Profitable Routed Network Services with Dense Virtual Routed Networking (DVRN)

CRESCENT NETWORKS

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Introduction

Recent advances in optical networking have fueled a view that end-to-end optical networks, large quantities of low-cost bandwidth and purely switched architectures might solve all subscriber demands. While all users want more bandwidth, many also require the media independence, resiliency, and flexibility that only a customized routed network can provide. Many network-reliant businesses – e.g. medium to large enterprises and new enhanced application providers, such as content, storage, and application service providers – can scarcely afford to build and operate their own routed network, but neither can they afford to live without the benefits of such a network.

Successful service providers know that bandwidth breakthroughs are ongoing and continuously commoditized. To counteract the falling margins on basic bandwidth, many providers recognize that Routed Network Services are a sustainable multi-billion dollar revenue opportunity.

But with today's tools, Routed Network Services have been a double-edged sword. On one hand, the cost of service deployment is too high, with stacks of dedicated routers and an unwieldy operations model. On the other hand, providers cannot afford to walk away from the strong demands of highly strategic customers. How can a service provider deliver large numbers of customized Routed Network Services within reasonable physical space, capital, and staff budgets?

Dense Virtual Routed Networking (DVRN) is a breakthrough architecture for delivering profitable customized Routed Network Services. By liberating the IP routing function from conventional dedicated routers, DVRN is the first solution that brings operations and capital economies of scale to customized routed networks. The DVRN technologies leverage investments in new IP/optical capacity, data center build-outs, and back-office operations systems, while extending the value of legacy SONET, frame relay, and ATM infrastructures.

Routed Network Services Defined

A *Routed Network Service (RNS)* is a network service that employs dynamic IP routing protocols (e.g. OSPF, BGP) to create a customized IP network for a specific customer. The Routed Network Service is provisioned by a service provider, such as an Interexchange Carrier (IXC), Local Exchange Carrier (LEC), Network Service Provider (NSP), or Application Infrastructure Provider (AIP). Collectively, these service providers are referred to as *Routed Network Providers (RNPs).*

IP routing protocols help keep the Routed Network Service flexible and resilient, while scaling up to large numbers of highly interconnected nodes. Since it is operated for a specific customer, the Routed Network Service supports private IP addressing, and can be customized in terms of Quality of Service and other value-added features.

Two primary applications illustrate the Routed Network Services opportunity.

- *Enterprise connectivity*

  Medium to large enterprises rely on secure, high performance intranets among their many locations. Intranets are increasingly complemented by extranets among suppliers, partners, and customers. Outsourcing these intranets and extranets to a Routed Network Provider can be an attractive proposition for many enterprises.

- *xSP Internetworking*

  A fast-growing mix of enhanced application providers (*xSPs*), such as Application Service Providers, Storage Service Providers and Content Delivery Networks, rely on high performance IP networks to deliver their services to their customers. With its scale and customization benefits, the Routed Network Service can be the ideal infrastructure for enhanced application providers.

How is a Routed Network Service different from other IP services?

- vs. Public Internet

  The *Public Internet* happens to be a routed network, but its service is fundamentally "one size fits all." Without support for customization and performance guarantees, it leaves many organizations with considerable IT challenges to adapt the service for business-class use, e.g. administering complex firewalls and network address translations (NATs).

- vs. IP VPNs

  Today's "*IP VPN*" is not Routed Network Service. IP VPNs evolved from technology designed for mobile worker remote access, and use one of several layer 2 tunneling techniques (e.g. L2TP, IPSec) to build dedicated point-to-point connections between hosts. Today's IP VPNs happen to run across a big routed network (the Public Internet) to exploit its low cost transport and widespread access, but they are fundamentally Layer 2 services that cannot scale to support the demands of larger enterprise and xSP customers.

Drivers for Routed Network Services

The primary driver for service providers is to build a portfolio of services with sustainable profitability. Service providers are under tremendous financial pressure to recoup their investments on high speed transport and core IP routing infrastructure, since building higher bandwidth pipes for basic transport service does not result in sustainable margins. Organizations that operate their own routed network represent an attractive customer base to service providers because of these organizations' pent-up demand and eagerness to outsource their routed network over a customized Routed Network Service.

