

Broadband Network Architecture – Serving a Multimedia World

As broadband gains widespread adoption with end users, there are globally applicable trends emerging that will shift the architecture of broadband networks. In this paper we'll look at a few of those trends, and provide some suggestions on how service providers should plan their network migration strategies to both take advantage of the opportunities those trends foreshadow and accommodate the challenges they pose.

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Market Dynamics

Scale and Speed

DSL-based broadband subscriber growth is expected to catapult from 63 million in 2003 to 150 million in 2008. Of the approximately 60 million lines deployed today, more than 20 million lines have been deployed within the past 12 months. France Telecom, British Telecom and other incumbent service providers expect broadband subscriptions to double by 2005.

In tandem with subscriber growth, another factor driving competition for broadband deployments is speeds as service providers have been facing serious threats from the likes of cable operators and others deploying faster service. Over the next two years DSL service speeds will be 4-6 Mb/s in Europe and 20-50 Mb/s in Asia.

- > In Asia, Korea Telecom is already offering VDSL in various speeds: 5 Mb/s service for \$30/month; 10 Mb/s for \$40/month; 20 Mb/s for \$50/month. KT has been using speed as a primary means for service differentiation and intends to extend residential VDSL service to 50Mb/s by end of 2004.
- > Europe is not far behind with service providers intending to accelerate speeds from 2 Mb/s to 6 Mb/s in 2004. France Telecom, Telecom Italia and BT are publicly committing to deliver higher-rate broadband services as part of their triple play service package.
- > North American operators under severe competition from cable have embarked on a fiber initiative (JPC) to deliver high bandwidth capabilities and advanced programming in an effort to overcome the current long loop limitations. The intent is to equip the homes with a last mile network capable of reaching 100 Mb/s of bandwidth.

Not only is the peak speed of Internet access services increasing, but the average utilization of those services has also increased dramatically, primarily driven by peer-to-peer applications. These three growth drivers — growth in subscribers, growth in peak bandwidth per subscriber, and growth in average bandwidth per subscriber — are creating new pressures on network infrastructure to deliver increased scale at an ever lower incremental cost.

Multimedia Consumer Services

Different service providers have different priorities depending on their unique circumstances, but a number of common drivers can be observed.

Beat the competition

The first driver is the need for incumbent local exchange carriers (ILECs) to respond to cable and competitive local exchange carrier (CLEC) competitors whose “triple-play” offer of video entertainment, high speed Internet (HSI) access, and telephony poses a serious threat to their customer base. Some ILECs are responding to this threat in the short term by forming partnerships with DBS (satellite) operators to bundle video services with DSL-based Internet access. This marketing initiative does help stem near-term threats from cable and CLEC operators but offers no sustainable long-term solution to the ILEC. ILECs can expect to gain little or no profit from this business structure while incurring costs in support of “parallel” wireline and satellite networks.

Many ILECs have therefore begun accelerating their deployment plans for multimedia services to consumers over their own wireline networks in order to better retain their customer base. Since the objective for these ILECs is to compete effectively with cable and “triple play” CLECs, the priority is on entertainment video, both broadcast TV, and video on demand (VoD).

Increase ARPU

The second driver is the need to improve profitability by adding new services over the same infrastructure; that is to increase average revenue per user (ARPU) with very small incremental costs. This is key as service providers are seeking to go beyond high speed Internet service to help drive top line growth.

Some service providers have used additional services to increase ARPU by 20 to 40 percent and reduce churn as much as 50 percent using bundling. Europe is leading the way with video services in addition to high speed Internet. In Asia, Korean and Japanese service providers are driving towards a multimedia portfolio as a means of increasing service value. US service providers are currently in the design phase of building a migration path for their networks towards advanced

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services. US markets are particularly interested in a network architecture that is capable of delivering bandwidth intensive applications such as high-definition television (HDTV) that have regulatory backing. Nevertheless, the current US access networks suffer from extensive local loop lengths, which will likely demand a migration towards fiber-based service delivery (typically “fiber to the node”) to achieve this service mix.

