Routers on the IP Edge

Overcoming the Triple Challenge of Video, Mobility, and Cloud

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I N F O N E T I C S   R E S E A R C H

EXECUTIVE SUMMARY

The Internet changed everything forever, and it certainly changed service provider networks. The great migration from TDM to IP services has been in motion for over a decade, but in the past few years we've been hearing about mounting problems.

Business Services Are Delivered on Separate Overlay IP Networks, but Shifts Are Causing Mounting Problems

Business and consumer services have already transitioned to IP, and we are in the midst of change in the mobile domain as those networks are upgraded to IP to support the transition to 3G/LTE data. But there is a new shift—from basic network connectivity and IP transport services to video-rich advanced consumer and mobile services. This shift is also about facilitating high performance, secure, flexible cloud connectivity.

The shift is about a transition from the earlier generation of IP networks built to deliver basic IP services at modest speeds, to delivering a broad spectrum of high performance, advanced services leveraging a network edge that can deliver 100Gbps high capacity, combine multiple services, and capitalize on edge router intelligence.

Today's challenges are dominated by the impact of video in its many forms. Managed video services, including IPTV, drive requirements for high video quality and an effortless multiscreen experience. The shift to increasingly on-demand video is having a monumental impact on the network, driving not only a need to scale bandwidth capacity, but also a more fundamental shift in how the IP edge behind consumer broadband networks is architected, requiring a move from today's centralized model to a more distributed model.

As many providers made the transition to IP/MPLS, they introduced a new IP overlay network for each type of service. The result is an operationally burdensome, inefficient architecture that is complicated and expensive to operate. The networks we have now were built to move away from TDM, and are not the networks we need to make the next step. The next steps are directly dependent on the latest advances in edge routing technology.

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Routers at the IP Edge Solve the Triple Challenge of Video, Mobility, and Cloud

Service providers have sunk a decade of investments into replacing single-service TDM networks with IP/MPLS networks, and this TDM to IP packet transformation is well understood and well along—the proof points are the IP networks of all the major service providers around the world.

But just as the Internet changed everything, and just as service providers see their IP packet network architecture goals nearing completion, three new challenges appear that may demolish these hopes and plans: video, mobility, and cloud. Of these, the greatest challenge is video due to its ability to overwhelm networks with sheer bandwidth. This triple challenge appears at the same time that revenue growth is scarce, margins are under pressure, competition is tough, and operating expenses are a major target for reduction.

Handling massive video and data traffic volumes is a serious problem that previously could be solved by connectivity and transport technologies but now requires new approaches.

The IP edge is the service point that sits at the most critical juncture between metro IP/MPLS network and customer access networks, and this service point is under the most extreme pressure. The IP edge is the bastion of the IP edge router (PE router), the home of subscriber management and control central of service definition and service delivery. It is the point of service differentiation and service quality, and the pressure point for increasing scale and service granularity.

Even though the challenges are ominous, and it's not easy to choose among the many solution possibilities of using new technologies and/or re-architecting networks, some service providers are leading the way by solving all or some of the new trio of challenges while making major improvements in operational efficiency.

In this paper, we catalog the challenges and threats only briefly, as they are well known. We explore:

- The requirements of the modern-day edge router for addressing the scale and performance required to meet bandwidth demand
- The need for a broad range of services across residential, business, and mobile applications
- The need for higher-value service capability for added service personalization and differentiation

We focus on examples of four leading service providers who have made the transition to a more distributed, modern IP edge architecture, and who are using IP edge routers with the advanced performance and intelligence to turn the triple challenges of video, mobility, and cloud into opportunities.

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"The right router makes it easier to accelerate the delivery of new services and new service bundles."

What to Look for in an IP Edge Router

Service providers are trying to streamline their network operations, principally by reducing multiple networks to a few—or ideally one—using their IP edge routers to concentrate multiple services, such as consumer broadband and mobile backhaul, or business services and WiFi hotspot backhaul. The right router makes it easier to accelerate the delivery of new services and new service bundles. Just as important as service velocity (the ability to quickly roll out new services), the IP edge router is the key to developing varied and more granular types of services through customization or personalization. As these new services generate more traffic, the IP edge router must accommodate the future with high density 10Gbps and 100Gbps capacities, with an eye toward the future at 400Gbps or 1Tbps.

This paper explores the following:

- Challenges of the IP edge

    - Networks' original design to move away from TDM is no longer enough

    - Growth of mobility, cloud, and video

    - Rising customer expectations

- Threats to service provider business models

    - Rising expense of operating an overlay network for each type of IP service

    - The shift from broadcast TV/video to on-demand, unicast video, compounded by over-the-top (OTT) video/content

    - A plethora of mobile devices with unique screens brings threats of customer churn, and the challenge to provide equal user experience quality over all

    - Customer churn when quality of experience is compromised, uncompetitive, or too expensive

- Leading-edge service provider case studies; actions of 4 leaders are converging their IP edge using IP edge routers to overcome challenges and turn them into opportunities

    - TELUS, Portugal Telecom, and Belgacom reduced opex by leveraging a common IP platform to deliver a combination of residential, business, and mobile services

    - British Telecom and Portugal Telecom solved the video onslaught with caching/content delivery networks (CDNs), delivery of high quality unicast video, and per-flow QoS

    - Portugal Telecom added multiscreen and network intelligence for applications

    - Portugal Telecom and Belgacom provide high performance, secure, flexible L2/L3 VPNs, and use them for access to cloud services

    - Operators now have the tools to increase revenue with CDN services, a broadband "turbo" button, and new service bundles that are impossible with separate service networks

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IP EDGE FACES CHALLENGES FROM MOBILE, VIDEO, AND CLOUD

IP Edge: Today's Design Includes Multiple Overlay Networks

Today's IP edge was designed for the connection and transport of IP-based services to residential consumers, mobile subscribers, and businesses. Its main purpose is to make the called-for connections, and to supply sufficient bandwidth to handle the traffic.

Many service providers have created separate networks for these three service types. Some may deploy IP edge routers for each of the three service types, or a single router may serve two or all three. But services are created, managed, and delivered in the edge router at the IP edge.

