NORTEL

White Paper

Carrier Ethernet Solutions for Residential Services

Introduction

A dramatic shift in the buying behaviours of residential customers is taking place, resulting in new pressures on service providers. Traditional voice revenues have been undermined by the combined pressures of alternative operators (AOs), mobile operators and VoIP providers. Faced with this challenge, service providers are launching triple-play services (consisting of voice, high-speed internet and video) to sell higher value services to their residential customers and increase revenues at a time when their traditional voice revenues are flat or decreasing. In addition, by offering residential users a more complete bundle of services it is hoped that customer churn can be decreased.

Standard triple-play packages consisting of two TV channels, a video-on-demand (VoD) channel, fast internet and voice can require 20 Mbit/s or more. However, with the emergence of high-definition TV (HDTV) and the ever increasing number of channels available, it is expected that within five years service providers will need to offer speeds of around 50 Mbit/s to remain competitive.

Existing downstream broadband networks have been based on DSL solutions (e.g. ADSL, VDSL), but it is expected that the increase in traffic demand will lead to higher speed technologies like fibre to the home (FTTH). In core networks service providers are beginning to upgrade their existing optical networks to address higher speeds, with 40G solutions now available on the market and a path to 100G outlined. This leaves the metropolitan and regional network as a potential bottleneck in the distribution of residential services. What's more, it is often the case that this part of the network proves to be the most intractable part of the business case, as the required investment cannot be directly tied to customer revenue, unlike the expenditure on access networks and core service platforms.

In their efforts to solve this issue, service providers are turning to Ethernet solutions. Recent innovations have made Carrier Ethernet suitable for deployment in metropolitan and regional networks. The resultant networks are ideally suited to provide high bandwidth connectivity for residential services in a more cost-effective manner than alternative WAN technologies.

This paper discusses how Carrier Ethernet meets the key challenges required to deliver both the bandwidth and cost points needed to support residential services.

Key challenges in residential service delivery

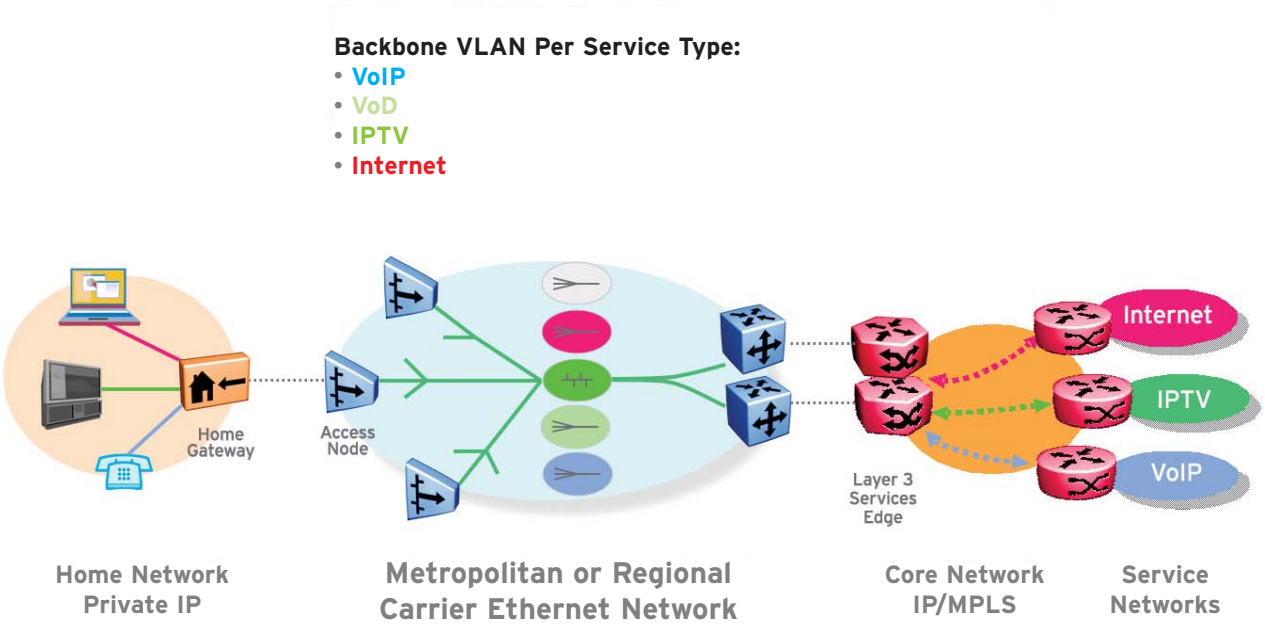
In order for service providers to successfully deploy Carrier Ethernet as part of a residential solution, the network must address a number of challenges:

- **Scalability** – Bandwidth requirements per customer are expected to reach 50 Mbit/s over the next couple of years, so the network must have the scalability to cope with this demand. Furthermore, metropolitan and regional networks must have the ability to scale to uniquely identify, isolate, and serve 100,000s of services and subscriber end-points in the network.
- **Security** – The network will be required to support multiple subscribers and it is important that this is achieved in a manner that prevents the illegal theft of services. In addition, the sheer number of unknown users and third-party service providers attached to the network make it vulnerable to malicious attacks or accidental events that could degrade performance or deny service to subscribers. Finally, as multiple subscribers are attached to the same network access point, it is important to secure individuals from other subscribers (e.g. prevent subscribers accessing another subscriber's PC). This means the network must secure itself against subscriber behaviours such as MAC spoofing and denial of service attacks.
- **Network efficiency** – The network must make efficient use of bandwidth resources when delivering broadcast content to multiple end users. Multicast schemes achieve this by delivering content over each link of the network once by creating copies only when the link to the destination node splits.
- **Reliability** – Quality of Experience (QoE) has emerged as an important measure of residential services and reflects the end-to-end performance as seen from the end-user perspective (e.g. video impairments, audio quality, service outages). Loss of traffic to a given subscriber will clearly affect QoE. Even network restoration, if not rapid, may leave a video signal impaired in a noticeable way. Consequently, networks must be constructed to ensure that there is no single point of failure and that protection mechanisms exist to rapidly restore nodal, link and network failures.
- **Simplicity** – Finally, the reason that Ethernet is attractive to service providers is that it offers cheap, scalable bandwidth. In order for Carrier Ethernet networks to successfully deliver residential services, the above functionality has to be added in a way that retains the simplicity and cost-effectiveness of Ethernet.

Nortel's Carrier Ethernet solution

As discussed, current metropolitan and regional networks are a potential bottleneck when faced with the bandwidth explosion expected from video and multimedia services. The diagram in Figure 1 illustrates the role a Carrier Ethernet network plays in delivering residential services.

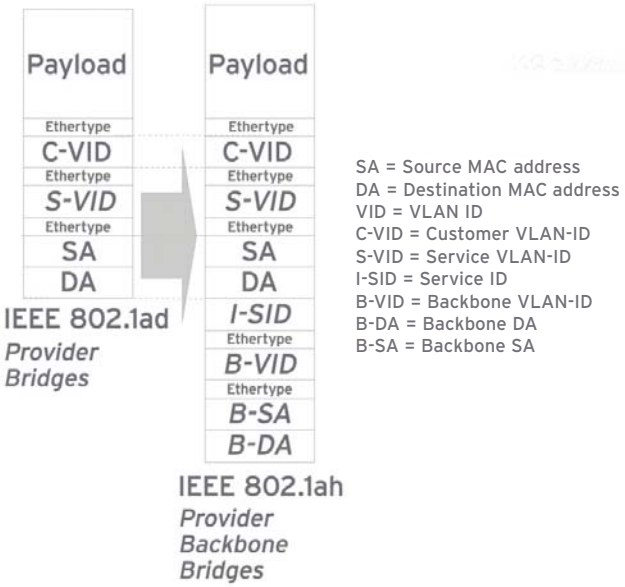
Figure 1: Residential Services Network



Traditionally, Ethernet has not been regarded as being suitable for use in service provider networks because of a lack of carrier-grade attributes. To a large extent these limitations have been addressed by the latest Ethernet standards. In particular the emergence of Provider Backbone Bridges (PBB), recently standardised as IEEE 802.1ah, has added massive service scalability to Ethernet. PBB is sometimes called MAC-in-MAC because it encapsulates the standard Ethernet MAC header and frame in a new MAC header dedicated for use in the backbone network. In Figure 2 the PBB frame is shown in comparison to the Provider Bridges (IEEE 802.1ad) frame, the new backbone header includes backbone source and destination addresses (B-SA and B-DA), backbone VLAN ID (B-VID) and service ID (I-SID).

