Leveraging Subscriber Management to Empower Backbone Routers

High-Speed Access Opportunities and Challenges

The widening deployments of new higher-speed broadband access technologies (such as DSL, fixed-wireless, cable-modems, etc.) are dramatically escalating both the opportunities and the challenges facing all network service providers, including ILECs, CLECs, and Internet Service Providers (ISPs).

Digital Subscriber Line (DSL) technology, for example, is one of the most popular alternatives because it can make use of existing telco copper wiring to establish high-speed digital connections between users and their local telco central office (CO). Essentially, DSL provides the best of both worlds by leveraging the ubiquitous availability of POTS wiring, while eliminating the analog modem bottleneck. Similar to DSL, other emerging broadband technologies, such as high-speed wireless and cable modem systems, also focus on giving each user a dedicated fixed-circuit connection into the network.

Although the revenue opportunity associated with providing high-speed access to millions of new consumer and business subscribers is very attractive, there are major provisioning challenges in evolving existing architectures to accommodate the large number of new subscribers interested in DSL (and other high-speed) services.

To address these technical challenges, an entirely new category of systems has now emerged on the communications landscape. Called Subscriber Management Systems (SMS), these hardware + software solutions are specifically designed and tuned to handle large numbers of broadband subscribers, combined with the dynamic IP handling required to optimize backbone router performance on the other side. In addition, the deployment of an SMS provides the network administrator with a very familiar operational model ("just like dial"), thereby enabling faster time-to-market and more rapid revenue for the provider.

Circuit Termination and Subscriber Management Are the Issue Today

It is important to note that the model for high-speed connectivity differs substantially from the dial access model. In the dial world, subscribers initiate calls from their modems, which are ultimately terminated in an ISP's remote access server (RAS), which then passes traffic to a backbone router for Internet access.

Each high-speed access model, whether for DSL, cable or wireless, however, is architected quite differently, and is the source of several of the issues outlined in this document. In the DSL access model, which is the focus of this paper, subscribers connect from their premises (via a DSL modem) to their DSL provider's DSL Access Multiplexer (DSLAM), which is located in a central office (CO). The DSL provider then bundles traffic destined for a given service provider and sends it to them via a high-speed connection such as a DS-3 or OC-3 circuit.

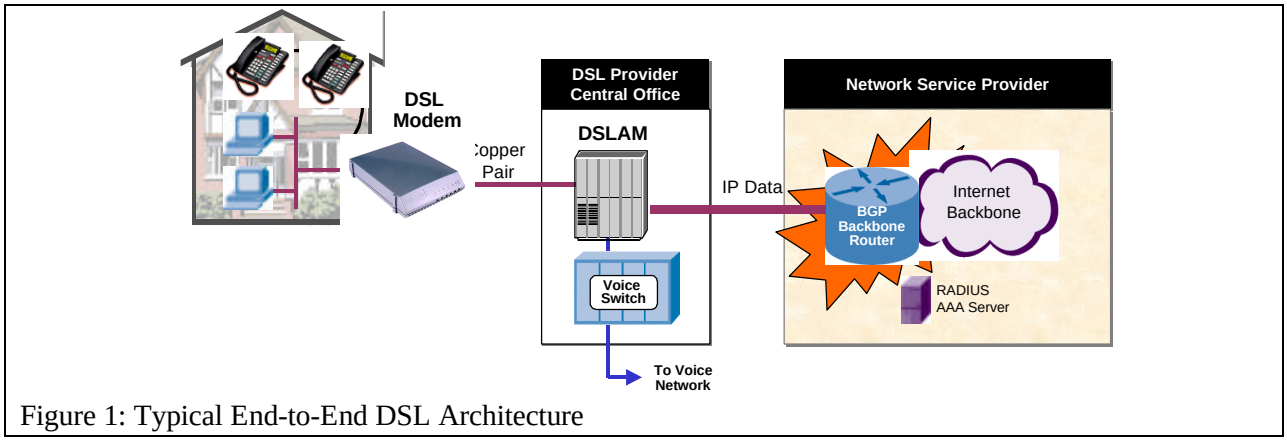

Figure 1: Typical End-to-End DSL Architecture

The first serious issue arises around how the service provider terminates all those new subscribers. Since, in the DSL model, there has not been an equivalent device to the RAS, ISPs and CLECs have been forced to use their backbone routers to terminate those DS-3 circuits. These routers were designed to dynamically communicate with thousands of networks via a limited number of individual connections – up to today's practical limit of around 256 connections. They were not designed to terminate thousands of simultaneous individual connections or subscribers, for several of the reasons explained in the section below.

