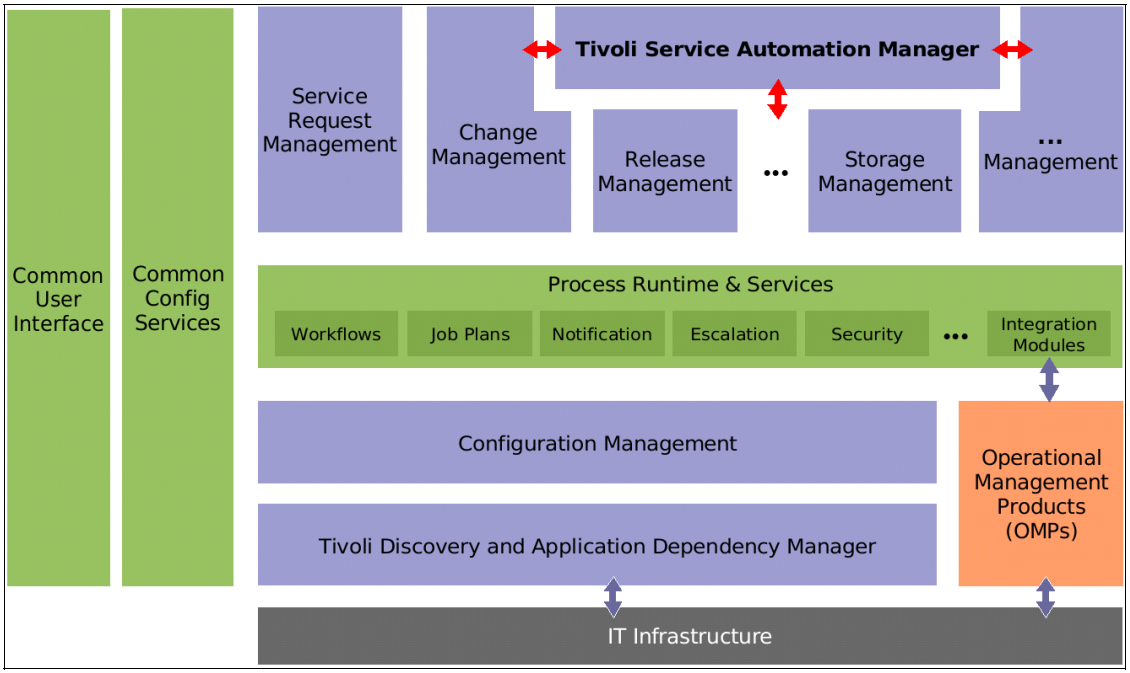

Figure 2-36 Tivoli Service Automation Manager and ISM Architecture

Tivoli Service Automation Manager (TSAM) allows to quickly roll out new services in the data center to support dynamic infrastructure and cloud computing services. The TSAM component is also based on the Tivoli Process Automation Engine (TPAe), implementing a data model, workflows and

applications for automating the management of IT services by using the notion of Service Definitions and Service Deployment Instances.

The set of applications provided by TSAM can be collectively referred to as the TSAM Admin User Interface (UI), which provides access to all TSAM-specific functionality. It should be noted that this UI is not aimed at users, because some level of detailed knowledge about TSAM itself and about the concrete types of services automated using TSAM is required. The TSAM Admin UI is therefore more likely to be used by designers, operators, and administrators of services.

A more user-centered interface for requesting and managing IT services automated through TSAM can be provided by exposing certain functionality as service catalog offerings using the Service Request Management (SRM) component. By means of service offerings and offering UIs, the level of complexity exposed for any kind of service can be reduced to a level consumable by users, hiding many of the details that are exposed by the TSAM Admin UI.

TSAM and SRM rely on the CCMDB component to access information about resources in the managed data center.

As illustrated in Figure 2-37, TSAM interlocks with Tivoli Provisioning Manager (TPM) to drive automated provisioning and deployment actions on the managed IT infrastructure. That is, while TSAM concentrates on the process layer of IT Service Management and hooks automation into these processes, TPM can be used for really implementing these automated actions in the backend.

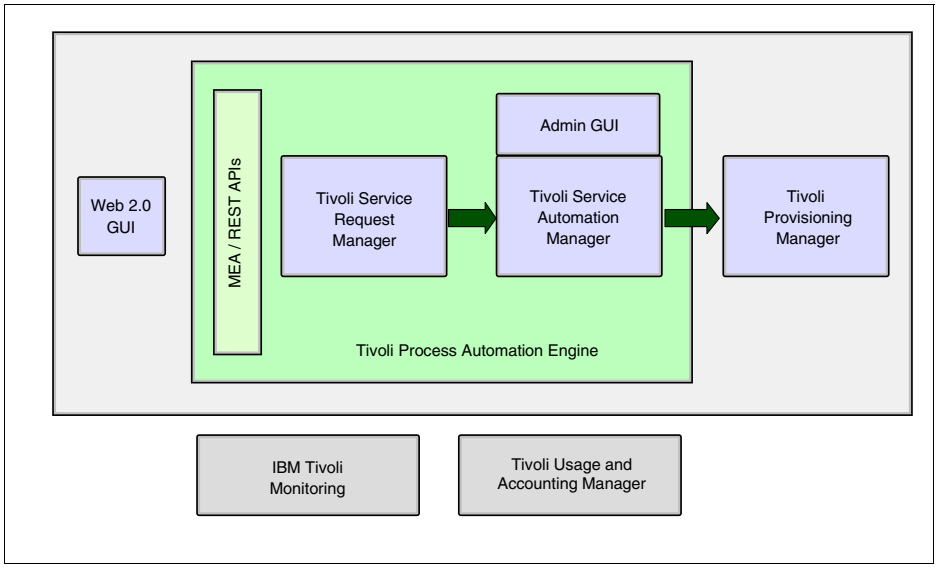

Figure 2-37 TSAM - high-level architecture

2.7.2 Event Management - Netcool/OMNIbus

IBM Tivoli Netcool/OMNIbus software delivers real-time, centralized supervision and event management for complex IT domains and next-generation network environments. With scalability that exceeds many millions of events per day, Tivoli Netcool/OMNIbus offers round-the-clock management and high automation to deliver continuous uptime of business, IT, and network services. Figure 2-38 shows an overview of Netcool/OMNIbus.

OMNIbus leverages the Netcool® Knowledge Library for SNMP integration with many different technologies (more than 175 MIBs), more than 200 different probes, and approximately 25 vendor alliances (including Cisco, Motorola, Juniper, Ciena, Checkpoint, Alcatel, Nokia, and so on) to provide extensive integration capabilities with third-party products.

Many external gateways are also available to provide integration with other Tivoli, IBM (DB2® 7.1, Informix® 9.20, and so on), and non-IBM products (Oracle 10.1.0.2 EE, Siebel, Remedy 7, and MS SQL).

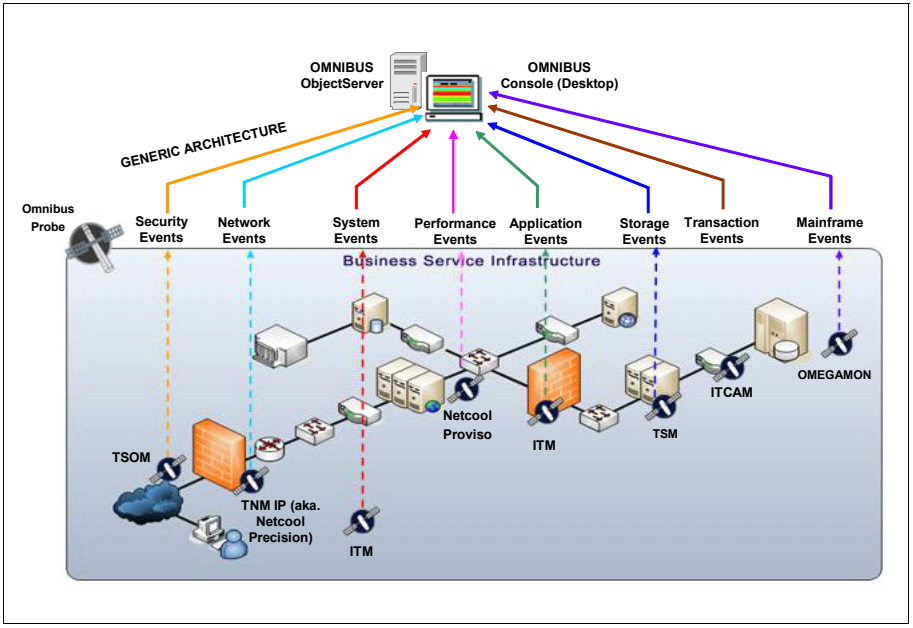

Figure 2-38 Netcool/OMNIbus overview

Tivoli Netcool/OMNIbus software is available on a variety of platforms, such as Microsoft Windows Vista, Sun Solaris and Linux on IBM System z. Operations staff can launch in context directly from Tivoli Netcool/OMNIbus events to detailed Tivoli Network Manager topology and root cause views, as well as other

views from the Tivoli Monitoring family, Tivoli Service Request Manager®, Tivoli Application Dependency Manager, and many more. Tivoli Netcool/OMNIbus can serve as a “manager of managers” that leverages existing investments in management systems such as HP OpenView, NetIQ, CA Unicenter TNG, and many others.

The current Netcool/OMNIbus version 7.3 includes, as the strategic Event Management Desktop, the web user interface previously provided by Netcool/Webtop. Netcool/OMNIbus v7.3 also includes Tivoli Netcool/Impact for the query and integration of data stored and generated by IBM Tivoli Software products only, and not for other data management or automation purposes with data sources that are not Tivoli products.

For example, Tivoli Netcool/Impact can be used to integrate with information generated by IBM Tivoli Netcool/OMNIbus or correlated with information from other licensed Tivoli product data stores, but cannot be used to integrate with non-Tivoli, custom or 3rd party data sources, read/write data to such data sources, or any resources managed by Tivoli products.

Netcool/OMNIbus V7.3 has implemented significant improvements and enhancements in the following areas:

- Performance and scalability
  - High performance Active Event List (AEL)
  - Ultra-fast event filtering through user-defined indexes and automatic filter optimization
  - Managed events from multiple silos (ObjectServers) in a single AEL
  - Improved multi-threading and event consumption rates
  - Tiered Architecture (ESF) configuration included in the default configurations and documentation
  - Enhanced event flood protection and event rate anomaly detection including new event generation at the probe
  - ObjectServer gateways with smarter resynchronization for improved disaster recovery performance
- Deployment integration and interoperability
  - Improved operator workflows
    - Ability to view and work with events from multiple ObjectServers in a single event list
    - New Active Event List configuration options providing familiar look and feel

        - New dashboard portlet to create monitor box views, supporting drag-and-drop configuration
    - Map Refresh
        - New graphics engine for improved look and feel
        - Improved user interactions with the map, including customizable mouseover effects
    - Native desktop convergence
        - Improved performance with more than 50 K events supported in a single AEL
        - Replacement of entities with system filters and views
    - Usability/consumability
        - Consistent “look and feel” based on Tivoli guidelines

Tivoli Netcool/OMNIbus provides “single pane of glass” visibility to help leverage and extend the native capabilities provided by the Tivoli common portal interface with cross-domain, multivendor event management, thereby enabling centralized visualization and reporting of real-time and historical data across both IBM and third-party tools. This information is consolidated in an easy-to-use, role-based portal interface, accessed through single sign-on, so that all the monitoring data and management information needed can be retrieved from one place.

2.7.3 IBM Tivoli Provisioning Manager

Main issues involved in the deployment of provisioning services include:

- The proliferation of virtual resources and images makes it time-consuming.
- The deployment process is error-prone.
- There is an inability to quickly provision and deprovision environments (for example, for building test environments).

With Tivoli Provisioning Manager, we address three major enhancement areas for the deployment of a virtualized infrastructure:

- Built on the new Common Process Automation Engine
    - Provides seamless process and data integration with Asset, Change, Release and Service Request Management flows.
    - Adds common runbook technology coordinates across products and human, process, and IT tasks.

- Enhanced virtualization management
  - Provides the ability to provision, delete, move, and configure virtual machines across multiple platforms.
  - Provides improved integration and management of storage infrastructure supporting virtual systems through IBM TotalStorage Productivity Center.
- Consolidated orchestration capability
  - Provides an integrated Tivoli Intelligent Orchestrator (TIO) product into the core TPM product for increased value at no additional cost.

Tivoli Provisioning Manager (TPM), current version 7.1.1, helps organizations to provision, configure, and maintain virtual servers, operating systems, middleware, applications, storage and network devices acting as routers, switches, firewalls, and load balancers. TPM can be integrated with an organization's best practices through both prebuilt and customized automation packages. Customized automation packages can implement a company's data center best practices and procedures and execute these in a consistent and error-free manner. These workflows can provide full end-to-end automation of the virtual server, storage, and network environment to achieve the goals of uninterrupted quick provisioning of changes.

Figure 2-39 on page 122 provides an overview of Tivoli Provisioning Manager functionality.

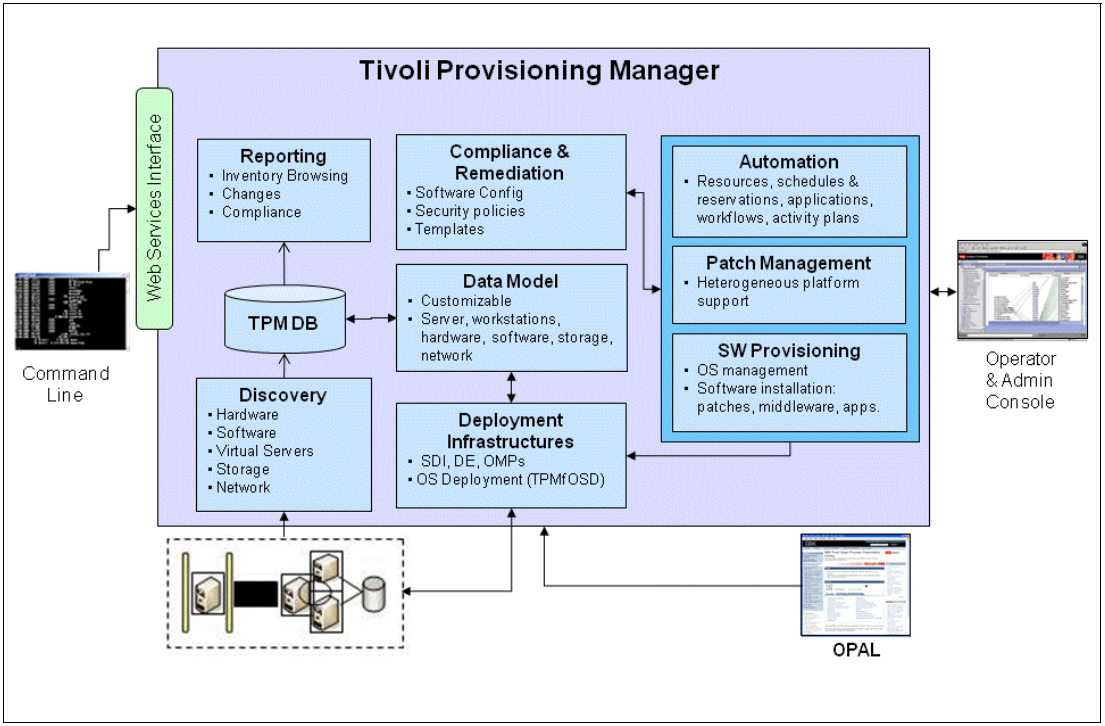

Figure 2-39 Tivoli Provisioning Manager core functionality

IBM Tivoli Provisioning Manager 7.1.1 software uses the Tivoli process automation engine that is also used by other IBM Service Management products (such as the Change and Configuration Management Database and Tivoli Service Request Manager) to provide a common “look and feel” and seamless integration across different products.

TPM simplifies and automates data center tasks. The main capabilities are summarized here:

- It provides operating system imaging and bare metal provisioning.

  TPM offers flexible alternatives for quickly creating and managing operating systems cloned or scripted installs such as dynamic image management, single instance storage, encrypted mass deployments, and bandwidth optimization.

- It provides software distribution and patch management over a scalable, secure infrastructure.

  TPM can automatically distribute and install software products defined in the software catalog without creating specific workflows or automation packages to deploy each type of software.

- It provides automated deployment of physical and virtual servers through software templates.
- It provides provisioning support for different system platforms.
  - It provisions new virtual machines on VMWare ESX servers.
  - It provisions Windows OS and applications onto a new ESX virtual machine.
  - It creates new LPARs on pSeries®.
  - It provisions new AIX OS onto a pSeries LPAR through NIM.
- It integrates with the IBM TotalStorage Productivity Center to provide a storage capacity provisioning solution designed to simplify and automate complex cross-discipline tasks.
- It supports a broad range of networking devices and nodes, including firewalls, routers, switches, load balancers and power units from leading manufacturers (such as Cisco, Brocade Networks, Extreme, Alteon, F5, and others).
- It provides compliance and remediation support.
  - Using compliance management, the software and security setup on a target computer (or group of computers) can be examined, and then that setup can be compared to the desired setup to determine whether they match.
  - If they do not match, noncompliance occurs and recommendations about how to fix the noncompliant issues are generated.
- It provides report preparation.

  Reports are used to retrieve current information about enterprise inventory, activity, and system compliance. There are several report categories. Each category has predefined reports that can be run from the main report page or customized, in the wizard, to suit the business needs. Also, the report wizard can be used to create new reports.
- It supports patch management.

  TPM provides “out-of-the-box” support for Microsoft Windows, Red Hat Linux, AIX, Solaris, HP Unix, and SUSE Linux Enterprise Sever using a common user interface. Accurate patch recommendations for each system are based on vendor scan technology.

2.7.4 Systems and Network management - IBM Systems Director

IBM Systems Director is the platform management family that provides IT professionals with the tools they need to better coordinate and manage virtual

and physical resources in the data center. It helps to address these needs by unifying under one family its industry-leading server and storage management products, IBM Systems Director and IBM TotalStorage Productivity Center, with newly enhanced virtualization management support.

IBM Systems Director (see Figure 2-40 on page 125) is a cross-platform hardware management solution that is designed to deliver superior hardware manageability, enable maximum system availability, and help lower IT costs. It is a platform manager, because it aggregates several single resources to provide an aggregated single or multi-system view. Single device-specific management tools do not provide policy-driven management and configuration; they are generally command line tools.

IBM Systems Director is included with the purchase of IBM System p, System x, System z, and BladeCenter systems. It is offered for sale to help manage select non-IBM systems. Because it runs on a dedicated server, it provides secure isolation from the production IT environment. It is a Web server-based infrastructure so that it can be a single point of control accessible via a Web browser. In the future IBM Systems Software intends to release virtual appliance solutions that include a pre-built Systems Director software stack that can run as a virtual machine and will include integrated High Availability features.

One of the most notable extensions to Directors that came out during 2009 is Systems Director VMControl™. IBM Systems Director VMControl is a cross-platform suite of products that provides assistance in rapidly deploying virtual appliances to create virtual servers that are configured with the desired operating systems and software applications. It also allows to group resources into system pools that can be centrally managed, and to control the different workloads in the IT environment. Figure 2-40 on page 125 shows the components of the IBM Systems Director.

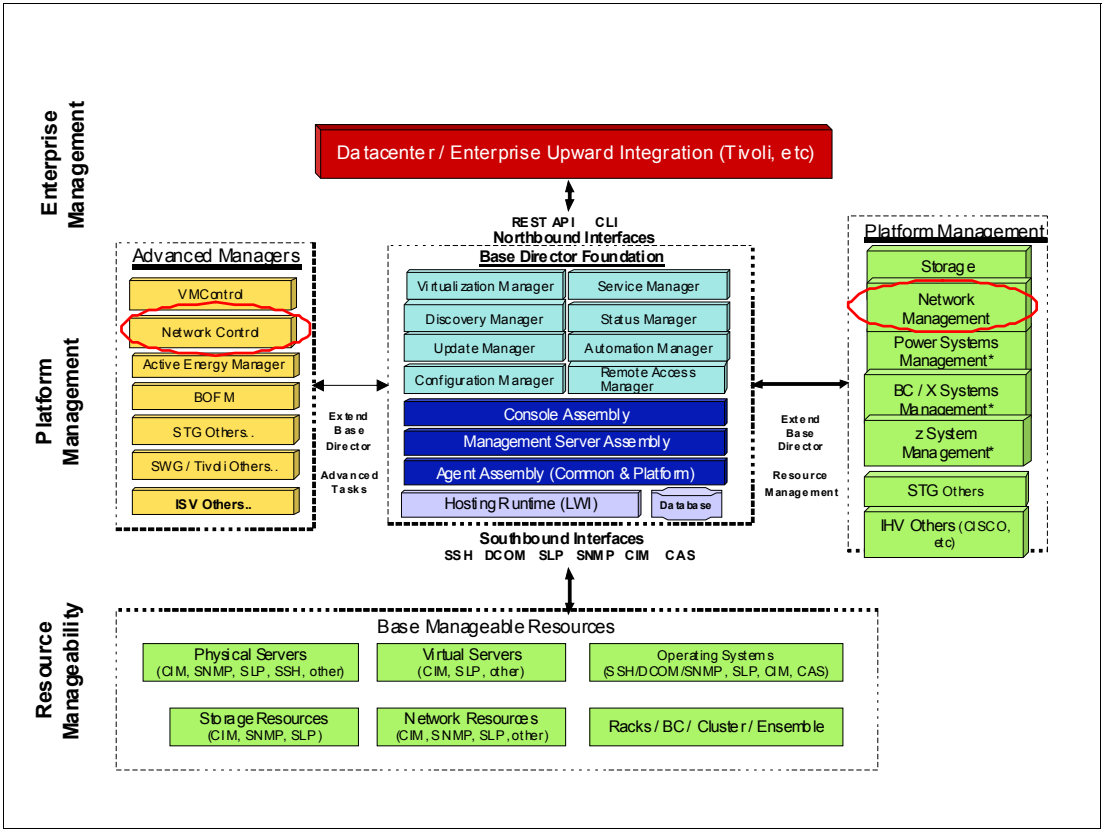

Figure 2-40 IBM Systems Director components

IBM Systems Director provides the core capabilities that are needed to manage the full lifecycle of IBM server, storage, network, and virtualization systems:

- Discovery Manager discovers virtual and physical systems and related resources.
- Status Manager provides health status and monitoring of system resources.
- Update Manager acquires, distributes, and installs update packages to systems.
- Automation Manager performs actions based on system events.
- Configuration Manager configures one or more system resource settings.
- Virtualization Manager creates, edits, relocates, and deletes virtual resources.
- Remote Access Manager provides a remote console, a command line, and file transfer features to target systems.

Apart from these basic features, there are platform-specific plug-ins for every IBM platform.

Enhancements improve ease of use and deliver a more open, integrated toolset. Its industry-standard foundation enables heterogeneous hardware support and works with a variety of operating systems and network protocols. Taking advantage of industry standards allows for easy integration with the management tools and applications of other systems.

Optional, fee-based extensions to IBM Systems Director are available for more advanced management capabilities. Extensions are designed to be modular, thereby enabling IT professionals to tailor their management capabilities to their specific needs and environments. Version 6.1, launched in November 2008, provides storage management capabilities. Version 6.1.1, which shipped starting in May 2009, also includes basic (SNMP-based) network management and discovery capabilities (Network Manager).

IBM System Director Network Manager provides platform network management for IBM Ethernet switches[7]:

- Network devices Discovery and Inventory
- Thresholds definition and monitoring
- Troubleshooting tools such as ping and traceroute
- A set of default groups of network resources to enable users to view status of a group of related devices or perform tasks across a set of devices

Using Figure 2-40 on page 125 as a reference, Systems Director integrations can be categorized into the following four macro areas:

- Through northbound interfaces

  This includes, for example, using REST APIs towards Tivoli products such as TEP (ITM) or to leverage ITNM network discovery capabilities, and also towards non-IBM products such as CA Unicenter, HP OpenView and Microsoft Systems Management Server.
- Through southbound interfaces

  This includes, for example, accessing physical network resources using SNMP.
- With other platform management tools

  Such tools provide launch-in-context capabilities with Cisco, Brocade, and Juniper fabric management tools and API-based integration in the future.

[7] For more information about the supported Network Devices, refer to this site: http://publib.boulder.ibm.com/infocenter/director/v6r1x/topic/director.plan_6.1/fqm0_r_supported_hardware_and_software_requirements.html

- With other System Director advanced managers

  These include, for example, the BladeCenter Open Fabric Manager (BOFM) or VMControl.

From a networking point of view, the pivotal element that provides integration with Tivoli products and the rest of the Data Center Infrastructure is Systems Director Network Control. IBM Systems Director Network Control builds on Network Management base capabilities by integrating the launch of vendor-based device management tools, topology views of network connectivity, and subnet-based views of servers and network devices. It is responsible for:

- Integration with Tivoli Network Management products
- Broadening Systems Director ecosystem
- Enhanced platform management
- Virtualization Automation

The differences between the basic Network Management functionalities (included in Director free of charge) and the Network Control enhancements (which are fee-based) are listed inTable 2-7.

Table 2-7 Network management functionality of IBM Systems Director

Task or feature	IBM Systems Director Network Management	IBM Systems Director Network Control
Network system discovery	Yes	Yes
Health summary	Yes	Yes
Request access (SNMP, Telnet)	Yes	Yes
Collect and view inventory	Yes	Yes
View network system properties	Yes	Yes
Network-specific default groups	Yes[a]	Yes[a]
View network problems and events	Yes	Yes
Network monitors and thresholds	Yes	Yes
Event filters and automation plans	Yes	Yes
Network diagnostics (ping, traceroute)	Yes	Yes
Vendor-based management tool integration	No	Yes
Network topology collection[b]	No	Yes

Task or feature	IBM Systems Director Network Management	IBM Systems Director Network Control
Network topology perspectives[b]	No	Yes
View systems by subnet	No	Yes

a. IBM Systems Director Network Control provides an additional “Subnets” group.
b. This is not supported on Linux for System p.

For more information about IBM Systems Director, refer to the Systems Director 6.1.x Information Center page at:

http://publib.boulder.ibm.com/infocenter/director/v6r1x/index.jsp

2.7.5 Network management - IBM Tivoli Network Manager

Today’s business operations are increasingly dependent on the networking infrastructure and its performance and availability. IBM Tivoli Network Manager (ITNM) provides visibility, control, and automation of the network infrastructure, ensuring that network operations can deliver on network availability service level agreements, thus minimizing capital and operational costs.

ITNM simplifies the management of complex networks and provides better utilization of existing network resources. At the same time it can reduce the mean time to resolution of faults so that network availability can be assured even against the most aggressive service level agreements. This is achieved through:

- A scalable network discovery capability (Layer 2 and Layer 3 networks including IP, Ethernet, ATM/Frame, VPNs, and MPLS)

  ITNM supports the discovery of devices, their physical configuration, and physical and logical connectivity between devices.

  ITNM populates and exposes a network topology model (based on TMF/SID data models) hosted on MySQL, DB2, or Oracle.

  This network topology model can be automatically updated by using scheduled discovery tasks or as network change is detected.

- Real-time web-based network topology visualization integrated with event management and business service views (provided by Netcool/OMNIbus and TBSM)

  Third-party tools such as CiscoWorks or HP OpenView can be in-context launched for device-specific monitoring, configuration, and troubleshooting.

- Accurate monitoring and root cause analysis

  ITNM can be configured to actively monitor the network for availability and performance problems. ITNM uses the network topology model to group related events and identify the root cause of network problems, thereby speeding mean time to repair.

  Event correlation uses a network topology model to identify the root cause of network problems. Network events can be triggered by setting personalized thresholds for any SNMP performance metrics including complex expressions such as bandwidth utilization.

Figure 2-41 on page 130 illustrates the Network Manager processes. The discovery agents discover the existence, configuration and connectivity information for network devices, updating the network connectivity and information model (NCIM). At the same time, OMNIbus probes receive and process events from the network.

The polling agents poll the network for conditions such as device availability and SNMP threshold breaches. If a problem or resolution is detected, the polling agents generate events and send them to OMNIbus.

The Event Gateway provides the communication functionality for ITNM to enrich and correlate events from OMNIbus.