Invest wisely

The third driver for service providers is to ensure that their investments in new network equipment help drive higher revenues and increase competitive advantages. As long as incumbent service providers are just wholesaling broadband access for a small fixed access charge to Internet service providers (ISPs), they are seeing only a small portion of the potential value chain. As incumbent service providers invest in improving the quality, cost, performance and reliability of broadband networks, they must worry about competitors with easy access to their enhanced networks capable of delivering innovative services, accelerating customer churn. Vonage and other VoIP competitors stand to reap telephony revenues at the expense of the ILECs, while CPE-based IP-SEC VPN vendors seek to displace their lucrative private line revenues. Looming threats include Movielink or other Internet-VoD providers who seek to earn high ARPU entertainment service revenues at the expense of the network providers.

These drivers force service providers to undergo a significant change. The transformation is from a network built to deliver one service (high speed Internet) to one that supports multiple services, while allowing the network provider to be a significant and differentiated player in the service delivery value chain. Because those new services are very different from each other and from HSI, changes to the network are required to enable those new services to be delivered successfully and profitably.

Multimedia Business Services

Despite the growing penetration of optical fiber connections directly to business customers, there is a large portion of the market that cannot be cost effectively reached via fiber, and will therefore have some form of copper pair or hybrid fiber/copper-based delivery for some time to come.

In many markets, DSL technology is synonymous with high speed Internet, to the extent that people are a bit surprised to learn that DSL access is used for various other service types. Predominant use of DSL access for business customers has been to deliver high speed Internet access, and business DSL is often differentiated from consumer services with features offering symmetric links (i.e., self-hosted web sites and e-commerce over G.SHDSL), higher performance or fault-response times and typically command a higher price point.

A living legacy

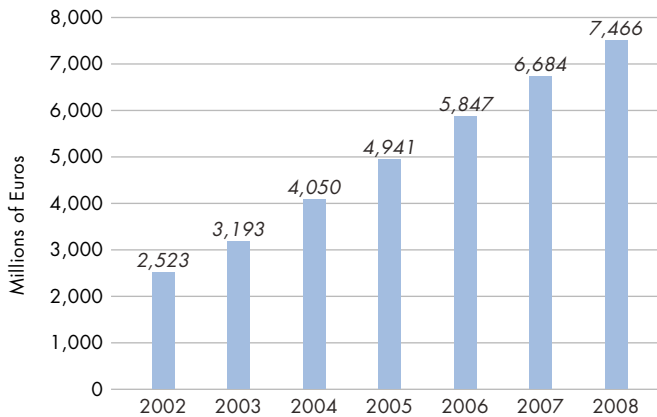
To date, DSL has had a slow start with business private data networking services despite its cost, reach, and performance advantages over “legacy” data access technologies such as frame relay (FR) over HDB3. This has been in part because of the technology maturity of FR solutions, and of the need to assure the reliability and performance of these services to match business requirements. In addition, service providers have, until recently, been reluctant to market these services for fear of cannibalizing their highly profitable existing data services. This is the case where a regulatory regime has forced an ILEC to wholesale DSL access, but not legacy data access. These issues are slowly being removed as competitive and cost pressures force service providers to move to the best technology for the job.

Business is booming

Broadband access as an enabler of business private networks and high speed Internet access for the business community is therefore poised for exponential growth. Much of the anticipated growth will come from service providers offering IP-VPN services to small and medium businesses who previously would not have purchased a private network at all. Also largely untapped is the potential for using broadband access to enable cost effective access to real-time IP communications, including IP Centrex, videotelephony and multimedia messaging. Looking at the European market as a prime example, Probe Research Group in a January 2004 report expects business DSL services to grow from EURO 3.2 billion in 2003 to EURO 7.5 billion in 2008 (Figure 1). To capitalize on this growth, service providers must adapt their broadband networks to deliver business quality services.

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Figure 1 - Business DSL Service Revenues in Europe, 2002-2008



Source: Probe Group LLC

Service Provider Strategies

For the most part, regional differences will dictate how service providers will respond to broadband evolution strategies that reflect large-scale deployments compounded by multimedia service offerings.