Beyond circuit termination, there is also the follow-on issue of how new subscribers are managed from an accounting, authentication and access standpoint – i.e. how is RADIUS functionality, previously provided by the RAS, deployed in a DSL environment? Here again, routers offer a far less than optimal solution, as they were not designed with subscriber management in mind.

In the end, the service provider is left with a serious challenge: how to scale the number of DSL subscribers to make a service profitable, while managing a major equipment (router) weakness that limits how those new subscribers are terminated and ultimately managed.

Why Routers Are Not Optimal for Subscriber Management

As noted in the last section, traditional backbone routers were not designed to perform subscriber management tasks. Specifically, routers have a number of inherent limitations when it comes to handling the PVCs (Permanent Virtual Circuits) that are used to connect with a DSL, cable or other fixed-circuit environment. Typically, a router has to individually handle each PVC by associating it with a static configuration - essentially dedicating a fixed connection to that specific circuit.

Over the years, IP router designs have been optimized for use in dynamic clustered topologies that scale overall system performance by adding interconnected routers, rather than by scaling the number of connections to a specific router. In essence, routers are optimized to communicate with thousands of networks, but by actually connecting to only a relatively few neighboring routers at a time, leading to an industry-accepted limitation of 256 actual connections per router. This limitation on a router's physical connections has never presented a problem in the "connection-less" world of IP routing because the underlying protocols route all traffic via multiple paths, and therefore never have a real requirement to "own the circuit".

However, the situation changes dramatically when the IP backbone router is required to interface to thousands of individual DSL virtual circuits that must somehow be terminated, aggregated and converted to IP streams. In this scenario, the router's logical limitation of 256 individual circuits makes it virtually impossible to directly terminate even a small portion of the connections coming in via a DS-3 or OC-3 link from the DSL provider's DSLAM (see Figure 1).

In an attempt to interface backbone routers to such large numbers of simultaneous virtual connections, many network administrators have resorted to relatively expensive and inefficient work-around architectures. Unfortunately, these types of work-around connections generally carry with them a number of critical downsides with regard to unnecessary expense, network inefficiencies and lack of control over subscriber-level services.

In one work-around alternative, the DS-3 connection from the DSL provider would first be run into an ATM switch, which would break up the thousands of subscribers into multiple DS-3s, each with just a few hundred subscribers. The DS-3 connections carrying fewer subscribers would then be separately channeled to multiple routers in order to spread the total subscriber load around throughout the router

cluster. The most obvious drawbacks to this work-around lie in the significant extra expense associated with deploying additional ATM switching equipment and multiple routers, as well as the increased overhead of managing multiple internal DS-3 connections to the routers.

Another work-around methodology might involve the use of a Bridged Virtual Interface between routers to overcome the 256 connection limitation by making them appear as one bridged network. Of course, this avenue has the inherent downsides of added complexity and a loss of some router-based security over the thousands of DSL users on the virtual network.

Perhaps the biggest downside to any sort of work-around is that to the degree it succeeds, by putting subscriber circuits directly into the router cluster, it also fails by diverting the network's routers from doing what they do best, the high-speed handling of dynamic IP traffic flows. Instead of minimizing the amount of additional overhead on the router cluster, each of these scenarios actually increases the number of unnecessary inter-router connections and the complexity of router-coordination requirements.

A New Solution Emerges: the Subscriber Management System

As DSL, cable and other high-speed access deployments have grown over the last year, and the issue of managing subscribers has become a critical one, a significant alternative has arisen: the Subscriber Management System (SMS). Designed specifically to address the issue of broadband subscriber management, the Subscriber Management System provides an intelligent solution for NSPs by terminating high-speed fixed circuit connections, such as DSL, from the subscriber side, and creating groomed IP streams optimized for backbone routers. In addition, the SMS integrates seamlessly with NSPs' existing RADIUS databases, greatly simplifying the task of managing subscribers' accounting and security data.

