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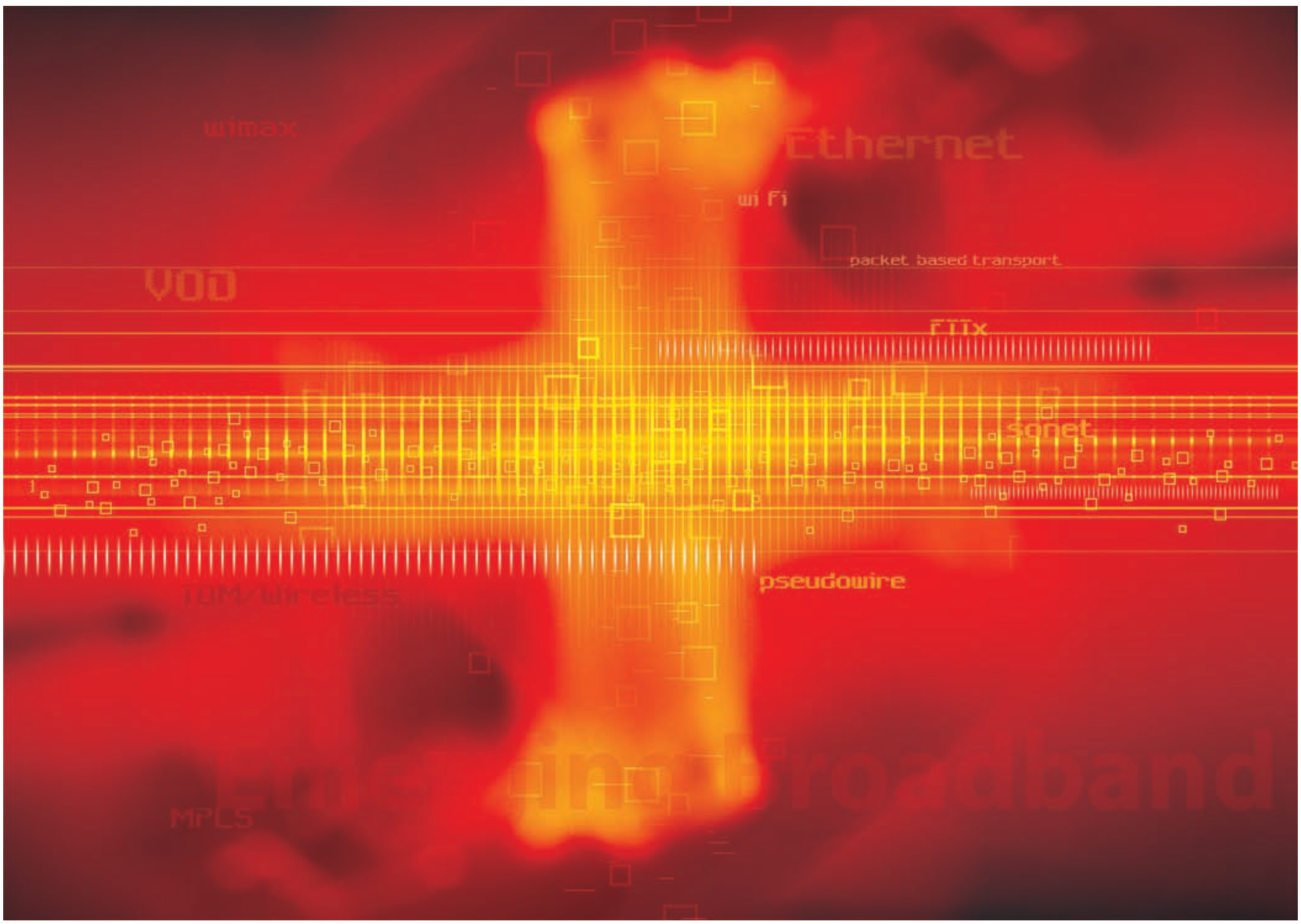
The Role of Emerging Broadband Technologies on the Converged Packet-Based Network



Introduction

The vision of network convergence toward a consolidated packet-based network has been discussed for years, though it is still not a reality. Currently, there are numerous overlay networks such as IP, ATM, FR, Ethernet, SONET, DWDM and wireless for different services. The evolution pace toward convergence has been slow due to economic, technical and regulatory issues.