Exhibit 1 - Today's IP Edge: Multiple Networks for Customer Services
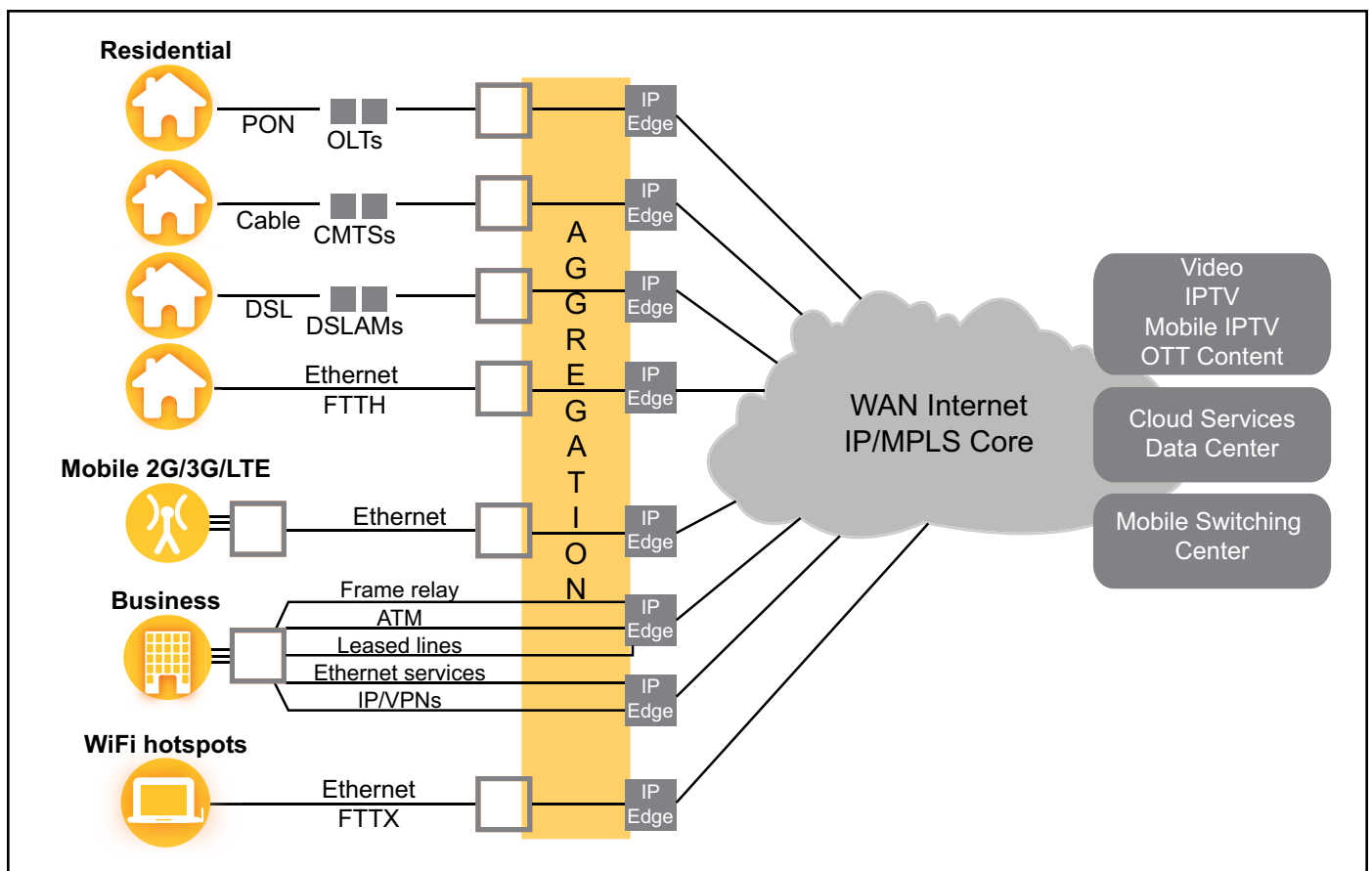
The information about who subscribers are, what services they are paying for, and how they are billed is part of subscriber management, which is administered at the IP edge via an IP edge router with BRAS (broadband remote access system) or its modern counterpart, the BNG (broadband network gateway). The IP edge is the main place where SLAs and policy guarantees are enforced.

"Many deployed IP edge routers cannot handle the service loads or multiscreen service granularity of the video and data services being delivered to a variety of user devices."

IP Edge: Today's Needs

The network environment has changed radically in the last three years: carrier networks must now respond to the demands of surging mobile backhaul traffic, the move to the cloud, growing video traffic, and expanding consumer expectations.

Mobile traffic: iPhones and other smartphones, along with their video applications, are driving upgrades to the RAN (radio access network), but the backhaul network must also scale cost-effectively to meet growing bandwidth demand. The result has been a transition to IP/Ethernet backhaul, which drives requirements for a new approach to OAM for network monitoring and resiliency, and the latest techniques for delivering timing and synchronization across the network to the cell site. IP edge routers involved in mobile backhaul must support a suite of features including 1588v2, synchronous Ethernet, and IPv6. They must also be optimized to connect and provide OAM functions to hundreds or thousands of subtended cell site devices for ensuring a highly reliable environment with strict control of parameters including latency and delay.

Cloud services: the move toward cloud computing is well underway. Businesses are moving to cloud-based storage, applications, and services. Corporations are already buying storage and server capacity located in the cloud, and droves of businesses have adopted Google's Gmail and Amazon AWS. The location of the most-popularly-accessed data keeps changing, with profound effects on the IP edge routers, which must respond not only to the new traffic patterns, but the unpredictability of the sources and destinations.

Video: the near-exponential growth of video has the potential to overwhelm today's networks within just a few years. It's not simply more video apps, but also the move to on-demand viewing requiring individual unicast rather than multi-user multicast. Surging video traffic cuts across all three user groups (mobile, business, consumer broadband), and demands so much bandwidth that service providers are redefining the very nature of the IP edge. IP edge routers are positioned in the network to deploy new functions of caching, CDN, and adaptive video streams for multiple screens, while scaling up in capacity and numbers and types of services.