Asia

- > In Korea and Japan, fierce competition has been driving up broadband speeds while leveraging the relative density of broadband users and their proximity to central offices. In Korea alone, nearly 85 percent of KT's customers are within 2 km of the central office. These service providers seek not only speed but also deployment of multimedia services off a common network. The corresponding architecture must therefore capitalize on advanced technologies capable of delivering faster speeds (ADSL2, ADSL2plus and VDSL) at lower network aggregation cost (IP/Ethernet), and yet maintain the resilient QoS features typical of today's ATM networks.
- > By contrast, the majority of the service providers in China (with some notable exceptions) and emerging markets are primarily focused on basic Internet access and thus looking to build their access networks to support high capacity on a low cost DSL infrastructure.

Europe

- > Europe has taken the global lead on video over DSL deployments as part of its intent to make multimedia services a reality. Companies like Telecom Italia and FastWeb have deployed DSL-based multimedia services to residential customers. Other European service providers such as France Telecom and Deutsche Telecom have public commitments for deployment in 2004 and 2005. European service providers are looking for network migration strategies that drive faster service speeds, lower aggregation costs and QoS features that support stringent requirements of multimedia services. Video and advanced multimedia services deployed over their installed base of DSL infrastructure are attractive means of driving ARPU while leveraging population densities and short reach broadband networks.

North America

- > North American service providers have similar motivations but face a more significant residential competitive threat owing to the high penetration of cable MSOs and the success of cable-based high speed Internet services. Regulatory issues also play a strong role in forming the approach for US, differing significantly from Asia and Europe.
- > In order to compete with a formidable competitor in cable now offering multiple simultaneous channels per household, a large variety in programming, high definition TV and VoD, US ILECs find themselves in need of more bandwidth (on the order of 15 to 20 Mb/s) than what is achievable over existing copper loops. They are therefore moving towards selective deployment of architecture with fiber optic distribution in the feeder network to a remote unit (RU) in a multi-tenant unit or a roadside cabinet. "Selective" means deployment mainly to denser and higher-income areas that are under competitive threat from cable. The last mile (which has now become the "last 100 meters") is still typically copper twisted-pair based using VDSL or ADSL2+. In some cases the fiber will extend to the customer premises itself, for example on the PON technology of the US RBOC's JPC tender.

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Network Migration Strategies