By providing separate MAC addressing schemes for use in customer networks and the service provider backbone network, PBB creates separate Ethernet layers for service delivery and transport. When applied to residential services PBB can be used to create B-VIDs across the metropolitan or regional network. The service provider can configure each B-VID with specific attributes to optimise the delivery of different service types (e.g. internet, VoIP and IPTV) to customers. Furthermore strict separation of the B-VIDs ensures that security considerations are addressed.

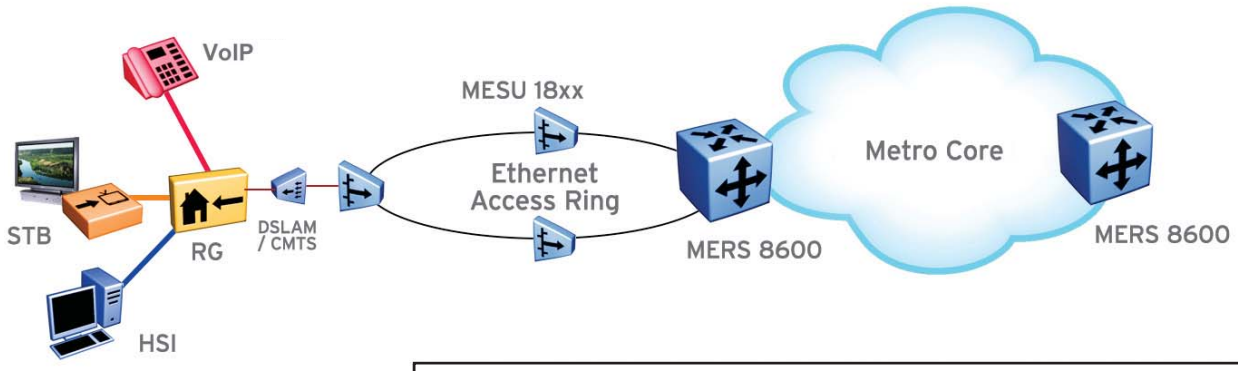
Figure 2: Ethernet Scalability



Another innovation that has helped ensure that Ethernet is suitable for carrier-grade networks is the addition of Operations, Administration and Maintenance (OAM). Ethernet OAM adds a set of comprehensive fault management tools to Ethernet that allow service providers to locate and troubleshoot faults in the network in a timely manner. These capabilities were standardised in IEEE 802.1ag (Connectivity Fault Management) and are complemented by the performance monitoring standard ITU-T Y.1731, that allows the service provider to measure critical parameters (e.g. frame loss, delay and delay variation) that can impact time sensitive applications like VoIP and IP TV.

Nortel's Carrier Ethernet portfolio implements PBB and Ethernet OAM, and in doing so transforms traditional Ethernet into the carrier-class technology required to address the growing demand for high-bandwidth, video and multimedia services. The diagram below introduces the products available in Nortel's portfolio.

Figure 3: Carrier Ethernet Portfolio



MERS 8600 = Metro Ethernet Routing Switch 8600
MESU 18xx = Metro Ethernet Services Unit 1800/1850/1860/1880
HSI = High-speed internet
STB = Set-top box
RG = Residential gateway

The cornerstone of Nortel's Carrier Ethernet portfolio is the Metro Ethernet Routing Switch 8600, a high-density, carrier-grade, Ethernet aggregation switch for deployment in metropolitan and regional networks. The Metro Ethernet Routing Switch 8600 offers advanced networking features, including PBB, PBB – TE (Provider Backbone Bridge – Traffic Engineering) and PLSB (Provider Link State Bridging), to help meet the key challenges of residential service delivery.

