PACKET

CISCO SYSTEMS USERS MAGAZINE

THIRD QUARTER 2004

ROUTING INNOVATION

CISCO.COM/PACKET

INNOVATION

TURNING THE CORNER ON INNOVATION

A new era dawns in IP networking.

The requirements of the IP routing market are rapidly maturing beyond best-effort data networking.

In the many years since the Internet boom began, routers have been hard at work in service provider backbones and enterprise networks, successfully delivering packets to their destinations. Most of the Web-based data applications in common use—e-mail and file sharing, for example—have tolerated moderate levels of packet loss, latency, and jitter with minimal impact on end users.

Over time, routers have advanced incrementally to support far greater levels of network availability and quality of service (QoS).

Great Expectations

As in any industry, however, expectations only continue to rise. In addition, new applications for IP networks keep emerging—and some of these applications are far more finicky about network performance than e-mail. Consider, for example, the strict latency and jitter sensitivities inherent in real-time IP voice subscriber services and wholesale voice backhaul applications. Then there are forthcoming IP virtual private networks (VPNs) with requirements for end-to-end "committed information rates" and the tricky multicast and QoS requirements of video-on-demand service delivery.

Icons: Rodney Davidson

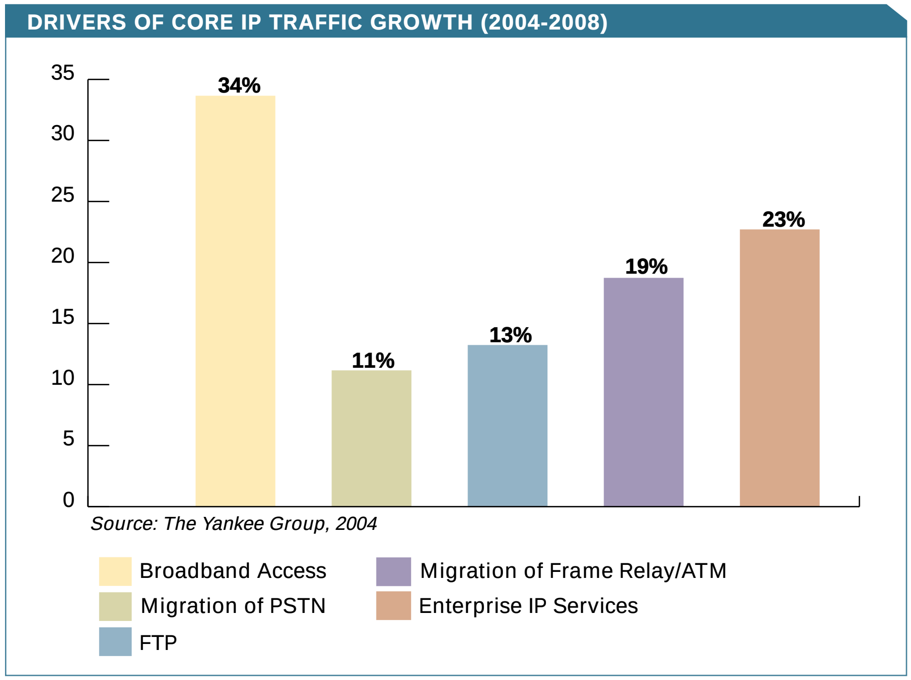
These services represent only a tip of the IP iceberg. The demands of service providers, enterprises, and consumers—and the sophistication of new applications—have reached a point where it has become necessary for the IP routing industry to begin turning a corner on architectural innovation.

To meet scalability and performance expectations in the coming years, owners of IP routing infrastructures will soon need a more available, scalable, and flexible services environment that can deliver on the true vision of network convergence. This vision—one built on converged IP Multiprotocol Label Switching (IP/MPLS) packet infrastructures and able to consolidate the many communications services that today still require separate networks—will be constructed using routing systems with fundamentally different architectures than those that have served the industry well in the past. These new routing systems will be capable of delivering multi-decade scalability, continuous system availability, and unprecedented service flexibility. They will help to alleviate much of the management complexity and costs associated with growing service provider points of presence (POPs) to add capacity for new services and subscribers.

Winds of Change

Why is the industry ripe for change now?

First, service providers would like their IP networks to begin yielding higher revenues. One way to achieve this goal is to deploy new services for which they can charge premium prices. At this juncture, the fees that carriers are able to charge for best-effort data networking services are declining rapidly in a commodity market. Being able to combine traditional best-effort services and "premium" services (those with strict guarantees for



IP TRAFFIC EVERYWHERE Core network traffic is set to explode, driven largely by network consolidation, broadband services, and enterprise IP services.

bandwidth, latency, jitter, and packet loss) onto one network requires router architectures that can deliver 99.999 percent ("five nines") availability or better, scale without disruption, and deliver extensive traffic classification and queuing capabilities using sophisticated high-speed packet processors.