Avoiding the Perils of Best Effort Architecture

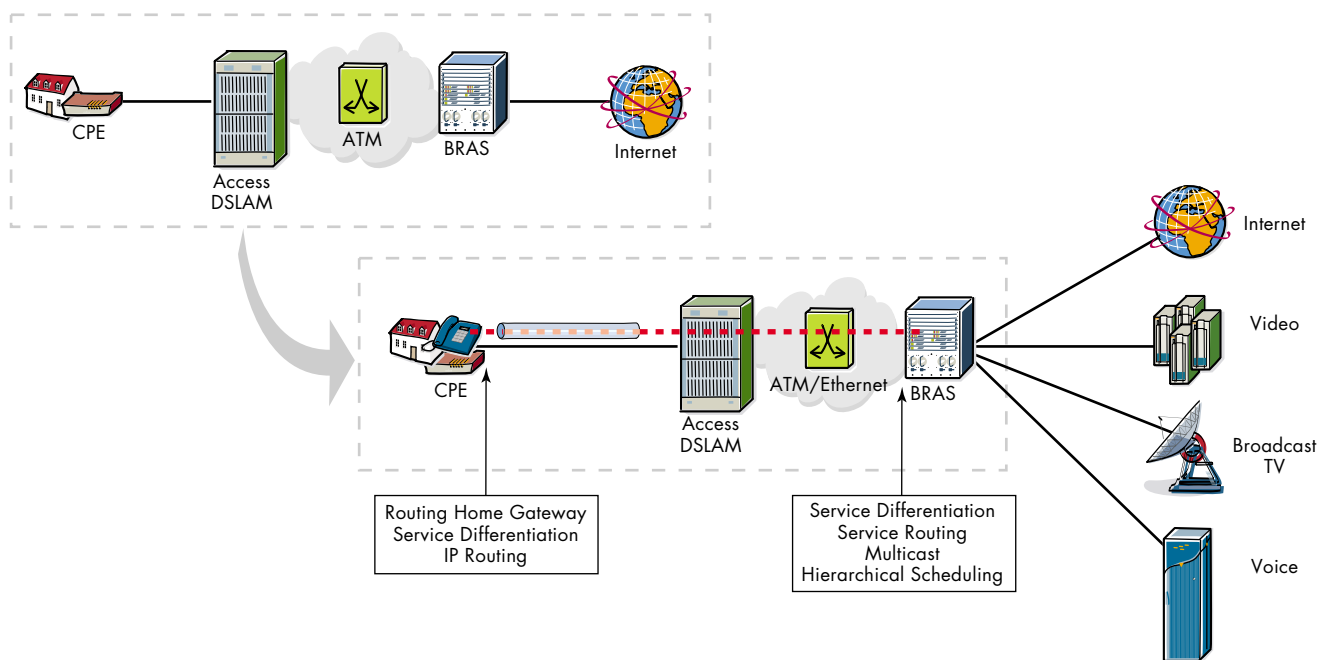
In order to address the changing market dynamics, today's network must evolve significantly. One approach in an effort to achieve the most effective network architecture in support of a multimedia service portfolio is to extend the existing architecture — built primarily for best effort Internet — to one that is capable of supporting multimedia services. This architecture suggests expanding the role of the broadband remote access server (BRAS) from today's best effort service termination to an intelligent routing platform. The role of the BRAS would require support for service differentiation, full layer 3 service routing, multicast functionality and hierarchical scheduling to avoid downstream congestion. It would further suggest that service providers run multiple service types (video, broadcast TV, voice, and data) over a single PVC/VLAN between the customer premises equipment (CPE) and the BRAS with the CPE acting as a high function routing gateway performing traffic engineering of multiple services at the home. Figure 2 describes the evolution to the proposed network architecture.

First impressions can be deceiving

At first glance, this plan seems to meet service provider objectives of deploying multimedia services over existing assets with minimal changes, however there are a number of challenges associated with this approach. We'll begin by highlighting some of the most notable concerns surrounding network level impediments in the service evolution process.

- > BRAS Vulnerability: Reliability of the access network takes on a whole new meaning with multimedia communication and entertainment services and thus exposes the BRAS as being the "Achilles heel" of the broadband network. Putting all services through a common failure node whose historical performance has been less than stellar yields obvious risks. Customers have little tolerance for network downtimes affecting their voice or video feeds, a situation common today in HSI networks. For many service providers, this has regulatory and political implications. If the design of the network is such that it is intrinsically incapable of ever carrying emergency (911/111) calls with the required reliability, this means that the service provider is required to operate a parallel public switched telephone network (PSTN)

Figure 2 - Evolution to a Multimedia Service Portfolio Architecture



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indefinitely. As technology evolves to new standards that no longer support “baseband” voice, this becomes even more of an issue. The fact that varying services have dramatically different reliability requirements means that putting them in a single edge is going to involve serious compromises to either the quality of the sensitive services, or the cost effectiveness of the less demanding services.

- > **CPE Intelligence:** Carrying a variety of services over a single PVC/VLAN from the edge to the CPE terminal requires a level of sophistication that does not exist in the current network architecture. To support upstream QoS requires that the “home gateway” be not only a router, but support differentiated QoS in the form of multiple queues for the upstream traffic. This is a level of intelligence not supported in today’s CPE, and adds cost and complexity at a high volume location in the network.
- > **Network Scale:** Current BRASs do not have the scale to cost effectively support video services. For example, consider a top-of-the-line Juniper ERX-1440, which has capacity for 12 GigE interfaces. With those GigE interfaces connected to VDSL remotes for delivery of 20 Mb/s per subscriber video services, an entire ERX-1440 could serve as few as 600 residential customers. A small central office with 20,000 residential subscribers, of whom half eventually take video services, would therefore require a room full of 15 ERX-1440s.
- > **Hierarchical Scheduling:** The BRAS is ill-equipped to handle congestion trafficking within the access and aggregation networks. This is not because hierarchical scheduling in the BRAS is impossible, but because of the difficulty of keeping the hierarchical scheduler informed of all the topology, dimensioning, and loading changes that occur at all potential downstream bottlenecks, from individual customer access lines and the internal architecture of aggregation elements to the configuration of transport links.
- > **Multicast Efficiency:** Performing multicast from the centralized BRAS means that there is a unicast stream per subscriber from the BRAS through the entire aggregation and access network. So, for a typical case (200 channels of 4 Mb/s MPEG2 video streams delivered from regional