However, the fact is that data traffic volume is now surpassing voice traffic volume. Traditional TDM voice traffic is moving to IP packets and TDM private line is moving to Ethernet private line. The wave of broadband applications such as Internet access, VOD, and IPTV create high bandwidth requirements for the network. These applications are packet-based, but have a much lower margin of profit for the service providers when compared to traditional voice service. Today's overlay and traditional circuit-based infrastructure will become less optimal for the new packet-based services as the profit margin decreases.

Most of the wireless networks in North America today are still circuit-based because most of the current wireless service is still voice-based. However, with emerging wireless access technologies such as WiMAX and Wi-Fi, more broadband wireless data and video services can be deployed. As a result, the wireless core network evolves toward a packet-based network.

Service offerings drive network evolution. As more packet-based broadband services are launched and bundled together in service offerings, service providers start to add more packet-aware features into their current network components. Eventually, network convergence toward a single packet-based network infrastructure is likely to become a reality for wireline and wireless networks.

Pseudowire is a promising MPLS-based packet transport technology that decouples the service layer from the underlying infrastructure so service providers can leverage their existing transport technologies. Whether the underlying infrastructure is SONET, DWDM or Ethernet, pseudowire provides a common encapsulation layer that can support the transport of TDM, ATM, FR, IP/PPP, and Ethernet services. Pseudowire can protect the service provider's current investment and provide a smooth migration path from circuit-based to packet-based networks.

In this paper, new emerging broadband technologies will be discussed. This paper illustrates how those technologies can be integrated together to provide a seamless converged wireline and wireless network, and outlines the challenges to make the vision of a packet-based network successful.

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Emerging Broadband, VoIP, and Wireless Services are all Packet-Based

In the last decade there has been a lot of talk about broadband and VoIP, but it was mostly hype because the enabling technologies were not proven, and lacked bandwidth in the last mile infrastructure for broadband applications. Recently, the enabling technologies for broadband and VoIP are more mature. RBOC FTTx projects are building an infrastructure of higher bandwidth closer to home. MSOs are pushing triple play services. As service providers are rolling out fiber access networks that can deliver higher bandwidth to the premises, IPTV with HDTV quality and VoIP applications become a reality.

In the wireless arena, the IEEE broadband wireless access standard called 802.16 has existed for years, but only recently attracted a lot of attention because 802.16 uses an advanced radio technology (OFDM) scheme to span distances greater than 30 miles with a shared data rate up to 75 Mbps. This standard is more secure and provides better QoS when compared to other wireless technologies. The industry sees 802.16 as a disruptive technology for the wireless access network and provides a complement for wireline technologies such as DSL, cable, and FTTx.

Most of the emerging broadband, VoIP, and wireless services are becoming packet-based. Analog TV signals are becoming digital MPEG packets. Traditional T1/T3/OC-n private lines are migrating to EPL, and VPN. Voice moves to VoIP. Broadband wireless data networks are emerging, with the goal of moving to an all-packet-based network. The vision of network convergence is coming back and is being driven by these emerging broadband wireline and wireless services plus the maturity of VoIP.

Inefficient Current Overlay Networks

There are a lot of existing overlay networks for different services such as an IP/MPLS network for IP, a frame relay network for frame relay services, an ATM network for ATM services, and a separate network for TDM/wireless services. In overlay networks, different services require different transport pipes to deliver the traffic, which is costly and inefficient. As more and more services become packet-based, and the core network migrates to IP/MPLS, it will be more efficient for the next-generation transport and access network to transport multiservice traffic over a common shared packet-based infrastructure as shown in Figure 1.