Enterprises and xSPs are examples of organizations that are currently purchasing, deploying and maintaining customized routed networks. They face a related set of drivers. Today these networks employ dedicated standalone routers over a set of layer 2 logical connections and layer 1 physical links (e.g. FR WAN or Ethernet). This is an expensive capital expenditure, but even more costly in terms of human capital. Router expertise is increasingly scarce, expensive, and mobile, meaning that the highly paid people who can operate a conventional routed network today might not be available tomorrow.

Organizations continue to absorb the costs of dedicated routed networks because it is the only way to get these essential benefits.

- Media diversity can best be supported by a routed layer 3 service. For instance, routed networks can connect different layer 1 / layer 2 technology islands such a headquarters and hosting center on optical ethernet, branch locations on Frame Relay, and partners and mobile workers on DSL and Remote Access VPNs. Conventional switched WAN networks such as ATM, Frame Relay, Optical and Ethernet require a homogeneous layer 1 or layer 2 network, which is unrealistic for most customers.

- Only routing addresses the "N^2 mesh" problems in highly interconnected custom networks. Greater interconnection is being fueled by the need to connect larger numbers of sites for collaboration and peer-to-peer applications. With layer 1 or layer 2 technologies (which include VPN tunneling mechanisms such as IPSec and L2TP), each pair of communicating sites must have a dedicated end-to-end connection, resulting in N^2 logical connections for a network of N sites. Administering these connections, especially for growing networks, is time-consuming and error prone. On the other hand, in a routed network solution, N sites can be networked with N logical connections, and any to any connectivity is automatically achieved by routing protocols.

- Routing protocols instill high resiliency and self-healing features to networks of any media type.

- Only a customized routed network can meet the QoS, performance and security requirements of enterprises and xSPs, especially as demanding applications like networked storage become more prevalent. Best-effort shared routed networks, such as the public Internet, cannot support these requirements.

- Existing private IP addressing schemes represent a major investment in time and energy, and can only be preserved with customized routed networks. To transport existing IP addresses across the Internet requires complex NAT/firewall administration that will not be transparent to many applications.

- Internet-driven business tools, such as web-based collaboration and workflow, rely on routed IP networks. When they run on QoS-enabled customized routed networks, rather than the public Internet, these business tools will perform much better.

Customized routed networks are not needed for all subscriber segments. For instance, residential and small business subscribers demand improved broadband Internet access. Providers and vendors are accommodating this demand with faster Internet access, low-end firewalls and portal-based self service. These services follow a single-ended connectivity model, in which the subscriber is a single entity that “plugs into” an enormous network cloud, connecting with shared resources such as core routers and web servers.

Contrast this with the demands of large to medium enterprises and xSPs. Their networks must be resilient to congestion and failure, support rapid and flexible changes in configuration and service, and scale from tens to thousands of endpoints. Aggregation into best-effort shared routed networks is not an alternative. A customized Routed Network Service must provide the same performance and control as a privately operated custom routed network, but at a lower cost to the end user.