POP-based BRAS to 10,000 subscribers in a central office [CO]), the service provider must provision 40,000 Mb/s through their aggregation network. That just doesn’t make sense when those same signals can be multicast from the CO itself, with an 80 percent saving in aggregation and transport bandwidth. At the same time it may not make sense to distribute the subscriber management for HSI by putting a BRAS in every CO. That means roughly ten times as many BRASs for a start, which is ten times as many service delivery points that operations needs to administer. The bottom line is that different services may have different optimized architectures owing to bandwidth requirements and interface densities: the requirements of a video edge tend to drive greater distribution while greater distribution reduces cost-effectiveness for HSI.

The above considerations require service providers to re-think the network evolution process in light of the service mix. Innovative multimedia service providers such as FastWeb have understood these concerns and thus have shied away from a single edge solution described above. They have concluded that delivery of QoS sensitive multimedia services requires a service-based architecture different from that of today with converged access and aggregation but multiple service edges.

Speed to market and ability to innovate are key for many service providers contemplating the delivery of new broadband services and an architecture that stifles innovation by limiting service deployment on a “single edge BRAS” vendor’s roadmap is therefore unacceptable to many customers. In some areas it may even be prohibited by law because of regulatory separation of a service provider’s business units.

Migrating Towards a Multimedia Service Architecture

In many markets customers have begun to make the shift towards a multimedia service set. Nevertheless, it is a market reality that some regions will lead this shift while others will follow with their own timetable. Alcatel’s vision for broadband access is a network in support of multimedia customers, the predominant customer type of tomorrow, and much of this discussion on network migration will be based around a multimedia service portfolio.

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Use what you have

If the goal is to build a multimedia-capable network, the most pertinent question is how best to do so with the network at hand (on the assumption that not all networks will evolve alike and thus the migration paths will differ accordingly). Consumer uptake of multimedia services will occur over time, which means that service providers should ideally transition their networks in step. For those customers seeking basic HSI service, the current architecture of DSLAM aggregation with BRAS session termination will facilitate this model. For new broadband customers and those multimedia service subscribers, the recommended network migration path is depicted in Figure 3.

The architecture depicted for residential customers would continue to take advantage of the existing BRASs for wholesale PPP/L2TP HSI service support, specifically for those customers that are not subscribing to advanced services or those subscribed to a third-party provider. Those customers seeking multimedia or business-grade services are routed through