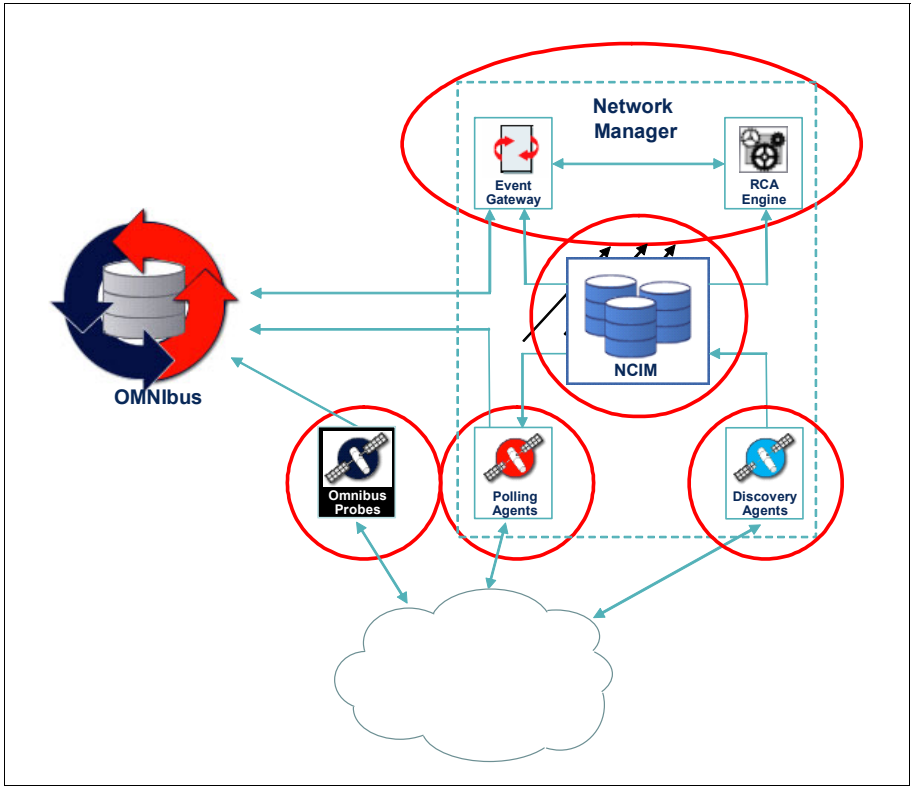

Figure 2-41 Network Manager process

Topology-based root cause analysis (RCA) consists of the event stream being analyzed in the context of the discovered relationships (physical and logical). Root cause analysis can be performed on any events from any source. Dynamic root cause analysis recalculates the root cause and symptoms as new events arrive.

The RCA process can include simple hierarchical networks or even complex meshed networks, with remote (OSPF and BGP, for example), intra-device correlation (such as card failure), and intra-device dependencies (such as cable failures). ITNM enriches events from Netcool probes and the Netcool Knowledge Library. SNMP traps and other events from Netcool probes are enriched from an extensive set of rules known as the Netcool Knowledge Library. ITNM further enriches these events with topology information to provide the user with useful contextual information including navigating to topology maps to see the device in various network contexts, and using diagnostic tooling. Events can be configured to alert the operator when network services, such as VPNs, have been effected, providing the operator with information about priority in order to perform triage.

IBM Tivoli Network Manager's latest release at the time of this writing is 3.8.0.2. It is available as a standalone product or integrated with Netcool/OMNIbus (O&NM - OMNIbus and Network Manager).

These are the most recently included features:

- IPv6 support
- Support for new technologies and products: Juniper, MPLS TE, Multicast PIM, Cisco Nexus 5000/7000, and Brocade 8000
- An option to use Informix to host the network topology model

ITNM can be integrated with Tivoli products such as ITM, TBSM, Netcool/OMNIbus, TPM, Impact, and others. Several scenarios illustrating these integrations are presented in the next section. A comprehensive overview of possible ITNM integrations is shown in Figure 2-42.

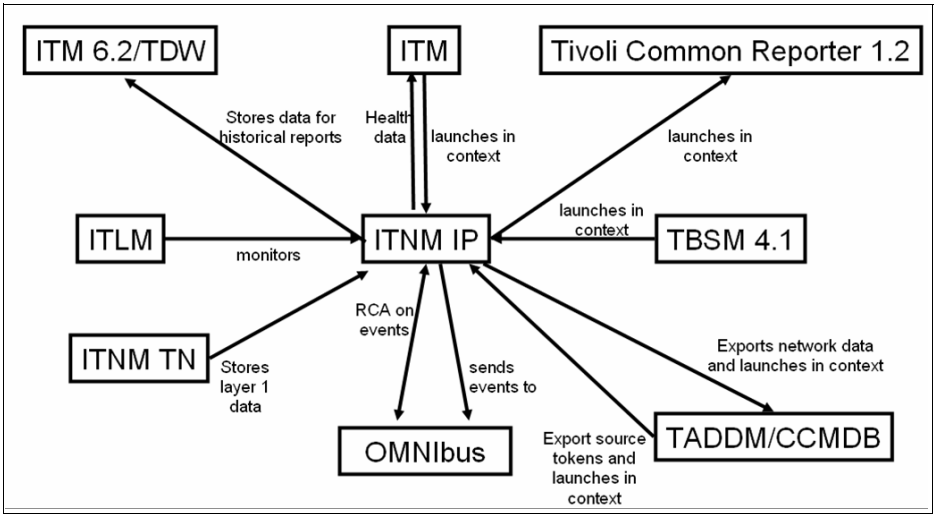

Figure 2-42 ITNM integrations

For more information about ITNM, refer to the IBM Tivoli Network Management information center at:

http://publib.boulder.ibm.com/infocenter/tivihelp/v8r1/index.jsp?toc=/com.ibm.netcool_OMNIbus.doc/toc.xml

2.7.6 Network configuration change management - Tivoli Netcool Configuration Manager

The IBM Tivoli Netcool Configuration Manager (ITNCM) provides a comprehensive network configuration and change management solution, as well as a policy-based network compliance solution for managing network devices in complex, rapidly changing environments. The ITNCM will normalize the resource configuration and simplify the resource configuration change request that will reduce the cost and increase the quality of resource and managed service that the client delivers to customers. It mediates the data and communication between the operational support systems (within the IT infrastructure library) implemented in the management architecture and the production infrastructure.

In this section, we briefly discuss the capabilities of the major functions of the IBM Tivoli Netcool Configuration Manager.

The network configuration and change management function forms the foundation for the IBM Tivoli Netcool Configuration Manager. Initially, clients load network device definitions into the application and organize these definitions into their specified categories, such as geography or function. Following the initial setup, clients can begin to manage their device configuration changes and backups through Tivoli Netcool Configuration Manager. The following capabilities are available under the network configuration and change management function of ITNCM:

- Back up device configurations dynamically or on a scheduled basis. The product maintains historical configuration versions as defined by the client.
- Detect out-of-band configuration changes and trigger a configuration backup.
- Apply configuration changes to device configurations:
  - You can make changes to a single device configuration.
  - You can make mass changes to multiple devices simultaneously.
  - Scheduled changes can execute during normal maintenance windows.
  - Templated changes configured and applied using command sets reduce errors that can result from manually applied changes.
- Upgrade device operating systems. An automated upgrade process upgrades the operating system on multiple devices.
- Access device terminals through the GUI that allows for access to devices:
  - The device terminal logs all keystrokes for a user session.
  - The device terminal allows direct access to devices by building a secure tunnel to the device.
  - The device terminal allows for automatic configuration backup following each terminal session.

The policy-based compliance management function of Tivoli Netcool Configuration Manager provides a rules-based tool for checking and maintaining network device configuration compliance with various sets of policies.

You can configure compliance checks to check for the presence or absence of specific commands or data in a device's configuration or a response from a query to a device. Based on the results of the compliance check, the tool either reports the results or, if desired, initiates a configuration change to bring a device back into compliance. You can organize and group related compliance checks into higher-level policies. You can schedule compliance checks to execute on a dynamic or scheduled basis. Likewise, you can set up compliance checks to trigger automatically as a result of a configuration change on a device.

The following capabilities are available in the policy-based compliance management function of Tivoli Netcool Configuration Manager:

- Policy-based compliance management uses reusable building blocks for creating compliance checks:
  - Definitions - The lowest level component that contains the configuration data to be checked
  - Rules - Composed of definitions and the actions to take if a device configuration passes or fails
  - Policies - Composed of rules, which can be grouped together across various device types and compliance checks
  - Processes - Group one or more policies to execute against a set of devices on a scheduled basis
- The function allows you to run compliance checks in either a dynamic, scheduled, or automatically triggered manner.
- The function automatically fixes out-of-compliance device configurations to get them back in compliance.
- Policy-based compliance management allows you to configure compliance reports for automatic generation and distribution.

The integration of Tivoli Network Manager, Tivoli Netcool/OMNIbus, and Tivoli Netcool Configuration Manager provides a closed loop network management problem resolution in one single solution.

Figure 2-43 on page 134 shows the closed loop problem resolution provided by the integration of Tivoli Network Manager, Tivoli Netcool/OMNIbus, and Tivoli Netcool Configuration Manager.

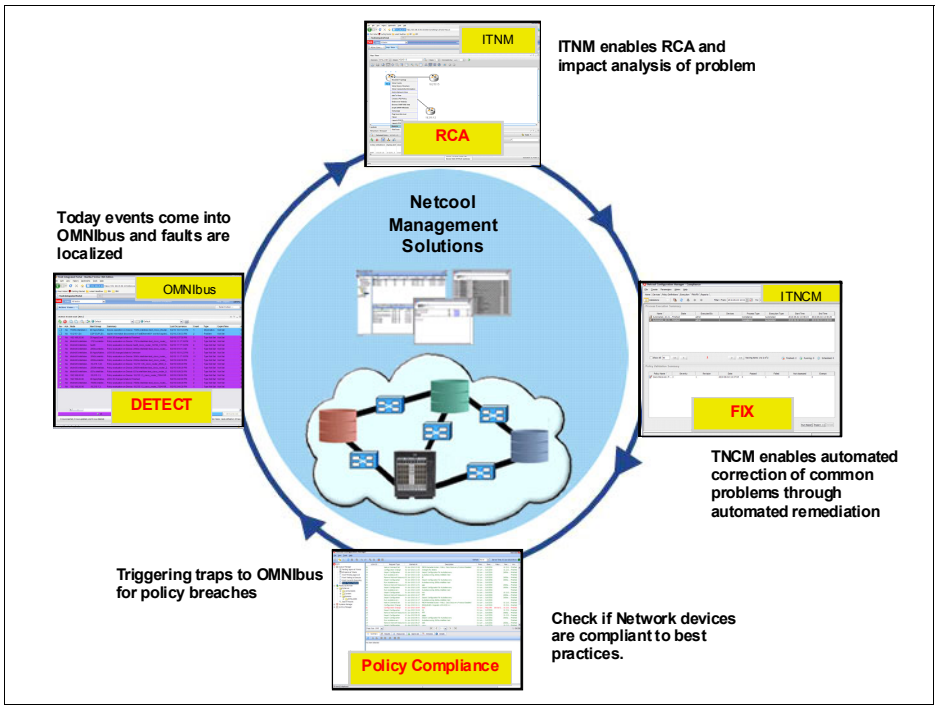

Figure 2-43 Closed loop problem resolution

The integration scenario described in this documentation provides the following benefits:

- The integration reduces inefficiencies associated with separate products to monitor different aspects of the same network. By sharing specific device information and preserving device groupings and hierarchies between Tivoli Network Manager, Tivoli Netcool/OMNIbus and Tivoli Netcool Configuration Manager, you reduce the need to run separate discoveries. The integration ensures both Tivoli Network Manager and Tivoli Netcool Configuration Manager have the same view of the network, and one that is constantly updated as the network changes. This ensures that the administrators for the two products have a consistent view of network outages and enables them to isolate the root cause of outages easily.
- Device configuration problems can be difficult to isolate and identify. By integrating with Tivoli Netcool Configuration Manager, a unified view of events is created that helps operators isolate the problems caused by changes to the network device configuration.
- Tivoli Netcool Configuration Manager maintains a backup of the network configuration, including audit trails. Accidental misconfigurations of a network

device are easy to spot, isolate, and rectify, by simply rolling back the changes via Tivoli Netcool Configuration Manager.

- The integration provides the ability to implement network policies and enforce compliance by utilizing the capability of Tivoli Netcool Configuration Manager to make a change to a large number of devices in one go, while ensuring that the changes are accurate without manual intervention. This reduces the time to value of network management implementation

Within a single application, ITNCM forms the foundation to the network and network services resource configuration, and a combined multi-service, multivendor device configuration management and service activation supporting platform.

In addition, the ITNCM application combines elements of internal workflow, inventory of the infrastructure under management, and automation of the activation of the business services to be deployed on the production infrastructure. Consequently it is possible that ITNCM can be used to launch services onto the network infrastructure in a low risk, low cost, efficient manner, providing a faster return of investment and a rapid service turn-up to customers on the infrastructure without the need to implement huge, complex, and expensive operational support systems (OSS) or business support systems (BSS) infrastructures.

OSS/BSS integration is a key element in the ITNCM solutions architecture. With ITNCM's network automation foundation in place and the Web Services API, ITNCM has the ability to integrate the network and network services, seamlessly into the business workflow, and client management systems at a later stage.

Built upon the patented Intelliden R-Series Platform, ITNCM offers network control by *simplifying* network configurations, *standardizing* best practices and policies across the entire network, and *automating* routine tasks such as configuration and change management, service activation, compliance and security of mission critical network. Figure 2-44 demonstrates this.

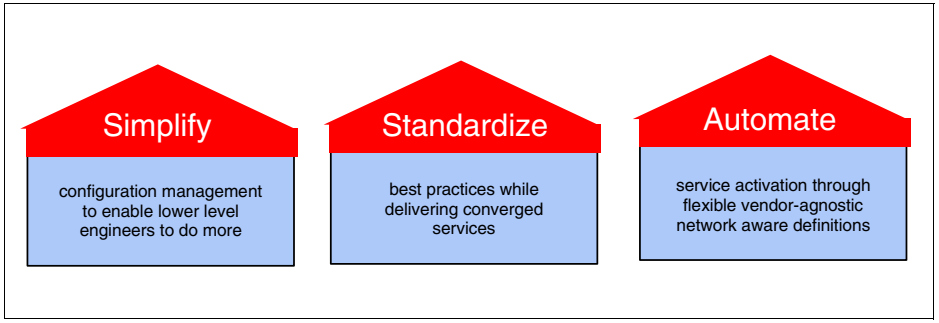

Figure 2-44 Network automation solutions

ITNCM provides flexibility to support a breadth of network changes for heterogeneous devices. By automating the time-consuming, error-prone configuration process, ITNCM supports the vast majority of network devices available from Cisco, Juniper, Brocade, and many other vendors' equipment.

Programmable templates allow you to make bulk changes to multiple devices simultaneously. Changes are driven by predefined policies that determine who can make what changes where in the network.

The key to policy-based change management is a configurable workflow engine for automating error-prone manual and scripted network configuration tasks. It also provides repeatability and a full audit trail of all network changes.

Key configuration management features:

- Change management implements security approvals and scheduled configuration changes.
- Automated conflict detection alerts you to potentially conflicting updates.
- Change detection identifies and reports on configuration changes.
- A complete audit trail tracks all changes, both through ITNCM and outside of the system.

2.7.7 System and network management product integration scenarios

Tivoli products can be used as standalone products. However, to fully address the needs of a dynamic infrastructure, these products can be integrated, thus providing a comprehensive system management solution to specific business requirements. For a more detailed analysis, see *Integration Guide for IBM Tivoli Netcool/OMNIbus, IBM Tivoli Network Manager, and IBM Tivoli Netcool Configuration Manager*, SG24-7893.

From a networking perspective, the various network management, provisioning, and automation products that can be integrated to deliver an integrated solution are shown in Figure 2-45 on page 137.

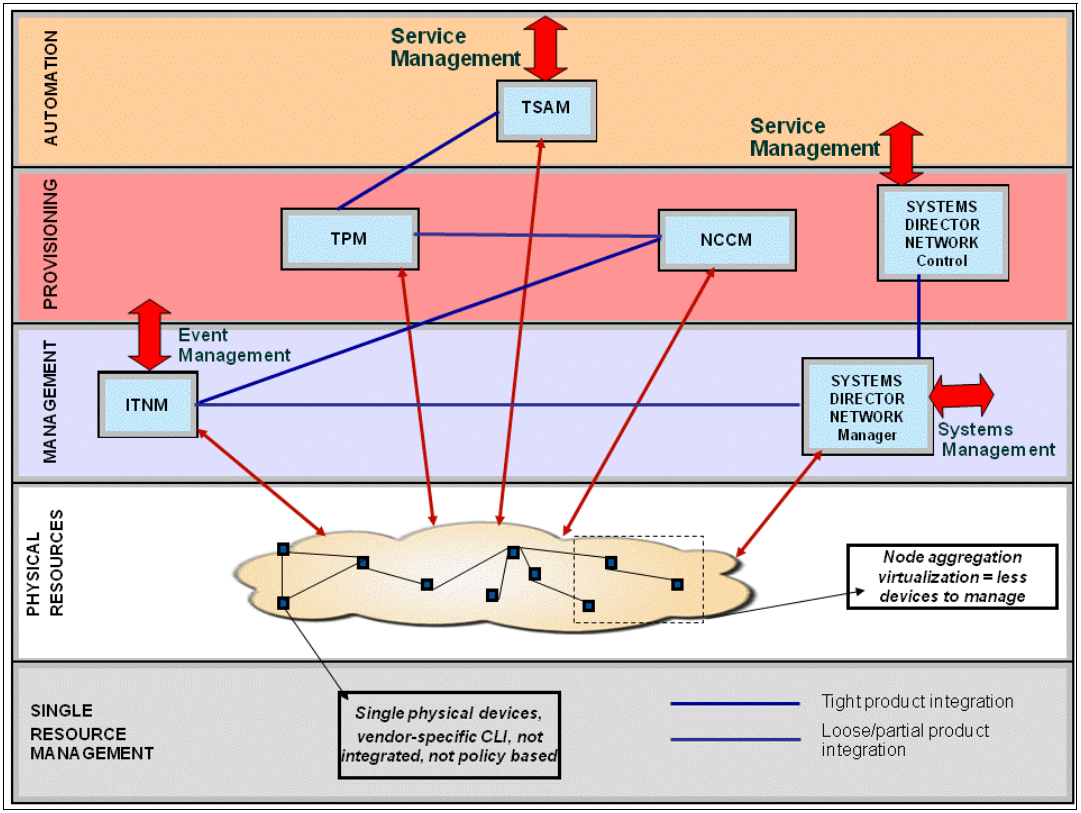

Figure 2-45 Network management integration framework

The three main areas of integration for network management are listed here:

- Integration with Event Management

  This allows the incorporation of network-related events into an overall event dashboard, for example ITNM-Netcool/OMNIbus integration.

- Integration with Systems Management

  This allows the inclusion of networking infrastructure management and provisioning within systems and storage management and provisioning tools, for example the Systems Director Network Manager module.

- Integration with Service Management

  This allows relating networking management and provisioning with IT service management provisioning. Also, the automation of recurring tasks can be performed, theoretically leveraging this kind of integration. The network infrastructure provisioning has to be orchestrated with the server and storage provisioning, for example the TBSM-ITNM integration.

Tivoli development started an integration initiative that provides a guideline about how to converge the products to a common set of rules to allow the products to work together. IBM is implementing this initiative with each product release to enhance the overall integration. The integration initiatives cover the following tracks:

- Security integration initiatives

  Security integration enables Tivoli products to integrate on security aspects, such as authentication and single sign-on, shared user registry support, centralized user account management, consistent authorization, audit log consolidation, and compliance reporting.

- Navigation integration initiatives

  Navigation initiatives allow seamless user interface transition from different Tivoli products when the context is needed. This seamless integration involves integrated user interface and launch in context (LIC) abilities.

- Data integration initiatives

  Data integration allows data structures to be exchanged to ensure the management context is available across different Tivoli products. This data integration includes event transfer and management resource consolidation.

- Task integration initiatives

  Task integration allows a Tivoli management application to use a facility that is provided by a separate Tivoli product. Therefore, it is not necessary to provide an overlapping functionality.

- Reporting integration

  Reporting integration provides centralized management reporting across various Tivoli products. This reporting integration is realized by using Tivoli Common Reporting.

- Agent management

  Agent management allows self-monitoring of various Tivoli products using IBM Tivoli Monitoring agents.

In addition, different levels of integration can be achieved regarding a certain aspect. For example, for navigation integration this can be provided by:

- Basic navigation, which is the ability to move seamlessly between views provided by multiple related products.
- Launch, where one product console can be launched from another.
- Launch in context, where the launched console comes up in the same context that the user had in the launching console. A user might be looking at an event about a problem with a computer system and launch in context to another product console. When it comes up, it displays further information

about that computer system. Single Sign On integration should also be enabled to provide a seamless navigation integration.

- Shared console is an even deeper level of integration. The same console has panels with information from multiple products. When the user changes contexts in one panel, the other panels switch to the same context. The Tivoli Integrated Portal can perform this function.

Generally speaking, the following integration technologies can be leveraged to accomplish these tasks:

- By using Application Programming Interfaces (APIs), for example RESTful
- By using IDML files exchange, using Discovery Library Adapters (DLAs) to translate data structures for different DBs, for example. DLAs are an easy-to-develop, lightweight solution that allows for rapid integration between management products, customer data, and other third-party data sources. These IDML files are created by DLAs on a periodic frequency (set by the client) and then sent to a common location (set by the client) for multiple management products to consume the same set of IDML files.
- Using Tivoli Integration Composer as a gateway between ex-Micromuse and ex-MRO products such as Maximo®.

For more information about these topics, see *Integrating Tivoli Products*, SG24-7757, available at:

http://www.redbooks.ibm.com/abstracts/sg247757.html?Open

2.8 IBM integrated data center solutions

Because demands for IT capacity are unrelenting and often unpredictable, CIOs have found it difficult to design an optimum data center to meet future needs. How can a large, capital-intensive data center be designed to last 30 years when the technology it supports changes every two or three years?

Integrated solutions become more attractive to overcome the complexity of today's IT environments. We present here a brief overview of the main IBM offerings in this space: iDataPlex and Cloudburst.

2.8.1 iDataplex

iDataPlex is an innovative, high density, scale out x86 computing solution. Its design goals are as follows:

- Optimized both mechanically as a half-depth server solution and component-wise for maximum power and cooling efficiency
- Designed to maximize utilization of data center floor space, power, and cooling infrastructure with an industry standard-based server platform
- Easy-to-maintain solution with individually serviceable servers, front access hard drives and cabling
- Customer-specific computer, storage, or I/O needs and delivered preconfigured for rapid deployment
- Common tools across the System x portfolio for management at the node, rack, or data center level

These design goals go far beyond a single server or a single rack level; they are goals for the entire data center. With the new philosophy and the new design, the iDataPlex solution promises to address the data center challenges at various levels:

- An innovative rack design achieves higher node density within the traditional rack footprint. Various networking, storage, and I/O options are optimized for the rack design.
- An optional Rear Door Heat eXchanger virtually eliminates traditional cooling based on computer room air conditioning (CRAC) units.
- An innovative flex node chassis and server technology are based on industry standard components.
- Shared power and cooling components improve efficiency at the node and rack level.
- Intelligent, centralized management is available through a management appliance.

Each of these innovations is described in the following paragraphs.

The iDataPlex rack

The iDataPlex rack cabinet design offers 100 rack units (U) of space. It is essentially two 42U racks connected and provides additional vertical bays. The iDataPlex rack is shown in Figure 2-46 on page 141.

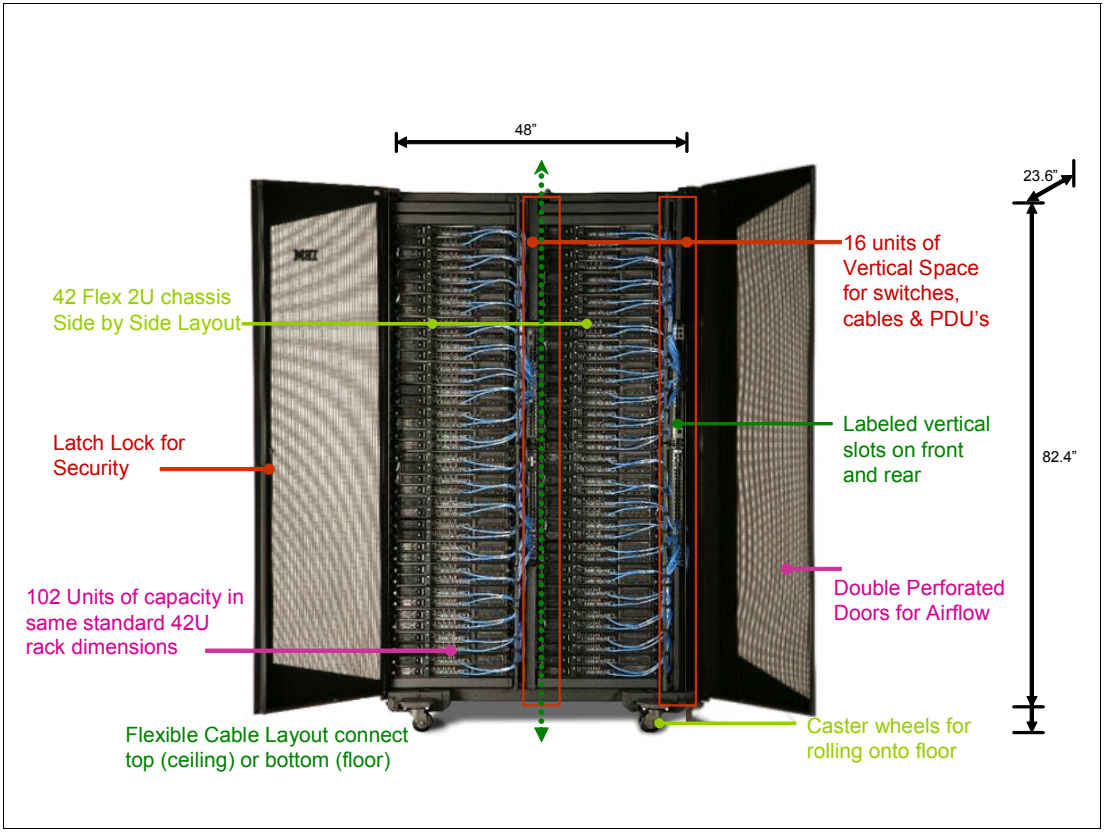

Figure 2-46 Front view of iDataPlex 100U rack

However, the iDataPlex rack is shallower in depth compared to a standard 42U server rack as shown in Figure 2-47 on page 142. The shallow depth of the rack and the iDataPlex nodes is part of the reason that the cooling efficiency of iDataPlex is higher than the traditional rack design (20% less cooling required, 63% less fan power), because air travels a much shorter distance to cool the internals of the server compared to airflow in a traditional rack.

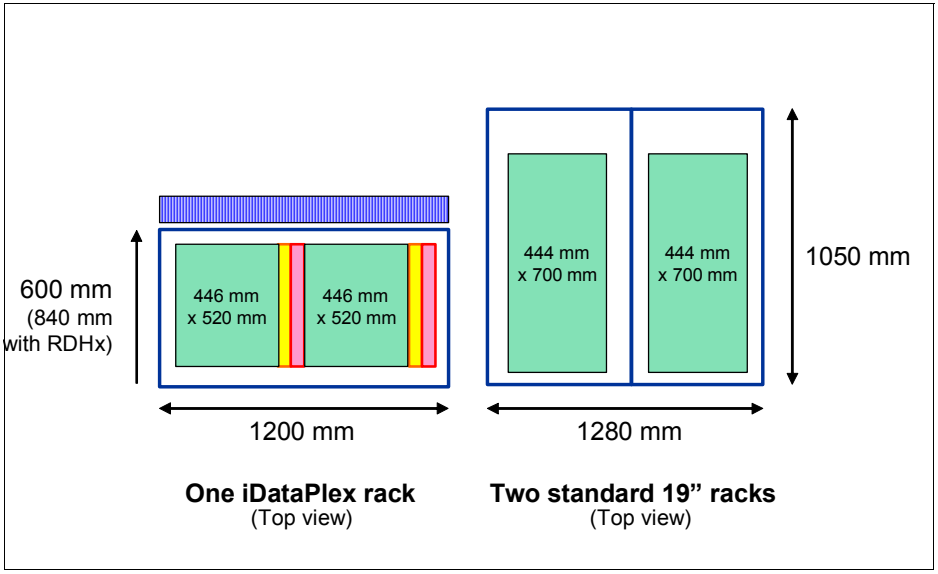

Figure 2-47 Comparison of iDataPlex with two standard 42U racks (top view)

An iDataPlex rack provides 84U (2 columns of 42U) of horizontal mounting space for compute nodes and 16U (2 sets of 8U) of vertical mounting space (sometimes called *pockets*) for power distribution units and networking equipment. This makes a total of 100U usable space on two floor tiles.