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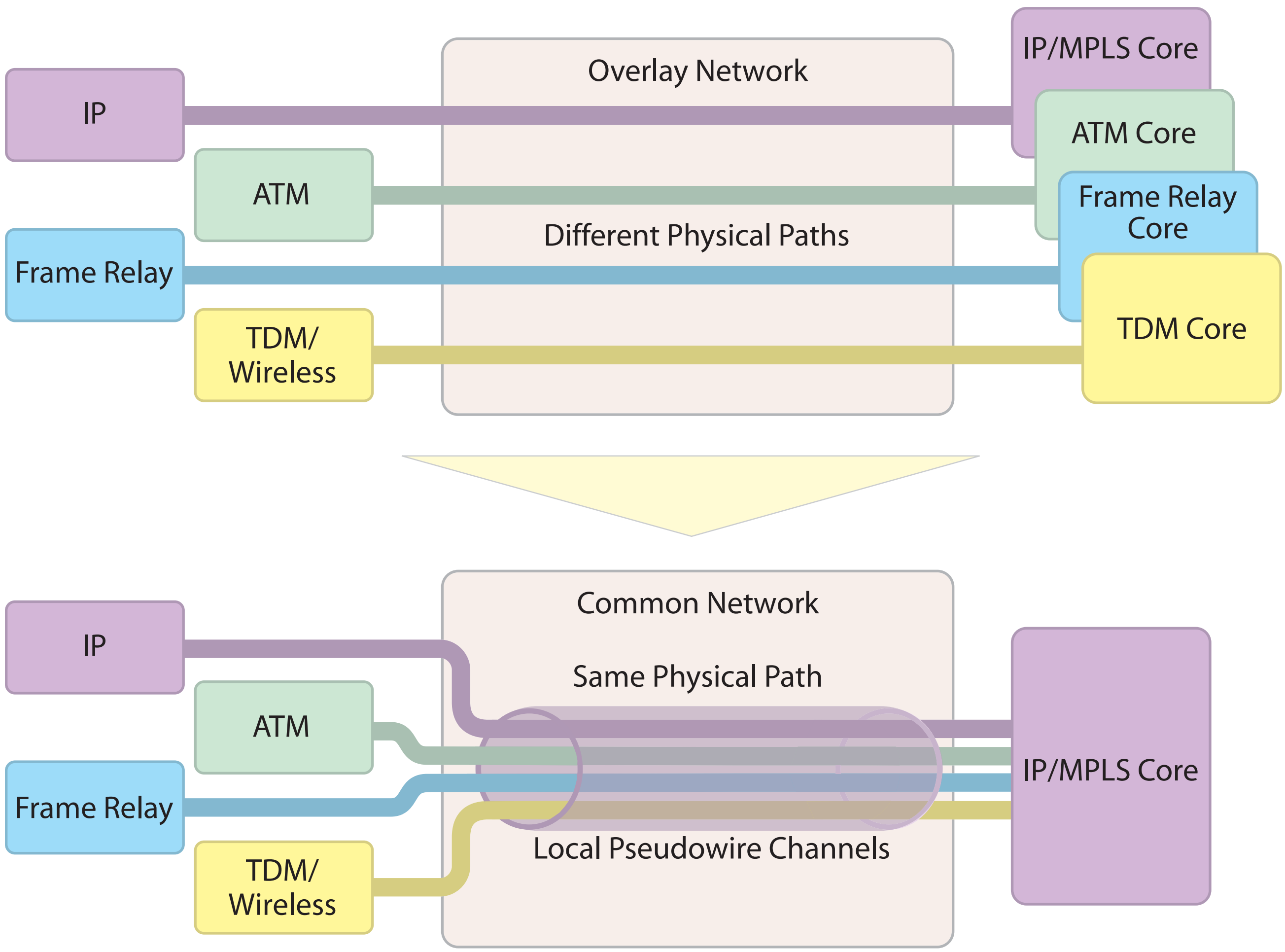

Figure 1: Overlay to Packet-Based Transport Network

Packet-Based Transport Network Evolution

There were several attempts (with mixed results) in the past decade that tried to cope with multiservice in a single converged network.