The new Cisco CRS-1 Carrier Routing System provides all of these capabilities with a massively distributed, "service-aware" architecture that enables nondisruptive scaling of interfaces, processors, and capacity. It supports complete partitioning of resources and provides packet forwarding mechanisms that can perform deep-packet inspection at wire speed. This allows it to service traffic with potentially thousands of queues per interface (see article, "Reinventing the Router," page 41).

"This is a significant differentiator for Cisco," says Mark Bieberich, program manager in the Communications Network Infrastructure group at the Yankee Group, a Boston, Massachusetts-based networking researching firm.

"The CRS-1 can apply QoS and traffic management for specific services or network functions using its partitioning capabilities," he observes. "Service providers have begun migrating mission-critical Frame Relay, ATM, and private-line traffic to an IP/MPLS network. As this migration effort progresses, the IP/MPLS network must match service-level agreements [SLAs] for those types of services," says Bieberich.

1985	1986	1987	1988
MEIS Subsystem is first Cisco product to ship	Cisco AGS (Advanced Gateway Server) is first commercial product shipped	Interior Gateway Routing Protocol (IGRP) is developed, the first protocol to permit the building of large internets	Multiport Communications Interface ships, the industry's highest-speed network interface

New Age of IP Networking

Meanwhile, consumers increasingly presume that they can do nearly everything related to communications using the Web, their computing devices, and personal communicators. These tasks have evolved beyond basic text e-mail to bundle voice, still video (camera), video messaging, live chat, online gaming, and any number of other services. The delivery of these services requires new levels of performance—not just pure speed, but also tight control over latency, jitter, and network availability.

Given the explosion in intranet- and Internet-based Web activity, combined with the influx of traffic created by the consolidation of ATM, Frame Relay, private-line, and voice networks, it is easy to conceive how the sheer volume of traffic joining IP/MPLS backbones is skyrocketing (see figure). All this communication is driving the need for routers to gain pure horsepower for scalability and performance. In fact, based on primary research conducted in 2004 with worldwide Tier 1 service providers, the Yankee Group predicts a healthy annual growth rate in IP/MPLS core traffic of 117 percent through 2006.

Eighty-five percent of the world's top 20 revenue-generating service providers already have network-consolidation projects underway, according to Bieberich. "These projects validate that carriers are gaining confidence that router architectures will make networks scalable and flexible enough to meet their multiple-service delivery needs," he says.

What have been missing, according to David Willis, vice president of technology research services at META Group, a networking research firm in Stamford, Connecticut, are the "very high levels of hardware scalability and redundancy that ensure very low failure rates."

What are the innovative developments allowing the industry to forge ahead into this new era of IP networking? They include the following:

- Architectures in devices such as the new Cisco CRS-1 that have been designed to deliver the levels of scalability, availability, and service flexibility required for service providers to build converged packet infrastructures and less complex POP architectures

- Performance in carrier and enterprise router architectures alike designed to scale and to suffer no degradation as additional services are turned on

- Maturing standards for the MPLS suite of control-plane protocols

- QoS advances in router hardware to better enforce prioritization and resource reservation markings signaled by router control planes

Router Reinforcements

Router hardware and software designs are beginning to borrow massively parallel processing and modular process-isolation concepts from the computing and telephony industries. One goal is to enable a given router to deliver the five-nines availability that is expected from public switched telephone network (PSTN) switches.

Historically, it has been possible to design routed networks that can deliver five-nines availability by deploying redundant routers in multiple, complex routing tiers, but such uptime was not consistently available from individual routers, points out Brian Daugherty, product marketing manager for Core and Edge Routing at Cisco. But that is changing with the Cisco CRS-1, he says, because of its "always-on," highly distributed hardware and software architecture, which distributes packet forwarding and control-plane processing in a way that greatly minimizes the effects any hardware or software failure can have on overall system availability.

Cisco IOS® XR—the latest member of the Cisco IOS Software family—has been developed specifically to address the scalability, availability, and flexibility requirements of converged packet infrastructures. Its highly modular nature allows for extremely granular process isolation and distribution, so that critical system processes can be started, stopped, or upgraded individually and even moved automatically to take advantage of processor resources anywhere in a multishelf system. Additionally, notes Daugherty, complex state information used by many system processes can even be maintained across process restarts to allow for hitless upgrades and fault recovery.