Consumer expectations: the distinction between consumer and business needs has blurred. Workers bring consumer devices (BYOD—bring your own device) and the expectations of anytime/anywhere/any device access to business life. And business applications and data must not only be available everywhere, they must also be secure. The impact of tablets and smartphones is transforming the breadth of mobile service offerings. Many deployed IP edge routers cannot handle the service loads or multiscreen service granularity of the video and data services being delivered to a variety of user devices.

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The New IP Edge

Service providers are aiming to consolidate their service networks from many to few and, preferably, just one. Most of the service providers highlighted in this paper have chosen a single edge router platform to get the biggest bang for their buck, whether for single or multiple services.

Exhibit 2 - The New IP Edge: Consolidated Multi-Service Delivery Point for IP Video, Mobile, and Cloud Services
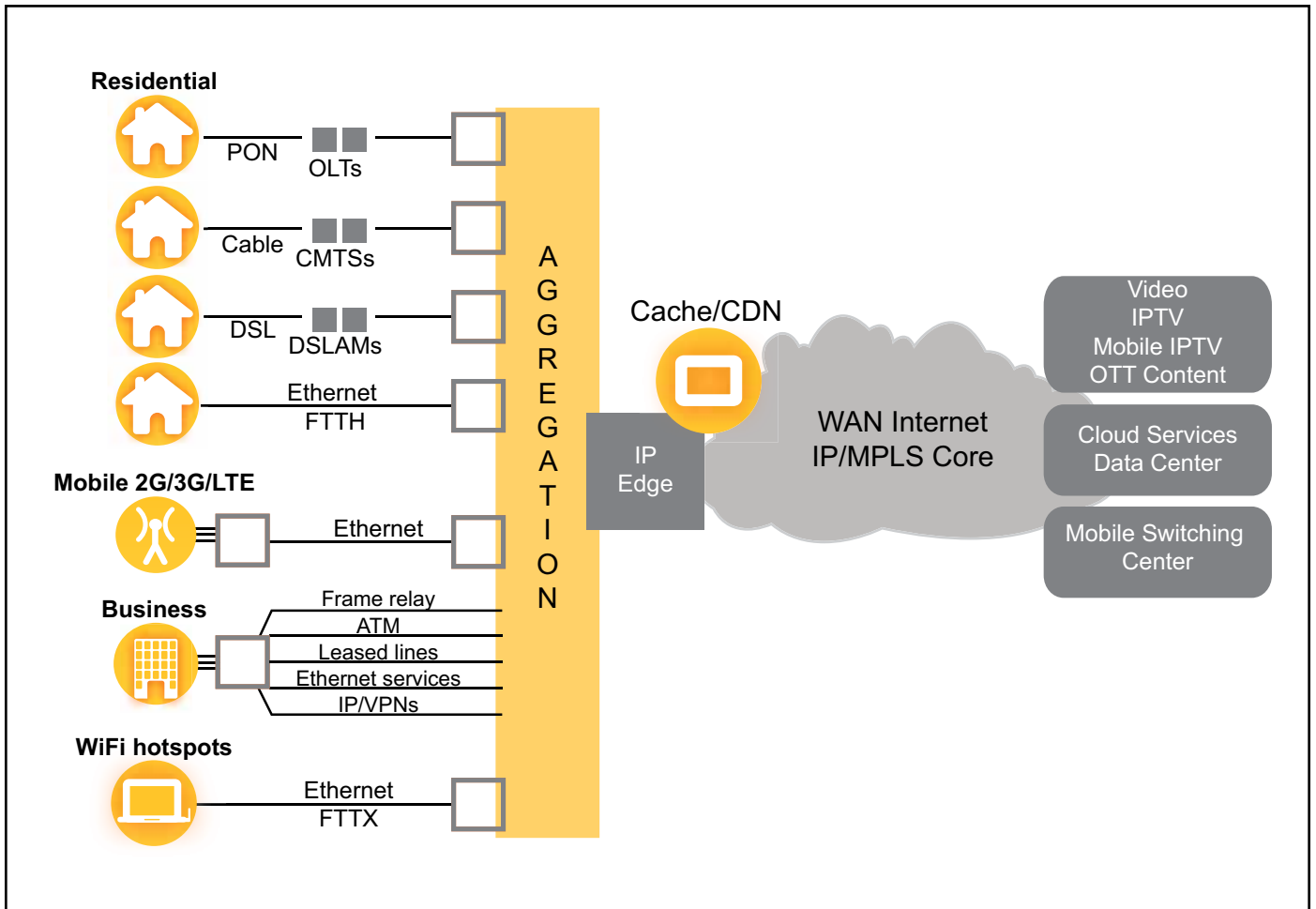
"The modern edge router leverages the intelligence within the network to deliver more personalized or lifestyle-centric consumer services while providing more control, visibility, and security for enterprise VPN services."

SERVICE PROVIDERS FACE THREATS FROM MANY DIRECTIONS

Some service providers report that their IP network traffic is growing at 40% to 60% per year and more. In the past decade, the philosophy was to build a network for each service, with a staff to support every network: voice, video, L2 service, IP VPN service, Internet service, mobile, and legacy TDM, FR, and ATM. In some cases there may be common transport infrastructure, but at the service layer, there are multiple networks, and even multiple networks for one service.

The bottom line is that multiple networks mean higher costs. Each network requires its own management, operations, and provisioning, and with multiple networks there is stranded capacity, especially dysfunctional in the face of rising traffic loads. As a result, we are in the midst of a longer-term evolution toward a consolidation of those networks, and the move to a common IP infrastructure is the unifying element. To facilitate this evolution, there is a requirement for IP service routing platforms that can support not only a range of IP services to enable consolidation, but that can scale to support the evolution of those services and keep pace with growing bandwidth demand.