ATM was developed in the early days, but it did not fair well due to its problems in cost, scalability, and complexity to manage. A current major effort is the development of next-generation SONET enabling technologies such as GFP, VCAT and LCAS to improve the voice-based SONET standards in transporting data and video. VCAT provides a finer granularity of SONET bandwidth mapping for transporting various video and data interfaces (STS-1-nv, STS-3c-nv). LCAS provides a mechanism to allow auto removal and auto recovery of failed paths, plus dynamic bandwidth allocation. Next-generation SONET with an MSPP is pretty successful because it can preserve the service provider's investment in SONET infrastructure when deploying new data and video services. As a result, vendors are adding more data features such as POS, Ethernet, DVB-ASI, Fibre Channel, RPR, and MPLS into their MSPPs. Wireless equipment vendors tried to combine their wireline and wireless switches together in hopes of providing some kind of integration, but this effort failed due to regulatory and technical issues. Wireless was not regulated, but wireline was, which created problems for service providers. The technical requirements for the early generation of wireless networks (in terms of signaling and protocol) were different from the wireline networks, and it is difficult to have one platform fit both.

However, with the new packet-based services and technologies, information including voice, data and video are rendered in a common packet/IP format, making network convergence possible. Using Ethernet as the transport layer is seen as an option since Ethernet is relatively inexpensive, commonly available and well-known in the LAN environment. However, Ethernet by itself lacks resiliency, QoS, and is not carrier class. By transporting Ethernet over pseudowire and MPLS, those problems are eliminated in the network.

Pseudowire is viewed by the industry as a critical element in the next-generation network because it can preserve the legacy service revenue while introducing new broadband data services. Pseudowire provides a common encapsulation layer that can protect the service provider's current investment and provide a smooth migration path from circuit-based to packet-based networks.

The future optimal converged packet transport network shall leverage the combination of IP, Ethernet, MPLS and pseudowire technologies as key building blocks. Figure 2 shows the protocol stack of the converged packet network.

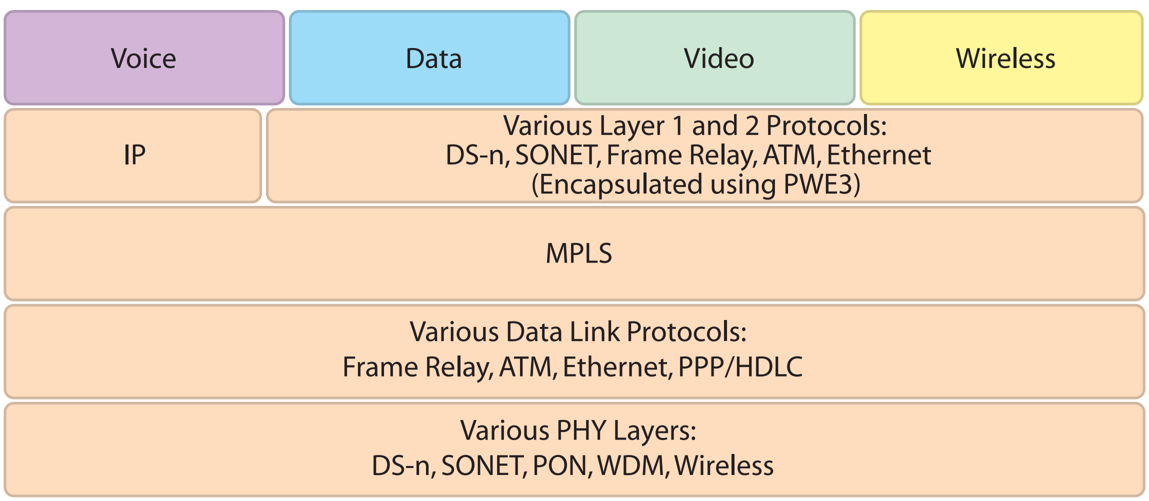

Figure 2: Converged Packet Transport Network Protocol Stack

What is Pseudowire?