Flex node technology

The servers for iDataPlex can be configured in numerous ways by using flex node technology, which is an innovative 2U modular chassis design. The iDataPlex 2U Flex chassis can hold one server with multiple drives or two servers in a 2U mechanical enclosure. Figure 2-48 on page 143 shows two possible configurations of the iDataPlex 2U Flex chassis.

Figure 2-48 Two possible configurations of the iDataPlex 2U Flex chassis

This approach provides maximum flexibility for data center solutions to incorporate a combination of configurations in a rack.

The big picture of iDataPlex

The iDataPlex solution has the following main components:

- A special iDataPlex rack
- Up to 42 2U chassis that are mounted in the rack
- Servers, storage and I/O components that are installed in the chassis
- Switches and power distribution units that are also mounted in the rack

Figure 2-49 on page 144 gives an idea of how these components are integrated.

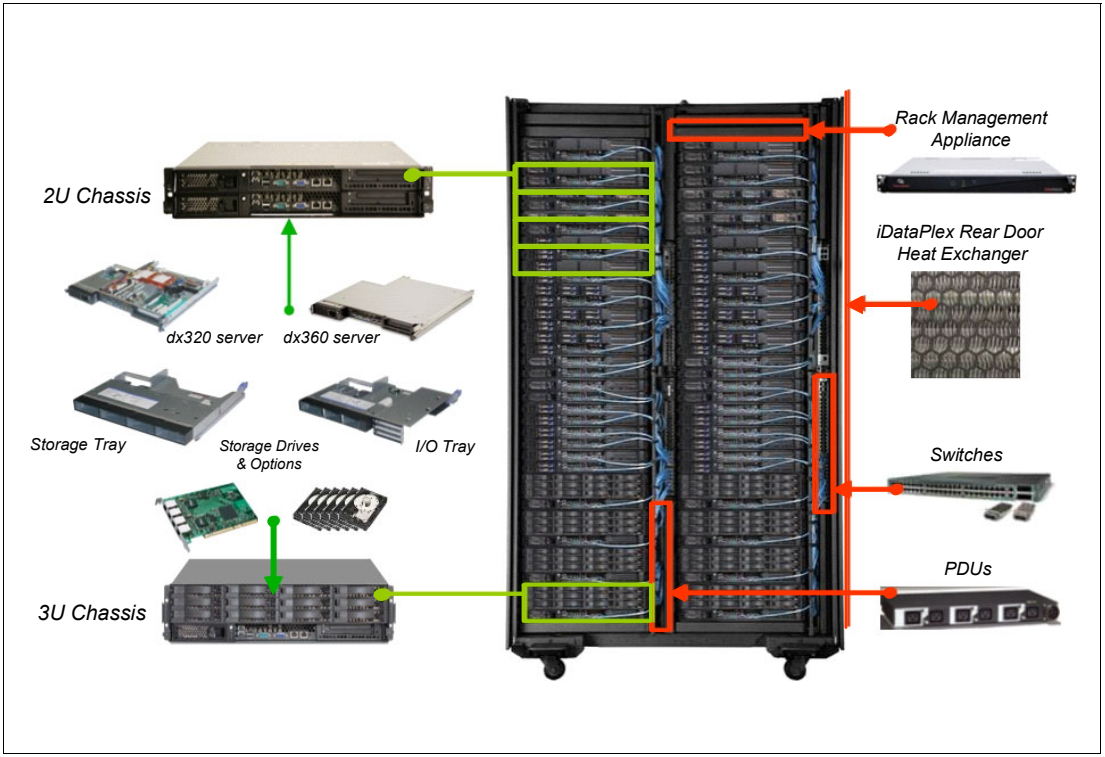

Figure 2-49 iDataPlex and its components

On the left side is a 2U (top) and a 3U chassis (bottom). These can be equipped with several different server, storage, and I/O components. The populated chassis are mounted in an iDataPlex rack (middle). This rack was specifically designed to meet high-density data center requirements. It allows mandatory infrastructure components like switches and power distribution units (PDUs), as shown on the right, to be installed into the rack without sacrificing valuable server space. In addition, the iDataPlex solution provides management on the rack level and a water-based cooling option with the Rear Door Heat eXchanger.

Ethernet switch options

Several Ethernet switches are supported, as listed in Table 2-8 on page 145. They cover a wide range of application scenarios.

Table 2-8 Supported Ethernet switches

Switch	Ports	Layer	Port speed
BNT RackSwitch™ G8000F	48	L2/3	1 Gbps[a]
BNT RackSwitch G8100F	24	L2	10 Gbps
BNT RackSwitch G8124F	24	L2	10 Gbps
Cisco 2960G-24TC-L	24	L2	1 Gbps
Cisco 3750G-48TS	48	L2/3	1 Gbps
Cisco 4948-10GE	48	L2/3/4	1 Gbps[a]
Force10 S50N	48	L2/3	1 Gbps[a]
Force 10 S2410CP	24	L2	10 Gbps
SMC 8024L2	24	L2[b]	1 Gbps
SMC 8126L2	26	L2	1 Gbps
SMC 8708L2	8	L2	10 Gbps
SMC 8848M	48	L2[c]	1 Gbps[a]

a. 10 Gb uplink modules available
b. Has L2/3/4 Quality of Service features
c. Has limited L3 capabilities

If the plan is to use copper-based InfiniBand and Ethernet cabling, then mount both switches horizontally, if possible. This is due to the number of cables that go along the B and D columns; all the copper cables take up so much space in front of the vertical pockets that proper cabling to vertically-mounted switches is no longer possible. Figure 2-50 on page 146 illustrates the recommended cabling.

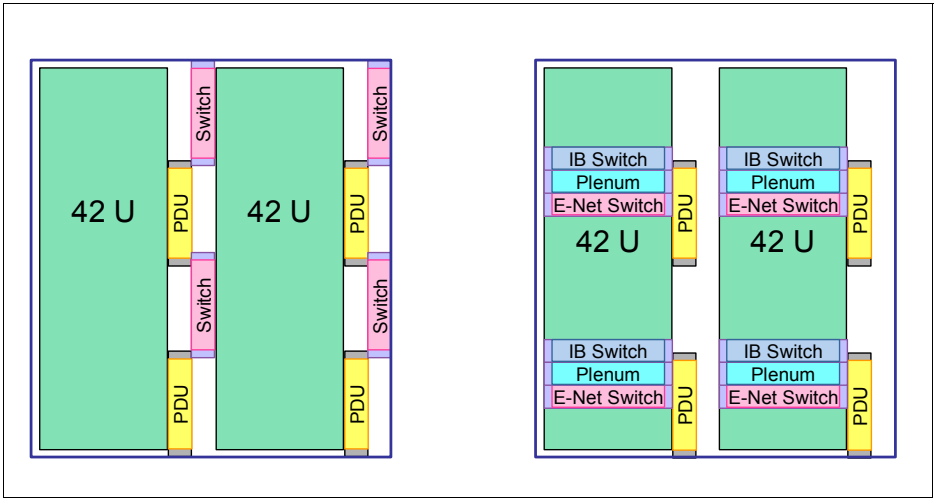

Figure 2-50 Recommended cabling for Ethernet-only (left) and Ethernet plus InfiniBand (right)

For more information, see *Implementing an IBM System x iDataPlex Solution*, SG24-7629 at:

http://www.redbooks.ibm.com/redbooks/pdfs/sg247629.pdf

2.8.2 CloudBurst

IBM CloudBurst is a prepackaged private cloud offering that brings together the hardware, software, and services needed to establish a private cloud. This offering takes the guesswork out of establishing a private cloud by preinstalling and configuring the necessary software on the hardware and leveraging services for customization to the environment. Just install the applications and begin exploiting the benefits of cloud computing, such as virtualization, scalability, and a self-server portal for provisioning new services.

IBM CloudBurst includes a self-service portal that allows users to request their own services, automation to provision the services, and virtualization to make system resources available for the new services. This is all delivered through the integrated, prepackaged IBM CloudBurst offering and includes a single support interface to keep things simple.

IBM CloudBurst is positioned for enterprise clients looking to get started with a private cloud computing model. It enables users to rapidly implement a complete cloud environment including both the cloud management infrastructure and the cloud resources to be provisioned.

Built on the IBM BladeCenter platform, IBM CloudBurst provides preinstalled capabilities essential to a cloud model, including:

- A self-service portal interface for reservation of compute, storage, and networking resources, including virtualized resources
- Automated provisioning and deprovisioning of resources
- Prepackaged automation templates and workflows for most common resource types, such as VMware virtual machines
- Service management for cloud computing
- Real-time monitoring for elasticity
- Backup and recovery
- Preintegrated service delivery platforms that include the hardware, storage, networking, virtualization, and management software to create a private cloud environment faster and more efficiently

IBM CloudBurst is a prepackaged and self-contained service delivery platform that can be easily and quickly implemented in a data center environment. It provides an enhanced request-driven user experience, and aids in an effort to help drive down costs and accelerate time to market for the business.

The service management capabilities of IBM CloudBurst include:

- IBM Tivoli Service Automation Manager.
  - Enhanced Web 2.0 interface image management capability
  - Resource reservation capabilities allowing environments to be scheduled
- The delivery of integrated IBM Tivoli Usage and Accounting capability to help enable chargeback for cloud services to optimize system usage.

  This enables the creation of resource usage and accounting data to feed into Tivoli Usage and Accounting Manager, which allows for tracking, planning, budgeting, and chargeback of system resource usage.
- A high availability option using Tivoli Systems Automation and VMware high availability that provides protection against unplanned blade outages and that can help simplify virtual machine mobility during planned changes.
- Integration with Tivoli Monitoring for Energy Management that enables monitoring and management of energy usage of IT and facility resources, which can assist with efforts to optimize energy consumption for higher efficiency of resources, in an effort to help lower operating cost.
- An optional secure cloud management server with IBM Proventia® Virtualized Network Security platform from IBM Security. IBM Proventia protects the CloudBurst production cloud with Virtual Patch®, Threat

Detection and Prevention, Proventia Content Analysis, Proventia Web Application Security, and Network Policy enforcement.

  - Detects and blocks network attacks and unauthorized network access.
  - Enables cloud computing service providers to deliver segmented security in multi-tenant virtual environments.
  - Integrates virtualized security with traditional network protection to reduce complexity of security operations.

- Support for the ability to manage other heterogeneous resources outside of the IBM CloudBurst environment (this requires the purchase of additional licenses).

Figure 2-51 The front view of a 42U rack for IBM Cloudburst

For more information, see:

http://www.ibm.com/ibm/cloud/cloudburst/

3

Data center network functional components

After presenting Chapter 2, “Servers, storage, and software components” on page 31, we now concentrate on network virtualization concepts and key functional areas that need to be understood and applied while designing data center networks. This chapter contains the following sections:

- Section 3.1 describes the domains of network virtualization technologies for the data center network.
- Section 3.2 describes the impact on the data center network of the server and storage consolidation and virtualization technologies described in Chapter 2, “Servers, storage, and software components” on page 31.
- Section 3.3 describes the impact on the data center network of consolidating multiple, scattered data centers into a “single distributed data center.”
- Section 3.4 presents the main network virtualization technologies that can be leveraged in the data center.

For a general overview of the main networking protocols and standards, refer to *TCP/IP Tutorial and Technical Overview*, GG24-3376, which can be found at:

http://www.redbooks.ibm.com/abstracts/gg243376.html?Open

3.1 Network virtualization

Network virtualization techniques can be leveraged in the networking infrastructure to achieve the same benefits obtained through server and storage virtualization. Moreover, the network, especially in the data center, must also support this new dynamic environment where the computing and storage infrastructures are consolidated and virtualized, to meet new requirements (VM mobility, for example) and facilitate the delivery of IT services across heterogeneous network access technologies to multiple user devices (see 3.3, “Impact of data center consolidation on the data center network” on page 157 and 3.4.2, “Traffic patterns at the access layer” on page 164 for more information).

Network virtualization can be seen as an umbrella term, since many different techniques exist at many different levels of the networking infrastructure. In the early ages of IT, communication lines were tightly coupled with systems and applications. The fact that one single link could carry traffic for different applications and systems was indeed one of the first manifestations of network virtualization, enabled by the standardization of interfaces, protocols and drivers. In this case one physical link can be seen as made up by different logical wires, so it is an example of one-to-many virtualization (or partitioning), that is, a single entity logically partitioned into multiple logical entities. The exact opposite is many-to-one virtualization (aggregation); in this case multiple entities are combined to represent one logical entity.

Current network virtualization techniques leverage both partitioning and aggregation and can be categorized generically as depicted in Figure 3-1 on page 151. All these features are discussed in detail in the next sections, along with the network requirements for the consolidation and virtualization of the rest of the infrastructure.

- Network interface virtualization - These techniques refer to the Ethernet NICs and how they can be partitioned or aggregated. Sometimes these features are categorized as I/O Virtualization techniques (see 3.4.7, “Virtualized network resources in servers” on page 185 for further details).
- Network Link virtualization - These techniques refer to how physical wires can be logically aggregated or partitioned to increase throughput and reliability or to provide traffic separation using the same physical infrastructure.
- Network Node virtualization - These techniques refer to how network devices can be logically aggregated (for example, using stacking) or partitioned (see 3.4.3, “Network Node virtualization” on page 166 for further details).

- Data Center Network-wide virtualization - These techniques extend the virtualization domain to the whole Data Center Network and even to the WAN in case there are multiple Data Centers.

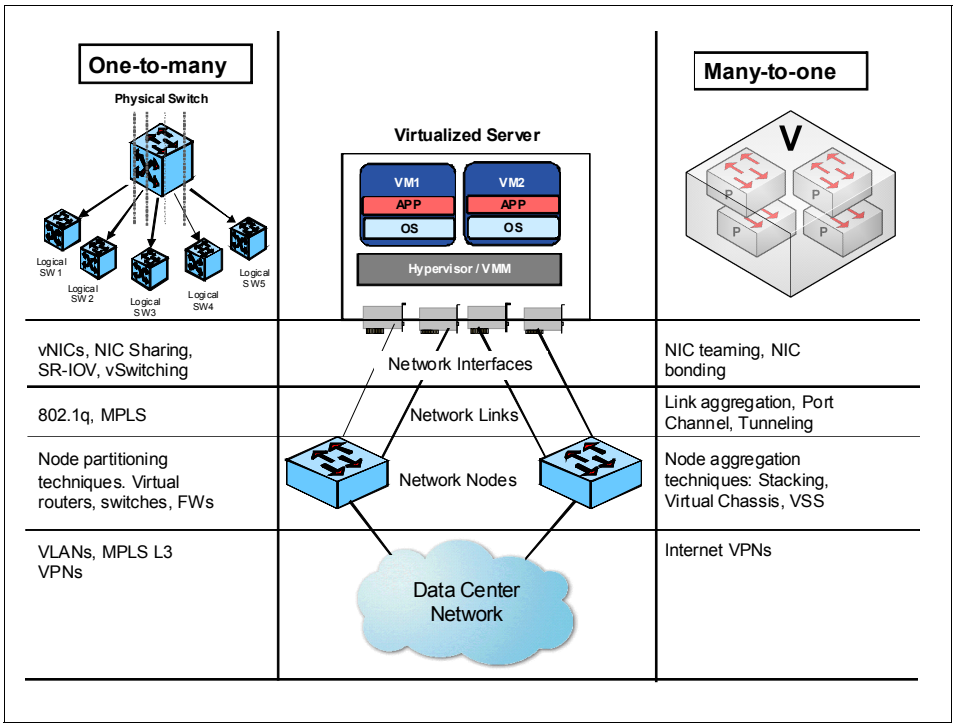

Figure 3-1 Network virtualization domains

Some of these virtualization features are based on open standards (such as 802.1q VLANs), but many others are still tied to specific vendor implementations, so interoperability is not always guaranteed.

The virtualization features that were introduced are targeted mostly at the forwarding and control planes. However, management plane and services plane virtualization techniques are also emerging in the marketplace.

- Management plane virtualization enables multitenant data center network infrastructures because different virtual networks can be managed independently without conflicting with each other.
- Services plane virtualization (see 3.4.5, “Network services deployment models” on page 176) allows you to create virtual services contexts that can be mapped to different virtual networks, potentially in a dynamic fashion. This is a pivotal functionality in a dynamic infrastructure because it provides

simplified scaling, reduced time-to-deploy and more flexibility compared to the appliance-based deployment model.

Another level of abstraction that is quite common in networking is the concept of an *overlay* network. This can be defined as a virtual network defined on top of a physical network infrastructure. An example of an overlay network is the Internet in its early stages, which was an overlay on the plain old telephone service (POTS). The same approach can be used for large scale content delivery and for video surveillance applications over IP, for example.

Other networking-related virtualization features can refer to the ways network addresses are used in the data center. Both layer 2 (MACs) and layer 3 (IP) addresses virtualization techniques are available and can bring management issues to the table.

3.2 Impact of server and storage virtualization trends on the data center network

The current landscape in the data center is characterized by several business issues and leading edge technology trends. From a business perspective:

- New economic trends necessitate cost-saving technologies, such as consolidation and virtualization, like never before.
- Mergers and acquisition activities bring pressure for rapid integration, business agility, and fast delivery of IT services.
- The workforce is getting increasingly mobile; pervasive access to corporate resources becomes imperative.
- Data security is becoming a legal issue. Companies can be sued and fined, or incur other financial damages for security breaches and for non-compliance.
- Energy resources are becoming a constraint and should be considered a requirement for an enterprise-grade network design.
- Users' dependency on IT services puts increasing pressure on the availability and resilience of the infrastructure, and competition and on demand for real-time access to services and support.

Those business drivers are causing new trends to develop in data center architectures and the network must adapt with new technologies and solutions, as follows:

- The new landscape brings the focus back to the centralized environment. The distributed computing paradigm may not always match the needs of this dynamic environment. Virtualization and consolidation together put more

traffic on single links since the “one machine-one application” correlation is changing. This can cause bottlenecks and puts pressure on the access layer network.

For example, the End of Row (EoR) model may be unfit to sustain this new traffic pattern and so the Top of Rack (ToR) model is rapidly becoming attractive. The access switch sprawl can be effectively managed by consolidating several access nodes into a bigger, virtual one.

Figure 3-2 shows the consolidation and virtualization of server and storage.

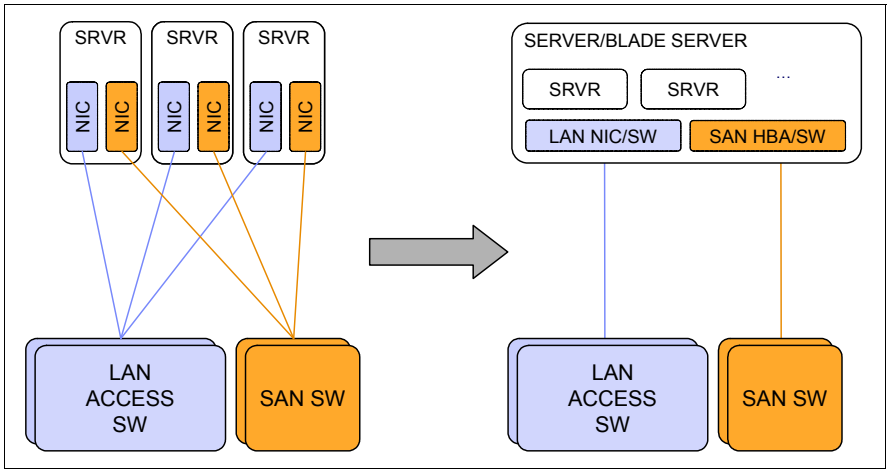

Figure 3-2 Server Consolidation

- Virtualization brings a new network element into the picture. The virtual switch in the hypervisor cannot always be managed efficiently by traditional network management tools, and it is usually seen as part of the server and not part of the network. Moreover, these virtual switches have limited capabilities compared with the traditional network hardware (no support for multicast and port mirroring, plus limited security features). However, virtual switches are becoming much more capable over time. Hypervisor development is opening up new opportunities for more feature-rich virtual switches.

  Figure 3-3 on page 154 shows networking challenges due to virtual switches and local physical switches.

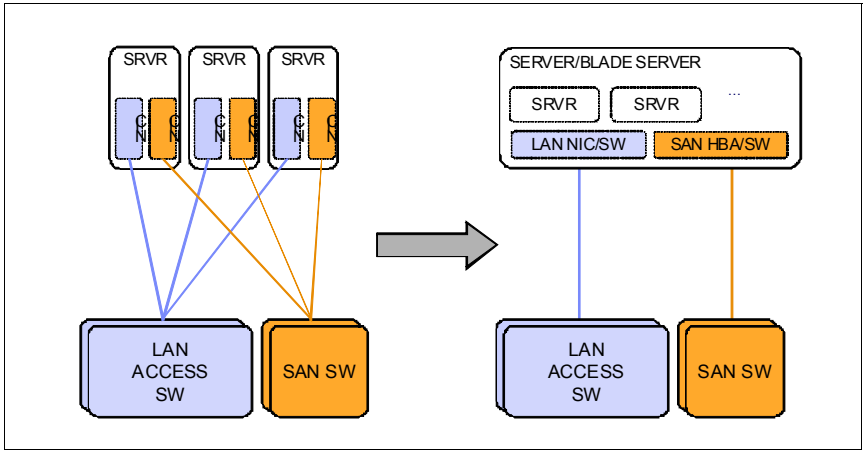

Figure 3-3 Server virtualization

- The server and its storage are being increasingly decoupled, through SANs or NAS, thus leading to the possibility of application mobility in the data center.
- The 10 Gb Ethernet is reaching its price point for attractiveness. This increased capacity makes it theoretically possible to carry the storage traffic on the same Ethernet cable. This is also an organizational issue because the storage and the Ethernet networks are usually designed by different teams.

  Figure 3-4 on page 155 shows storage and data convergence and its impact on the network infrastructure.

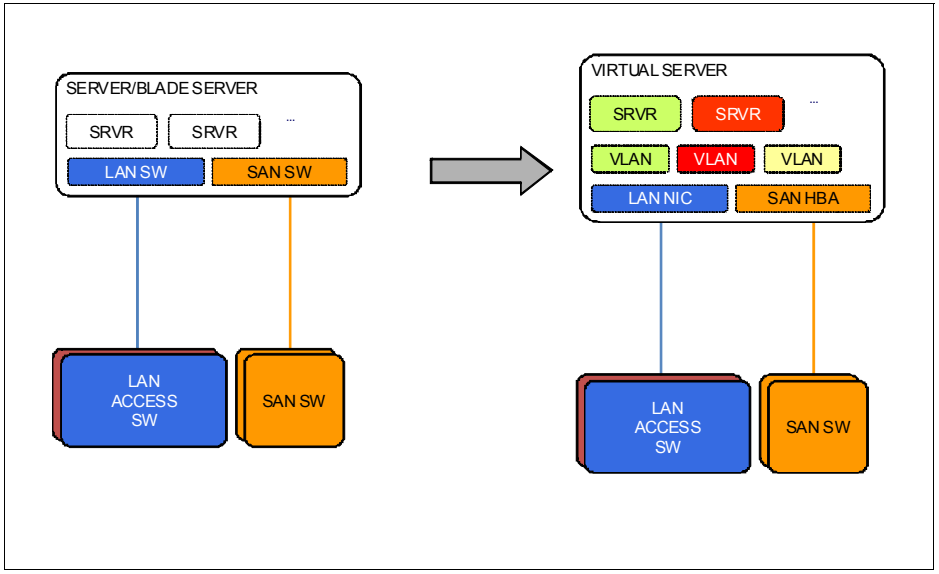

Figure 3-4 Storage and data convergence impact on the network infrastructure

- The consolidation of the distributed IT environment into single distributed data centers struggles with an increasingly mobile workforce and distributed branch offices. Distance, and thus latency, increases for remote access users. New technologies are available to address this issue and bring better response times and performance to this scattered user base.

  This becomes even more critical for applications that exchange significant amounts of data back and forth, because both bandwidth and latency must be optimized on an application and protocol level, but optimizing network utilization is not usually a priority during application development.

Figure 3-5 shows how increasing distance may impact application response time. This diagram does not show security layers, which also add end-to-end latency.

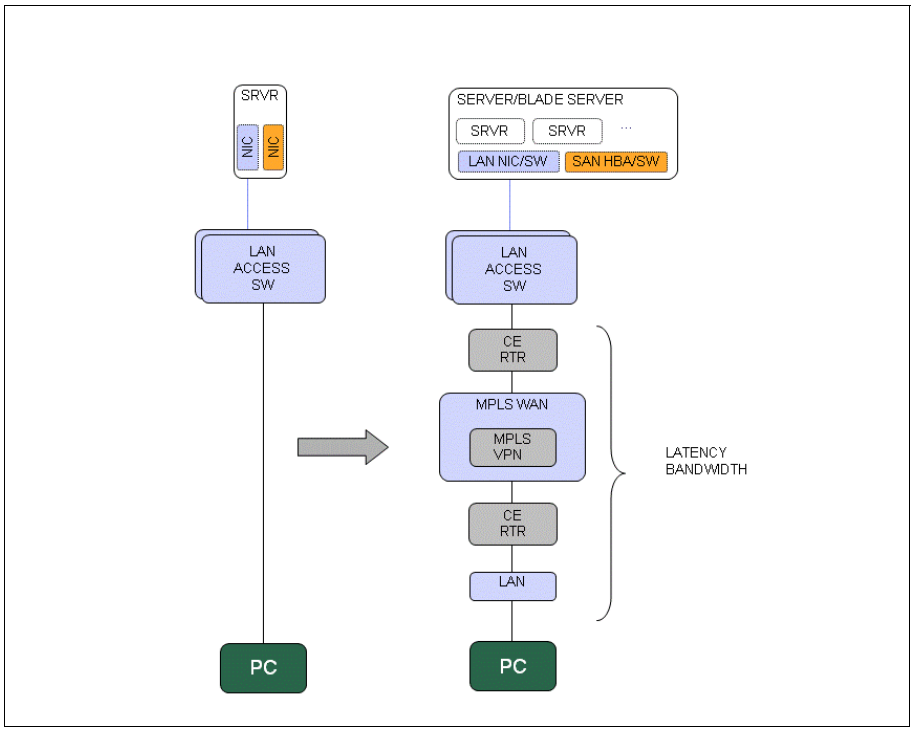

Figure 3-5 Impact of increasing distance on latency

- Designing a traditional data center network usually implied deploying firewalls between the users and the applications, but this is rapidly changing because network and security must be designed together with a comprehensive architecture in order to ensure that security appliances do not decrease end-to-end performance. The high-level design should include secure segmenting based on business needs and priorities. Security services should be coupled with the applications even if these are mobile across data centers.

  Additional technologies can be used to provide this secure segmentation, for example VRFs. At the same time remote users must be authenticated and access is to be controlled and virtualized to enter the IP core and use the centralized, virtualized IT resources.

  Figure 3-6 illustrates access control and defined policies, as well as support for remote and mobile application access.