Service providers face diverse threats to their profitability—capacity/service demands on their networks, customer churn, and operational expenses. The most-dire threats are (1) rising opex, which is upsetting business models, and (2) the move to unicast video, which is straining network architecture. Many in the industry maintain that OTT also threatens business models, but customers are lining up for more capacity to experience the OTT services, driving up the numbers of subscribers desiring access to YouTube, FaceBook, and Gmail.

At the same time, basic connectivity services like direct Internet access are becoming commoditized, and profit margins are eroding; customer churn impacts the top and bottom lines. Service providers need to differentiate their services from the competition. The modern edge router can help by leveraging the intelligence within the network to deliver more personalized or lifestyle-centric consumer services while providing more control, visibility, and security for enterprise VPN services.

New Video Demands Threaten Business Models

The biggest threats service provider networks face are (1) the shift that's underway from traditional broadcast using multicast (one stream to all users) to more on-demand broadcast video to unicast (one stream to one user) and (2) OTT video consumption. The video shifts hit mainly the consumer and mobile segments, but they impact businesses as well. Meeting the video demands in less than optimal ways may lead to customer churn, yet the expense of meeting them well may impact operational expenses.

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Some service providers have deployed caching with CDN capability to offer more support to applications and OTT providers, as shown in the next diagram. The first few service providers to deploy this are gaining new revenue from this capability, and IP edge routers are involved in various aspects:

- A streaming video service offers a "turbo button": a user can choose to get faster and smoother downloads through the service provider creating a special channel for the data transfer—for a fee that can be shared between the telco and content provider

- Subscriber online behavior is anonymously captured and sold to advertiser brokers or advertisers for a fee

- Caching and CDN intelligence is used to reduce network traffic, and also for revenue generation by charging service providers for caching/CDN services and businesses for website acceleration

Exhibit 3 - Next Gen IP Edge: Higher Value to Content Providers Results in Compensated Traffic
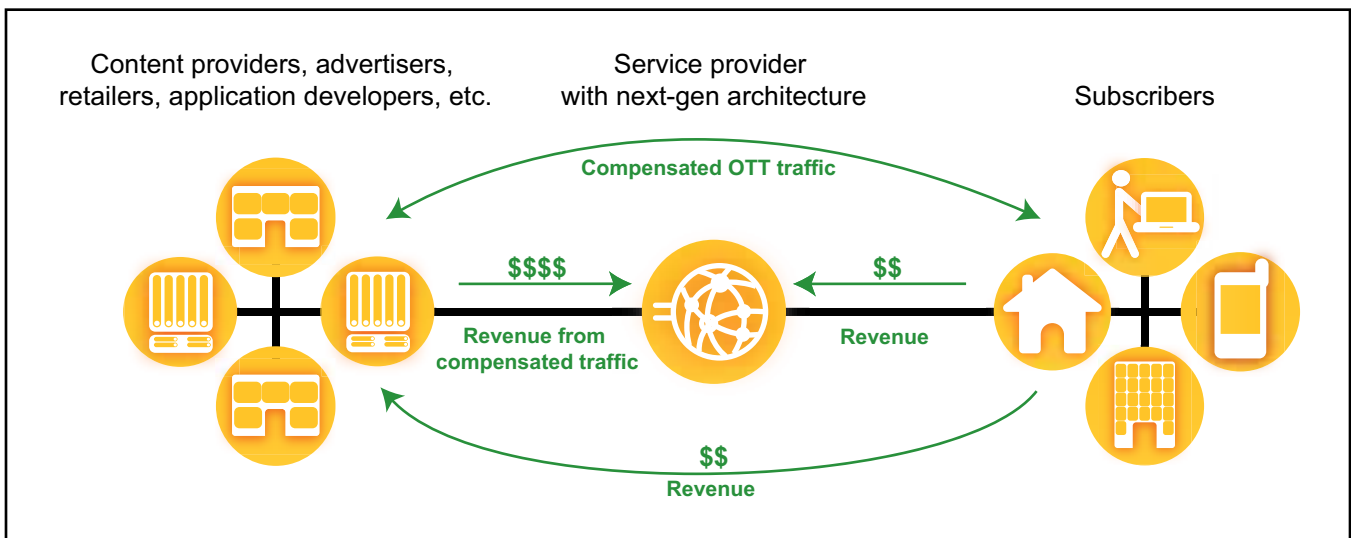
Rising Opex Also Threatens Business Models

For the past several years, service providers across the globe have been managing their capex with historically low capital intensity ratios (capex/revenue) and are now increasing them into a healthier 12-13% range. As traffic, customers, and competition dictate more services and network upgrades, the costs of operations rise. Though capex has been under control, behavior by carriers hasn't adjusted sufficiently. Service providers must reduce this rising opex as the area with the biggest impact, and reducing the number of networks is the best way to do so, although it is neither simple nor easy.

There are organizational challenges and many other barriers to converging or consolidating multiple overlay networks. But the answer doesn't need to be one IP network for everything—there are as many possible combinations as there are service providers.

The key is having the flexibility to put together the right combinations for the needs of each operator. Choosing the right edge router can make a difference. It may make sense to combine carrier Ethernet services with Ethernet cell tower backhaul, or to augment an L2 VPN service with a L3 VPN service, or to collapse the video edge and consumer edge—wherever the returns are the greatest.

FOUR SERVICE PROVIDERS LEADING THE WAY TO MEET THE CHALLENGES

IP edge networks are facing immense pressure. Are service providers ready for what's to come? Many deployed routers aren't up to the task. But a number of service providers are leading the way in using the latest IP edge routers to re-architect their networks, add new capabilities, or innovate new services. In effect, these service providers are moving from a separate IP edge for each service overlay network toward a single converged IP edge. We highlight 4 innovators in this section.

British Telecom (BT)

The Challenges

BT faced the full gamut of service provider challenges as described above: rapidly growing bandwidth demand (more video, more content from OTT providers) increasing backhaul costs, rising opex, more complex operations, and declining service margins. BT had over 10 network platforms supporting various services, with BRASs in 15 to 20 locations around the UK, all of them approaching their limits. BT's existing network simply couldn't handle the rampaging requirements of new video services, and in particular, the BBC's iPlayer.