The Metro Ethernet Services Unit (ESU) 18xx series are high-density, compact Ethernet aggregation devices that can be deployed in the last-mile aggregation, in ring or point-to-point topologies. These devices can be deployed as part of the access solution itself (i.e. deployed in the building) or provide aggregation for a broadband access network (e.g. DSL, GPON, and FTTH).

Key features of Nortel's Carrier Ethernet solution for residential services

As discussed, if Carrier Ethernet networks are to be adopted to deliver residential services they must address several key challenges. Nortel's solution solves each of these in the following manner.

Scalability

Traditional Ethernet networks use a technique called IEEE 802.1ad Provider Bridges (also known as Q-in-Q or stacked VLANs) to improve Ethernet scalability for service provider networks. Adding a new service provider VLAN-tag (S-VID) to the Ethernet frame allowed the service provider to administer their own core VLANs to identify individual customer and infrastructure services. The IEEE 802.1ad approach remains limited for consumer and converged service provider networks in that only 4,094 service provider VLANs are supported. The limit is amplified by the need for unique VLANs to be set aside for third-party service providers, management, multicast and control planes.

The Nortel solution eliminates this limitation in services scale by making use of PBB. As explained in Figure 2, PBB encapsulates a standard Ethernet frame with a new Ethernet header. Instead of using additional Q-tags to separate infrastructure services the 24-bit I-SID in the service provider MAC header is used, enabling a maximum of 16 million unique service instances to be supported, completely removing the scalability issue.

In addition, Nortel's Metro Ethernet Manager (MEM) solution provides comprehensive network and service management capabilities, including:-

- The ability to quickly and efficiently provision new services.
- Fault management capabilities that allow the service provider to isolate and troubleshoot faults.
- The latest performance monitoring standards allow the service provider to detect problems in the network before they are reported.
- Intuitive graphical user interface (GUI) that allows the service provider to view the network from a nodal or service perspective.

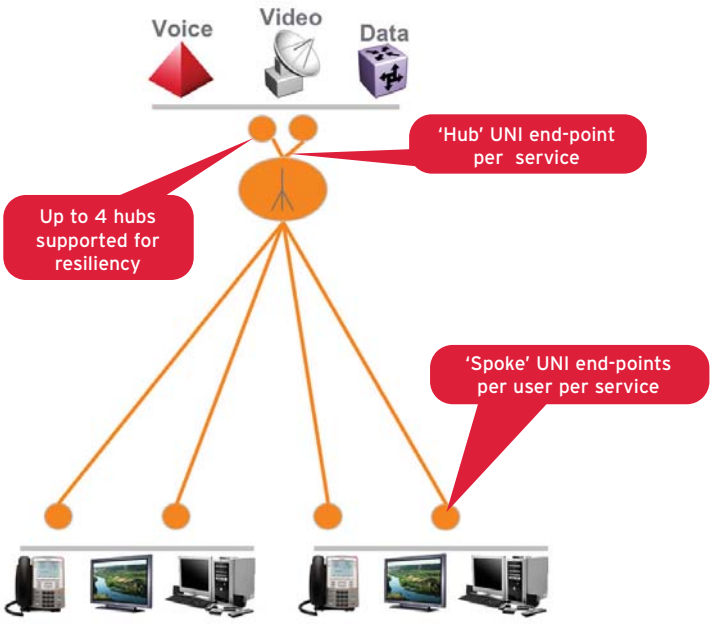
The simplified operational processes created by MEM provide the functionality required to manage 100,000s of customers and applications.

Security

A key requirement in the delivery of residential services is that direct user-to-user communication must be prevented otherwise individual users could view someone else's services or access their PC. This requirement lends itself naturally to an E-Tree (or point-to-multipoint) service, one of the standardised Ethernet services defined by the MEF (Metro Ethernet Forum). E-Tree services consist of a hub node that is connected to multiple leaves or spokes. Nortel's solution supports E-Tree services by performing directed multicast on a Service ID (I-SID), as shown in Figure 4.