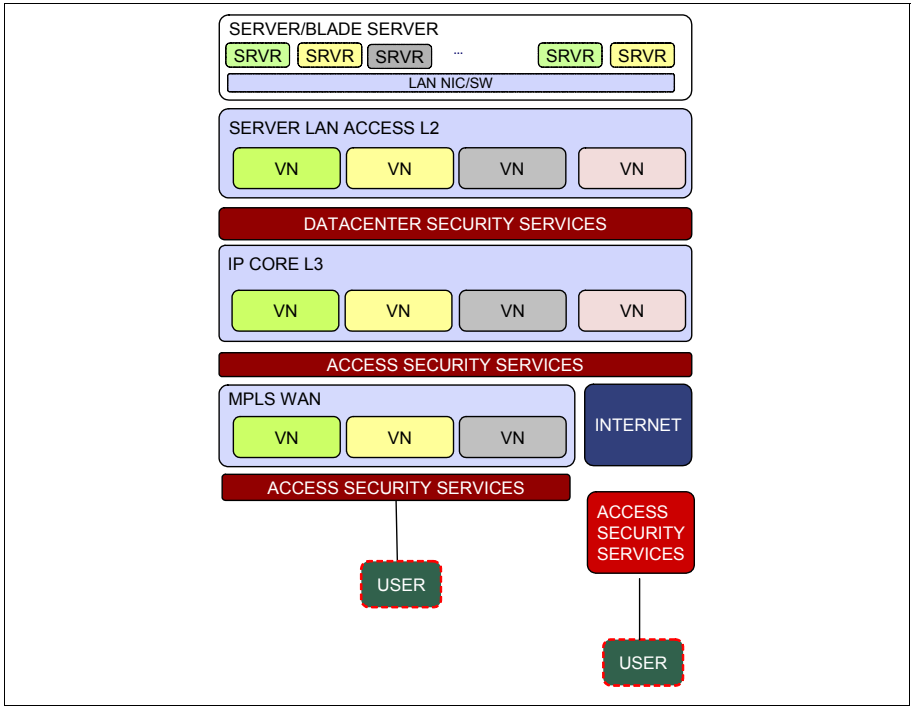

Figure 3-6 Access control and defined policies

3.3 Impact of data center consolidation on the data center network

Currently there is a clear trend in how applications are delivered to clients over the network: a return to a centralized IT model and away from distributed computing environments. This gives birth to the concept of a “single distributed data center,” which means that multiple data centers can behave logically as one single entity. The main enablers of this recentralization include:

- Server consolidation patterns across enterprise data centers resulting from the constantly increasing computing power available in the same physical space.

  This consolidation makes it possible to simplify administration, management, backup, and support by keeping the IT resources concentrated in one place rather than having a distributed model, and also allows adherence to regulatory compliance.

- Server virtualization patterns that allow many applications to run concurrently, yet independently, on a single physical server.
- The increasing availability of WAN services at lower prices. Application servers can be positioned in a central data center, accessed across a WAN and still be responsive enough for business requirements.

Server consolidation and virtualization combined clearly increase the average traffic volume per server dramatically, thus increasing the risk of network congestion.

The main effects of consolidating several geographically dispersed data centers into a single logical one are listed here:

- Infrastructure scalability requirements become more important. The architecture of a single, very large data center is very different from the one supporting multiple, smaller data centers.
- Single faults affect a larger part of the infrastructure. Hardware problems occurring on a single physical machine may affect multiple services that rely on the logical servers inside the physical host.
- From a network point of view, the forwarding plane becomes more complex. Additional resiliency is required using, for example, load sharing solutions to avoid chokepoints and single points of failure.

In addition to recentralization of the IT infrastructure, users now also need to access these resources from increasingly scattered locations. Laptop computers, mobile devices and wireless connectivity (such as WiFi and cellular networks) allow users to meet their business requirements in an increasingly “connected-yet-dispersed” fashion.

Users that access centralized applications from branch offices or remote locations expect LAN-like performance regardless of the connection they are relying on. However, this requirement can be difficult to fulfill and also very expensive if it is addressed only by acquiring more WAN bandwidth. This approach may also be ineffective in some cases due to, for example, the TCP transmission window mechanism.

Furthermore, with applications growing richer in content and application developers often overlooking the need to optimize network consumption, it becomes challenging to offer LAN-like performance to remote users accessing centralized IT applications. This is especially true because low priority applications share the same WAN resources used by business-critical applications and congestions may occur. This is why it is very important to classify applications according to a consistent QoS model and apply it end to end.

This scenario also impacts the latency that users experience when accessing applications, given that data travels over a longer distance and more appliances are involved in the traffic flow. This is particularly harmful for applications that rely on a large number of small packets travelling back and forth with a small amount of data (*chattiness*).

In addition to WAN slowing down the application access to users, another critical requirement in this scenario is the availability of the centralized IT infrastructure. A single fault, without a proper single point of failure avoidance and disaster recovery (or even business continuity) strategy, would affect a very large population with a dramatic negative impact on productivity (service uptime and revenues are increasingly tightly coupled).

Increased application availability can be provided by:

- Leveraging increased HA features of single systems and components

  From a network perspective, this also means being able to upgrade software and hardware components without turning off the entire system. This becomes even more important if the system leverages virtualization technologies because several logical systems may experience downtime.

- Providing redundancy at every level in the network
  - Interface level (NIC teaming, NIC sharing, and so on)
  - LAN Link level (either spanning tree-based or with an active/active model)
  - Device level (node aggregation)
  - WAN Access level (Dual/Multi-homed Service Provider Connectivity that can be implemented using BGP or dedicated appliances)
  - Site level (disaster recovery, global load balancing). This can also be implemented with an Active-Active scheme (DNS-based or using dedicated devices) to maximize resource utilization.

As consolidation initiatives arrive at a concrete implementation phase, bandwidth costs may still be an important item in the business case for emerging economies. IT managers might have a need to properly manage their connectivity to make sure critical-application traffic gets priority over traffic that can be delayed or that is not time sensitive. In more mature markets, prices for bandwidth are decreasing but traffic shaping is still a possible method for approaching these situations and preventing slow response times during high usage conditions and avoid increasing bandwidth for some locations including the data center links.

Concurrent access to centralized applications and sources of data from several branch offices, from an application resources perspective, might not pose any problems, even if the committed rate of the connectivity itself looks to be enough for average traffic. Traffic shapers have to be considered when the need is to allocate precisely the right amount of bandwidth resources to the right service

and thus have a means to guarantee the operational level agreement with the business units. Figure 3-7 on page 161 demonstrates policy enforcement using traffic shapers.

From a data center perspective this implies that a certain slice of bandwidth is dedicated to the single branch office to deliver the mission-critical services. Classification of traffic needs to be done in advance because the number of applications that travel the wide area network (WAN) can be vast, and traffic shapers can also limit the bandwidth of some kind of applications (for example ftp transfer, p2p applications) so that all services are available but performance can vary over different conditions.

This approach gracefully avoids service disruption by preventing services from contending for the same network resources. Classification needs to evolve with traffic patterns and applications that change over time. This aspect is critical for management of the solution and does not have to turn into something overwhelming for the IT department. A sound financial analysis is advisable in order to understand what should be done strategically over time to guarantee the service levels to all branch offices and other external users.

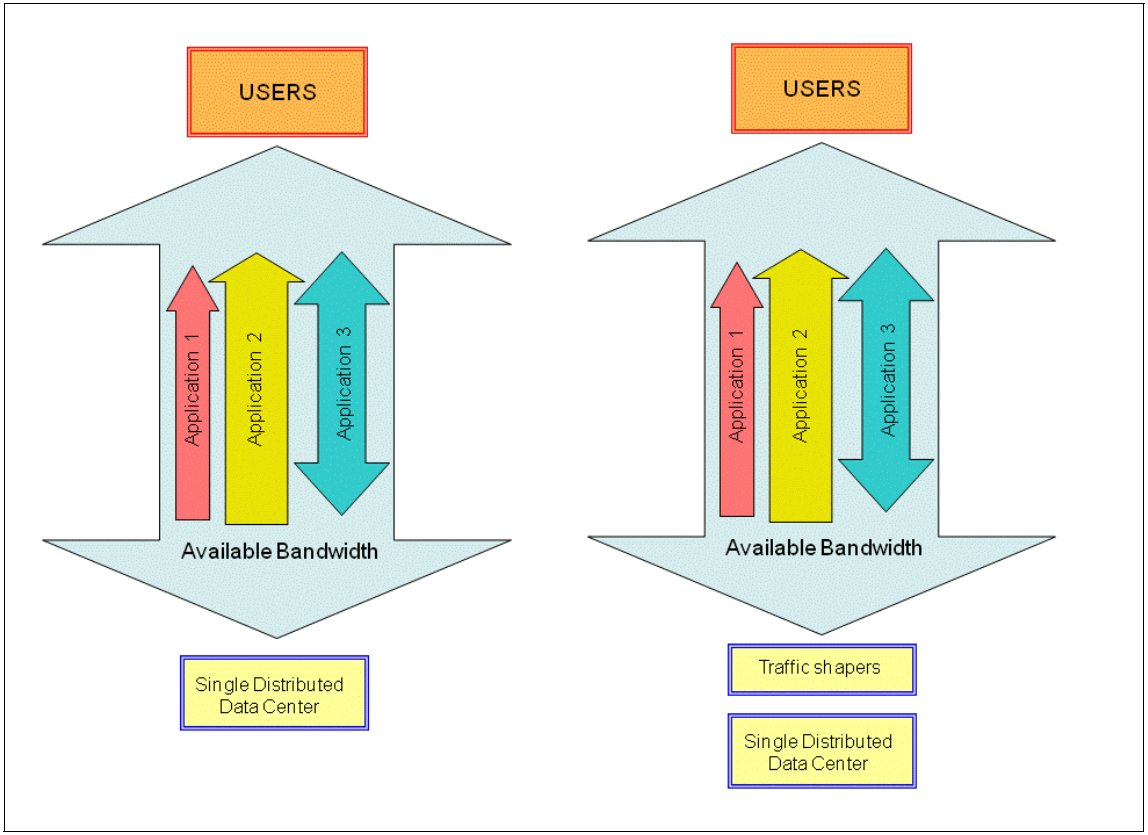

Figure 3-7 Policy enforcement with traffic shapers

Another technique that can be used to optimize bandwidth resources is WAN optimization. WAN Optimization Controllers (WOCs) are appliances deployed in a symmetrical fashion, both in the data center and in the remote office, creating a “tunnel” between sites that need to be accelerated. The goal of WOCs is to use bandwidth more efficiently and to free up some space for new applications or flows to be delivered over the wide area network.

WOC techniques can also reduce latency at the session level, not at the link level, which depends on other factors the WOC cannot change. This is important because WOCs do not accelerate traffic on the link but are appliances that sit in the middle of the session to understand the packet flows, avoid data duplication and combine and reduce packets of the application sessions in order for a single IP datagram sent over the tunnel to carry more packets of the same or different sessions, thus reducing the overall latency of a single session.

An additional approach is to deploy application front-end special-purpose solutions known as Application Delivery Controllers (ADCs). This asymmetric WAN Optimization approach is provided by deploying feature-rich and application-fluent devices that are capable of handling Layer 4 through Layer 7 information, together with the traditional load balancing features such as server health monitoring and content switching. As stated above, this layer sits in front of the application to mainly offload servers from:

- Terminating the SSL sessions, leaving more processor cycles to the application
- Serving repetitive and duplicate content to the users by instructing the users' browser to use the dynamic or static objects that will be cached locally.

This approach has the benefit of lowering the use of disk, memory, and processor resources in both a virtualized or traditional environment. For example, the consequence in a virtualized data center is more VMs per physical server due to reduced resource utilization.

Another aspect of ADCs is that they are tied to the application layer and, as application traffic, are adapted to VM migrations, even between data centers or to the cloud. Downtime and user disruption are therefore avoided by accelerated data transmission and flexibility in the expansion of the overall service delivery capacity of the service delivery. Other features to consider when approaching ADC solutions are compression that allows less data to be sent over the WAN, and TCP Connections management.

Note that this process can be transparent to both server and client applications, but it is crucial to redirect traffic flows in real time if needed. It is also important that the choice of where to deploy the envisioned solution is meeting the performance and, above all, cost objectives. These functions, just as the other network services, can be implemented using different deployment models (see 3.4.5, "Network services deployment models" on page 176 for more details).

For example, software-based ADCs are entering the market from various vendors. A hybrid deployment model can also be used, leveraging hardware platforms for resource-intensive operations such as SSL termination, and offloading other functions such as session management or load balancing to software-based ADCs.

Each of the described approaches can address different aspects of the overall design and does not necessarily mean that one excludes the other. In fact, the combination of features can efficiently solve the identified issues in bandwidth management.

3.4 Virtualization technologies for the data center network

In this section we present the main virtualization technologies that can be exploited in a data center network context.

3.4.1 Data center network access switching techniques

In this section we present the main techniques that can be leveraged to attach virtual machine-based server platforms to the physical network infrastructure. The term access switch is used to represent the first network device (either physical or logical) that aggregates traffic from multiple VMs up to the core of the data center network.

These techniques can be generally categorized as follows:

- Top of Rack switching - ToR - using fixed form factor, appliance-based switches to aggregate traffic from a single rack and offer connectivity to the data center network core via copper of fiber uplinks. It requires more switches than the End of Row technique (but at a lower price per box), but it simplifies cabling and it is a good fit to enable modular, PoD-based data centers. Note that this is the only option available today (together with Blade switches) for converged access switch solutions capable of handling both Ethernet and fiber channel traffic (Fiber Channel Forwarders - FCFs).
- End (or Middle) of Row switching - EoR (MoR) - using chassis-based modular switches. This model implies having switches in dedicated racks at the end or middle of each row of racks to aggregate traffic from the different racks and connecting them to the data center network core. Usually uplink oversubscription is an issue with this approach since it is not dealt with in a rack-by-rack fashion, and it is difficult and expensive to scale if the number of racks exceeds a certain threshold. On the other hand, there are fewer switches to manage compared with the ToR model, but cabling is more difficult and less flexible.
- Models that mix the best of the ToR and EoR worlds are emerging (for instance virtual End of Row (vEoR) switching, for example using unmanaged (that can act like remote line cards) or managed appliances (fixed form factor switches that can be logically aggregated) in dedicated racks instead of chassis-based switches. This approach aims at minimizing the number of management points and creating a single, big, logical switch that can satisfy the scalability and flexibility requirements driven by consolidation and virtualization.

- Blade Switching - Using Blade Center modules that perform switching functions for the Blade servers and aggregate traffic all the way to the data center network core. These switches have most of the features of the ToRs and EoRs but are specific for a certain Blade server chassis, so there is limited flexibility and also less choice.
- Virtual Switching (vSwitching) - Using part of the hypervisor resources to perform Ethernet switching functions for intra-server VM-to-VM communications. These techniques have limited functionalities compared to physical switches and are typically hypervisor-specific, as shown throughout Chapter 2, “Servers, storage, and software components” on page 31.

The latency introduced by having multiple switching stages (and also, depending on the design, perhaps multiple security stages) from the server to the data center network core, and the availability of high port density 10 GbE core switches is driving the trend towards the delayering of the data center network, which can achieve both significant cost benefits (less equipment to manage) and service delivery improvement (less latency turns into improved application performance for the users).

On the other hand, servers equipped with 10 GbE interfaces induce higher bandwidth traffic flowing to the core layer, so oversubscription on the access layer uplinks may become detrimental for service performance. The development of IEEE standards for 40 GBE and 100 GBE will alleviate this potential bottleneck going forward and help simplify the data center network design.

3.4.2 Traffic patterns at the access layer

During the design phase of a dynamic infrastructure, the traffic patterns of the applications are generally not known by the network architect and are difficult to predict. Without this data, you have to consider trends that will have an impact on the network.

Because of the increasing virtualization of servers, the availability of more powerful multicore processor architectures, and higher bandwidth I/O solutions, it is obvious that the access layer will face huge growth in terms of bandwidth demands.

On the other hand, this trend faces limitations in highly virtualized environments because I/O operations experience significant overhead passing through the operating system, the hypervisor, and the network adapter. This may limit the ability of the virtualized system to saturate the physical network link.

Various technologies are emerging to mitigate this. For example, bypassing the hypervisor using a Single Root I/O Virtualization (SR-IOV) adapter allows a guest

VM to directly access the physical adapter, boosting I/O performance significantly. This means that the new network access layer becomes the adapter, which incorporates switching capabilities.

However, there is no “one-size-fits-all” solution. For example, there may be different requirements for north-to-south traffic (client to server) and east-to-west traffic (server to server). Because IT services are delivered using an increasing number of different servers that can reside in the same data center (favored by application development methodologies such as SOA), the interaction between these hosts (east-to-west traffic) may play a fundamental role for overall performance, even more important than traffic patterns coming in and out of the data center (north-to-south traffic).

Sometimes the I/O subsystem can be the bottleneck of system virtualization performance, but for other processor-intensive workloads (for example, analytics), I/O subsystem performance may not be an issue.

The outcome of these trends is that the access layer is evolving towards Top of Rack (ToR) topologies rather than pure End of Row (EoR) topologies. A ToR topology is more scalable, flexible, and cost-effective, and it consumes less energy than an EoR topology when dealing with the increased bandwidth demands at the access layer.

In the long term it is desirable to have 10 Gbps capability as close as possible to the servers, especially when a converged access switch solution is installed at the access layer. A converged server can utilize the converged 10 Gbps adapter to burst large files over the Ethernet, if the SAN traffic is low, and the downstream Ethernet network must be able to properly deliver the required bandwidth throughout the network.

Because the traffic pattern varies from data center to data center (actually it is the architecture of the applications and how users are accessing the applications that will generate requirements on the design of the access layer) it is difficult to provide baselines for developing a design.

The modular ToR approach can provide a sufficient solution for today’s bandwidth demands. Because bandwidth can be added where it is needed, it is important that port utilization (both server and uplink ports) is monitored with proper management tools so that bandwidth can be added to the data center infrastructure before bandwidth constraints are recognized by users.

The growth of traffic volume generated at the access layer is tightly coupled with the increase of latency, which is originated by having additional switching stages (virtual switches or blade switches, for example). To lower the latency introduced by the data center network, different architectural patterns are emerging. One possible option is to adopt a two-tiered network by collapsing the core and

aggregation layer. Another alternative is to adopt a cut through ToR switching architecture for the access layer. This switching architecture in the Ethernet world is not something new (it has been popular for Infiniband networks), but it is gaining traction again due to the reduced latency brought by these kinds of switches. Manufacturers are releasing devices with this architecture, which has differences compared to the traditional Store and Forward model:

- Cut through switches forward the Ethernet frames as soon as the Destination MAC address is read.
- No error correction/CRC means that a requirement for cut through switches is that a very low error rate is needed because otherwise physical or data link layer errors will be forwarded to other segments of the network. The host's NIC must perform the discard function instead.
- Virtual Output Queueing architectures are needed to avoid head-of-line blocking, and thereby avoid having the cut through switch behave like Store and Forward due to port contentions. Using windowed protocols such as TCP can exacerbate this situation by increasing response times.

3.4.3 Network Node virtualization

Traditional network virtualization techniques such as VLANs may not be fit to match the complexity and requirements of today's data centers, depending on factors such as scale and requirements. Recently, other techniques have emerged to address this limitation by simplifying the network topology by reducing the nodes count (aggregation), or by reducing the number of nodes needed to sustain the network infrastructure (partitioning). These are all proprietary techniques tied to a specific vendor, but they are key enablers for the next generation dynamic data center.

Node aggregation

Node aggregation techniques are similar to server clustering in some ways because many physical entities are logically grouped as one, single entity. The network impact of this approach is that there are fewer logical nodes to monitor and manage, thus allowing you to disable the spanning tree protocol aggregating links across different physical switches. At the same time, risk is reduced because nodes are still physically redundant, with no single point of failure. In fact the network becomes a logical hub-and-spoke topology with a proprietary control plane replacing the spanning tree protocol. Figure 3-8 on page 167 illustrates node aggregation techniques.

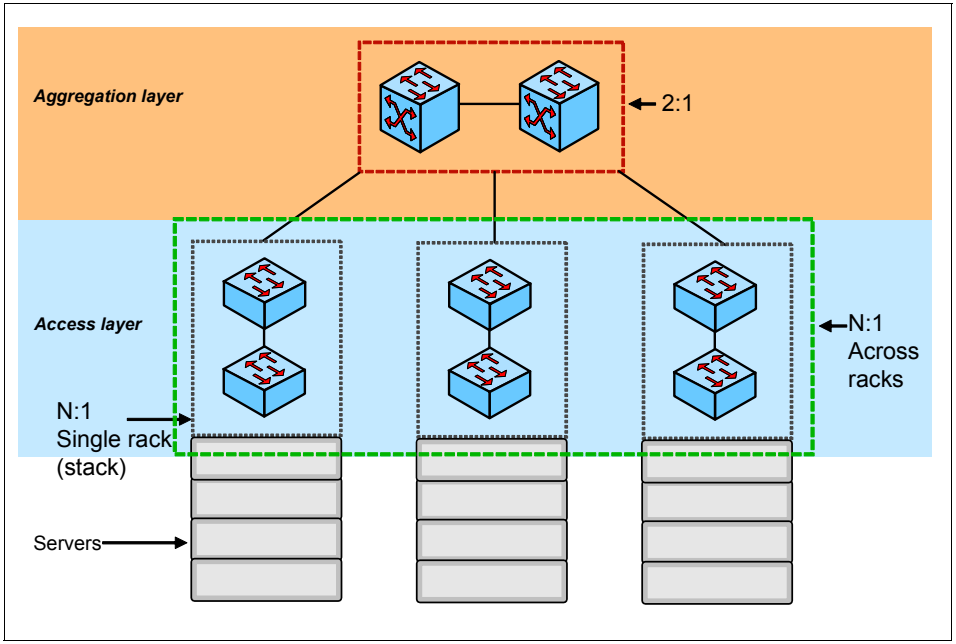

Figure 3-8 Node aggregation techniques

These techniques can be separated into two types:

- 2:1 aggregation

  This is performed at the core or aggregation layer, providing an extended backplane and simplifying dual-homing topologies. This allows for active/active configurations and link aggregation techniques. The logical network becomes a point-to-point topology, so spanning tree protocol can be disabled. By using a logical hub-and-spoke topology you can use all the available bandwidth with multichassis link aggregation techniques that logically group multiple links across different appliances into a single one.

  This also allows to disable default gateway redundancy (such as VRRP), providing the same level of resilience and availability. The L3 processing and routing tables are also simplified because they are shared by two physical nodes.

- N:1 aggregation

  This is performed at the aggregation or access layer and allows many physical switches (especially Top of Rack, or ToR) to be seen as one. This is very important because it simplifies the ToR model, which can add a high degree of complexity even if it better suits the need for an easy-to-manage yet dynamic data center.

N:1 aggregation can be used in the same physical rack by stacking and interconnecting many access servers. Or it can be used across different racks to virtualize the whole access/aggregation layer. Furthermore, with this approach the aggregation layer can be reduced if not eliminated. More traffic can be confined within the access layer.

Sample scenarios of this virtualized environment are many ToR switches that act like a single ToR, or multiple blade switches that act as a single ToR. In these scenarios, multiple uplinks can be combined into an aggregated link to provide more capacity with the same resilience. If one link fails, the overall capacity is reduced but the overall availability is preserved.

Note that the classic L2 topology (Spanning Tree based) is replaced by a private topology that requires some degree of understanding in order to properly design the network, and it may not always be possible to extend these functionalities in a multivendor network environment.

Node partitioning

Node partitioning techniques allow you to split the resources of a single node while maintaining separation and providing simplified (and thus improved) security management and enforcement. Partitioned nodes go beyond virtualizing the forwarding and control planes, such as you have with VLANs.

This type of virtual node also virtualizes the management plane by partitioning the node's resources and protecting them from one another. In this scenario a multitenant environment can be implemented without needing dedicated hardware for each tenant. Another possible use case of this technology is to collapse network zones with different security requirements that were physically separated on the same hardware, thereby improving efficiency and reducing the overall node count.

This model is analogous to the server virtualization techniques in which a hypervisor allows multiple operating system instances to run concurrently on the same hardware. This approach allows for cost-effective, responsive, and flexible provisioning but needs a low-latency network for location-independence.

Typical deployment scenarios are virtual routers, switches, and firewalls that can serve different network segments without having to reconfigure the whole environment if new equipment is added inside the data center. This can be extremely helpful for firewalls because these virtual firewall solutions reduce the need for dedicated in-line firewalling that can become bottlenecks, especially if the link speed is very high.

3.4.4 Building a single distributed data center

The trend to physically flatten data center networks highlights the need for a well thought out logical network architecture that is able to embrace different physical data center technologies, tools and processes to offer to the entire enterprise the correct levels of reliability, availability and efficiency.

The idea is to create an overlay logical network that can transport data providing to the services a single virtualized view of the overall infrastructure. The final goal that this approach can provide is efficiency in the operational costs that can derive from the following factors:

- Better resources utilization: virtualized resource pools that comprises processor, memory and disks, for instance, can be planned and allocated with a greater degree of flexibility by leveraging underlying physical resources that are available in different, yet unified data centers. Also, new workloads can be provisioned leveraging resources that are not necessarily tied up to a physical location. The role of the “standby” data centers can change considerably to an “active” role, with the immediate advantage of better utilization of investments that have been made or are planned to be made. In fact, the scalability of one data center can be lowered because peaks can be handled by assigning workloads to the other data centers.
- Lower service downtime: when data centers are interconnected to create a single logical entity, the importance of redundancy at the link level becomes critical in supporting this model. Redundancy needs to be coupled with overall utilization of the links, which needs to be continuous and at the expected level of consumption. Capacity planning becomes key to enable the overall availability of the services that rely on the IT infrastructure.
- Consistent security policy: distributed yet interconnected data centers can rely on a level of security abstraction that consists of technologies and processes that tend to guarantee a common set of procedures that maintain business operations and are able to address crisis management when needed. Secure segregation of applications and data in restricted zones is also extended to the virtualized data center layer to ensure compliance with the enterprise security framework.
- Correct level of traffic performance by domain or service or type: interconnecting data centers results in even more business transactions contending for network resources. A possible methodology to adopt to address this aspect could be as follows:
  - Gain complete visibility of all the traffic flows.
  - Guided by business requirements, set the right level of priorities mainly from an availability and performance point of view.

  - Enable solutions that can adapt network resources (such as bandwidth on WAN links) depending on the agreed needs (for example, traffic managers) or that can reduce traffic on the WAN links by avoiding deduplication of data patterns (WAN Optimization Controllers).
  - Monitor the overall service performance.

Three major areas need to be considered to plan the interconnection between data centers:

- Layer 2 extension: some applications need to rely on layer 2. If high availability or workload mobility are among the drivers for interconnecting data centers, the layer 2 of the single data center needs to be extended to all the data centers that are relevant to the service.
- Layer 3 extension: some applications (such as backups) can rely on layer 3 and therefore adequate IP connectivity needs to be provisioned between data centers.
- Storage Area Network extension: data within the enterprise is considered a critical asset. Not only the replication, but the availability of data is essential to achieve significant efficiency in the overall journey of building a single distributed data center.

Figure 3-9 on page 171 shows a sample scenario.

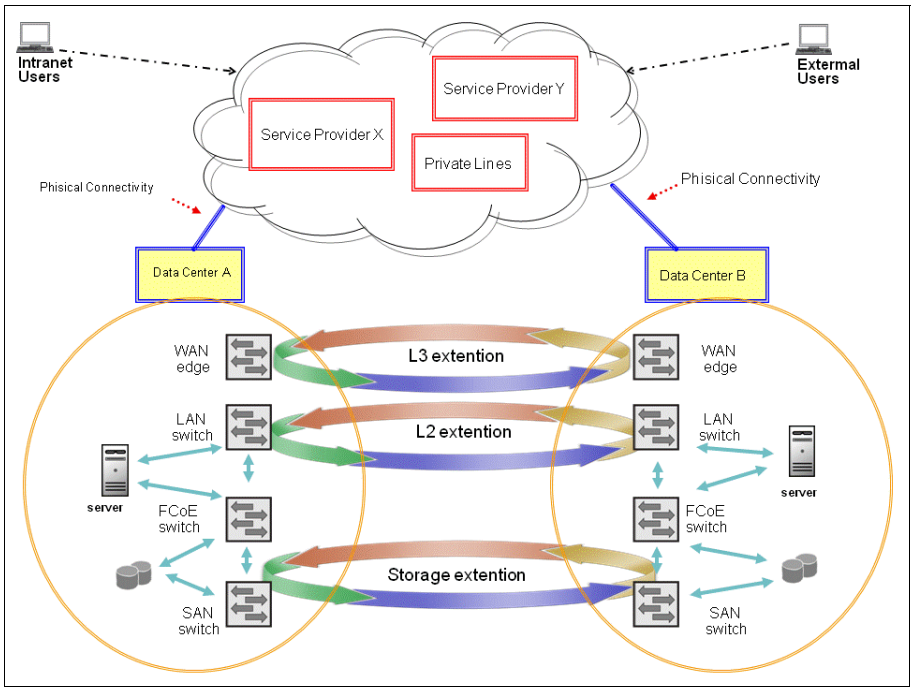

Figure 3-9 Interconnecting data centers

Examples of the drivers behind layer 2 extensions, creating larger bridged domains, are:

- The need for applications that use “hard-coded” IP parameters that cannot be easily modified to be available from different locations. That is, the same subnet needs to be available in different remote locations.
- Data center consolidation initiatives or the feasibility of outsourcing models can result in a portion of the server farm to be moved to another location.
- Layer 2 heartbeat mechanism to deploy high availability server clusters.
- Virtual machine mobility.
- There are network, server load balancing, and security devices that require high availability, as well as heartbeat and First Router Hop Protocols that need bridged connectivity.