BT saw the solution: simplify the network architecture and move IP network functions toward the edge, closer to subscribers, without disrupting services in the process.

The Solutions

BT is instituting four innovative steps in moving to solve its dilemma:

- Use the same routers for business services and consumer broadband, thereby increasing operational efficiency by reducing two networks to one—the most basic change with the largest payback.

- Migrate away from a centralized BRAS architecture. BT's new broadband network gateways (BNGs) sit on edge routers and distribute the BRAS function to potentially over 100 locations in the UK, thereby efficiently delivering high bandwidth connectivity to subscribers.

- BT simultaneously installed caching and a content delivery network (CDN) in those same locations, greatly reducing traffic on their UK backbone. Caching is especially important for BT as it carries the BBC's broadband iPlayer service that provides BBC programming on demand.

- For consumer and business customers, BT can create a single IP address per connection; subscribers can have multiple applications, each with its own QoS level, in each connection. This means that business traffic, VPNs, YouTube browsing, BBC iPlayer services, etc., can be allocated resources accordingly. The single IP address also facilitates the migration from IPv4 to IPv6, which every service provider must do at some point.

Exhibit 4 - Move from Central BRAS to Distributed BNG
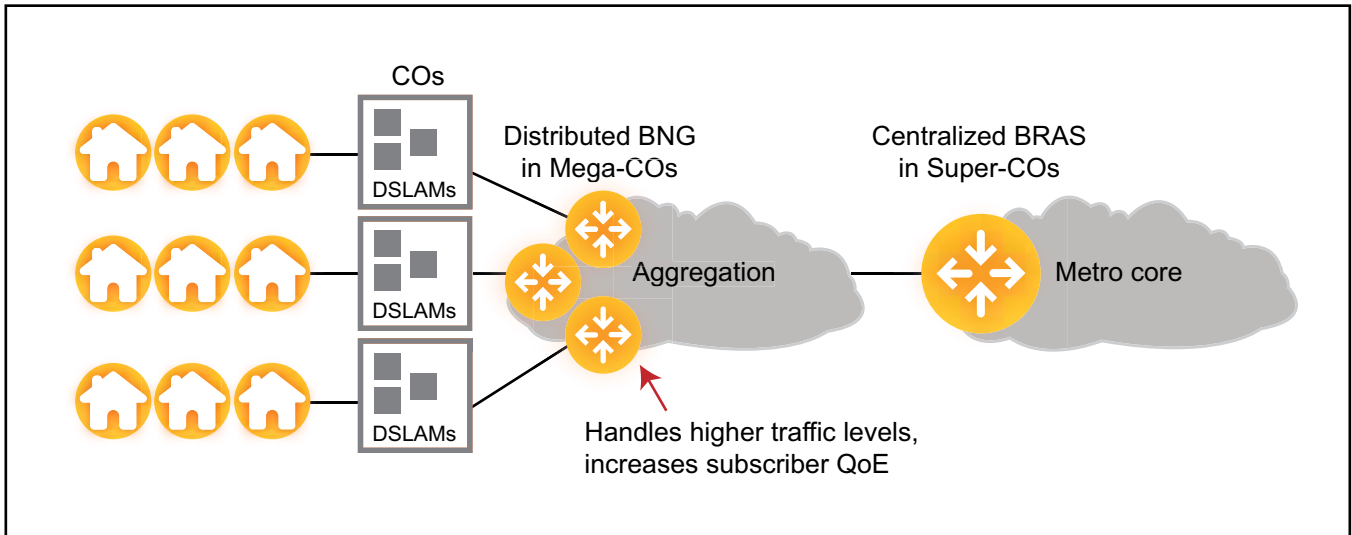
The Role of the Edge Router at BT

BT was able to use its IP edge routers for the combined L2/L3, business, and residential services, enabling an evolution toward fewer IP networks with consolidated services.

Service providers are able to converge their IP networks today thanks to the greatly increased capacity and intelligence in their edge routers, which enable deep packet inspection, caching/CDNs, and video intelligence.

Exhibit 5 - IP Edge Routers at BT

British Telecom	
Turning Challenges into Opportunities	**The IP Edge Router Payoff**
Distributed BNG; move IP edge closer to users, a more optimal placement for caching	Handle higher traffic loads; lower transit costs/bit
Single network for mobile and fixed traffic	• Use router for combined services • Create new services • Increase operational efficiencies • Reduce capex
Single IP address for customer connection facilitates migration from IPv4 to IPv6	Make use of various options of IPv4/IPv6 migration

TELUS

100-year old TELUS has annual revenues in excess of $10 billion and around 13 million customer connections, including over 7 million mobile subscribers. TELUS offers a range of communications products and services, including data, IP, voice, wireless, entertainment, and video, in its position as the 2nd largest service provider in Canada.

The Challenges

TELUS was challenged to stay ahead of traffic demands as business models were pushing up against network limitations. Customer services were delivered across multiple IP edges for multiple networks, each dedicated to specific services. There were physical and logical capacity limitations, static service provisioning, and an edge architecture that lacked dynamic knowledge of the Internet and, as a result, was unable to optimally use bandwidth resources and control flows. Operations costs were hard to control, and the company's ability to scale was made difficult by the edge network's architecture as well as the existing equipment.

The Solutions

When faced with the need for a costly major network upgrade, TELUS decided to go all the way and move to a single IP/MPLS network, with services delivered at the IP edge. The company is one of the first Tier1 service providers in the world to do so. Its converged IP edge uses the intelligence of edge routers to support all consumer and business services. The operator has moved away from static service provisioning to a flexible, fine-grained, hierarchical QoS. TELUS can do service provisioning by policy, which greatly simplifies the development, management, and provisioning of new services.