By using I-SIDs to deliver customer services, the network has a level of built-in security. Each service is identified by a unique I-SID and individual users receive only the traffic

Figure 4: E-Tree Directed Multicast



streams associated with the services they have subscribed to. In addition, the directed multicast feature is used to define end users as spokes, and end points co-located with service platforms as hub nodes. As described in the definition of an E-Tree service, spokes can only communicate with the hub nodes, allowing users to access services while preventing direct communication between end users. This prevents an end user from accessing content being viewed by another user. In Nortel's implementation of an E-Tree service up to four hubs can be defined, to provide resiliency in the event of a nodal failure.

In addition to the fundamental security provided by the E-Tree service construct, Nortel's solution provides a rich set of features to provide additional security for residential services. These capabilities include:-

- Access control lists on UNI interfaces allowing service providers to prevent access to network resources.
- Broadcast filtering allowing the service provider to limit the rate of (or block altogether) broadcast or multicast traffic entering the network in order to prevent denial of service attacks due to accidental or malicious flooding of the network.
- MAC address filters allow service providers to block specific MAC addresses (or unknown MAC addresses) from accessing the network.

Network efficiency

There are two types of video service available to residential users: video on demand and broadcast TV. Video on demand is used when an individual user requests specific video content, which is then unicast to that user only (i.e. point-to-point). The key requirement here is to ensure the traffic is delivered securely to a single user. In comparison broadcast TV is used to distribute content to all of the users in the network (i.e. point-to-multipoint). In this instance the key challenge is to ensure that one copy of the video stream is broadcast per link and copies are only created when the links to the destinations split. Ideally, a single I-SID would be used to distribute broadcast content to all of the users, but service providers usually sub-divide the network into different IP subnets so that 100,000s of unique IP addresses can be easily managed. This means that a separate I-SID is required to serve each IP subnet, resulting in multiple copies of the same broadcast TV stream. This is shown in Figure 5, where two I-SIDs are used to distribute broadcast TV (multicast) and VoD (unicast) to the end-users.

Nortel's video/target merge feature simplifies this delivery model by injecting the broadcast TV content (video I-SID) into the unicast content (target I-SID). This merging of traffic streams occurs on the edge Metro Ethernet Routing Switch 8600 and the set-top box is presented with a single I-SID (the target I-SID). The result is that a simple and low-cost set-top box with support for a single VLAN can be used. From a network perspective, a single video I-SID is merged with multiple target I-SIDs and used to distribute broadcast TV content, ensuring an efficient utilisation of network capacity. Figure 6 illustrates how the video/target merge functionality is used to deliver broadcast and video-on-demand content.