There are several different approaches available today for extending layer 2 networks, and others that are in draft version in the standardization bodies. Each approach needs to be carefully evaluated in terms of how they meet different requirements such as availability features, implementation processes, cost, and management. We outline three approaches:

- The first approach is to create a switching domain, made of multiple switches that operate as a unified, high bandwidth device. Multi-Chassis-Link aggregation techniques are an example of this approach: switches that are in different data centers can be linked over optical links (over dark fiber or a protected WDM-based network) over large distances. This technique is especially suitable for dual site interconnection. Security on the link can be added as an option. Also, the technique has the additional feature of leveraging link aggregation (formerly known as 802.1ad, which has recently been moved to a stand-alone IEEE 802.1AX-2008 standard).

  Another important aspect when designing the interconnection between data centers at this level is the speed of links and related standards. With the objective of providing a larger, more durable bandwidth pipeline, IEEE have announced the ratification of IEEE 802.3ba 40 Gb/s and 100 Gb/s Ethernet, a new standard governing 40 Gb/s and 100 Gb/s Ethernet operations that considers distances up to 40 km. For data centers that need to be interconnected within this distance, this option can extend the core switching infrastructure.

- The second major approach is to deploy Virtual Private LAN Service (VPLS). The primary purpose of VPLS is to extend Layer 2 broadcast domains across WANs/Metro Area Networks (MANs) using a Multiprotocol Label Switching (MPLS) backbone. Enterprises that decide to deploy VPLS have found the deployment easy, a low latency variation, and a very scalable solution. In fact, VPLS can scale to a very large number of MAC addresses.

  Additional features that can be deployed aim to manipulate virtual local area networks (VLANs) within a bridge domain or a virtual private LAN service (VPLS) instance. VLAN translation is an example of such features.

- The third approach is based on internet standards that are not yet finalized. Cisco-sponsored Overlay Transport Virtualization (OTV) and the efforts of the IETF L2VPN working group (also known as E-VPN) are examples of potential alternatives to consider in the short-to-medium term. An IETF draft has been submitted to describe OTV. At the time of this publication, the draft can be found at:

  http://www.ietf.org/id/draft-hasmit-otv-01.txt

  OTV can be considered as a very recent alternative for extending Layer 2 domains because it relies on a “MAC in IP” technique for supporting L2 VPNs over, mainly, an IP infrastructure. OTV can be positioned at the L2/L3 boundary at the DC aggregation and promises operational simplicity. Additional requirements that need to be carefully examined when considering OTV are:

  – MAC addresses scalability
  – VLAN scalability
  – Convergence time

– Additional VLAN features (for example, VLAN translation and VLAN re-use)

The IETF L2VPN working group is the same group that is working on VPLS.

While alternatives are available and the business relevance is increasing today, there can be some aspects that need to be considered and addressed in all the components just stated but that are particularly severe for Layer 2 extensions:

- Latency - Since there is no market solution today that can address the latency derived from the speed of light, this aspect might not always be an issue when data centers are within shorter distances. Latency becomes an important factor to be considered when data centers are to be “actively” interconnected over longer distances.
- Bandwidth - Workload mobility and data replication require high-speed connectivity that is able to support a large amount of traffic. Moving virtual machines across data centers means that the snapshot of the virtual machine needs to cross the links between the data centers. If the end-to-end link between the sites does not comply with the vendor specification, the switch off of a VM and the restarting of a new one can fail.

  The real challenge is data synchronization across data centers, with the objective of having the most recent data as close as possible to the application. In both situations, techniques such as WAN Optimization Controllers can help in reducing the amount of bandwidth by avoiding deduplication of data. Quality of Service complemented by traffic shapers could also be an alternative for preserving the overall operational level agreements (OLAs).
- Organization (that is, DC team and WAN team) - Alternative selection criteria is also based on the enterprise organization structure and the skills associated with each alternative. For example, the fact that VPLS is based on an MPLS infrastructure implies that skills have to be in place, either internal or external to the organization if VPLS will be selected as a Layer 2 extension.
- Data flows of multitier applications - When data centers are servicing users, the changes in traffic flows that are built within the overall network infrastructure need to be well understood and anticipated when moving a service. Especially when the service is built upon a multilevel application approach (that is, front end service - application service - data service), moving single workloads (front end service layer) from one data center to another might result in increased latency and security flow impacts in the overall business transaction. In many situations, security needs to be applied within the flow and this layer needs to be aware of transactions that are going through different paths that must be created, or that the path is changing within interconnected data centers.

- Fast convergence - The longer convergence times of spanning tree protocol (STP) are well known in the industry. When extending layer 2 in data centers, the simple STP approach can result in unpredictable results as convergence is concerned, and resynchronization of a large STP domain can take too much time for business requirements. Because MPLS relies on the underlying IP network, some critical configuration parameters of both IP and MPLS have to be analyzed. Moreover, the convergence time that an IGP, EGP, and First Hop Router Protocol (for example, VRRP) with default parameters provide is usually not suitable for today's business requirements. In an MPLS network, two main types of fast convergence architectures can be used:
  - MPLS Fast Rerouting Traffic Engineering (FRR TE)
  - IP Fast Rerouting (IP FRR)
- In order to achieve a sub-second convergence time, the following aspects have to considered:
  - Failure detection
  - Label Distribution Protocol session protection mechanisms
  - IGP tuning
  - BGP tuning
  - First Hop Router Protocol (FHRP) tuning
  - System scheduler tuning
- Scalability (MAC/VLANs/Data Centers) - Large enterprises have the need to extend a certain number of VLANs across data centers. Also, the number of MAC addresses that the network must be aware of can grow significantly, in the order of thousands of entries. Each node at the edge should have the information of where the different MAC addresses are in order to send the frames to the correct data centers.The number of sites that need to be connected is also relevant to the technology choice. For example, a large number of sites that are connected can have a Layer 2 domain that is too big for STP to handle.
- Policy synchronization - The security framework includes policies related to how the services are protected. Interconnecting data centers are an opportunity for policy enforcement to match in all locations. On the other hand, it represents a challenge where enterprises strive to create an homogeneous set of policies and do not necessarily own the infrastructure, but are renting it or are outsourcing a service or part of it.

  Also, encryption and security play an important role: the merger of Layer 2 and Layer 3 can have important implications on the current security framework. When the MPLS services are outsourced to a service provider, security from the service provider has a very important role in the chain. Encryption can be an option to think about. In the same conditions PE routers

are shared among multiple clients. Both aspects and, in general, internal audit requirements, might impact the overall solution approach.

- Management - Determining the impact of deploying new technologies and other IT-related services and analyzing how the management infrastructure will support the related architectures aims at network efficiency and overall reduction in the cost of ownership. Understanding the gaps in the current network management processes or tools is advisable. For instance, MPLS connectivity management might address the need for dynamic and automated provisioning, as well as resource management for tunnels. Also, troubleshooting differs from that for a routed network. Therefore, diagnostic capabilities are an important aspect of all the management processes.
- Storms or loops - A major difference between a router and a bridge is that a router discards a packet if the destination is not in the routing table. In contrast, a bridge will flood a packet with unknown destination addresses to all ports except to the port it received the packet from. In routed networks, IP routers decrease the TimeToLive value by one at each router hop. The TTL value can be set to a maximum of 255, and when the TTL reaches zero, the packet is dropped.

  This, of course, does not solve loops consequences in a routing domain but considering that in a bridged network there is no such mechanism, the available bandwidth can be severely degraded until the loop condition is removed. When interconnecting data centers at Layer 2, the flooding of broadcasts or multicasts or the propagation of unknown frames needs to be avoided or strictly controlled so that a problem in one data center is not propagated into another one.
- Split brain - This situation might occur if both nodes are up but there is no communication (network failure) between sites. Of course this situation needs to be avoided by carefully planning the redundancy of paths at different levels (node, interface, and link).

Cloud computing models imply additional thinking for the interconnection of data centers. The alternatives offered by the market—private, public, or hybrid cloud—all have in common the need for a careful networking strategy to ensure availability, performance and security. Especially in multitenant environments where service providers offer shared services, it is essential to consider which aspects of service levels and security have strong relationships with the networking and therefore must be addressed in a complementary manner.

Interaction with cloud models may imply different locations for the applications and the related connectivity with respect to users. The techniques for the interconnection with the cloud should not only deliver reliable and secure data between different points, but must, above all, adapt to the variability of resources that can be dynamically and automatically relocated geographically and in real

time, inside and outside the cloud. An example is the availability in the cloud of additional processing power to meet peaks in the workloads on the same day or the temporary allocation of additional storage for specific projects. The network must be designed with flexibility in the ability to modify and extend the service to the rest of the cloud in a way that is completely transparent to end users.

In designing and implementing cloud models, the networking component should be built in synergy with and sustain all other system components of cloud computing, such as applications, processes, delivery, and automation systems.

3.4.5 Network services deployment models

There are many network service appliances in today's network market. In this section, we focus on current appliance virtualization technology. These appliances fall into the following categories:

- Application delivery appliances - Improve end-to-end response time; ADC, WAN accelerator, caching device (proxy), content distribution.
- Resource utilization optimization - Balances the traffic among distributed servers and data centers; Server Load Balancers, Global Load Balancing, traffic shapers.
- Network security - Enables authentication, authorization access control, and contents inspection; Firewall, IPS/IDS. VPN, AAA, and NAC.
- IP network service - Provides IP assignment and IP resolution to servers or clients; DNS and DHCP.

In this section, we focus on the possible deployment models for those services, highlighting how virtualization can be leveraged and pointing out the pros and cons of each approach.

Focusing on application acceleration and security services, the trends in the marketplace can be summarized by these three deployment models:

- Physical appliances

  This is the mainstream deployment model. It consists of deploying dedicated hardware to perform a specific function for a specific network segment.

- Virtualized appliances

  This model consists of deploying shared and virtualized hardware to perform one or more specific functions for different network segments.

- Soft appliances

  This is an emerging deployment model. It consists of deploying a software-based appliance to perform a specific function for one or more

specific virtual machines (VMs) in the same network segment. Both traditional vendors and new entrants are focusing on this kind of technology.

The deployment models can be mixed when addressing different categories of network service, depending on the specific functions and their requirements. For example, some functions that are resource-intensive still need to be performed in hardware to avoid performance bottlenecks.

On the other hand, application delivery functions can be broken down further and then split depending on the best deployment model for each function. Using application delivery as an example, SSL termination may be a better fit for a hardware platform, while other more application-specific functions may be virtualized.

The characteristics of each approach can be expressed in the following terms:

- Performance - Generally indicated by how many packets are processed per second by the appliance or other similar performance metrics. This can impact the performance of the entire network (if the appliance becomes a bottleneck) or the hypervisor, in the case of a software appliance.
- Provisioning effort - Defined as the time and effort required to get the network service up and running. An appliance approach needs to consider all of the aspects of a dedicated hardware in terms of hardware provisioning and setup that might be shared among other services with software-only models.
- Scalability - In networking terms, the ability to grow incrementally. Scalability can be horizontal (scale out model), adding network nodes in the systems or vertical (scale up model), adding resources to a single network node.
- Management integration - Defines the possibilities in terms of systems management integration.
- Functional richness - Defines the various functions a single appliance or cluster carries out.
- Point of enforcement - Defines where network services can be deployed.
- Location - Defines where the appliance is located and with how much flexibility it can be relocated.
- Cost - Defines the required financial impact of each deployment model.

Physical hardware appliances have a broader applicability because they perform their functions as long as the protocols they rely on are running and supported throughout the network. Some applications that cannot be virtualized or are chosen not to be virtualized still need to rely on this type of deployment model for network services. Performance can be very high, depending on the traffic load for each appliance, but it may come at a very high price. Moreover, physical appliances may incorporate several functions that are not required in most

deployments. Virtualized appliances, in contrast, are generally based on modular hardware, with different blades or service modules that can be deployed as needed for specific functions or to allow growth with a scale up model.

Virtual appliances are a better fit for cloud computing networking infrastructures because of their infinite scalability and the ability to closely integrate with the virtual infrastructure because the services can easily be moved to another physical host.

3.4.6 Virtual network security

Although the virtualized environment provides benefits, it also presents new security challenges. Many existing security solutions are not optimized for security threats in the virtual environment. In this section, we briefly list the main security functional components for the virtualized environment from the data center network viewpoint and some IBM products.

IBM has developed a high-level security framework. This is shown in Figure 3-10 on page 179. The IBM Security Framework was developed to describe security in terms of the business resources that need to be protected, and it looks at the different resource domains from a business point of view.

For more information, refer to *Introducing the IBM Security Framework and IBM Security Blueprint to Realize Business-Driven Security*, REDP-4528, and the *Cloud Security Guidance IBM Recommendations for the Implementation of Cloud Security*, REDP-4614.

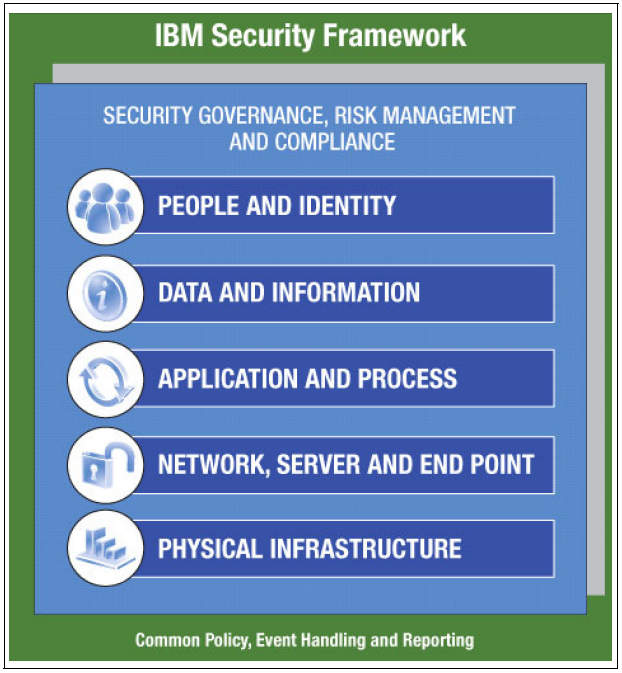

Figure 3-10 IBM Security Framework

As shown in Figure 3-10, network security is only a component of the overall framework and can be seen as the enforcement at the network level of the enterprise security policies. In a highly virtualized data center, for example, security boundaries are no longer defined only by physical appliances but those move inside the server and storage platforms. Also the server-to-server communications often occur within the same physical box and traditional network security appliances such as firewalls cannot enforce the security policies within the hypervisor. This new environment shift is depicted in Figure 3-11 on page 180.

A functional view of network security can be categorized in the following areas:

- Remote access (SSL/IPSec VPN) - Both site-to-site and to allow remote users to access enterprise resources outside of the perimeter.
- Threat management - Network level, network boundary security enforcement (firewalling, IPS, IDS, Anti-Spam) Layers 2 through 4 in the OSI model.
- Threat management - Application level security enforcement (application firewalling) Layer 7 in the OSI model. Functions such as URL filtering fall into this category.

- Resource access management and identity management to control and audit who is entitled to access the network resources in order to monitor, manage and configure the various appliances.

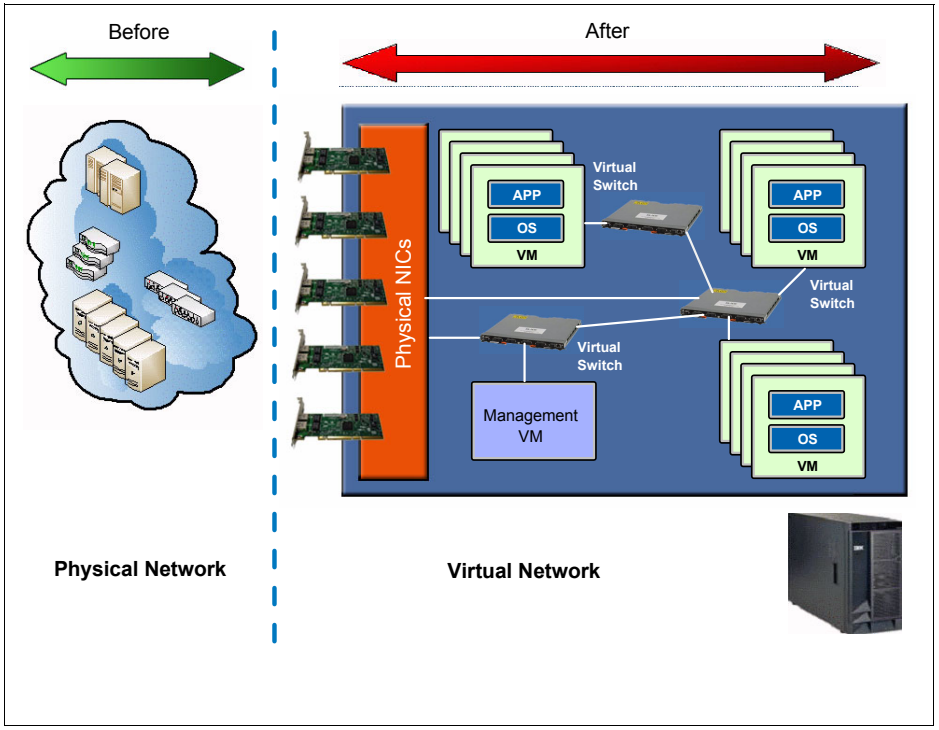

Figure 3-11 Network security shift from physical to virtual

Bear in mind that all these functional components can be deployed using the different models that have been presented in the previous section.

We will now briefly describe some relevant IBM products in the virtualized data center network environment.

The IBM security product portfolio covers professional and managed security services and security software and appliances. To learn about comprehensive security architecture with IBM Security, see *Enterprise Security Architecture using IBM ISS Security Solutions*, SG24-7581.

IBM Security network components

The protocol analysis module (PAM) is a modular architecture for network protection. PAM is the base architecture throughout all IBM Security products; it includes the following components:

- IBM Virtual Patch technology

  This shields vulnerable systems from attack regardless of a vendor-supplied software patch.

- Threat detection and prevention technology

  This detects and prevents virus and worm attacks, and hacker obfuscation.

- IBM Proventia Content Analyzer

  This monitors and identifies the content of network flow to prevent data leak or to satisfy regulatory requirements.

- Web Application Security

  This provides web application vulnerabilities protection, such as SQL injection and command injections.

- Network Policy Enforcement

  This enforces policy and controls to prevent risky behavior, such as the use of P2P applications or tunneling protocols.

IBM security has a research and development team known as X-Force®. X-Force discovers and analyzes previously unknown vulnerabilities in critical software and infrastructures, such as email, network infrastructure, Internet applications, security protocols, and business applications. PAM's protection is always up-to-date with X-Force research through automatic deployment.

IBM Virtual Server Security for VMware

IBM Virtual Server Security for VMware (VSS) provides a multilayered IPS and firewall technology to protect the virtual data center in a solution that is purpose-built to protect the virtual environment at the core of the infrastructure. VSS runs on vSphere 4. It cannot run on previous versions of VMware. An overview of this component is shown in Figure 3-12 on page 182Figure 3-12 on page 182.

A virtual security appliance is installed on a virtualized server such as VM. The VM is hardened to prevent access from other VMs or external access, except management access; it is named Security VM (SVM). The appliance utilizes the hypervisor API to inspect and control the virtual switch network and VM behavior. VSS utilizes the vSphere API, which is provided as VMsafe. For more information about vSphere and VMSafe, refer to "vSphere vNetwork overview" on page 86.

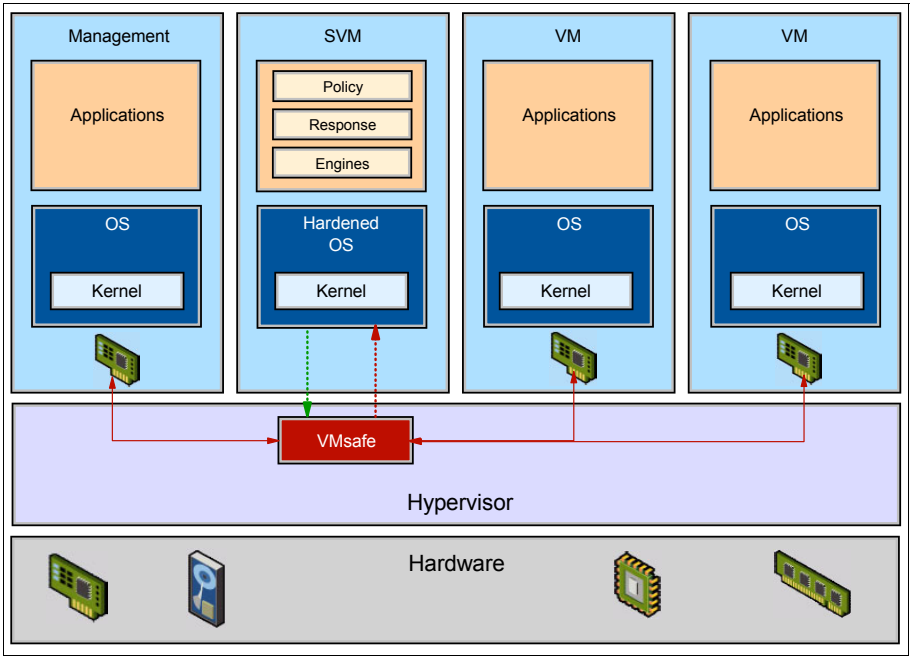

Figure 3-12 Virtual Security appliance

Each SVM on virtualized servers is managed and configured through Site Protector (SP), which is the central manager of SVM.

VSS has the following functions:

- Inter-VM IPS and Firewall
- Virtual Machine Observer (VMO)
- Antirootkit (ARK)
- Network Access Control (NAC)
- Discovery
- License and Update Management (LUM)

Inter-VM IPS and firewall

The VSS IPS module monitors all traffic involving VMs on a single ESX server. Only one SVM is allowed per physical server. One SVM can protect up to 200 VMs. The IPS covers the following traffic flows:

- Traffic between a VM and an outside host
- Traffic between VMs on the server
- Traffic to SVM itself

There are two ways to monitor traffic. One way is by using VMsafe architecture, called DV filters, and the other is by using accelerated mode.

With DV filters, all NICs of VMs are monitored. An overview of a DV filter is shown in Figure 3-13. A DV filter does not require any configuration changes to the internal network.

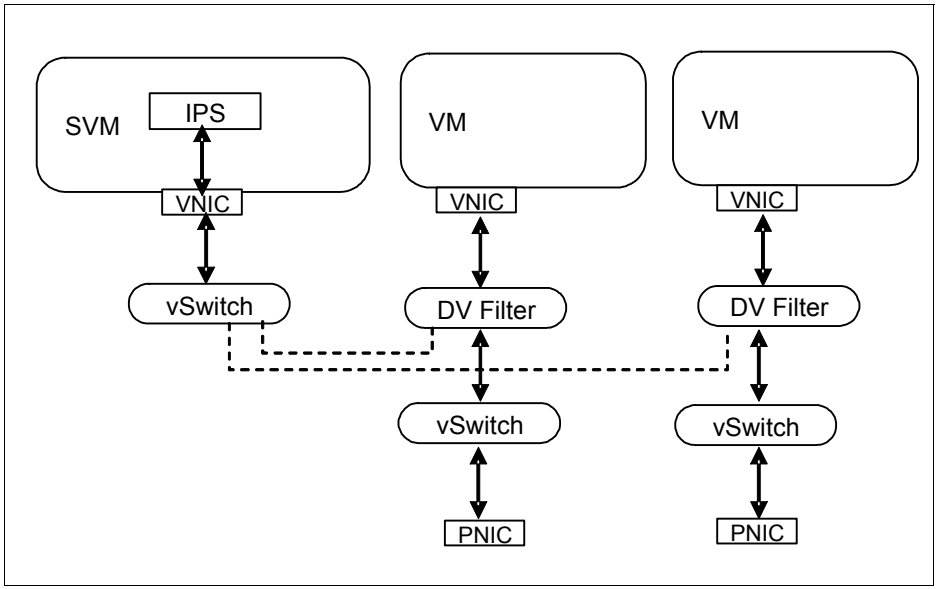

Figure 3-13 DV filter

Because of performance and resource consumption considerations, *accelerated mode* can be configured. Unlike a DV filter, accelerated mode monitors vSwitch inbound and outbound traffic. Thus, inter-VM traffic within vSwitch is not monitored. This mode is illustrated in Figure 3-14 on page 184.

In both methods, the same IPS function is supported, but traffic coverage is different.

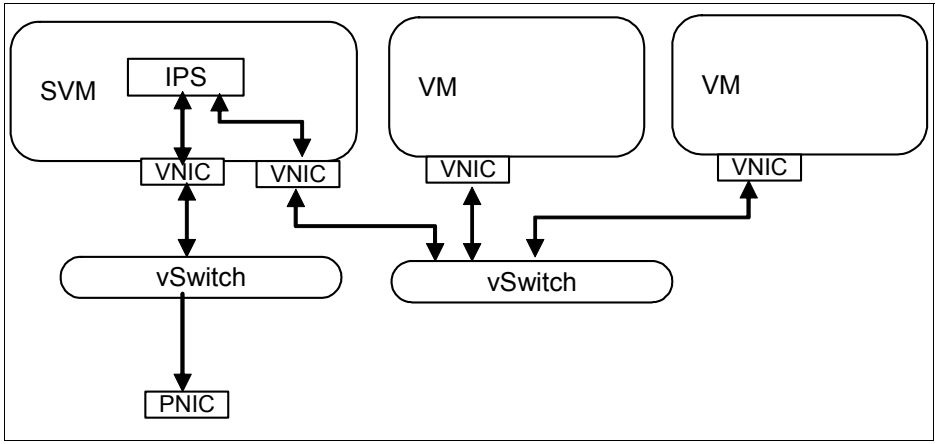

Figure 3-14 Accelerated mode

VSS also provides protocol access control like a normal IPS appliance from ISS. It filters network packets based on protocol, source and destination ports, and IP addresses. It can be enabled or disabled globally or for specific VMs. Because the VMware internal network does not support Layer 3, this function does not support L3 security zoning, which normal firewall appliances can.

Virtual Machine Observer

The main task of Virtual Machine Observer (VMO) is to communicate with the ESX server and obtain information on VM state changes, such as VM powered on and off. VMO facilitates configurations to bring VMs into protection based on policies. It also records VM inventory information such as IP addresses. If VMO finds a new VM, it sends signals to the VSS discovery function.

Discovery

The discovery module collects inventory information about VMs, such as operating system name and version, open TCP ports, and so on. A vulnerability check is not performed in this version.

Antirootkit (ARK)

A rootkit is a program that is designed to hide itself and other programs, data, and/or activity including viruses, backdoors, keyloggers and spyware on a computer system. For example, Haxdoor is a known rootkit of the Windows platform, and LinuxRootkit targets Linux OS. Generally, it is difficult to detect a rootkit that rewrites kernel code of OS. However, in a virtualized environment, it is possible that the hypervisor can monitor OS memory tables from outside OS. VMsafe supports a vendor tool that inspects each memory table on VM. VSS can detect malicious software inside OS by inspecting each kernel memory space.

Network Access Control

Network Access Control (NAC) controls which VMs can access the network. It classifies each VM as trusted or untrusted. The trusted list is maintained manually. Any VM that comes online, and is not on the trusted list, is quarantined.

3.4.7 Virtualized network resources in servers

Historically, the network has consisted of separate Network Interface Cards (NICs) per server or a pair of separate NICs for redundancy. The connection to this NIC from the upstream network device was a single Ethernet link at speeds of 10/100/1000 Mbps. As virtualization appeared and multiple operating systems lived in one server, standards had to be developed to manage network connectivity for guest operating systems. The *hypervisor* is responsible for creating and managing the virtual network components of the solution. Hypervisors are capable of different levels of network virtualization.