Exhibit 6 - TELUS's Strategy for Single IP Network Platform for All Services
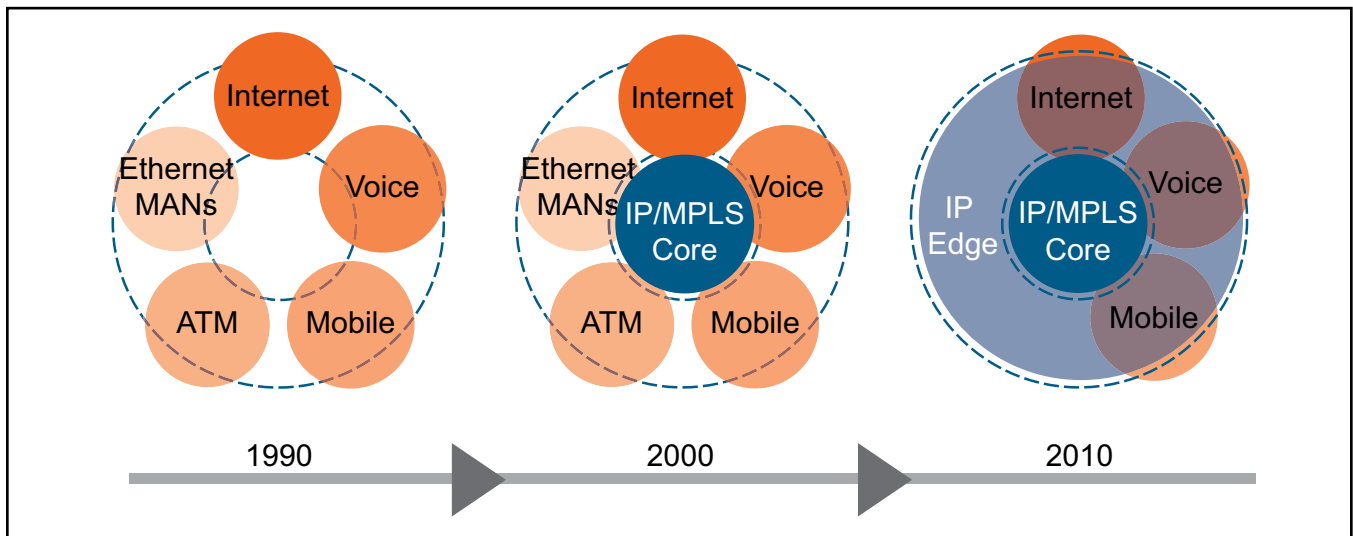
Source for diagram: TELUS

"The operator is now in the position to consider caching and CDNs as a means of building partnerships with OTT content providers, with potential revenue sharing from features such as faster downloads or streaming."

By offering more types of services, TELUS is able to retain customers and attract new business. The operator can now also bundle services to customers, a task virtually impossible to perform across multiple IP edge networks.

TELUS can now scale up capacity at the IP edge as needed with 10GE and 100GE edge router blades, and with 400GE at some point in the future.

The operator is now in the position to consider caching and CDNs as a means of building partnerships with OTT content providers, with potential revenue sharing from features such as faster downloads or streaming.

The Role of the IP Edge Router at TELUS

The basic notion of converging the network edge is based on converging on IP, which means deploying IP edge routers that provide a single platform for mobility, Internet, business connections, and video. TELUS can now deliver multicast and unicast video services across the single converged edge. The intelligence and capacity of modern IP edge routers are what makes this move possible.

Exhibit 7 - IP Edge Routers at TELUS

TELUS	
Turning Challenges into Opportunities	**The IP Edge Router Payoff**
Consolidate services from multiple IP networks onto a single IP edge network	Handle higher traffic loads; lower transit costs/bit
In position to deploy caching and CDN	• Easier to provision services and use policy • Ability to offer bundled services, gain bandwidth efficiencies, control individual flows of various services, and offer new types of services • Scalability from 10Gbps to 100Gbps, and to 400Gbps in the future
Single IP address for customer connection facilitates migration from IPv4 to IPv6	Can look for CDN services revenue with OTT content and wholesale providers

Portugal Telecom (PT)

Portugal is not a large country: 11 million people in a land the size of the US state of Minnesota. Nevertheless, Portugal Telecom has a global reach, with 90 million customers in 12 countries.

The Challenges

Portugal Telecom, as Portugal's incumbent provider, has a regulated responsibility to provide high quality service to its customers, and its multiple networks had threatened to hold it back, since it is very difficult, if not impossible, to deliver services on multiple networks. Without the complexities and scale of a giant provider in a large country, PT was able to move quickly toward a converged IP network.

The Solutions

PT achieved what many service providers talk of doing: a single modern IP/MPLS network that handles all services: mobile backhaul, mobile broadband, 3G and 4G rollouts, and consumer broadband. PT has 50% of the smartphone market in Portugal, and 45% of the mobile broadband market.

PT established 1,600 WiFi hotspots around the country. And, like BT, PT has installed caching to move content closer to subscribers and reduce backbone traffic. PT provides a multiscreen experience for subscribers, who can get their video on regular TVs, tablets and PCs, or smartphones.

PT claims the best fiber network in Europe, with 1.6 million FTTH-passed homes, and 88% of its mobile backhaul stations fiber connected.