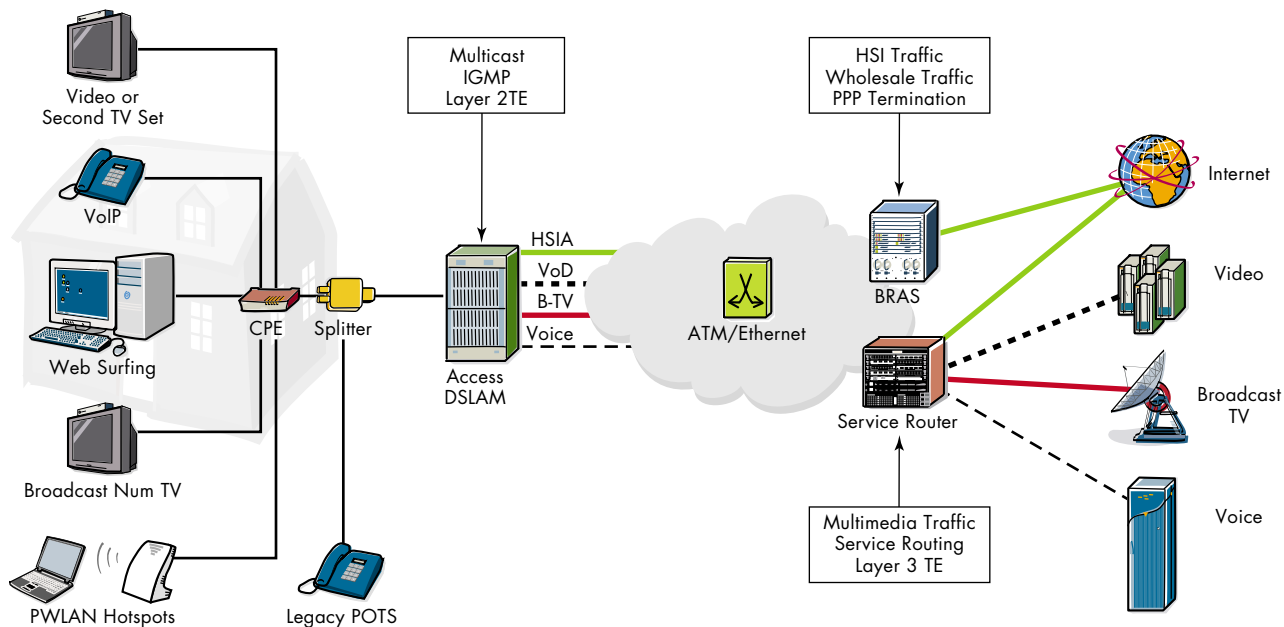
the service router in order to match the quality, reliability and availability metrics.

A step-wise approach

The vast majority of residential broadband networks deployed today are based on ATM. The migration steps, listed below, are certainly more involved but appropriate in support of the service mix desired.

- > **Service specific L2 connections to customers** – In an analysis of industry best practices, service deployment based on dedicated PVC per service from the customer has emerged as the method of choice for multimedia service providers. Service providers — Telefonica, Belgacom, FastWeb, France Telecom and others — have concluded that provisioning PVCs on a per-service basis mapped directly to priority network paths offers the QoS assurances desired for multimedia applications. Service-specific PVCs in the last mile provide end-users with minimal effects from jitter, latency and congestion that might otherwise affect

Figure 3 - Migration Path to Multimedia-Capable Network



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service quality, and because they are “normally present” do not need special customer specific provisioning.

- > **Evolve the DSLAM** – DSLAMs take on further responsibility in ensuring that the variety of service types associated with end users are properly aggregated and service classified to VLANs or PVCs extending into the “second mile” of the aggregation network. DSLAMs must also be able to handle multicast and IGMP features required for video services including broadcast TV. Innovative service providers such as FastWeb share this view by pushing the multicast feature as close to the customer as possible to limit bandwidth congestion in the metro access networks. DSLAMs with dedicated bus architectures to support the video, voice and data mapping bandwidth requirements of the service to bus speeds are another way service providers are assuring service quality. In addition, advances such as improvements in scale (e.g., GigE uplinks) and security features (tracking users to a port to prevent fraudulent activity) are critical features in the network evolution process. Over the longer term, Alcatel is actively investigating and developing a future generation of access mux that supports the many changing requirements of multiservice delivery. All of these measures allow cost effective growth in per-subscriber bandwidth and the introduction of service-specific QoS mechanisms. Some also incorporate more intelligence in the access mux where this enables the delivery of better broadband solutions (e.g., enhancing security).
- > **Uplinks and aggregation** – For reasons of cost and scalability, service providers will likely upgrade these existing access mux to Gigabit Ethernet up-links as they introduce video. Depending on how distributed their video edge will be, they may introduce a layer of Ethernet aggregation networks consolidating traffic before presentation to the video edge.
- > **Service-specific edges** – The network routing requirements have significantly increased with the introduction of multimedia services. The change in the authentication and auto-configuration model from PPP (used widely today for this) to introduce dynamic host configuration protocol (DHCP) (ubiquitously used for video set-top boxes) is only

a small part of this change. Service providers are adopting purpose-built edges capable of delivering exactly the functions, scale, performance, security, and cost effectiveness required by a specific service. The subsequent architecture would typically continue to use the existing BRASs for HSI services (at least while they continue in a wholesale PPP/L2TP mode) while other advanced services are routed through other edges. In reality this is just an architectural recognition that what today’s BRAS does is Internet access and that same platform is usually not optimal for other services.