Figure 5: Broadcast TV and Video-on-demand Delivery

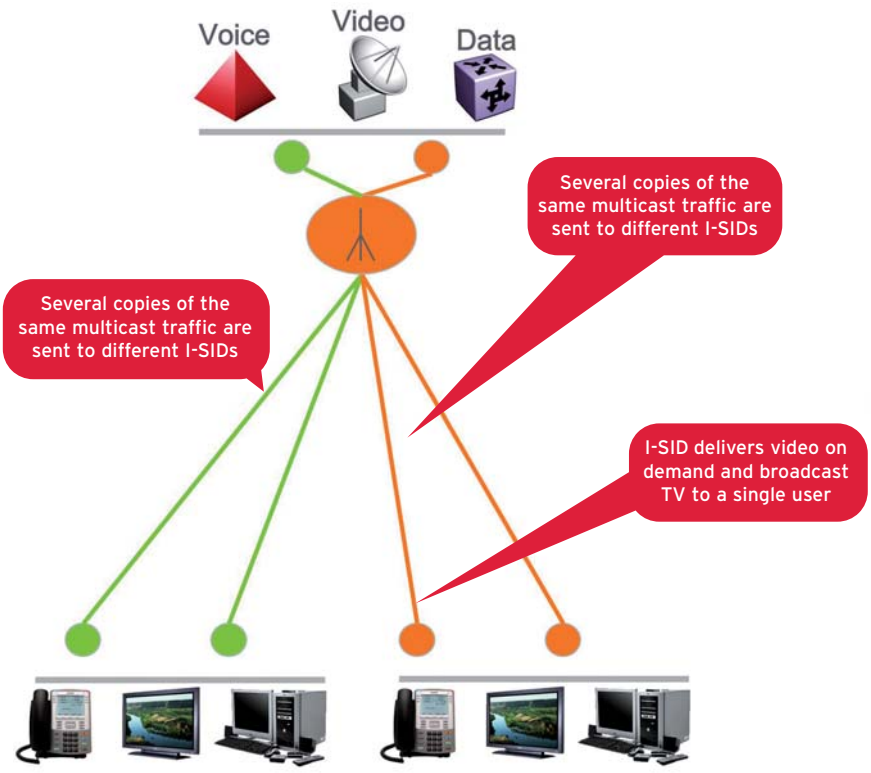
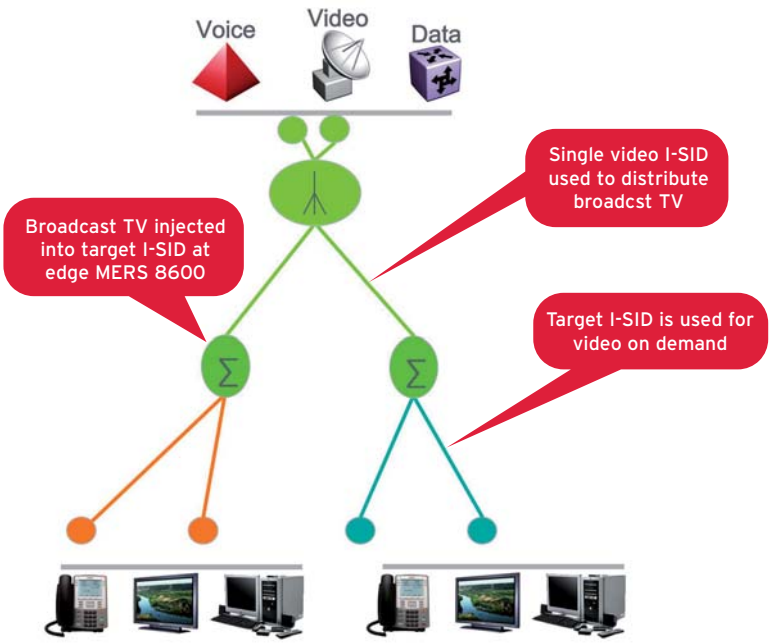


Figure 6: Video-Target I-SID Merge



Furthermore, Nortel's solution uses the Internet Group Management Protocol (IGMP) to manage the membership of IP multicast groups, delivering end-customer channel change capabilities. For example when an end user wants to subscribe to a given TV channel, the user sends out a join message to indicate that it wishes to receive the content relevant to that IP multicast group. The ESU 18xx portfolio and the MERS 8600 support IGMP snooping, to create a multicast forwarding table so that those multicast streams are only forwarded to the ports where they are really necessary. Furthermore, as the MERS 8600 controls the ESU access ring, it will only send a requested stream once into the access ring and each participating ESU will take a copy of that stream. These mechanisms prevent unnecessary flooding and bandwidth dissipation.

To relieve the multicast router from IGMP requests from potentially thousands of IGMP messages for the same ten most popular channels, the MERS 8600 supports IGMP proxy function. This means that only the first request for any channel will be forwarded and subsequent subscribers will automatically be served by the MERS 8600. As long as at least one subscriber is requesting that channel the MERS 8600 will keep up the session to the multicast router on behalf of all subscribers.