This section introduces best practice options for virtualized network resources in servers. The following approaches are discussed:

- NIC sharing
- vNIC - Virtual Switching
- NIC teaming
- Source Route - I/O Virtualization

NIC sharing

The most basic of the new connectivity standards simply assigns an operating system to share available network resources. In its most basic format, each operating system has to be assigned manually to each NIC in the platform.

Logical NIC sharing allows each operating system to send packets to a single physical NIC. Each operating system has its own IP address. The server manager software generally has an additional IP address for configuration and management. A requirement of this solution is that all guest operating systems have to be in the same Layer 2 domain (subnet) with each guest operating system assigned an IP address and a MAC address. Because the number of guest operating systems that could reside on one platform was relatively small, the MAC address could be a modified version of the NIC's burned-in MAC address, and the IP addresses consisted of a small block of addresses in the same IP subnet. One additional IP address was used for the management console of the platform.

Features to manage QoS and load balancing to the physical NIC from the guest operating systems were limited. In addition, any traffic from Guest OS 1 destined

to Guest OS 2 traveled out to a connected switch and then returned along the same physical connection; see Figure 3-15. This had the potential of adding extra load on the Ethernet connection.

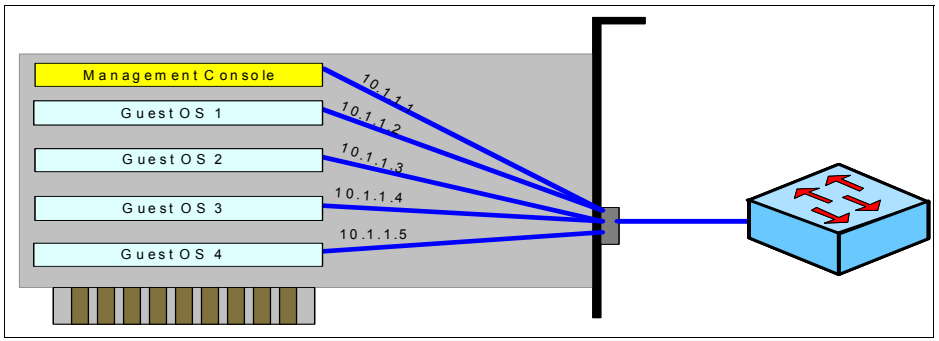

Figure 3-15 NIC sharing

vNIC - virtual switching

The advent of vNIC technology enables each server to have a virtual NIC that connects to a virtual switch. This approach allows each operating system to exist in a separate Layer 2 domain. The connection between the virtual switch and the physical NIC then becomes an 802.1q trunk. The physical connection between the physical NIC and the physical switch is also an 802.1q trunk, as shown in Figure 3-16 on page 187.

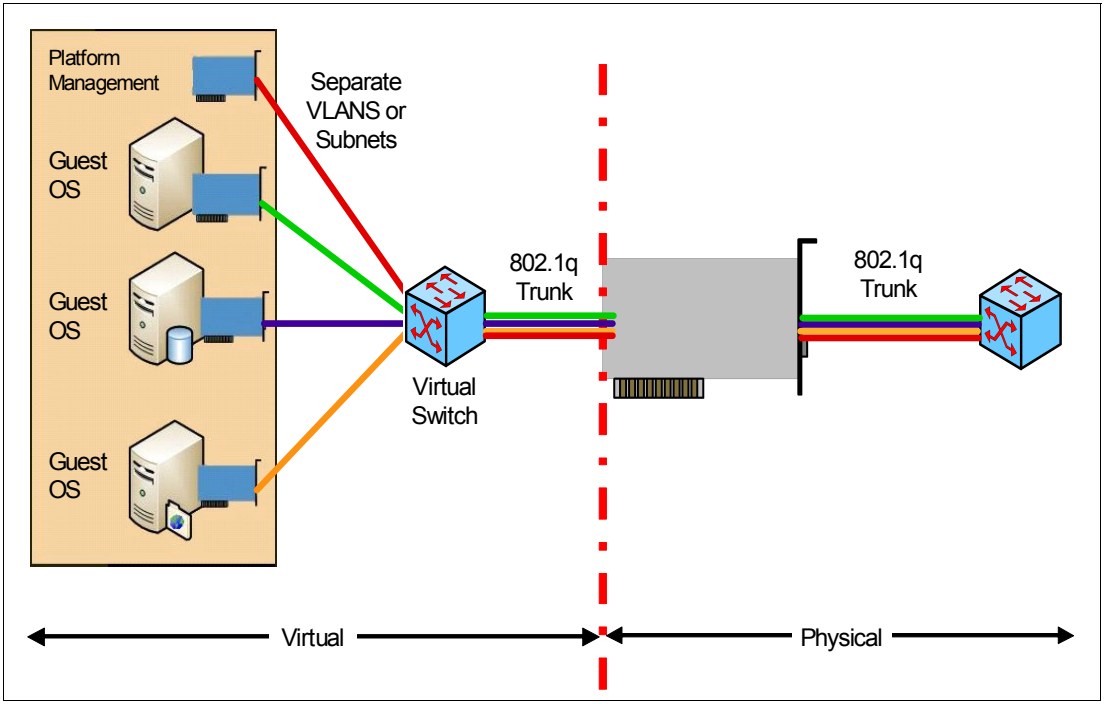

Figure 3-16 Virtual switching

A Layer 3 implementation of this feature allows traffic destined for a server that resides on the same platform to be routed between VLANs totally within the host platform, and avoids the traffic traversing the Ethernet connection, both outbound and inbound.

A Layer 2 implementation of this feature effectively makes the physical Layer 3 switch or router a “Switch-on-a-stick” or a “One-armed” router. The traffic from one guest operating system destined for a second guest operating system on that platform traverses the physical NIC and the Ethernet two times.

The challenge that this presents to the network architecture is that now we have a mix of virtual and physical devices in our infrastructure. We have effectively moved our traditional access layer to the virtual realm. This implies that a virtual NIC (vNIC) and a virtual switch all have the same access controls, QoS capabilities, monitoring, and other features that are normally resident and required on access-level physical devices. Also, the virtual and physical elements may not be manageable from the same management platforms, which adds complexity to network management.

Troubleshooting network outages becomes more difficult to manage when there is a mixture of virtual and physical devices in the network. In any network architecture that employs virtual elements, methods will have to be employed to enable efficient monitoring and management of the LAN.

NIC teaming

To eliminate server and switch single point-of-failure, servers are dual-homed to two different access switches. NIC teaming features are provided by NIC vendors, such as NIC teaming drivers and software for failover mechanisms, used in the server systems. In case the primary NIC card fails, the secondary NIC card takes over the operation without disruption. NIC teaming can be implemented with the options Adapter Fault Tolerance (AFT), Switch Fault Tolerance (SFT), or Adaptive Load Balancing (ALB). Figure 3-17 on page 189 illustrates the most common options, SFT and ALB.

The main goal of NIC teaming is to use two or more Ethernet ports connected to two different access switches. The standby NIC port in the server configured for NIC teaming uses the same IP and MAC address (in case of Switch Fault Tolerance) of the failed primary server NIC. When using Adaptive Load Balancing, the standby NIC ports are configured with the same IP address but using multiple MAC addresses. One port receives data packets only and all ports transmit data to the connected network switch. Optionally, a heartbeat signaling protocol can be used between active and standby NIC ports.

There are other teaming modes in which more than one adapter can receive the data. The default Broadcom teaming establishes a connection between one team member and the client, the next connection goes to the next team member and that target and so on, thus balancing the workload. If a team member fails, then the work of the failing member is redistributed to the remaining members.

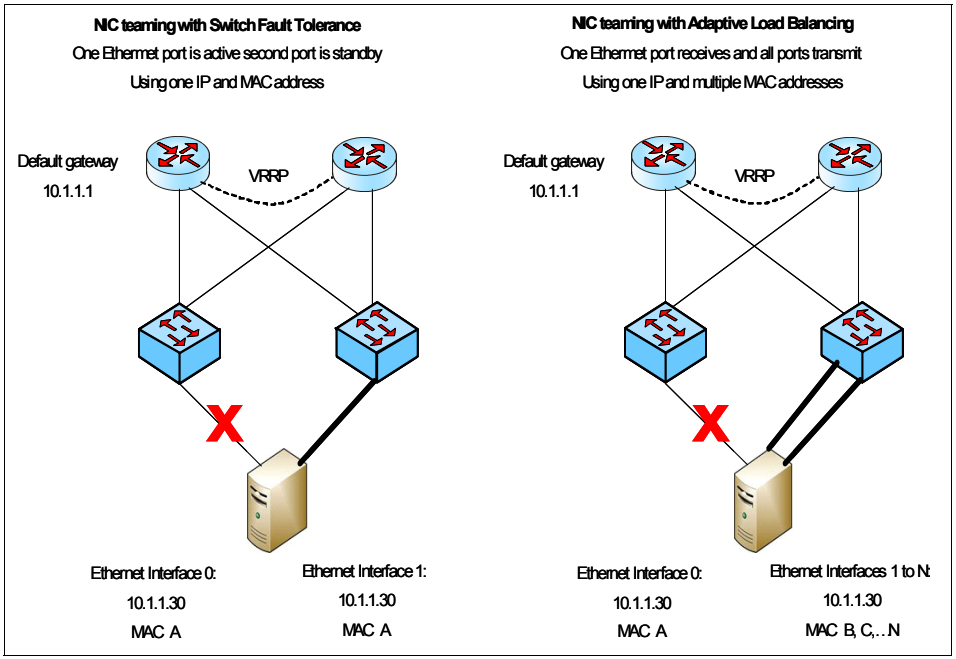

Figure 3-17 NIC teaming with Switch Fault Tolerance Adaptive Load Balancing

Single root I/O virtualization

Today's server virtual switching infrastructure (such as Hypervisor) associates a VM entity to access the network through a virtual switch port. With the advent of PCIe adapters supporting multiqueue, multifunction, or Single-Root I/O Virtualization (SR-IOV), methods for directly sharing I/O are becoming available for x86 server models.

These virtualization approaches enable a Virtual Machine's device driver to bypass the Hypervisor and thereby directly share a single PCIe adapter across multiple Virtual Machines (VMs).

The PCI Special Interest Group (SIG) standardized the North side of I/O virtualization in a server. The network functions, such as switching or bridging, were outside the PCI SIG scope. For a detailed description of SR-IV and sharing specifications, see the following website:

http://www.pcisig.com/specifications/iov/single_root/

The configuration of that generic platform is composed of the following components (see Figure 3-18 on page 191):

- Processor - general purpose, embedded, or specialized processing element.
- Memory - general purpose or embedded.
- PCIe Root Complex (RC) - one or more RCs can be supported per platform.
- PCIe Root Port (RP) - one or more RPs can be supported per RC. Each RP represents a separate hierarchy per the PCI Express Base Specification.
- PCIe Switch - provides I/O fan-out and connectivity.
- PCIe Device - multiple I/O device types, for example network, storage, and so on.
- System Image - software that is used to execute applications or services.

To increase the effective hardware resource utilization without requiring hardware modifications, multiple SIs can be executed. Therefore, a software layer (Virtualization Intermediary (VI)) is interposed between the system hardware and the SI. VI controls the underlying hardware and abstracts the hardware to present each SI with its own virtual system.

The intermediary role for I/O virtualization (IO VI) is used to support IOV by intervening on one or more of the following: Configuration, I/O, and memory operations from a system image, and DMA, completion, and interrupt operations to a system image.

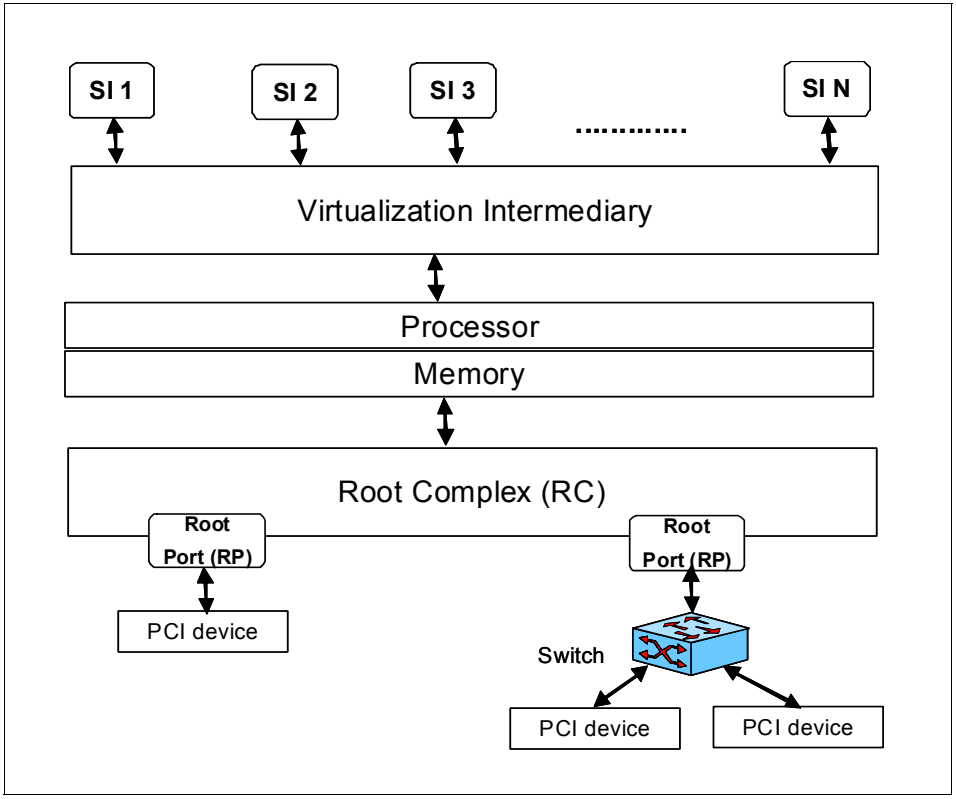

Figure 3-18 Generic SR-IOV platform

Network design considerations

Virtualized network technologies add complexity and specific design considerations that should be addressed when these technologies are introduced into an architecture, as explained here:

- Does the virtual switch in the proposed hypervisor provide all the required network attributes, such as VLAN tagging or QoS?
- Quality of service, latency, packet loss, and traffic engineering requirements need to be fully understood, documented, and maintained for each proposed virtual device.
  - Will applications running on separate guest operating systems require different levels of latency, packet loss, TCP connectivity, or other special environments?
  - Does each guest operating system require approximately the same traffic load?

- Will the converged network traffic to each guest operating system oversubscribe the physical NIC?
- Do any of the guest operating systems require Layer 2 separation?
- Does each guest operating system require the same security or access restrictions?
- Who will be responsible for the end-to-end network architecture?

  Enterprise naming standards, MAC address standards, and IP address standards need to be applied to the virtual devices.

  Separate Layer 2 domains may exist in the virtual design. They need to adhere to the enterprise architecture standards.
- Are there organizational issues that need to be addressed pertaining to services management? Historically, different groups own management of the servers and the network. Will organizational roles have to be redefined or reorganized to allow efficient management of the dynamic infrastructure?
- What combination of tools will be used to manage the infrastructure?

  Currently, there are no tools that perform end-to-end network management across virtual, logical, and physical environments. Several network management systems have plans for this functionality but none have implemented it at this time.
- Can the selected platform and hypervisor support a virtual switch?
  - If so, can this virtual switch support QoS?
  - Does it participate in Layer 3 switching (routing)? What routing protocols?
  - Does it do VLAN tagging?
  - Can it assign QoS tags?

All of these considerations will affect the network architecture required to support NIC virtualization.

4

The new data center design landscape

This chapter describes the new inputs, approaches and thinking that are required for a proper data center network design given what has been described in the previous chapters.

- Section 4.1, “The changing IT landscape and data center networking” on page 195 discusses the market landscape for data center networking with the goal of highlighting key trends in the industry from both sides of the business: Network Equipment and IT vendors and customers.
- Section 4.2, “Assuring service delivery - the data center network point of view” on page 201 describes the new challenges that the DCN faces at the light of the new business requirements that are described in Chapter 1, “Drivers for a dynamic infrastructure” on page 1. The burgeoning solutions that are or will be available are briefly presented, highlighting how these solve some of the challenges at the price of introducing additional points of concern that clients must face to be successful in this new environment.
- Section 4.3, “Setting the evolutionary imperatives” on page 212 presents some mindshifting evolutionary imperatives that must be used as general guidelines in order to overcome the points of concern we discussed in 4.2.
- Section 4.4, “IBM network strategy, assessment, optimization, and integration services” on page 220 describes the IBM Integrated Communications Services portfolio, focusing on how Enterprise Networking Services can help

clients navigate through the available options and achieve their business goals of minimizing risks and future-proofing the technology choices.

4.1 The changing IT landscape and data center networking

As organizations undertake information technology (IT) optimization projects, such as data center consolidation and server virtualization, they need to ensure that the proper level of focus is given to the critical role of the network in terms of planning, execution, and overall project success. While many consider the network early in the planning stages of these projects and spend time considering this aspect of these initiatives, many more feel that additional network planning could have helped their projects be more successful.

The most common types of network changes in IT optimization projects include implementing new network equipment, adding greater redundancy, increasing capacity by upgrading switches, improving network security, and adding network bandwidth. However, many network requirements associated with these changes and the overall initiative are typically not identified until after the initial stages of the project and often require rework and add unanticipated costs. Regardless of project type, network challenges run the risk of contributing to increased project time lines and/or costs.

The networking aspects of projects can be challenging and user complaints about the network are frequently heard. Important challenges include the inability to perform accurate and timely root-cause analysis, understand application level responsiveness, and address network performance issues. Simply buying more network equipment does not necessarily or appropriately address the real requirements.

Looking ahead, many expect that the network will become more important to their companies' overall success. To address this, networking investments related to support of server and storage virtualization are currently at the top of the list for consideration, followed by overall enhancement and optimization of the networking environment.

To support virtualization of the entire IT infrastructure and to continue to optimize the network, IT organizations need to make architectural decisions in the context of the existing infrastructure, IT strategy, and overall business goals.

Developing a plan for the network and associated functional design is critical. Without a strong plan and a solid functional design, networking transitions can be risky, leading to reduced control of IT services delivered over the network, the potential for high costs with insufficient results, and unexpected performance or availability issues for critical business processes.

With a plan and a solid functional design, the probability of success is raised: a more responsive network with optimized delivery, lower costs, increased ability to meet application service level commitments, and a network that supports and fully contributes to a responsive IT environment.

4.1.1 Increasing importance of the data center network

A wave of merger and acquisition activity in the IT industry focused on data center networks is easily visible to observers of the IT and networking scene. IT and networking companies have realized that a highly consolidated and virtualized data center environment cannot succeed if the network is an afterthought. In response, they are bringing products and services to the market to address a myriad of new networking challenges faced by enterprise data centers. Some of these challenges are:

- Selecting standards, techniques, and technologies to consolidate I/O in the data center, allowing fiber channel and Ethernet networks to share a single, integrated fabric.
- Dealing with a massive increase in the use of hypervisors and virtual machines and the need to migrate the network state associated with a virtual device when it moves across physical hardware and physical facilities.
- Instituting a virtual data center, where the data center is extended to several physical sites to resolve room and power limitations.
- Supporting business resilience and disaster recovery, often under the pressure of regulatory requirements.
- Introducing high levels of network automation when minor changes in network configurations may affect the entire infrastructure because, unlike servers and storage, network devices are not a collection of independent elements—they exchange information among each other and problems are often propagated rather than isolated.

With so many vendor, product, and technology options available and so much to explore, it is easy to fall into the trap of working backwards from product literature and technology tutorials rather than beginning a network design with an understanding of business and IT requirements. When focus is unduly placed on products and emerging technologies before business and IT requirements are determined, the data center network that results may not be the data center network a business truly needs.

New products and new technologies should be deployed with an eye towards avoiding risk and complexity during transition. When introducing anything new, extra effort and rigor should be factored into the necessary design and testing activities. Also, it would be atypical to start from scratch in terms of network

infrastructure, networking staff, or supporting network management tools and processes. That means careful migration planning will be in order, as will considerations concerning continuing to support aspects of the legacy data center networking environment, along with anything new.

4.1.2 Multivendor networks

The 2009 IBM Global CIO Study, "The New Voice of the CIO"[1] showed that IT executives are seeking alternatives to help them manage risks and reduce costs. Introducing a dual or multivendor strategy for a data center network using interoperability and open standards can enable flexible sourcing options for networking equipment. It also can help to address the high costs that can result from depending on a single network technology vendor to meet all data center networking requirements.

It is good to keep an open mind about technology options and equipment suppliers by evaluating vendor technologies based on best fit rather than past history to achieve the right mix of function, flexibility, and cost. Of course, it is wise to look before taking a leap into a multivendor approach by analyzing the existing data center network and making an assessment of the readiness to move to a multivendor networking environment. The current data center network technology and protocols need to be considered as well as the processes and design, engineering and operational skills used to run and maintain the network. In addition, a migration to a multivendor network must be supportive of business and IT strategies and based on networking requirements.

4.1.3 Networks - essential to the success of cloud computing initiatives

An IBM study from April 2009[2] showed that moving from a traditional IT infrastructure to a public cloud computing service can yield cost reductions, with even more significant savings made possible by migration to a private cloud infrastructure[1]. This study corroborates much of the discussion about the cost benefits of cloud computing. In addition to cost savings, a survey by IBM of 1,090 IT and line-of-business decision makers published in January 2010[3] indicated that speed of service delivery, increased availability, and elasticity that allows for easy expansion and contraction of services are other drivers toward an interest in

[1] 2009 IBM Global CIO Study, "The New Voice of the CIO" - ftp://public.dhe.ibm.com/common/ssi/ecm/en/cie03046usen/CIE03046USEN.PDF

[2] Advantages of a dynamic infrastructure: A Closer Look at Private Cloud TCO - http://www-01.ibm.com/software/se/collaboration/pdf/CloudTCOWhitepaper_04212009.pdf

[3] Dispelling the vapor around cloud computing: drivers, barriers and considerations for public and private cloud adoption - ftp://public.dhe.ibm.com/common/ssi/ecm/en/ciw03062usen/CIW03062USEN.PDF

cloud computing. The study findings validate that many organizations are considering cloud computing with 64% rating private cloud delivery as “very appealing or appealing,” and 38% and 30% giving a similar rating for hybrid cloud computing and public cloud computing, respectively.

By definition, cloud computing uses the network to gain access to computing resources—the network becomes the medium for delivery of enormous computing capability and hence plays a critical role. This critical role means that it is crucial to “get the network right” in terms of the right levels of performance, security, availability, responsiveness, and manageability for the selected cloud computing deployment model.

Enterprises that adopt cloud computing have a range of deployment models from which to choose, based on their business objectives. The most commonly discussed model in the press is public cloud computing where any user with a credit card can gain access to IT resources. On the other end of the spectrum are private cloud computing deployments where all IT resources are owned, managed and controlled by the enterprise. In between, there is a range of options including third-party-managed, third-party-hosted and shared or member cloud services. It is also possible to merge cloud computing deployment models to create hybrid clouds that use both public and private resources.

Each cloud computing deployment model has different characteristics and implications for the network. That said, organizations select their cloud deployment models based on business requirements and needs. Whether a company opts to buy from a cloud provider or build its own private cloud computing environment, the enterprise network design must be revisited to validate that security, reliability and performance levels will be acceptable.

In particular, the networking attributes for a private cloud data center network design are different from traditional data center network design. Traditionally, the data center network has been relatively static and inflexible and thought of as a separate area of IT. It has been built out over time in response to point-in-time requirements, resulting in device sprawl much like the rest of the data center IT infrastructure. The data center network has been optimized for availability, which typically has been achieved via redundant equipment and pathing, adding to cost and sprawl as well.

The attractiveness of a private cloud deployment model is all about lower cost and greater flexibility. Low cost and greater flexibility are the two key tenets the network must support for success in cloud computing. This means the network will need to be optimized for flexibility so it can support services provisioning (both scale up and down) and take a new approach to availability that does not require costly redundancy. An example of this could be moving an application workload to another server if a NIC or uplink fails versus providing redundant links to each server.

Private cloud adoption models require a new set of network design attributes; these are demonstrated in Figure 4-1.

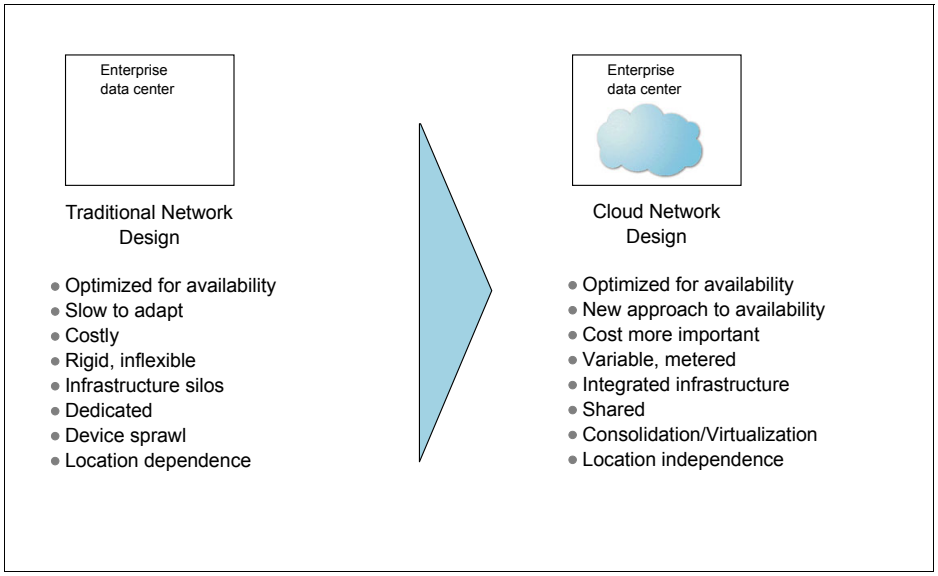

Figure 4-1 Private cloud adoption models

In addition, network design can no longer be accomplished as a standalone exercise. The network design must encompass key requirements from other areas of the data center IT infrastructure, including server, storage, security and applications. The central design principles for the network must be based on present and planned application workloads, server and storage platform virtualization capabilities, IT services for internal and external customers, and anticipated schedules for growth and investment.

From an organizational standpoint, the network design must address existing boundaries between the network, servers and storage and establish better interfaces that allow operational teams to work effectively in virtualized and dynamic environments. This requires the networking team to develop a greater operational awareness of server and storage virtualization technologies, capabilities and management.

4.1.4 IPv6 and the data center

The public Internet and most enterprise networks route traffic based on the IPv4 protocol, developed by the Internet Engineering Task Force (IETF) in 1981. The address space available in IPv4 is being outstripped by a spiraling number of servers and other network-attached devices that need or will need

addresses—traditional computer and networking equipment, smart phones, sensors in cars and trucks and on outdoor light and utility posts, and more.

A newer protocol, IPv6, also developed by the IETF, is available. IPv6 offers a bigger address space to accommodate the budding need for new IP addresses. IPv6 also promises improvements in security, mobility and systems management. While IPv4 and IPv6 can coexist, ultimately the network of every organization that uses the public Internet will need to support IPv6. Once the available IPv4 address space for the world is exhausted, the ability to route network traffic from and to hosts that are IPv6-only will become a requirement. No matter the reason why a company introduces IPv6, deployment of IPv6 will take focus, planning, execution and testing and require operational changes, all of which will impact servers, other devices in the data center and applications, in addition to the network itself.

The Number Resource Organization (NRO)[4], the coordinating body for the five Regional Internet Registries (RIRs) that distribute Internet addresses, says that as of September 2010 just 5.47% of the worldwide IPv4 address space remains available for new allocations (see Figure 4-2). When the remaining addresses are assigned, new allocations will be for IPv6 addresses only.