As multimedia and other new services grow and broadband subscriber growth rates continue to double, service providers can rely on service-specific edges to answer the scalability, reliability and service routing concerns common to multiservice delivery architectures.

Network Migration – The Long-Term View

The long-term network view is one in which multiple services with radically different network requirements can be enabled in software over existing broadband assets. Delivery of any service is as effortless and cost-free as clicking a button on a web page.

Because services are soft-provisioned over a flexible network in real-time, as new services are invented they can be seamlessly deployed across existing infrastructure, unlocking a flood of service innovation. Speed to market accelerates as service providers realize that they can fine-tune a service as they go instead of having to get it perfect from day one. Asset obsolescence fades from the radar map as the utility of new assets is not tied to the success of any one service.

Not your grandpa’s Internet

These services will be IP based, but largely not the “Internet”. Through IP networks tailored to requirements of performance, reliability, security, functionality, and pricing, service providers will be able to offer superior value propositions to customers and deliver them profitably. Think presence-enabled video-telephony to displace the phone call — or personalized, convenient, any-content-any-time entertainment displacing channelized TV.

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To support this, the entire broadband network will need to become more flexible and more intelligent, more capable of dynamic reconfiguration to meet changing service needs. Management systems will need to be more cleanly integrated and flexible. The realization of network functions currently embodied within specific network elements will become more fluid. In some cases network intelligence will be unified within distributed edge devices, in others it will be specialized and centralized. Traditional product concepts like the “BRAS”, the “DSLAM” and the “aggregation switch” are being decomposed and reformed to enable the new flexible multiservice network. Each element is acquiring the ability to securely carry multiple services with differentiated QoS. Elements are being upgraded to support new levels of subscriber density and bandwidth per subscriber. Previously unstable elements are being hardened. Intelligence is being distributed to improve security and network efficiency.

The specific architectural form a customer will choose is shaped by the many unique factors that make service providers different from each other: their target service set, the size and density of the markets they serve, their competitive situation, their lifecycle stage, their existing assets, and the regulatory framework within which they operate. In China, the key benefit of the new products may be the delivery of products that support unprecedented scale and cost effectiveness. In the US it may be the delivery of video-rich infrastructure, which enables ILECs to compete effectively with cable MSOs. In Europe it may be the ability of those products to support rapid service innovation into voice and multimedia over IP opportunities.

Architectures for a Multimedia Future

There is little doubt that the future of access networks is to support the multimedia customer. It is reasonable to believe that service providers are therefore in need of migration strategies to transform their networks from best effort Internet to hosting voice, video and data-based services.

While the best solution will vary from country to country, many will see the same general architectural principles in play:

- > Change from single “best-effort” HSI service to multiservice broadband with demanding QoS and reliability requirements
- > Multiple services delivered over common access and aggregation typically using a “VC per service” in the customer-specific access network
- > Increased reach of fiber into the access network
- > Typically little change to existing HSI service delivery to existing customers
- > Networks usable for both business and residential services, and optimized to support the QoS requirements on a per service basis
- > Multiple service-specific edges deployed at different physical locations in the network and optimized to the function, scale, security, QoS/performance, reliability and cost demanded of that service set

The next generation of broadband network will embody the realization of these architectural principals, with access nodes capable of service differentiation, higher bandwidths, greater reach and minimized operational expenditures. To complement the new generation of access nodes, service edge routing platforms become a central item to fulfill the QoS and reliability requirements of new services. It is through these product development activities that service providers are able to negotiate a successful transition to multiservice broadband.

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