Breaking Down the Barriers to Profitability

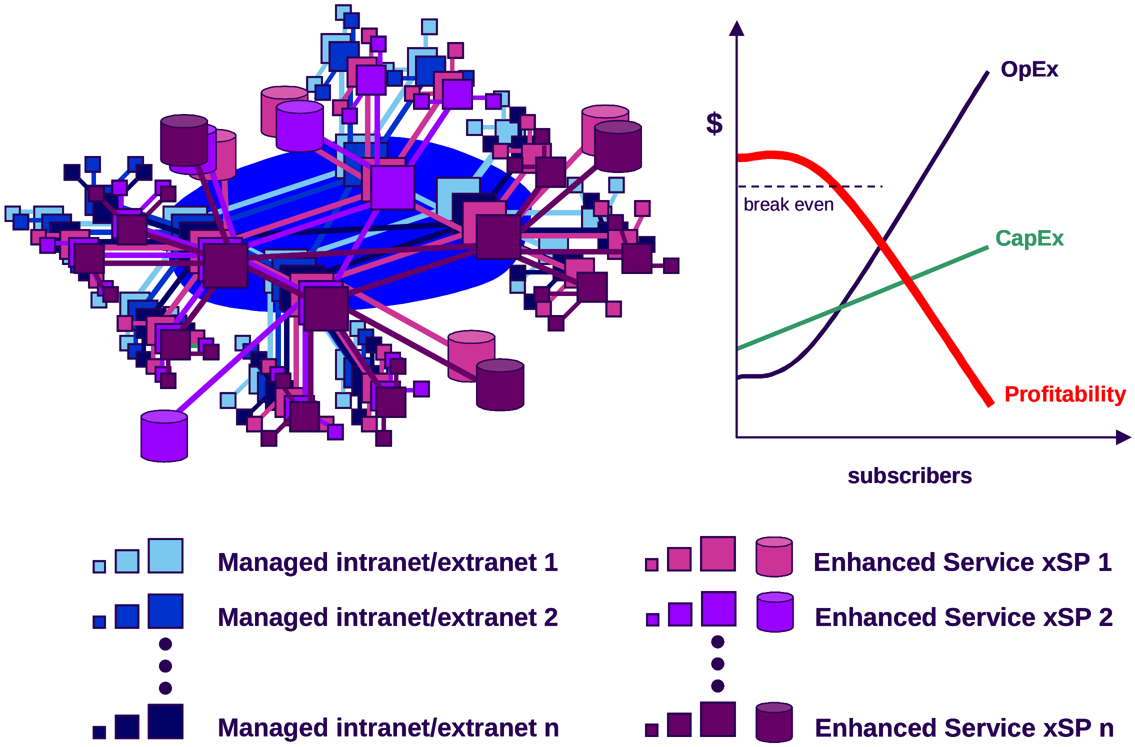

Figure 1. Barriers to Routed Network Services Profitability

To handle the most pressing Routed Network Service demands today, Routed Network Providers must build physically separate dedicated routed network overlays, with racks of routers and roomfuls of expensive router experts (Figure 1). This approach has three fundamental problems:

- *Physical inefficiencies:* To approach the full range of services with sufficient isolation among customers, the provider must deploy many racks worth of expensive, power-hungry equipment. Each high-rent point-of-presence (POP) quickly outgrows the standard 10x10 foot space. Each new service request is constrained by the time to order, stage, install, and configure many physical boxes.
- *Functional limitations:* Dedicated customer specific routed network overlays are complex to manage, taking months and many people to install and provision. Move/add/change backlogs grow out of control, and the brute force techniques to support SLAs don't scale. As a result, the pain increases exponentially with each new customer, and the 10^{th} customer is much harder to support than the first.
- *Fiscal barriers:* The physical and functional problems have a direct negative impact on the service provider's bottom line. Slim margins and pricing that inhibits customer adoption, along with massive staff demands and slow time-to-revenue, quickly create negative scale economies and negative margins (see Figure 2). Most service providers understand this unfortunate dynamic, and are reluctant to deploy Routed Network Services until a more profitable operational model is possible.