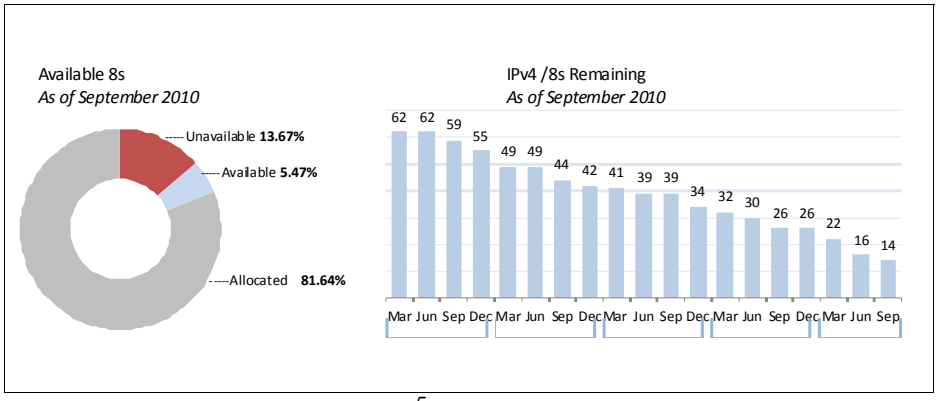

Figure 4-2 IPv4 address space status[5]

Network equipment providers ship new equipment that is IPv6-ready. Telecommunications carriers can, in many cases, handle IPv6 traffic or have backbone upgrade projects underway. However, for a specific enterprise, the network, network-attached devices, the tools used to manage data centers and

[4] Internet Number Resource Status Report - September 2010, Number Resource Organization http://www.nro.net/documents/presentations/jointstats-sep10.pdf

[5] Global IP Addressing Statistics Sheet, American Registry for Internet Numbers (ARIN), September 2010 https://www.arin.net/knowledge/stats.pdf

other IT resources, and the applications that are used to run the business need to be checked for their readiness to support IPv6 and plans must be made and executed for any upgrades. Also, each enterprise must determine its strategy for the coexistence of IPv4 and IPv6—tunnelling, translation, dual stack or a combination because both protocols will need to be supported and interoperate until IPv4 can be retired.

Depending on the geography, the IP address range allocated to an organization, and any workarounds in place to conserve IP addresses, such as Network Address Translation (NAT) or Classless Inter-Domain Routing (CIDR), planning and readiness for IPv6 may be considered prudent or essential. However, it is risky to wait until IP addresses and workarounds are exhausted or important customers or supply chain partners—or government bodies—require IPv6 as a condition of doing business and implementation must be hurried or performed in a makeshift fashion. This is especially true in an environment like the data center that has limited change windows and cannot afford unplanned downtime or performance degradation.

4.2 Assuring service delivery - the data center network point of view

As described in Chapter 1, “Drivers for a dynamic infrastructure” on page 1, the business requirements that impact a CIO’s decision-making process in a global economy significantly influence the IT environment and hence the data center network, which must support broader IT initiatives. The purpose of the data center network in this new context can be summarized with one simple goal: assuring service delivery. This objective’s impact on the data center network can be broadly categorized along two main axes:

- Service drivers

  The data center network must support and enable broader strategic IT initiatives such as server consolidation and virtualization, cloud computing and IT optimization. In this sense the network must ensure performance, availability, serviceability and shorten the time required to set up new services.

- Cost drivers

  The data center network must achieve the service delivery objectives at the right cost. In this sense, the data center network must be consolidated and virtualized itself in order to achieve the same cost savings (both on OPEX and CAPEX) gained through server and storage consolidation and virtualization.

The structure of this section and the flow of the presented content are described by Figure 4-3.

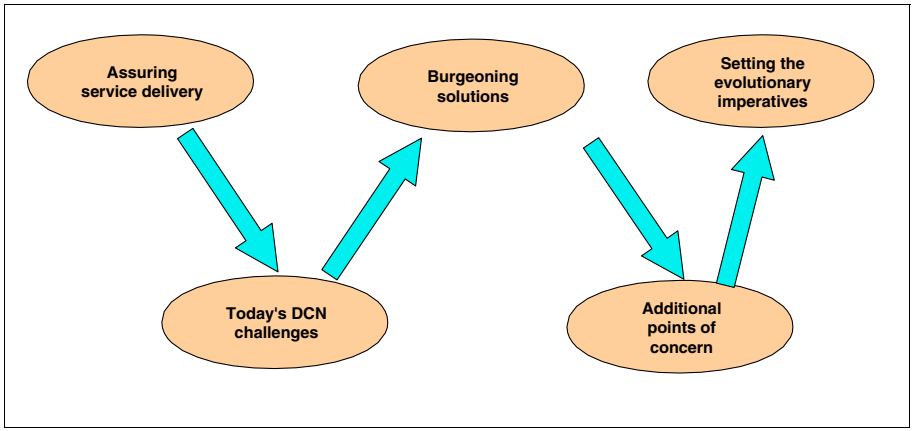

Figure 4-3 Content flow

These business and service objectives cause nontrivial challenges for data center network managers and architects since the traditional data center network infrastructure is not up to the task of satisfying all these new requirements. In fact, many technology-related challenges arise in this context.

In order to overcome the limitation of the data center network's static, traditional physical model, emerging standards and new architectural alternatives (described in 4.2.2, "Burgeoning solutions for the data center network" on page 208) can be exploited. The drawback of this path, however, is that while alleviating today's challenges, additional points of concern emerge. These will be presented in 4.2.3, "Additional points of concern" on page 209. The only way to overcome these is to set high level but yet actionable guidelines to follow, as shown in Figure 4-3. These will be presented and discussed in section 4.2.3.

4.2.1 Today's data center network challenges

In this section we focus on highlighting the key challenges with today's data center networks and how they impact the data center networks' non-functional requirements (NFRs). The NFRs (introduced in Chapter 1.) do not really change in this new context from a definition standpoint. What changes dramatically is the priority of the NFRs, the way they are met and their inter-relations.

In order to frame the discussion around functional areas, the data center network functional architecture that has been presented in Chapter 1, "Drivers for a dynamic infrastructure" on page 1 is shown again in Figure 4-4 on page 203.

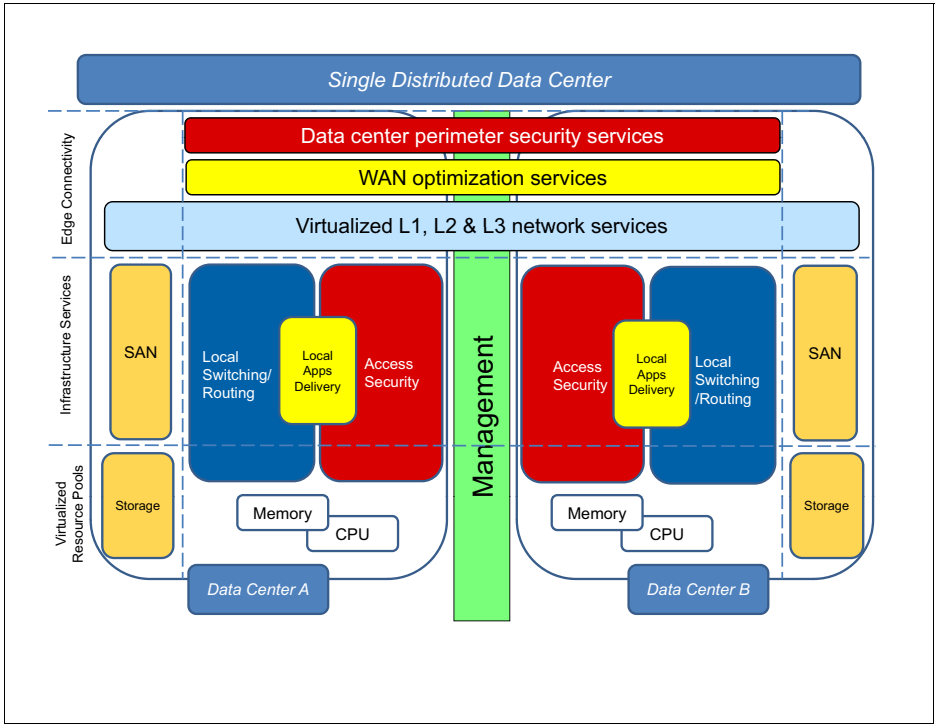

Figure 4-4 Data center network logical architectural overview

This diagram can be used as a guide to document client-server flows and impacts on the overall data center network infrastructure. In fact, for clients accessing the data center services, the IT infrastructure looks like a “single distributed data center”. The geo-load balancing components take care of redirecting the client to the most appropriate data center (if these are active/active) or it may redirect clients in case of a disaster recovery situation. The Wide Area Network (WAN) acceleration layer optimizes the delivery of services for the remote clients. It is important to highlight that these functions (WAN optimization and perimeter security as well) may be different if the clients are accessing via the Internet or intranet. So in order to document these differences, different diagrams should be used.

The interconnection shown between data centers (there are two in Figure 4-4 but there can be more) has to encompass traditional Layer 1 services (for example, dense wavelength division multiplexing or DWDM connectivity for storage extension) and Layer 3 services (for example, via multiprotocol label switching or MPLS), but also, a Layer 2 extension may be needed, driven by server virtualization requirements.

The trend towards virtualized resource pools for servers and storage has a two-fold implication from a networking point of view:

- Some network-specific functions may be performed within the virtualized server and storage pools, as described in Chapter 2. For example, access switching and firewalling functions may be performed within the hypervisor, and the storage infrastructure may leverage dedicated Ethernet networks.
- Some server and storage-specific functionalities may significantly impact the network infrastructure that has to be able to support these virtualization-driven features, such as virtual machine (VM) mobility.

As shown in Figure 4-4, network-specific functions such as local switching and routing, application delivery and access security may be performed at the server virtual resource pool level. While access security and switching are needed in most situations, application delivery may be optional for some specific application requirements (but can be performed both at a physical or virtual level). Infrastructure management (shown in green in the diagram) should encompass the whole infrastructure end-to-end, and in this context the integration between system and network management becomes more meaningful, for example.

Figure 4-5 on page 205 shows examples of how the diagrams can be used in different situations:

- Example A shows a typical client-server flow where access security, application delivery, and local switching functions are all performed in hardware by specialized network equipment.
- Example B shows a client-server flow where switching is also performed virtually at the hypervisor level and access security and application delivery functions are not needed.
- Example C shows an example of a VM mobility flow between Data Center A and Data Center B.

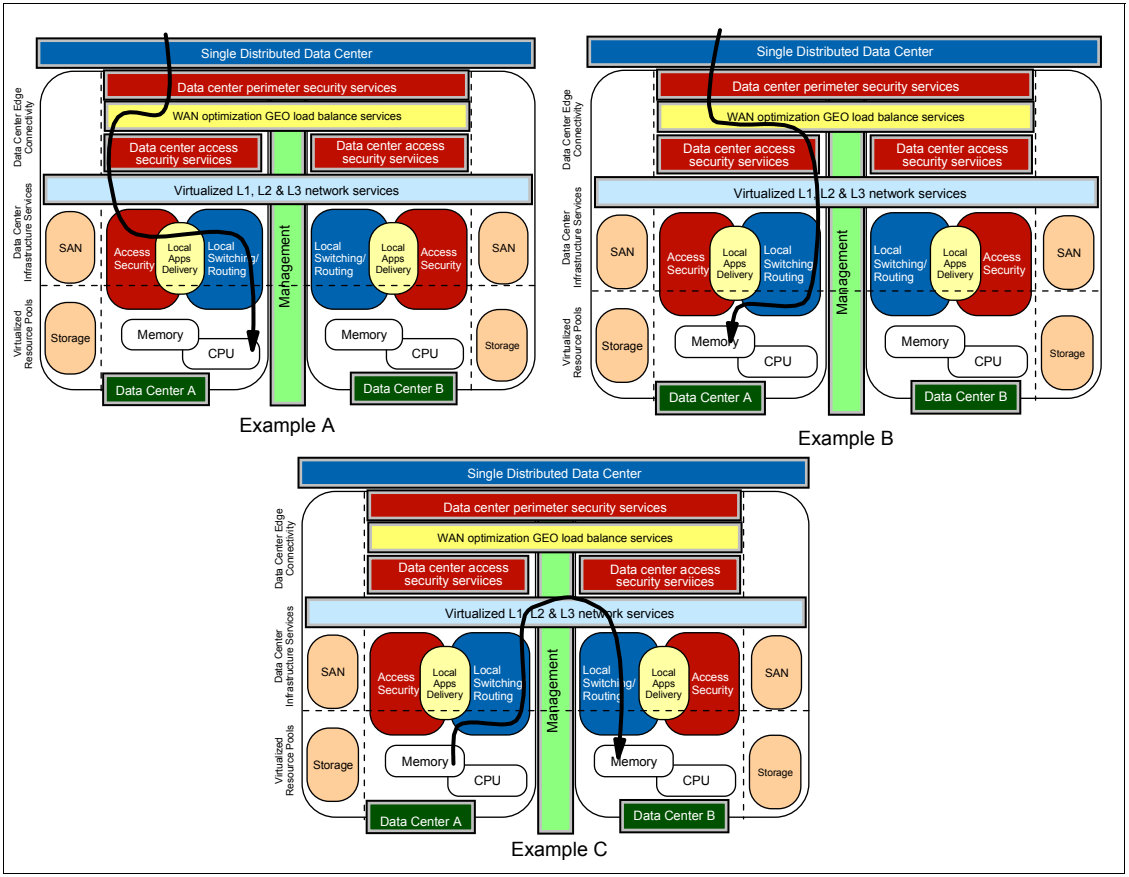

Figure 4-5 Data center network logical architectural overview

Given the complex situation we just described, we now provide a list of the most relevant of the networking challenges in the data center, from a technology point of view, that need to be addressed in order to obtain a logical, functional view of the infrastructure as shown in Figure 4-5. Note that the order does not imply relative importance of the impact of these challenges on the specific environment, processes, and requirements.

The first set of challenges described here is related to the service drivers as they impact the data center because the network must support other strategic IT initiatives.

- Layer 2 extension

  The widespread adoption of server virtualization technologies drives a significant expansion of the Layer 2 domain, and also brings the need to extend Layer 2 domains across physically separated data centers in order to

stretch VLANs to enable VM mobility using technologies such as VMware, VMotion, or POWER Live Partition Mobility. These are very challenging requirements to satisfy in order to achieve the service delivery objectives since they directly impact the scalability (in terms of new MAC addresses that can be included in a Layer 2 domain) and flexibility (in terms of the time and effort needed to deploy new services) of the data center network.

- Control plane stability

  The stability of the control plane in a typical Layer 2 data center network is typically controlled by the spanning tree protocol—STP or one of its many variants. This approach, however, does not have the robustness, flexibility and efficiency that is required to assure service delivery to the business. For example, the typical convergence time required to recover from a link failure is not in synch with the needs of today's network-dependent and high-paced business environment. This limitation hence has a huge impact on the availability and reliability of the data center network.

- Optimal use of network resources

  Another drawback of the STP is that in order to avoid loops in a Layer 2 network, a tree topology must be enforced by disabling a subset of the available links. So usually 50% of the available links are idle and the efficiency of the capacity usage is suboptimal at best. This can be mitigated by balancing the available VLANs across different STP instances, but it goes without saying that being able to exploit 100% of the available capacity would be a huge improvement from a data center network performance point of view.

- Obtain VM-level network awareness

  As described in detail throughout Chapter 2, "Servers, storage, and software components" on page 31, the VM is the new building block in the data center and the importance of physical NICs for the network architecture fades when compared to the virtual networking realm inside the server platforms. On the other hand, it is difficult to manage both the virtual and the physical network environment with a consistent set of tools and orchestrate changes in an end-to-end fashion. This trend puts a lot of pressure on the serviceability and manageability of the data center network and can also impact its availability if changes are not agreed across different functional teams in charge of the infrastructure management.

- End-to-end network visibility

  Server consolidation and virtualization initiatives demand more bandwidth per physical machine and the same is true on a WAN scale when consolidating scattered data centers into fewer ones. This and the fact that it is very difficult to obtain end-to-end visibility of the network flows (different teams in charge of managing virtual resources inside servers, Blade switches, LAN switches,

and WAN routers) have the risky consequence that it is becoming increasingly more difficult to spot and remove network bottlenecks in a timely and seamless fashion. Clearly this has a significant impact on the performance and even the availability of the enterprise network if the quality of service (QOS) model is not designed and enforced properly.

- Support new, network-demanding services

  New services and applications that have very demanding network requirements, such as video, cannot be accommodated easily in traditional data center network environments. So the challenge is to be able to exploit these new technologies that are demanded by the business while minimizing the CAPEX expenditures that are needed and the risk of heavily changing the data center network infrastructure, whose stability has been traditionally enforced by it being static. These challenging new requirements impact both the performance and the capacity planning nonfunctional requirements.

The next set of data center network challenges is related to the cost drivers because the network must bring operating expenses (OPEX) and capital expense (CAPEX) cost savings, exploiting automation, consolidation and virtualization technologies leveraged in other IT domains such as storage and servers.

- Appliance sprawl

  Today's data center network environments are typically over-sophisticated and characterized by dedicated appliances that perform specific tasks for specific network segments. Some functions may be replicated so consolidation and virtualization of the network can be leveraged to reap cost savings and achieve greater flexibility for the setup of new services without the need to procure new hardware. This appliance sprawl puts pressure on the scalability and manageability of the data center network.

- Heterogeneous management tools

  The plethora of dedicated hardware appliances has another consequence that impacts the operating expenses more than the capital expenses. In fact, different appliances use different vertical, vendor and model-specific tools for the management of those servers. This heterogeneity has a significant impact on the manageability and serviceability of the data center network.

- Network resources consolidation

  Another challenge that is driven by cost reduction and resource efficiency is the ability to share the physical network resources across different business units, application environments, or network segments with different security requirements by carving logical partitions out of a single network resource. The concern about isolation security and independence of logical resources assigned to each partition limits the widespread adoption of those technologies. So logically sharing physical network resources has a

significant impact on the security requirements, but may also limit performance and availability of the data center network.

4.2.2 Burgeoning solutions for the data center network

After listing and describing the main challenges in today's data center network environment, this section discusses the new architectural alternatives and the emerging standards that have been ratified or are in the process of being ratified by bodies of standards such as IEEE and IETF, which can be leveraged to alleviate these challenges. Among these are:

- Vendor-specific data center network architectures such as Cisco FabricPath, Juniper Stratus and Brocade Virtual Cluster Switching (VCS™). By enabling features such as multipathing and non-blocking any-to-any connectivity in a Layer 2 domain, these solutions look to alleviate the challenges induced by today's inefficient and spanning tree-based Layer 2 data center network topology by introducing a proprietary control plane architecture. At the same time, the ability to manage the network as one single logical switch drives cost savings because the network is easier to manage and provision.
- Standards-based fabrics, leveraging emerging standards such as IETF TRILL (Transparent Interconnect of Lots of Links) and IEEE 802.1aq[6], Shortest Path Bridging (SPB). Early manifestations of these fabrics are appearing on the market. The basic idea is to merge the plug-and-play nature of an Ethernet Layer 2 network with the reliability and self configuring characteristics of a Layer 3 IP network. The challenges that these standards aim to solve are the same as the vendor fabrics but also guaranteeing interoperability across different network equipment vendors.
- The price attractiveness of 10 gigabit Ethernet (GbE) network interface cards and network equipment ports make it easier to sustain increased traffic loads at the access layer virtualizing and consolidating server platforms. The imminent standardization of 40 GBE and 100 GbE makes this even more true in the near future in order to be able to handle the increased server traffic at the core layer.
- Fiber Channel over Ethernet (FCoE) disks and network appliances make it possible to converge storage and data networks in order to achieve cost savings by sharing converged network adapters, collapsing Ethernet and Fiber Channel Switches in the same physical appliance, and simplifying cabling. The FCoE standard provides the foundation for the forthcoming converged data center fabric, but other protocols are also needed in order to deliver a fully functional, end-to-end, DC-wide unified fabric. The IEEE standards body is working in the Data Center Bridging task group[7] (DCB) to

[6] For more information on IEEE 802.1aq refer to http://www.ieee802.org/1/pages/802.1aq.html
For more information on IETF TRILL refer to http://datatracker.ietf.org/wg/trill/charter/

provide a framework to ensure lossless transmission of packets in a best-effort Ethernet network.

- New deployment models for network services such as multipurpose virtualized appliances and virtual appliances can be exploited in order to consolidate and virtualize network services such as firewalling, application acceleration, and load balancing—thereby speeding up the time needed to deploy new services and improving the scalability and manageability of the data center network components.
- Regulatory and industry-specific regulations together with IPv4 address exhaustion drive the adoption of IPv6 networks.
- In order to bridge the gap between physical and virtual network resources, standards are being developed by IEEE (802.1Qbg and 802.1Qbh) to orchestrate the network state of the virtual machines with the port settings on physical appliances, thus enabling network-aware resource mobility inside the data center. Again, these are standards-based solutions that can be compared with vendor-specific implementations such as Cisco Nexus 1000v and BNT VMReady.
- Network resources can also be logically aggregated and partitioned in order to logically group or share physical appliances to improve the efficiency and the manageability of the data center network components.
- In order to overcome the limits of the vendor-specific network management tools, abstraction layers can enable network change and configuration management features in a multivendor network environment. These tools, more common in the server and storage space, can also provide linkage to the service management layer in order to orchestrate network provisioning with the setup of new IT services, speeding up the time to deploy metrics and reducing capital and operating expenses associated with the growth of the data center infrastructure.

4.2.3 Additional points of concern

In this section we present additional points of concern to those discussed in 4.2.2. In fact, the new possibilities presented in the previous section alleviate some of today's data center network challenges at the expense of raising new issues that must be faced by network managers and architects.

These issues are not just technology related; they can be broadly categorized in three main areas: technology, business, and organization.

[7] For more information on IEEE DCB refer to http://www.ieee802.org/1/pages/dcbridges.html

- Technology:
  - The ability of navigating through vendor-specific alternatives in the data center network solution space is a challenging task. Also, these solutions are solving some concrete challenges that available standards are not ready to overcome. This situation poises a serious threat to the interoperability of Ethernet networks, which has been a key characteristic over the years in order to minimize vendor transition cost and assure seamless interoperability. In a way the data center network LAN is shifting towards a SAN-like model, where the functionality lowest common denominator is not high enough to make multivendor networks an attractive solution for clients.
  - The journey towards IT simplification is a recurring theme in the industry, but there is a significant gap between the idea of shared resource pools that can be leveraged to provision new services dynamically and the reality of today's heterogeneous, scattered, and highly customized enterprise IT environment.
  - New cutting-edge technology solutions that significantly enhance packet services delivery are very promising in order to overcome some of the data center network challenges, but these are not the universal panacea for the data center network manager and architect headaches. In fact, a network services and application-aware data center network requires the ability of linking the data plane understanding with control plane and management plane services, and also a broader understanding of the overall IT environment.
  - The consolidation and virtualization of server platforms and network resources has to be carefully balanced in order to adapt to the security policies. The tradeoff between resource efficiency and guaranteeing secure isolation is a significant point of concern when collapsing services with different security requirements on the same physical resources. A high-level scenario of this is shown in Figure 4-6 on page 211. This has a twofold implication: the hardware vendors should be able to prove this isolation (both from a security and from a performance independence standpoint) and this has to be proven for auditing, adding a regulatory compliance dimension to this issue.

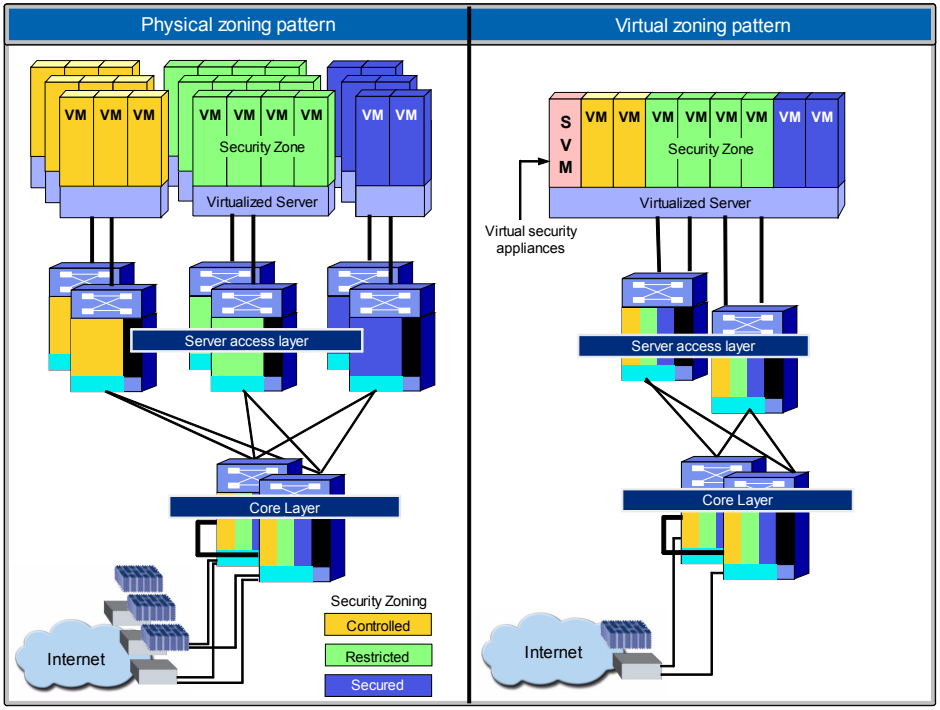

Figure 4-6 Collapsing different security zones on shared server and network hardware

- Business:
  - The cost reduction imperative driven by the global economy has put a lot of stress on enterprise IT budgets, so that projects and initiatives that cannot clearly demonstrate the value for the business have very little chance of being approved and launched by the decision makers. In this context, network and IT managers are struggling to obtain tools and methodologies that can show clear return on investment to their business executives.
  - Networking industry consolidation and the forces driving new alliances among IT and networking vendors may impact the existing business relationships together with the integration and interoperability governance that have been in place previously.
- Organization:
  - IT organizations can no longer be grouped into independent silos. The interdependencies between different teams managing and developing new solutions for the data center are just too many to rely on the traditional organizational model. Just to name a few examples: application characteristics that cannot be ignored by network architects and

managers, virtual switch management boundaries blur and storage and data converged network project responsibilities have to be carefully balanced between the storage and the network teams.

– The data center professionals' mindset must include the new evolutionary step. T-shaped skills (the vertical bar on the T represents the depth of related skills as expertise in a same field, whereas the horizontal bar is the ability to collaborate across disciplines with experts in other areas, and to apply knowledge in areas of expertise other than their own) must be developed and the over-specialization paradigm has to be complemented by skills in adjacent disciplines (for example hypervisors, storage, and security). So it is a matter of new skills that must be sought after both from a technological standpoint and from a communication and teamworking point of view.

4.3 Setting the evolutionary imperatives

As discussed in these previous sections, there are several technology alternatives and solution options and concepts that can be considered. The overall governance of the data center network becomes pivotal to guaranteeing the expected service delivery at the right cost. This section illustrates what an enterprise should consider for its needed governance around the data center network.

Important goals to consider in order to set the enterprise networking guideline principles are:

- Accelerate the investment decision-making process.
- Build plans that leverage networking technologies and solutions for business advantage.
- Facilitate consensus across the organization.
- Mitigate risk by providing guidance and suggestions that help enhance availability, resiliency, performance, and manageability of the networking infrastructure.

The definition of these principles should also avoid:

- Delay in the time to market of service delivery because the current networking infrastructure may not support new business initiatives.
- Improper use of the enterprise IT organization structure that could lead to inefficiencies that might arise from new projects that are not deployed in a timely or prioritized fashion.
- Delays in justifying technology investments.

- Duplicated or suboptimal investments in tools and resources.

In the following sections we present three key evolutionary imperatives that help to overcome the required shift in terms of mindset.

4.3.1 Developing a strategic approach

IT managers are in the position to enable networking solutions to achieve current and future business objectives and streamline day-to-day operations management.

The contribution of IT, and in particular the identification, prioritization and optimization of networking investments, becomes critical to achieving the enterprise business goals. Setting business priorities for networking initiatives will provide synergy among IT domains.

Since networks are not acting as a “network interface card to network interface card” domain anymore, the IT infrastructures such as servers, storage, and applications have dependencies on what networking has to offer. Keeping a tactical approach can result in the networking domain bringing a suboptimal performance to the enterprise. Also, networking is not made exclusively by data packet forwarding fabrics, but other networking services that guarantee the service delivery objectives within and outside the enterprise. This is the reason why the IT organization should orchestrate the change with the current service delivery assurance in mind, but also looking at the horizon in order to organize the infrastructure, processes, and people around the necessary level of flexibility, efficiency, and future service delivery models.