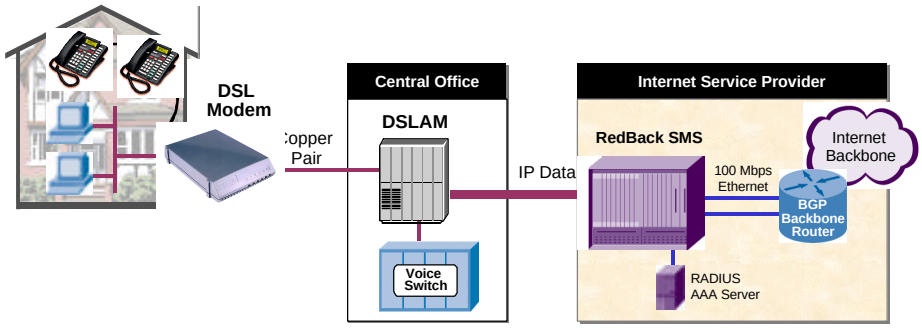

Figure 2: DSL Architecture with SMS Used at ISP POP

As shown in the above diagram for a DSL implementation, the SMS can simultaneously accept high concentrations of traffic from multiple DSLAMs, while independently performing all of the aggregation, management and conversion functions necessary to output router-ready IP streams to the backbone. By completely off-loading the backbone router(s) from all of the frame-translation activities required for each virtual circuit, the SMS actually relieves network congestion rather than contributing to it, like the above-described router work-around methods. In addition, by acting as a standard RADIUS client, the SMS provides the network administrator with seamless manageability over all of the DSL subscribers, bringing them directly under the umbrella of a cost-effective, established operations model.

Just as importantly, the SMS can serve as the catalyst for the NSP to create a new array of value-added services, which in turn can greatly increase an NSP's profitability. By leveraging the Subscriber Management System's unique ability to create multiple RADIUS-compliant routing domains, the NSP can dynamically direct a subscriber to multiple value-added IP services, such as teleworker services, premium or "gold level" access, gaming services, etc.. The ability to direct a subscriber to multiple services is made possible by a technology called multiple contexts. Inherent to the SMS, multiple context technology is a major breakthrough because it overcomes the previous requirement to have each DSL (or other high-speed access) circuit logically "nailed up" to a fixed connection in the router environment. Essentially, the SMS now allows any high-speed circuit to enjoy the kind of dynamic connections previously achievable only in the low-speed dial-up model.

In essence, a Subscriber Management System effectively provides three critical benefits:

1. The scalability of an ATM switch with the capacity to simultaneously handle multiple thousands of subscribers
2. The routing functionality of multiple routers to optimally direct subscriber traffic into the backbone environment (each SMS "context" represents a virtual IP router)
3. The ability to dynamically direct user-level protocols (such as PPP) across the entire Subscriber-to-Router virtual connection.

Real-World Deployment of Subscriber Management Systems

Subscriber Management Systems are now actively being deployed in a number of ways to enhance high-speed access-to-IP connectivity.

A primary application is as an "edge-device" within an NSP's "SuperPOP" installation. The recent optimization trend within the Internet's IP core has been toward the deployment of higher-speed IP routers with fewer interfaces, in order to maximize overall backbone performance. By taking complete responsibility for terminating, managing and aggregating the thousands of DSL or other high-speed connections coming into the SuperPOP, the SMS helps by offloading the IP router(s) from high-overhead interconnection functions, instead providing backbone routers with fully-groomed IP streams on 100 Mbs full-duplex Ethernet links. Many NSPs, from the largest Tier 1 players to local Tier 3 firms, have implemented Subscriber Management Systems to streamline their provisioning of high-speed access services such as DSL.

Additionally, many network providers, such as several of the Regional Bell Operating Companies (RBOCs) and several Competitive Local Exchange Carriers (CLECs), have adopted Subscriber Management Systems as a critical component in the architecture of their wholesale networks. These providers have leveraged the powerful multiple context technology to easily and cost-effectively wholesale high-speed access services, such as DSL, to downstream NSPs.

Truly the “Best of Both Worlds”

The primary bottom line benefit of a Subscriber Management System is that it optimizes both the connection-oriented subscriber side of the high-speed access model and the connectionless IP backbone to do what they do best. At its core, an SMS provides a highly-scalable foundation for efficiently managing large numbers of individual subscribers across disparate switching and routing environments, while maximizing the services available to the individual and empowering the router backbone clusters to operate at their peak efficiency.

By completely relieving backbone routers from the inappropriate termination, aggregation and management of individual fixed-circuit connections, SMS can preserve and extend the network providers existing router investments while at the same time providing improved levels of service throughout the network.