Exhibit 8 - Portugal Telecom's Next Gen IP Network Platform
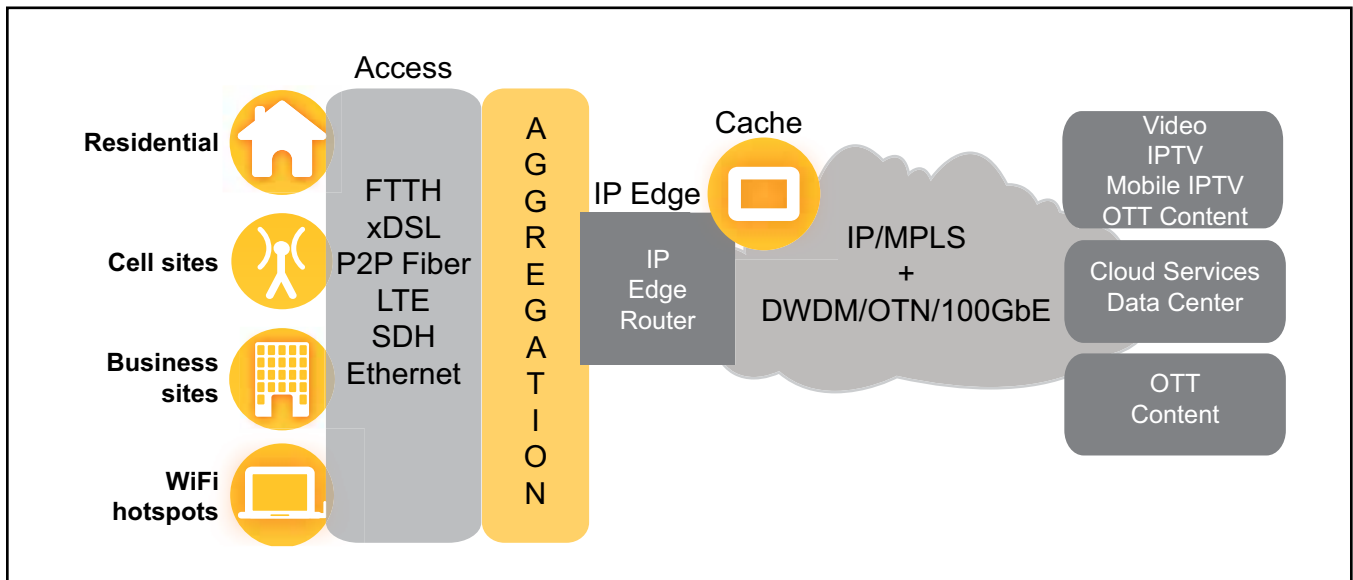
"PT was able to move to a single IP edge network because modern IP edge routers are so capable, both in terms of their throughput and service granularity."

The Role of the Edge Router at Portugal Telecom

PT was able to move to a single IP edge network because modern IP edge routers are so capable, both in terms of their throughput and service granularity. In much of the country, a single edge router handles all traffic and services for smaller cities; in larger cities, such as Lisbon, two routers may divide the work. Caching, multiscreen capabilities, and adaptive video are all deployed on their IP edge routers.

Exhibit 9 - IP Edge Routers at Portugal Telecom

Portugal Telecom	
Turning Challenges into Opportunities	**The IP Edge Router Payoff**
Single IP service network for consumer broadband (FTTx), mobile backhaul, business, and WiFi hotspots	• Greater operational efficiencies • Ability to offer new services, bundle services easily
Caching near distributed BNG	• Reduce traffic and transit costs • Reduce capex
Multiscreen video delivery	• Deliver IPTV and mobile IPTV services • Increase customer excitement and loyalty
Cloud services in data centers	IP services edge for customers to use L2/L3 VPNs and Ethernet services to access cloud services

Belgacom

Belgacom is the largest telecommunications company in Belgium, with operations in 8 additional European countries.

The Challenges

Belgacom wanted to simplify its own networks by eventually retiring legacy networks and simplifying the delivery of services to customers. As Belgium is a small country, Belgacom could move without undue strain to a single IP/MPLS network. And as it is in a fiercely competitive market, Belgacom needed to drive service differentiation.

The Solutions

Since Belgacom is a regulated incumbent, it wasn't able to eliminate currently offered services, so it wanted to provide an incentive to attract customers to its new network.

Belgacom wanted to provide new services to its customers over a single IP network called "Explore." Belgacom touts Explore as a single, scalable MPLS-based network that uses IP edge routers to deliver services to customers. Explore's integrated communications services are available to all connected customers, whether fixed or mobile. Explore's converged, single network handles headquarters and remote office traffic, remote wireless users, and mobile backhaul.

Particularly for business customers, Explore provides a lot of control over the services rendered, with customers getting reports on how applications are doing. Customers can change their applications' priorities and, in effect, control their own application traffic. The combination of application monitoring and reporting with application performance management enables solid and granular performance SLAs.

Exhibit 10 - Customer View of Belgacom's Explore IP Services Platform
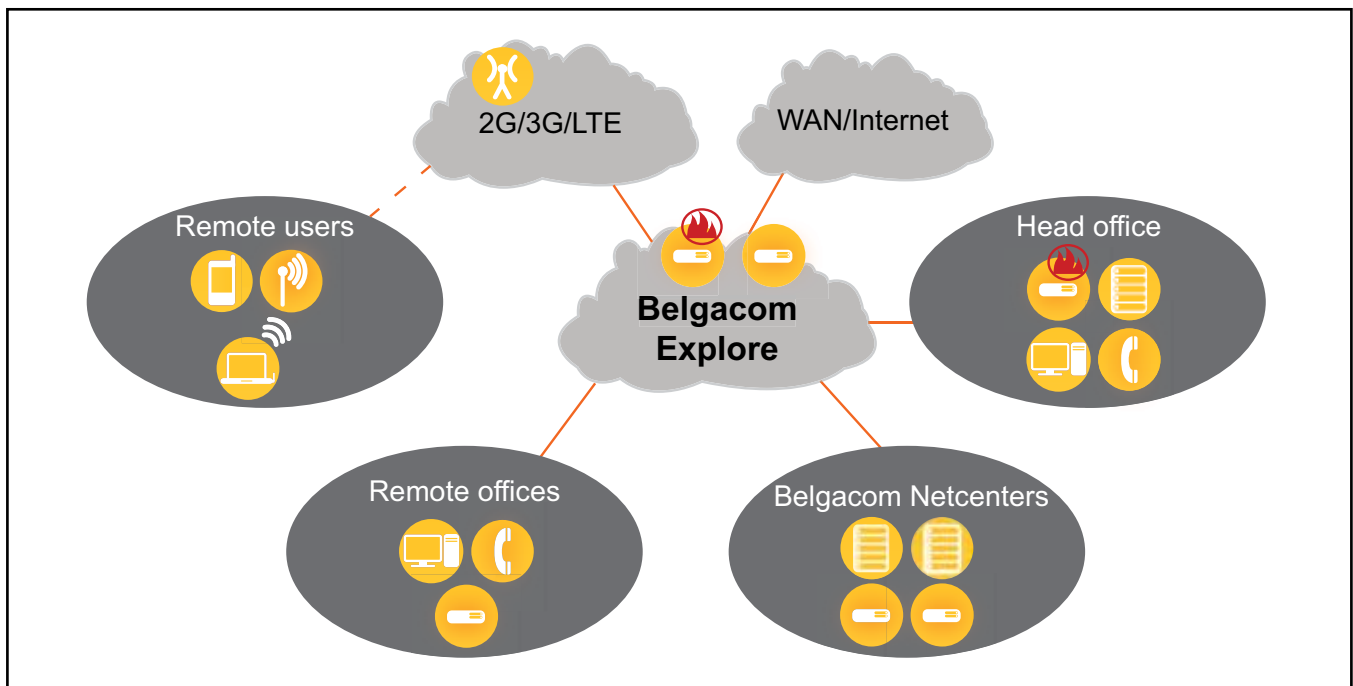
Belgacom's goal of 'all services to all customers' is under development, and it is the company's target for a fully integrated converged IP/MPLS network. Belgacom is working toward adding more services to Explore, including hosted IP telephony, application awareness and acceleration, and end-to-end LAN/WAN and security SLAs.