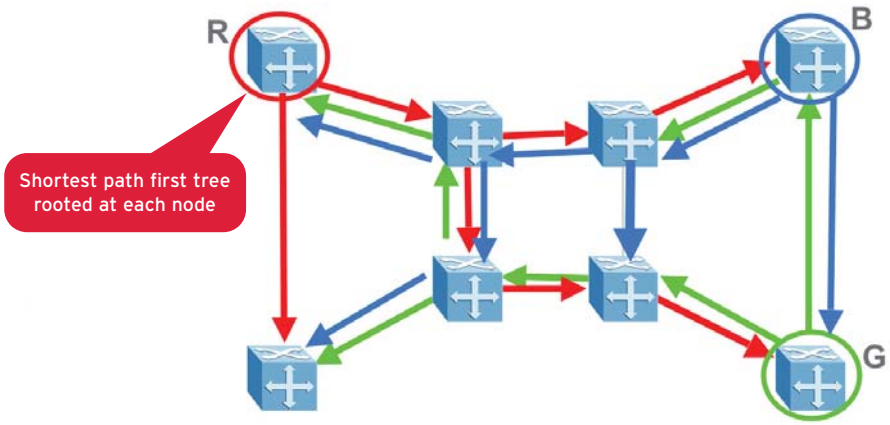
Reliability

As discussed, Nortel's Carrier Ethernet solution uses PBB to encapsulate the standard Ethernet frame in an additional backbone MAC header, resulting in improved network scalability. However, PBB uses Spanning Tree Protocol (STP) as the Ethernet control plane and many service providers do not consider STP a carrier-grade solution.

The problem stems from the fact that STP computes a single spanning tree for the entire network and ports not on the tree are blocked. This ensures that loops are avoided, because there is only one valid path between every pair of nodes. However, when a failure occurs in the network, STP blocks all ports while the shortest path tree is recalculated. This ensures that transient loops can not be formed, but it also means that every node in the network is affected by the outage. Furthermore, the re-convergence times for STP can run into multiple seconds and this is generally considered unacceptable in a carrier network.

This has led to the emergence of Provider Link State Bridging (PLSB) to replace STP. As the name suggests, PLSB is based on a link state protocol, namely Intermediate System to Intermediate System (IS-IS). The key benefit of this approach is that IS-IS can calculate and install a shortest path tree in 100s of milliseconds. As a result, PLSB improves the protection switching time of the network under failure conditions. In addition, PLSB calculates a shortest path tree for every node in the network, as shown in Figure 7. This means that when a node or link fails, only nodes connected to that failure via a shortest path tree are affected while IS-IS re-converges. By limiting the impact of any given incident on the network, PLSB provides a further improvement in reliability.

Figure 7: PLSB Supports Multiple Shortest Path Trees



Simplicity

The fundamental principle behind Nortel's solution is that carrier-grade functionality is achieved through extensions to traditional Ethernet. The key Carrier Ethernet innovations used (PBB, Ethernet OAM and PLSB) are backward compatible with existing networks and rely on basic Ethernet forwarding behaviour. This means that the network forwards Ethernet frames (based on the PBB header) and as a result is based on cost-effective Ethernet switches.

Summary

The erosion of traditional voice revenues has encouraged service providers to offer higher value residential services to their customers, which it is hoped will lead to greater customer loyalty. Driven mainly by an increased demand for video content, these residential services require much higher broadband speeds than those that are typically available. As discussed, the ubiquity, simplicity and cost of Carrier Ethernet have made it the de facto choice for addressing the requirements of multimedia video-centric services and the evolution of metropolitan networks toward this end is well under way.

In leading this transformation, Nortel has drawn upon considerable experience gained over many years deploying networks supporting business services and mobile backhaul services on a global basis. Significant innovations in the application of Ethernet technologies to service provider challenges, developed through that experience, now offer a cost-effective network infrastructure and high bandwidth connectivity for residential services.

Nortel is a recognised leader in delivering communications capabilities that make the promise of Business Made Simple a reality for our customers. Our next-generation technologies, for both service provider and enterprise networks, support multimedia and business-critical applications. Nortel's technologies are designed to help eliminate today's barriers to efficiency, speed and performance by simplifying networks and connecting people to the information they need, when they need it. Nortel does business in more than 150 countries around the world. For more information, visit Nortel on the Web at **www.nortel.com**. For the latest Nortel news, visit **www.nortel.com/news**.

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