States Robert Whiteley, an associate analyst at Forrester Research in Cambridge, Massachusetts: "Cisco has leapfrogged the industry with the CRS-1 to build a product on par with the PSTN."

Whiteley, for example, says he is most impressed with the CRS-1's switch fabric. The router, unlike older architectures in the industry, has a three-stage switch fabric that is upgradable in-service, dynamically self-routed, and well architected for delivering multicast traffic. For example, the router can natively replicate multicast traffic directly within the fabric for up to

1989

Border Gateway Protocol (BGP) is developed and implemented on Cisco routers

Development of cBus and cBus controller and deployment of FDDI, the first high-speed technology interface; additional Ethernet interfaces with up to six Ethernet ports on a cBus card are developed, enabling high-speed switching

1990

Cisco IGS is the first remote access router introduced

AGS+ modular router chassis and the *ciscoBus* five-slot high-speed backplane are introduced

NetCentral network management software introduced

1992

Cisco's first patent, No. 5,088,032, is received for IGRP (Feb.)

Cisco Communication Server Family introduced (May)

1 million multicast groups, offloading the need for multicast packet replication from the packet processors.

"By the time a packet reaches the output interface, all the work is done. In the old days, a packet wouldn't be replicated in the actual switch fabric. Instead, it would reach a line card, then go to the switch fabric, then back again, and so forth. It was inefficient," Whiteley says.

According to Whiteley, it is difficult to retrofit core router switching fabrics and line cards to handle multicast, which he predicts is going to be very important going forward for applications like video on demand. "Now, the multicast replication process is graceful, and it takes place at wire speed," he says.

Inklings of Innovation

Among the characteristics of the router architectures that will usher in a new generation of IP networking are the following:

- Massively parallel processing
- Checkpointing of state information
- Process distribution
- Service partitioning
- Fault isolation
- CPU and memory separation among applications
- Multiple logical internal routers within a multichassis device
- Deep-packet inspection of multiple services across thousands of queues at wire speed for QoS

These developments exemplify the innovation that will usher the industry into a new era of communications.

Minimizing Disruptions

Cisco's Daugherty points out that enabling network operators to scale their POP architectures nondisruptively and to extend the lifespan of equipment in a given POP are also a sign of the times. As traffic volumes explode and the traffic from multiple networks consolidates within a given POP, the past approaches cannot scale—from a cost, reliability, or manageability standpoint.

"Historically, the approach has been to add more routers," says John Doyle, director of marketing for Core and Edge Routing at Cisco. "But with the performance-sensitive services merging into a given POP, not only do network operators need to be able to scale their networks without service disruption, they also need to alleviate the extra administrative burden that comes with adding more hardware, redundancy, and interconnections."

This consolidation spills over to enterprise networks as well, both in large sites and small. In branch offices, for example, with limited technical staff, simple high-performance integrated systems will emerge for the same reasons that service provider POPs require simplification (see sidebar, "Enterprise Requirements").

MPLS Matures

Given that IP was created as a simple and connectionless protocol, MPLS was able to bring some semblance of deterministic performance and behavior to IP by predetermining paths and marking MPLS labels for priority QoS. MPLS Traffic Engineering—preselecting paths through a network based on performance or other administrative criteria—is yet another application of MPLS.

History has demonstrated that vision can sometimes lag implementation, given the realities of the standards process and interoperability testing. So while the industry has been making strides with MPLS for many years, the key standards needed to kick MPLS into full action have recently solidified, rendering the control-plane protocol suite finally ready for prime time on a large scale.

Some of these include Internet Engineering Task Force (IETF) standards for Layer 2 tunneling and interworking through MPLS. This means that the legacy Layer 2 subscriber services that have for so long generated handsome revenues for carriers—namely, Frame Relay and ATM—can now all be harmoniously converged alongside newer IP services in an IP/MPLS backbone. The standards for these capabilities—including tunneling between either like or dissimilar endpoints (for example, Frame Relay to Frame Relay or Frame Relay to Ethernet through an IP/MPLS backbone) are now in place.

To further ease service provisioning and management in converged IP/MPLS networks, operations, administration, and maintenance (OAM) features have finally become available for MPLS-based IP networks. MPLS management tools help service

1992

Cisco 3000 Series low-end router platform launches (Aug.)

CiscoWorks router management software introduced (Sept.)

Cisco 4000 Series modular routers for regional and branch offices unveiled (Sept.)