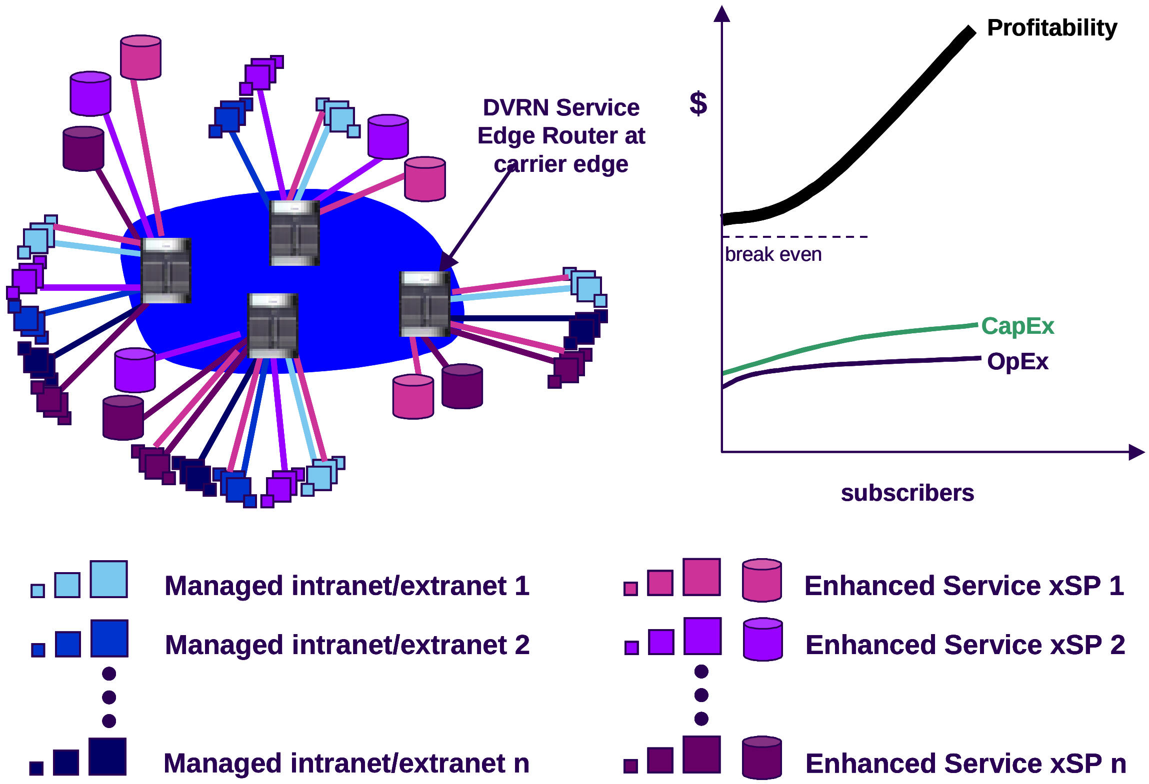

Figure 2. Profitable Routed Network Services with DVRN

By contrast, DVRN is tailored to the customized Routed Network Services business. It retains the customization benefits of a dedicated routed network per customer, yet achieves mass-market economies of scale. As shown in Figure 2, DVRN is deployed with a platform of DVRN-capable Service Edge Routers in the provider POPs and service management software in the NOC. DVRN delivers order of magnitude improvements in the physical equipment, space, and power requirements, dramatically improves SLA and operations functionality, and establishes a capital and operations expenditures basis for fiscal success.

DVRN Technologies

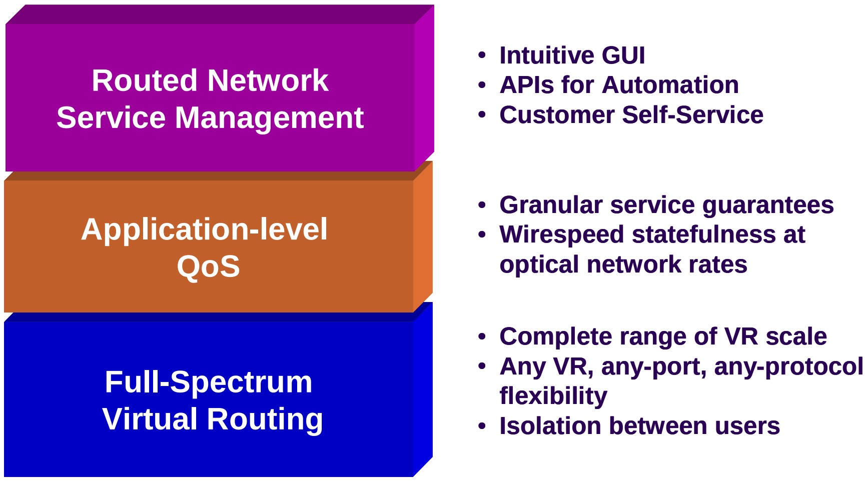

Figure 3. Dense Virtual Routed Networking (DVRN) Technologies

The DVRN architecture leverages three synergistic technology breakthroughs (Figure 3): *Full-Spectrum Virtual Routing, Application-level QoS, and Routed Network Service Management.*

- ***Full-Spectrum Virtual Routing***

  Full-Spectrum Virtual Routing supports many different classes of virtual routers, *simultaneously in a single chassis-based system*. It covers the complete range of standalone conventional routers, from a low-end plug-and-play model that supports a single static route, to sophisticated Internet-scale routers responsible for hundreds of thousands of routes and hundreds of peering sessions. Each DVRN virtual router is independent and customizable, running unique instances of dynamic routing protocols and maintaining separate forwarding information in hardware to attain wirespeed forwarding performance. Furthermore, each DVRN virtual router has complete any-port, any-protocol flexibility, freeing the provider from architectures that constrain a virtual router to a specific processor on a specific line card.