As with other operators in this study, Belgacom's network is no longer one of mere connectivity and transport, it has become a vehicle for business-critical applications.

The Role of the Edge Router at Belgacom

Belgacom leveraged its IP edge routers for residential and mobile backhaul services (Belgacom TV, video on demand, TV e-mail, TV banking, gaming, VoIP Internet, and Belgacom National Wholesale). Enterprise customers have a clear view of how much bandwidth various applications are using—a key element of Belgacom's Smart Networking initiative, which is geared toward bringing greater intelligence to its networks. Enterprises are concerned about the performance of applications they access from the cloud, and this performance clarity greatly reduces those concerns.

Exhibit 11 - IP Edge Routers at Belgacom

Belgacom	
Turning Challenges into Opportunities	**The IP Edge Router Payoff**
Converge many single service networks to a single, multiservice IP network	• Reduce operations efforts for multiple networks • Develop new services • Bundle services • Reduce the capex of multiple networks
Put mobile backhaul and business services on the same network	Leverage the same equipment to handle multiple services, reducing operations efforts
Customer applications priority control	• Encourage customers to move off legacy services to new IP network • Fine-grained applications control for customers • Retain customers • Add new revenue

"Operators are using IP edge routers with functionality to solve their most critical challenges and threats."

BOTTOM LINE:

HOW SERVICE PROVIDERS ARE TURNING THREATS AND CHALLENGES INTO OPPORTUNITIES

In summary, we have highlighted brief case studies of four service providers who are leading the way to meet the challenges of video, mobility, and cloud, and overcoming the threats of surging video/content, rising operational expenses, and customer churn. The biggest payback comes from consolidating the services of several networks onto fewer IP/MPLS networks, with the services delivered at a converged IP edge on an IP edge router. The operators are using IP edge routers with functionality to solve their most critical challenges and threats:

- TELUS, PT, and Belgacom reduced opex by leveraging a common IP platform to deliver a combination of residential, business, and/or mobile service

- BT and PT solved the video onslaught with caching, delivery of high quality unicast video, and per-flow QoS

- PT added multiscreen and network intelligence for applications

- PT and Belgacom provide high performance, secure, flexible L2/L3 VPNs, and use them to access cloud services for data

- Operators now have the tools to increase revenue with CDN services, a broadband "turbo" button, and new service bundles that were not possible with separate service networks

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Summary: How Routers Help Converge the IP Edge

The IP edge sits at the critical juncture in service provider networks: between customer access and the IP/MPLS core where services are created, monitored, and controlled in their delivery to the appropriate customers with paid-for qualities of service. The IP edge router plays the key, critical, and instrumental role in this service delivery.

The following table highlights how IP edge routers help facilitate edge router functions.

Exhibit 12 - The Critical "Converged IP Edge" Role of IP Edge Routers

Edge Router Functions	How Edge Routers Help

Multiple services on the same router platform at scale with granularity of individual customer applications QoS and visibility	• Fewer networks or a single network is the top method for reducing rising opex
	• Support fixed and mobile functions; reduce the number of networks, for example:
	  • Business + business with layer2/layer3
	  • Business + residential broadband consumer
	  • Business + 2G/3G/LTE mobile + WiFi hotspots + consumer broadband
	• Bonus: can easily bundle services

Subscriber management and policy enforcement of differentiated services at scale	• Support varied new services to increase revenue • Attract new customers, reduce churn • Capture anonymized subscriber behavior dynamically, sell it to advertising brokers
Caching, CDNs, video intelligence	• Reduce traffic and network transit cost-per-bit • Potential new revenue from CDNs • New revenue from content providers via high quality streaming; for example, a subscriber turbo button
Video intelligence, caching, CDNs for IPTV and other managed video services	• Reduce traffic and network costs • High quality streams competitive with TV quality to attract and retain customers • Multi-screen delivery
Capacity and scaling: 10Gbps, 100Gbps, and future 400Gbps, 1Tbps	Scaling of: • Number of subscribers • Amount of bandwidth • Number of services • Depth of individual services
Per service, fine grained QoS; packet and timing/synch; IPv6' DPI apps visibility	• Differentiated business and consumer services • Applications and VPN assurance • Mobile backhaul • Custom/personalized services • IPv6 transition

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- Small Cells and Carrier WiFi
- Mobile Backhaul and Microwave
- Service Provider VoIP and IMS
- Broadband Access
- Pay TV
- Service Enablement and Subscriber Intelligence
- Carrier Routing, Switching, and Ethernet
- Optical
- Networking Ports
- Vendor Services
- Service Provider Capex and Subscribers
- Data Center and Cloud
- Security
- Enterprise Networks
- Enterprise Voice, Video, and Unified Communications
- Equipment Vendor Scorecards
- Overall Market Trends and Forecasts

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