Three-phase program for ATM interfaces is mapped out (Oct.)

1993

Cisco 7000 Series high-end, multiprotocol router platform redefines high-performance routing (Jan.)

Cisco 2000 Series remote access router platform extends the enterprise network to remote sites (June)

Patent No. 5,274,631 for Computer Network Switching System (Dec.)

Cisco is first multiprotocol router vendor to support national ISDN-1 standard (Dec.)

First ATM interface for a router is developed and implemented on the Cisco 7000 Series providers guarantee service levels for MPLS-based IP VPN services, for example, independent of subscriber interface, while also fulfilling SLAs for traditional Layer 2 services tunneled through MPLS in a converged-network environment.

Software Toughens Up

META Group's Willis considers the management capabilities inherent in the Cisco CRS-1 IOS XR an industry innovation. He observes that Extensible Markup Language (XML) support in the software enables the CRS-1 to work directly with any existing operations support system (OSS) and to take "more of a systems view than an individual-box view in terms of management."

Overall, "IOS XR turns away from being all things to all people to a purpose-built operating system directly tailored to the needs of carriers," Willis says.

Forrester's Whiteley agrees. "Other router vendors have modularized their software, though not to the same extent," Whiteley says. "Cisco took things a step further, by virtualizing the processes and distributing them to any processing resource across multiple chassis. If you separate BGP and OSPF [routing protocols] within the management plane that connects the two functions, you can much more easily troubleshoot a problem."

He says such a setup is a boon to real-time services, such as voice over IP (VoIP). "Now, carriers have the correct foundation for the reliability they need to offer the real-time and converged services we hear so much about," Whiteley says. "They also have the ability to deeply inspect packets at 40-Gbit/s speeds [the speed of the CRS-1 line cards] for QoS, so they can lay the entire proper framework."

Enterprise Requirements

Router innovation is not reserved solely for the service provider backbone. While Tier 1 carrier core networks have the largest requirements from a pure scalability perspective, real-time application traffic generated by even the smallest networks will commingle with packets in the heart of the largest service provider backbones.

The concepts of being able to turn on additional services without performance degradation or service disruption, the need for five-nines availability, and the goals of minimizing administrative complexity and improving price-performance apply to network operators of all sizes.

With such goals in mind, Cisco data center and branch office routers continue to integrate services, such as many aspects of security technology, voice, and video. Most recently, Cisco enterprise routers gained capabilities to optimize edge routing in sites that are dual-homed, based on best-path performance characteristics at the time of transmission and least-cost routing.

For more on the latest developments in the enterprise routing space based on enhancements to Cisco IOS Software, see "IOS: Routing's Crown Jewel," page 47.

Moving On

The networking industry is making its way from running a circuit-switched telephony network for voice, a Frame Relay/ATM network for business data, and a best-effort IP network for consumers (at a minimum) to one next-generation network that supports all requirements. Convergence of this nature has always been a goal, but getting there has been more of a technical challenge than the industry might have envisioned when the commercial Internet took off, and both service providers and router vendors were challenged to simply "keep up" with demand.

The world's network operators are poised to move off their service-specific infrastructures to converged packet infrastructures based on IP/MPLS to handle the next era of networking. At the end of the day, the sheer volume of traffic and the stringent performance requirements of the applications to be supported by tomorrow's networks no longer allow network operators to continue purchasing isolated hardware devices to scale their networks. Rather, large, very fast routers designed to deliver unprecedented levels of scalability, availability, flexibility, and management ease—while vastly simplifying network architectures—will serve network operators well for at least the next decade. ■

1994

Cisco 2500 Series for small and branch offices introduced (Jan.)

Patent No. 5,280,500, method and apparatus for multilevel encoding for LANs (Jan.)

CiscoFusion internetworking architecture is unveiled (Feb.)

Cisco Catalyst® Switch, the first intelligent switch for client/server workgroups, is introduced (Feb.)

First Cisco ATM switch is shipped (Sept.)

Cisco 7000 Router Family is enhanced with a Silicon Switch Processor that nearly triples the routers' throughput (Sept.)

IP Multicast routing technologies introduced that enable massively scalable distribution of data, voice, and video streams efficiently to millions of users

New interface for Cisco 7000 Series—the fruit of an OEM agreement between IBM and Cisco—represents the first time a mulitprotocol router can connect directly to a mainframe ESCON channel

Hot Standby Router Protocol (HSRP) introduced; HSRP overcomes previous limitations that host-based network software imposed on "network convergence"—the ability of the host to adapt to changes in network topology