- ***Application-level QoS (AQS)***

  Application-level QoS (AQS) performs dynamic, fine grained traffic classification filtering and policing at wirespeed on optical rate (multi-Gigabit/sec) links. AQS employs deep packet inspection, stateful application awareness and subscriber/policy provisioning for millions of flows across a network. AQS also gathers detailed multigigabit rate statistics for SLAs and billing, to enable new services and enhance customer trust over evolving network infrastructures.

- ***Routed Network Service Management***

  This new service management approach turns Dynamic Virtual Routing and Application QoS into deployable, profit-generating custom Routed Network Services. Its breakthrough approach to routed network and service management is a dramatic improvement over the conventional approach of complex, box-by-box and port-by-port management with Command Line Interfaces. Three components of this management solution are:

- an intuitive network-level GUI with wizards, pre-defined templates, and policy-based provisioning;
- backoffice automation and integration with powerful flow-through APIs to other OSSs and directories;
- a secure and evolving web self-service capability, to offload the provider staff and improve customer response times.

Building a Dense Virtual Routed Network

A DVRN deployment consists of DVRN-capable service edge routers (SERs) plus DVRN services management software, as shown in Figure 4. The DVRN SER combines several types of virtual routing with essential MPLS Label Edge Routing functions. Virtual Router types include Virtual Access Routers (VARs) for individual subscribers, and a VBR (Virtual Backbone Router) for SER reachability and aggregate traffic engineering. DVRN service management automates much of the service design and provisioning process, requiring minimal intervention (through an API or GUI) to customize the service for a given subscriber.