The network strategy and planning must therefore be driven by the business requirements and guided by a set of common design principles. In addition, the network must provide efficient, timely collection and access for the information services and must enable the protection of enterprise assets, while facilitating compliance with local, country, and international laws.

An enterprise should identify the scope, requirements and strategy for each identified networking initiative inside the enterprise’s unique business environment, obtain visibility of the current IT infrastructure (for example, performing an assessment of the current environment), analyze gaps and set the actionable roadmap to define the potential for the effects such a strategy could have on the organization, the networking, and the IT infrastructures.

We have seen how envisioning a single distributed data center network that provides reliable access to all authorized services, provides efficiencies in management and cost, and enables more consistent service delivery needs,

goes through a well-defined process that aims to make educated and consistent decisions on network infrastructure and network application growth.

The methodology that needs to be enforced is tightly linked to business objectives and overall IT governance and needs to consider all the specific interdependencies that provide a framework for the development of the scope and direction of the data center network.

Enterprises should assess the current status of the networking environment and uncover the networking future state requirements by analyzing both business and IT objectives. This methodology often needs to leverage reference models, best practices, and intellectual capital. The analysis will then identify technology solutions that address a migration process that leverages the current IT investments in a sustainable operating environment.

A fundamental aspect is to understand how IT integrates with the business domain. Aspects that should be defined include:

- Business environment and objectives
- Current IT environment and plans
- Current technology environment
- Current networking environment:
- Current principles and standards
- Budget and IT investments process
- IT strategy and plans
- Business satisfaction with the existing network

The next steps aim at unleashing the potential of a sound transformation that matters to the enterprise:

- Determine the existing versus the required state.
- Identify the gaps between the enterprise's current environment and the new networking strategy.
- Build a portfolio of initiatives that overcome the gaps.
- Prioritize the different identified initiatives and the networking and overall IT dependencies.
- Determine the initiative’s overall impact (including on the organization) and transition strategy.
- Plan an actionable roadmap in conjunction with the business ROI expectation in terms of costs versus the value derived.

- Develop possible solution approaches for each planned initiative and select which approach to pursue.
- Schedule initiatives.
- Complete the transition plan.

With the reiteration of this process the enterprise has set the strategy and the path to a comprehensive networking design that encompasses and unifies networking data forwarding, networking security and networking services.

4.3.2 The value of standardization

As described in the previous sections, the typical data center environment is characterized by heterogeneous technology domains and heterogeneous physical appliances in each domain. These two levels of complexity need to be dealt with in order to leverage virtualized resource pools to simplify and speed up the creation of new IT services and lower operating and capital expenses. Standardization is also the first step in order to enable orchestrated automated infrastructure provisioning because it is somehow difficult, expensive and risky to achieve this in a highly customized and heterogeneous environment.

From a high-level point of view, standardization in the data center spans these three dimensions:

- Technology: for example, rationalizing the supported software stacks (operating systems, hypervisors, data bases, application development environment, applications but also network appliances OSs) and their versioning simplifies the development process, lowers license costs and suppliers management costs and shortens the creation of service catalogues and image management tools and processes.
- Processes: for example, centralizing processes that span the organization (for example procurement, external support, and crisis management) improve consistency and speed up lead time. Also, cost savings can be achieved by eliminating duplicate processes optimizing resource efficiency both physical and intellectual.
- Tools: for example, reducing the number of vertical tools that are required to manage and provision the infrastructure can bring cost benefits in terms of required platforms and skills and also improve service delivery by leveraging consistent user interfaces.

So the goal of standardization in this context can be broadly categorized as follows:

- Lower transition costs to new technologies or suppliers by leveraging standard-based protocols. But also vendor-specific features that are de facto

standards can be leveraged in this context, not just IEEE or IETF ratified ones. This also implies that procurement processes across different technology domains (for example, network and security equipment) should be centralized and coordinated in order to avoid duplication and ensure a common strategy and interoperability.

- Lower coordination costs (which also encompass skills and time) by decoupling the functional layer from the implementation layer. Tools that provide this abstraction layer are pivotal in order to use standard interfaces (such as APIs) that application developers and other infrastructure domains can understand, regardless of the low-level implementation of the specific function.
- Lower management costs and improved service delivery by using common interfaces and operational policies so that advanced functions like correlation and analytics can be implemented without requiring complicated and time consuming ad-hoc customizations.
- External and internal regulatory compliance is easier to achieve and demonstrate because changes, inter-dependencies and control are easier to trace back and fix.

On the other hand, there are also barriers to the standardization process as it has been previously described:

- Standards might offer limited functionality, lower adoption rates and less skills available than other more customized alternatives, which may already be in use.
- It is not always easy to coordinate across different organizational departments.
- It is very difficult to have an over-encompassing view of the overall infrastructure and its interdependencies because applications, technology domains and even data centers may be handled independently and not in a synchronized, consistent fashion.
- The upfront capital investments that may be required and the risks of shifting away from what is well known and familiar are also barriers in this context.
- Network professionals typically operate through command line interfaces (CLIs) so a shift in terms of tooling, mindset and skills is required in order to integrate network management and configuration into more consumable interfaces, such as the one used in the storage and server arenas.
- The over-sophisticated and highly customized and heterogeneous IT world struggles with the end goal of a homogeneous resource pool-based IT environment without actionable, well-understood and agreed-upon milestones and initiatives that might depend on tools and technologies that offer limited functionalities compared to what is required.

Standardization is a journey that requires coordination and understanding of common goals across people, tools, technologies and processes. On the other hand, it is a key enabler for automation, cost and service delivery optimization and is something that should always be kept in mind when integrating new functionalities and technologies inside a dynamic data center infrastructure.

4.3.3 Service delivery oriented DCN design

A collaborative approach is needed to gain consensus among all IT domains, networks, servers, applications, and storage. In fact, the needs of the enterprise services (for instance core business processes, HR applications, safety-related services) impact IT with a series of requirements that strategic planning can help optimize from the very beginning. An overall architectural governance of the various specialties of IT is needed to ensure that while assembling different domain components, a common objective is met. The ultimate goal is to identify the strengths and weaknesses of the current organization and culture in relation to the stated business strategy, vision, and goals in order to set key priorities for transformation.

The data center network should be designed around service delivery starting from a high-level design that outlines the basic solution structure to support the enterprise strategy and goals by establishing a set of guiding principles and using them to identify and describe the major components that will provide the solution functionality. Typically, items that should be developed are:

- Guiding principles: Principles relate business and IT requirements in a language meaningful to IT and network managers. Each principle is supported by the reason or the rationale for its inclusion and the effect or the implications it will have on future technology decisions. Each principle refers to at least one of the enterprise's key business requirements. The principles are also developed to help explain why certain products, standards, and techniques are preferred and how these principles respond to the needs of enterprise security, servers, applications, storage and so on.
- A network conceptual design: This is the first step in crafting a network solution to support business requirements. It describes the relationship between the building blocks or functions that comprise the network and services required to meet business needs. This design also shows the interactions between networking and other IT domains. At this level, technology is not specified but support of the business purpose is shown. Business requirements are then mapped to the network through guiding principles, conceptual network design diagrams and application flows.
- A specified design: This process refines the conceptual design by developing the technical specifications of the major components of the solution in terms of interfaces, capacity, performance, availability, security and management,

and how they relate to other IT domains. This approach gives detailed specification of the topology, sizing, and functionality of the network. At this point decisions are made, sorting through architectural and functional alternatives.

- A physical design: This documents the most intricate details of the design that are required for the implementation. At this level of the design, it is important to:
  - Identify product selection criteria.
  - Select products that meet specific requirements.
  - Select connection technologies.
  - Rationalize and validate the design with the architectural governance.
  - Develop infrastructure and facility plans for the network.
  - Develop a detailed bill of materials.
  - Prepare a network infrastructure implementation plan that also lists organizational impacts and dependencies for the master plan that the architectural board needs to craft.

Once the physical design is complete, the enterprise will have a level of detail appropriate to execute the initiative.

In Figure 4-7 on page 219, the possible interactions among the IT infrastructure teams that are needed for a service-oriented DCN design are depicted, along with examples, that the network domain might experience with other IT and non-IT domains.

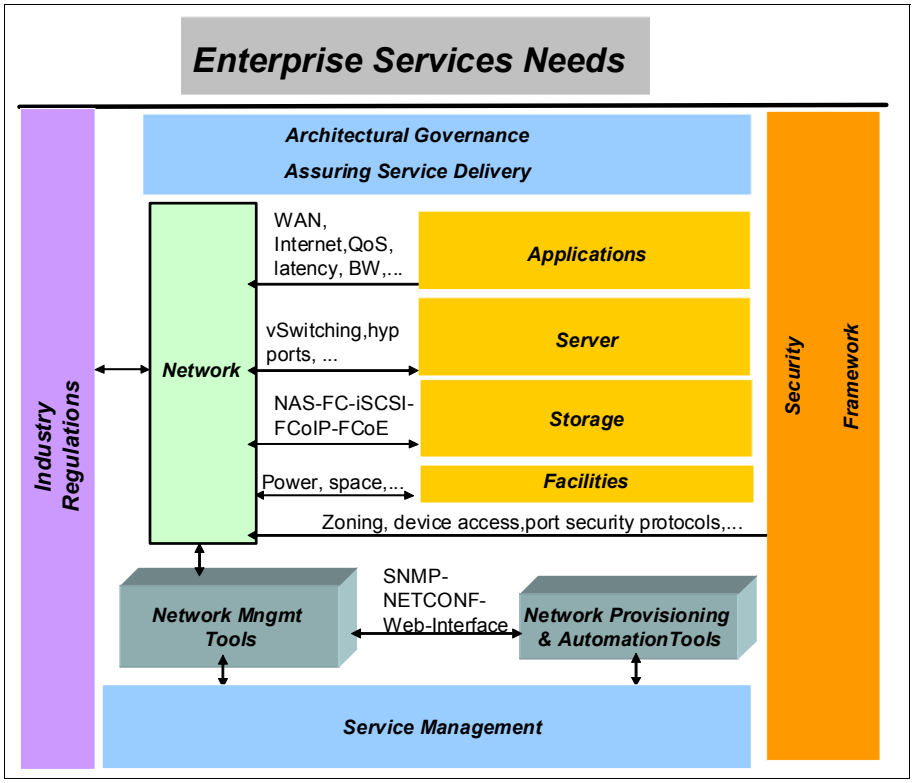

Figure 4-7 Data center network design requirement gathering

Networking is in a truly unique position to connect the pieces of the IT environment and drive the transformation towards efficiency at the right cost for the business.

While we see industry regulations as external yet mandatory to follow, for each of the planned IT initiatives, the network team, as shown in Figure 4-7, can leverage and work with:

- Application teams to determine how the network should treat the flows and assure the required availability. It is also important to prove to the business the cost that the network must sustain in order to satisfy all the requirements. For example, the expected level of availability of a certain application has to be matched with similar (if not higher) network availability. This holds true both for client-to-server and server-to-server traffic flows.
- Server teams to define the right level of synergy to avoid layer and functionality duplications and delays in the application flow processing. For example, the virtual switching functions implemented in the hypervisors are

important requirements to document at this stage to clearly define the infrastructure management boundaries.

- Storage teams to explore and implement ways to improve the overall transaction quality and cost while maximizing data security. For example, data and storage convergence initiatives should be architected and implemented with the storage, server, and network teams acting as a single entity.
- Security teams to protect data with the right impact on the operations service agreements following the guiding principles, constraints, and requirements that govern, control or influence the final solution design and delivery. In this sense the network must be the manifestation of the enterprise security policies (for example, zoning, port access security, and so on) by adopting the broader security framework. For example, network and security features may be implemented on the same appliance, thus bringing the need to synchronize architecture and operations between the network and security teams.
- Site and facilities teams to understand the consequences that new initiatives have on cabling, cooling, and rack space. For example, even if rack space is not an issue, power constraints may be a barrier for a data center augmentation.
- Service management teams to assess the current and planned portfolio of management tools and processes for the IT environment and identify any gaps or overlaps in the coverage provided by that portfolio. For example, service provisioning and automation tools may need specific configurations on the network side both on the physical devices and on a network management level.

Deep skills and extensive experience are necessary to detail and specify the complete enterprise architecture. It is necessary to link network services and security to other aspects of IT and business organization at key design decision points, including systems management, applications development, organizational change, testing and business continuity. The approach we recommend enables the enterprise to deliver a robust and resilient solution that aligns with and supports the ever changing business and industry regulations environment.

4.4 IBM network strategy, assessment, optimization, and integration services

Business demands for greater cost efficiency while being able to respond faster to market changes to stay competitive is driving the IT industry to innovate like never before. Consolidation and virtualization technologies are enabling greater

IT resource efficiencies while cloud computing is changing the paradigm of how IT resources are sourced and delivered. This major shift in how IT resources are perceived and utilized is changing how the IT infrastructure needs to be designed to support the changing business requirements and take advantage of tremendous industry innovation.

When equipped with a highly efficient, shared, and dynamic infrastructure, along with the tools needed to free up resources from traditional operational demands, IT can more efficiently respond to new business needs. As a result, organizations can focus on innovation and aligning resources to broader strategic priorities. Decisions can be based on real-time information. Far from the “break/fix” mentality gripping many data centers today, this new environment creates an infrastructure that provides automated, process-driven service delivery and is economical, integrated, agile, and responsive.

What does this evolution mean for the network? Throughout the evolution of the IT infrastructure, you can see the increasing importance of stronger relationships between infrastructure components that were once separately planned and managed. In a dynamic infrastructure, the applications, servers, storage and network must be considered as a whole and managed and provisioned jointly for optimal function. Security integration is at every level and juncture to help provide effective protection across your infrastructure, and across your business.

Rapid innovation in virtualization, provisioning, and systems automation necessitates expanding the considerations and trade-offs of network capabilities. Additionally, the ultimate direction for dynamic provisioning of server, storage and networking resources includes automatic responses to changes in business demands, such as user requests, business continuity and energy constraints, so your current network design decisions must be made within the context of your long-term IT and business strategies.

IBM Global Technology Services (GTS) has a suite of services to help you assess, design, implement, and manage your data center network. Network strategy, assessment, optimization and integration services combine the IBM IT and business solutions expertise, proven methodologies, highly skilled global resources, industry-leading management platforms and processes, and strategic partnerships with other industry leaders to help you create an integrated communications environment that drives business flexibility and growth.

IBM network strategy, assessment and optimization services help identify where you can make improvements, recommend actions for improvements and implement those recommendations. In addition, you can:

- Resolve existing network availability, performance, or management issues.
- Establish a more cost-effective networking and communications environment.
- Enhance employee and organizational productivity.

- Enable and support new and innovative business models.

IBM Network Integration Services for data center networks help you position your network to better meet the high-availability, high-performance and security requirements you need to stay competitive. We help you understand, plan for and satisfy dynamic networking demands with a flexible, robust and resilient data center network design and implementation. Whether you are upgrading, moving, building or consolidating your data centers, our goal is to help improve the success of your projects.

To help you deliver a reliable networking infrastructure, we offer services that include:

- Network architecture and design based on your data center requirements.
- A comprehensive design that integrates with your data center servers, storage, existing networking infrastructure and systems management processes.
- Project management, configuration, implementation, network cabling and system testing of server-to-network connectivity, routers, switches, acceleration devices and high-availability Internet Protocol (IP) server connections.
- Options for proactive network monitoring and management of your enterprise network infrastructure to help achieve optimal levels of performance and availability at a predictable monthly cost.

4.4.1 Services lifecycle approach

Based on a tested and refined lifecycle model for networking, IBM Network Strategy and Optimization Services and Network Integration Services can help ensure your network's ability to provide the level of availability and performance your business requires.

Figure 4-8 on page 223 depicts the approach taken for the IBM services approach.

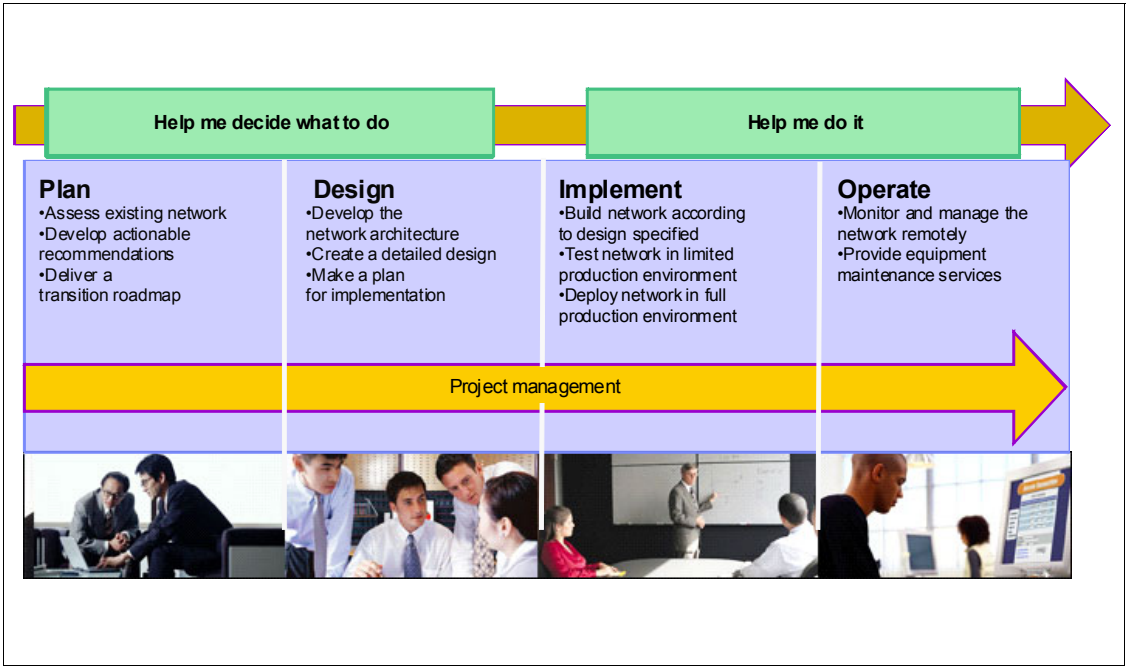

Figure 4-8 Services lifecycle approach

In all phases shown in Figure 4-8, we will work with you to:

- Plan
  - Understand your current IT and networking environment.
  - Collect and document your requirements.
  - Identify performance and capacity issues.
  - Determine your options.
  - Compare your current environment to your plans.
  - Make recommendations for transition.
- Design
  - Develop a conceptual-level design that meets the identified solution requirements.
  - Create a functional design with target components and operational features of the solution.
  - Create a physical design to document the intricate details of the solution, including vendor and physical specifications, so that the design may be implemented.
  - Deliver a bill of materials and a plan for implementation.

- Implement
  - Review the implementation plans.
  - Perform a site readiness survey.
  - Procure the equipment.
  - Develop installation procedures, solution testing and certification plans.
  - Stage the solution.
  - Implement and test the solution.
  - Train your in-house support staff.
- Support the network - monitor and manage the environment
  - Review information about your networking environment.
  - Configure remote monitoring and management of your devices.
  - Test and start the service.
  - Provide proactive 24x7 monitoring.
  - Manage and report based on the level of service you have selected.
  - Deliver these services for a monthly fee based on the number of devices under management.

4.4.2 Networking services methodology

The foundation of our networking services methodology is based on the IBM Unified Method Framework and IBM Reference Architectures. The IBM Unified Method Framework provides a single framework to establish a common language among all IBM practitioners delivering business solutions. It is the fundamental component in our asset-based services, providing a mechanism for IBM practitioners to reuse knowledge and assets using a consistent, integrated approach.

IBM Reference Architectures provide a blueprint of a to-be model with a well-defined scope, the requirements it satisfies, and architectural decisions it realizes. By delivering best practices in a standardized, methodical way, Reference Architectures ensure consistency and quality across development and delivery projects. It consists of a set of formal Unified Method Framework assets, defining requirements, and functional and operational aspects.

IBM is world-renowned for employing solid project governance during the execution of a project. IBM's project managers establish a framework for communications, reporting, procedural and contractual activities for the project. IBM adheres to the Project Management Institute (PMI), Project Management Body of Knowledge (PMBOK) and uses the PMBOK phase processes to aid in project delivery. For the execution of all projects, IBM leverages appropriate proven tools, templates and processes. This critical oversight is imperative to deliver both cost effectiveness and accelerated and optimized timelines. IBM recognizes the importance of effective planning and governance in managing

large, complex projects such as this project. Establishing the appropriate planning and governance frameworks at the outset will define the business partnership relationships at varying levels and help both organizations maximize the value and objective attainment that each can realize from this relationship.

4.4.3 Data center network architecture and design

IBM understands that the first step to modernizing the network infrastructure is to develop a sound enterprise network architecture that takes the business and IT environments, security and privacy policies, service priorities, and growth plans into account. We analyze your business, current IT and networking environment and plans, and use the analysis to establish network design requirements; any previously performed assessments are also input to this analysis. Following data collection and analysis, we develop an architecture and design using three progressively more detailed levels of granularity, each providing more detail as the networking requirements are refined.

Solution architecture and high-level design

The IBM solution architecture and high-level design develop the basic solution structure and design to support your strategy and goals by establishing a set of guiding principals and using them to identify and describe the major components that will provide the solution functionality. Typically, IBM develops and documents the following items:

- Guiding principles

  Principles relate business and IT requirements in a language meaningful to IT and network managers. Each principle is supported by the reason or the rationale for its inclusion and the effect or the implications it will have on future technology decisions. Each principle refers to at least one of the client's key business requirements. The principles are also developed to help explain why certain products, standards, and techniques are preferred.

- Network high-level design

  A network high-level (conceptual) design is the first step in crafting a network solution to support business requirements. It describes the relationship between the building blocks or functions (that is, connections for point of sale terminals) that comprise the network and services required to meet business needs. At this level, technology is not specified but support of the business purpose is shown. Business requirements are mapped to the network through guiding principles, conceptual network design diagrams, and profiles. The security design is elaborated and included during the design cycle.

Solution logical design

The IBM solution logical (specified) design activity refines the conceptual design by developing the technical specifications of the major components of the solution in terms of interfaces, capacity, performance, availability, security, and management. The “specified” level of design is an intermediate step that will take all the architectural decisions made in the solution architecture and use them to give detailed specification of the topology, sizing, and functionality of the network and all components.

The solution logical design contains information about the topology, sizing, and functionality of the network, routing versus switching, segmentation, connections, and nodes. The solution logical design is where the decisions are made concerning OSI Layer implementation on specific nodes. Sizing information is taken into account for connections and nodes to reflect the requirements (for example, capacity and performance) and the nodes' ability to handle the expected traffic. Functionality is documented for both nodes and connections to reflect basic connectivity, protocols, capabilities, management, operations, and security characteristics.

The solution logical design addresses physical connectivity (cabling), Layer 2 characteristics (VLANs, Spanning tree), Layer 3 characteristics (IP design), Quality of Service design, topological units (access, distribution, core, remote office, WAN, data center), network management, and traffic filtering.

Solution physical design

The IBM solution physical design documents the most intricate details of the design that are required for implementation, including: profiles of each type of product to be installed, exact hardware and software configurations, and tools.

At this level of the design, IBM identifies product selection criteria; selects products that meet specific node requirements; selects connection technologies; rationalizes and validates the design with you; develops infrastructure and facilities plans for the network; develops a detailed bill of materials; and prepares a network infrastructure implementation plan.

Once the solution physical design is complete, you will have an architecture and design specified to a level of detail appropriate to execute a network procurement activity and, following delivery, to begin implementation of the new network.

4.4.4 Why IBM?

As a total solutions provider, IBM can offer a single source for the components that are necessary for a turnkey networking solution, including architecture, design or design validation, integration, logistics, ordering support and

procurement, site preparation, cabling configuration, installation, system testing, and project management.

IBM has the deep networking skills and extensive experience necessary to assist you in detailing and specifying a data center network architecture. Our Network Integration Services team links network services and security to other aspects of your IT and business organization at key design decision points, including systems management, applications development, organizational change, testing and business continuity. Our approach enables us to deliver a robust and resilient solution that aligns with and supports your changing business. A strong partner ecosystem with suppliers like Cisco, Juniper, F5, and Riverbed also enables our network and security architects to support the right combination of networking technology for you.

Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this book.

IBM Redbooks

For information about ordering these publications, see “How to get Redbooks” on page 231. Note that some of the documents referenced here may be available in softcopy only.

- *Best Practices for IBM TEC to Netcool Omnibus Upgrade,* SG24-7557
- *Communications Server for z/OS V1R9 TCP/IP Implementation Volume 1 Base Functions, Connectivity and Routing*, SG24-7532
- *Communications Server for z/OS V1R9 TCP/IP Implementation Volume 2 Standard Applications*, SG24-7533
- *Communications Server for z/OS V1R9 TCP/IP Implementation Volume 3 High Availability, Scalability and Performance*, SG24-7534
- *Communications Server for z/OS V1R9 TCP/IP Implementation Volume 4 Security and Policy-Based Networking*, SG24-7535
- *IBM Systems Virtualization Servers, Storage, and Software*, REDP-4396
- *IBM System z Capacity on Demand*, SG24-7504
- *IBM System z Connectivity Handbook*, SG24-5444
- *IBM System z Strengths and Values*, SG24-7333
- *IBM System z10 BC Technical Overview*, SG24-7632
- *IBM System z10 EC Technical Guide*, SG24-7516
- *IBM System z10 EC Technical Introduction*, SG24-7515
- *Introduction to the New Mainframe - z/VM Basics*, SG24-7316
- *Migrating to Netcool Precision for IP Networks - Best Practices for Migrating from IBM Tivoli NetView*, SG24-7375
- *PowerVM Virtualization on IBM System p Introduction and Configuration 4th Edition*, SG24-7940
- *z/VM and Linux Operations for z/OS System Programmers*, SG24-7603
- *GDPS Family - An Introduction to Concepts and Capabilities,* SG24-6374

- *Clustering Solutions Overview - Parallel Sysplex and Other Platforms,* REDP-4072
- *Cloud Security Guidance IBM Recommendations for the Implementation of Cloud Security*, REDP-4614
- *IBM Scale Out Network Attached Storage Architecture, Planning, and Implementation Basics*, SG24-7875
- *IBM zEnterprise System Technical Guide*, SG24-7833
- *IBM zEnterprise System Technical Introduction*, SG24-7832
- *IBM XIV Storage System: Architecture, Implementation, and Usage*, SG24-7659
- *IBM System Storage Solutions Handbook*, SG24-5250
- *Integration Guide for IBM Tivoli Netcool/OMNIbus, IBM Tivoli Network Manager, and IBM Tivoli Netcool Configuration Manager*, SG24-7893
- *IBM System Storage N Series Hardware Guide*, SG24-7840
- *IBM System Storage N series Software Guide*, SG24-7129
- *IBM b-type Data Center Networking: Design and Best Practices Introduction*, SG24-7786
- *IBM b-type Data Center Networking: Product Introduction and Initial Setup*, SG24-7785
- *IBM j-type Data Center Networking Introduction*, SG24-7820
- *TCP/IP Tutorial and Technical Overview*, GG24-3376
- *IBM BladeCenter Virtual Fabric Solutions*, REDP-4673
- *Cloud Security Guidance IBM Recommendations for the Implementation of Cloud Security*, REDP-4614
- *Enterprise Security Architecture using IBM ISS Security Solutions*, SG24-7581
- *IBM BladeCenter Products and Technology*, SG24-7523

Online resources

These Web sites are also relevant as further information sources:

- ICS SalesOne Portal

  `http://w3-03.ibm.com/services/salesone/S1_US/html/htmlpages/networkingsvcs/ns_splash.html`

- Virtual Ethernet Port Aggregator Standards Body Discussion, Paul Congdon, 10th November 2009

  www.ieee802.org/1/files/public/docs2008/new-congdon-vepa-1108-v01.pdf

- First Workshop on Data Center - Converged and Virtual Ethernet Switching (DC CAVES)

  http://www.i-teletraffic.org/itc21/dc-caves-workshop/

- VSI Discovery and Configuration - Definitions, Semantics, and State Machines

  http://www.ieee802.org/1/files/public/docs2010/bg-sharma-evb-VSI-discovery-0110-v01.pdf

- Trivial TLP Transport (T3P) - Proposed T3P DU and State Machines

  http://www.ieee802.org/1/files/public/docs2010/bg-recio-evb-t3pr-0110-v01.pdf

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