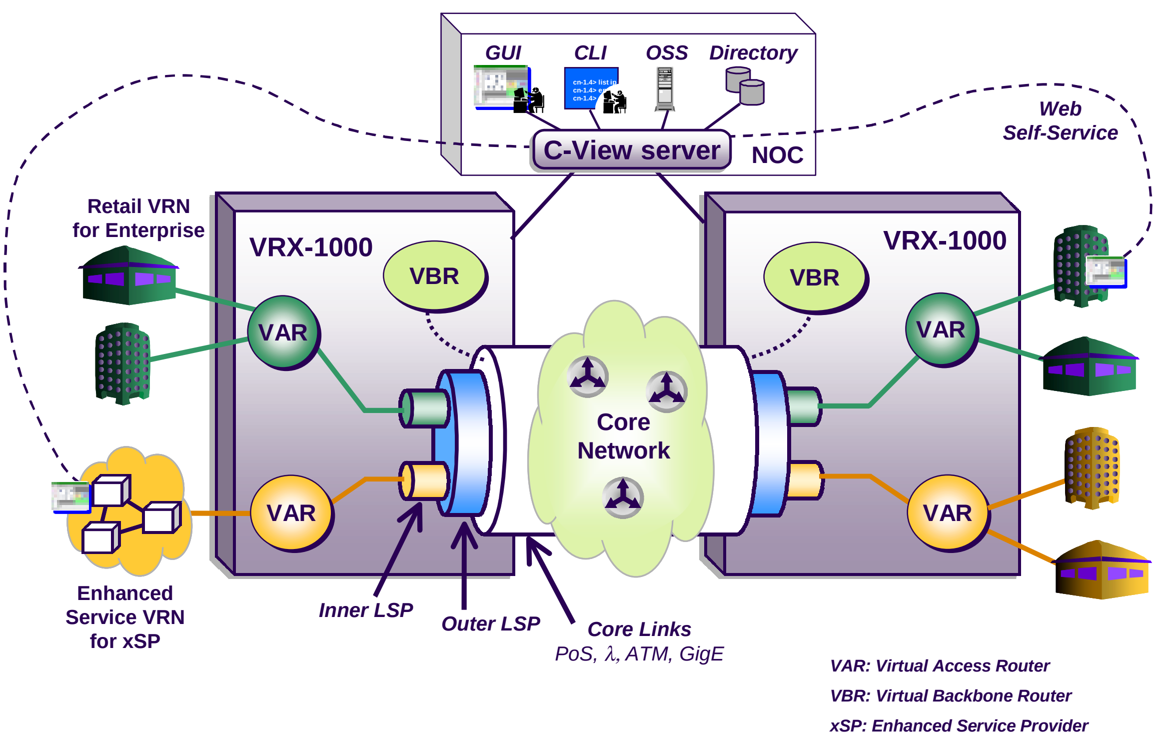

Figure 4. DVRN Architecture

DVRN can be considered a form of MPLS VPN, in that MPLS is used by the SERs to segregate traffic by customer and/or Class of Service across core network links. MPLS is a scalable, uniform connection layer that helps build distinct Virtual Routed Networks out of individual Virtual Routers. Carrier deployment of MPLS has achieved critical mass as a proven method to isolate customer addresses and QoS domains, and offers better scaling than other L2-based tunneling mechanisms. MPLS enables the DVRN architecture to evolve seamlessly from legacy switched or routed networks to emerging MPLS/optical or MP(lambda)S. A native MPLS core is not required, as the SERs can encapsulate MPLS "transparently" across non-MPLS domains, e.g. across an ATM PVC mesh or over dedicated Optical Ethernet.

As highlighted in Figure 3, DVRN core connectivity uses stacked MPLS label switched paths (LSPs). Outer LSPs act as aggregated trunks, and may be traffic engineered in conjunction with other core label switch routers. Within each outer LSP are many inner LSPs, for separate subscribers and distinct class of service types. This stacked label approach balances tremendous granularity for individual subscribers with core scalability, by aggregating the many routed network instances into a manageable number of logical connections into the core.

Imagine a DVRN network with SERs deployed in New York, Chicago, Dallas, and San Francisco. To create a VRN for a subscriber with a national presence, virtual routers are created at each SER, and then access links are connected to simple customer premise equipment. The VRN is completed by enabling routing and core connectivity between the desired adjacent virtual routers. Note that the Routed Network Provider has complete flexibility and control over each VRN's routing adjacencies, link topologies and QoS. These service variables are established by the NOC staff, using predefined templates, or via an API to a workflow OSS or policy directory. As part of the service, the customer may also have web self-service capabilities for monitoring and control.

Once a VRN has been established, VRN sites can be easily added or deleted, and additional service enhancements can be added beyond the basic Routed Network Service. For instance, a new hosted storage service with particular QoS demands can be provisioned through a single "drag-and-drop" action onto the VRN, rather than requiring hours worth of complex command line reconfiguration.

DVRN Applications

The DVRN architecture is capable of supporting a wide range of applications. For instance, a Routed Network Provider might base their business on improved enterprise connectivity services, and add increasing value as they bundle xSP applications infrastructure services. Each VRN operates as a distinct customized routed network, tuned to the needs of its particular customer and applications.

For enterprise customers, DVRN provides a seamless suite of intranet, extranet, and internet access services. VRNs can create dynamic any-to-any connectivity between a corporate headquarters over optical ethernet, branch offices over Frame Relay and DSL, teleworkers and partners over remote access VPN tunnels. If an IT-managed routed network was already in place, this network can be rolled to a provider-based customized Routed Network Service with no impact on the customer's addressing.

On the same DVRN platform, the provider can also develop a complementary business for xSP Internetworking. The VRN becomes the medium through which xSPs become seamlessly networked partners with their enterprise customers. VRNs can be provisioned for xSP partners like application service, storage service, and content providers, as well as LECs looking for out-of-region expansion. These VRNs make extensive use of BGP and self-service operations, and tend to be higher bandwidth than their enterprise connectivity counterparts.

The DVRN Difference

How does DVRN compare with other forms of IP networking? A few examples will show that DVRN is distinct from and often complementary with these other technologies.

- ***Edge/Aggregation routers*** emphasize high port density, and are designed to scale up Internet access services. While the DVRN Service Edge Router (SER) also has high port density and supports Internet access services, its virtualized approach to customized Routed Network Services enables a much richer set of enterprise and wholesale services. Furthermore, DVRN's service management functions cover a breadth of network-level and subscriber-level needs far beyond the scope of conventional router management schemes.
- ***Core routers*** support massive aggregated throughput and route tables, large numbers of peering sessions, and some QoS, but are not designed for subscriber-level intelligence, customization, and differentiation. The DVRN SER is an ideal edge complement to next generation core routers, especially as they add MPLS traffic engineering and QoS guarantees.
- ***IP Service Switches (IPSS)*** have some high-level similarities with DVRN – both deliver a combination of scale economies and value-add features. However, today's IPSSs target small businesses, MTUs, and consumer subscribers with a single ended service model, while DVRN targets higher scale multisite enterprise and xSP subscribers with a customized Routed Network Service model. Some IPSS have a form of virtual router, but generally are limited to static or small route tables. Many of these platforms also have sophisticated service/subscriber management software, but their focus is on the services used by the smaller customer. Since DVRN targets different services and end users, IPSS and DVRN platforms may be deployed side by side by many service providers.
- ***3rd party Service Provisioning Software*** provides essential flow-through management for end-to-end multivendor service provisioning, but by nature tends to take a generic view of specific services and network element features. DVRN's service management component provides superior routed service and subscriber management, and can be integrated via public APIs with these other service provisioning tools.
- ***IP VPNs based on Layer 2 tunneling*** (e.g. IPSec or L2TP) are best suited for point to point remote access to a corporate network. The tunneling mechanisms actually operate as Layer 2 connections, and leave the provider with all of the scale, flexibility, and operations challenges of other pure layer 2 networks (as previously described). When operating across the public Internet, tunneled IP VPN services carry additional burdens of encryption performance and Public Key Infrastructure (PKI) scaling. Alternatively, DVRN offers an uncompromised solution for higher scale multisite networks, with all the benefits of Routed Network Services.
- ***"BGP/MPLS VPNs"*** based on IETF RFC2547 are a means to virtualize routed IP core networks for private addresses, at a scale sufficient for wholesale services. This form of MPLS VPN requires the provider to operate iBGP and MPLS protocols in their core. It permits limited customization of QoS and traffic engineering, no routing customization, and relies on highly

complex router configurations. While a DVRN SER can be configured to interoperate with other RFC2547 edge routers, DVRN inherently supports a richer portfolio of customized Routed Network Services.

Conclusion

Dense Virtual Routed Networking (DVRN) is a mass customization solution for Routed Network Services, built on a platform of next generation Service Edge Routers (SERs) and service management software. Many service providers want to offer customized Routed Network Services to their enterprise and xSP customers. Prior to DVRN, these providers have encountered numerous physical, functional, and fiscal barriers to profitable Routed Network Service deployment. The DVRN architecture addresses each of these barriers through a combination of full-spectrum virtual routing, application QoS, and powerful service management technologies. Finally, DVRN enables service providers to adapt their evolving optical data networks for sustainable profitability.

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Acronyms

AIP	Application Infrastructure Provider
ASP	Application Service Provider
DVRN	Dense Virtual Routed Network
LEC	Local Exchange Carrier
MPLS	Multi-Protocol Label Switching
MP S	Multi-Protocol Lambda (wavelength) Switching
NSP	Network Service Provider
POP	Point of Presence
RNS	Routed Network Service
RNP	Routed Network Provider
SER	Service Edge Router
SSP	Storage Service Provider
VR	Virtual Router
VRN	Virtual Routed Network
xSP	Enhanced Service Provider

About Crescent Networks

Crescent Networks, Inc. is a privately held company headquartered in Lowell, Massachusetts providing the first carrier-class solutions for profitable routed network services. Utilizing Dense Virtual Routed Networking (DVRN) with full-spectrum dynamic virtual routing, optical-rate application-aware quality of service and simple, but powerful service management, Crescent Networks' solutions dramatically reduce incremental capital equipment costs and the ongoing operations expense of supporting numerous overlay, routed networks and enables network service providers to finally deliver routed network services profitably throughout their network.

Crescent Networks is funded by industry-leading investors led by top-tier venture firms – Bessemer Venture Partners, JAFCO Ventures, St.Paul Venture Capital and Venrock Associates. Its top-notch talent has a proven track record for developing successful networking solutions at leading companies including 3Com, AT&T, Cabletron, Cascade, Ciena, Digital, Intel, Lucent Technologies, MCI WorldCom, Newbridge and Nortel Networks. For more information visit http://www.crescentnetworks.com.

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