A pseudowire is a bi-directional connection of two service ports of the same type (e.g., Ethernet, ATM, FR) across an underlying packet switched network. It emulates the essential attributes of a point-to-point connection (e.g., a wire) of a telecommunications service over a packet switched network. The PSN, which provides transport for pseudowire, can be either MPLS- or IP-based. A pseudowire is carried in a PSN tunnel, which is similar to a TDM trunk. The underlying PSN tunnel is a trunk that aggregates multiple pseudowires. For the PSN, the most appropriate pseudowire tunnel mechanism is an MPLS-based tunnel. An MPLS label accomplishes pseudowire demultiplexing. A pseudowire over an MPLS tunnel constitutes a two-label MPLS stack.

The IETF is developing the initial set of standards for pseudowire in the PWE3 working group. The focus of this work has been to support additional services over IP networks. ITU SG 15 has recently started work on a new recommendation—G.8010.1, "Applications of MPLS in the Transport Network." It is believed that MPLS-based packet transport only requires a subset of the IETF-specified MPLS and pseudowire technology. G.8010.1 will specify this subset. Figure 3 provides a pseudowire reference model.

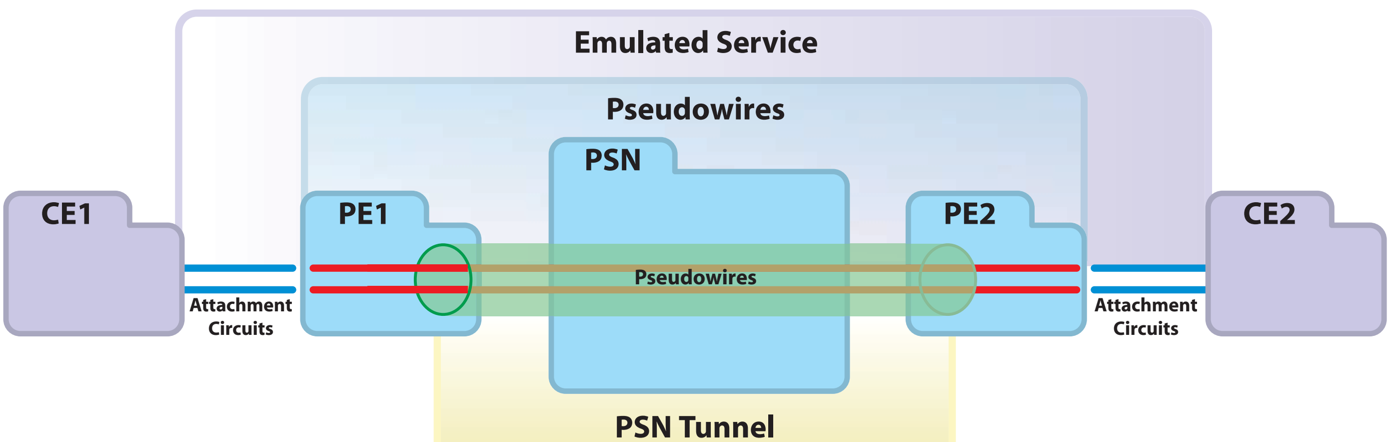

Figure 3: Pseudowire Reference Model

A pseudowire interconnects two attachment circuits of a chosen service across a PSN. An attachment circuit is a physical or virtual circuit, which connects a CE node to a PE node. An attachment circuit can be an Ethernet port, a VLAN, a FR or ATM virtual circuit, a DS1, DS3, or a SONET STS-3.

Pseudowires, which are carried by PSN tunnels, are similar in concept and application to SONET OC-3 and OC-12 paths that are carried in OC-48/OC-192 trunks. The PSN tunnel that carries pseudowires is similar to the SONET line layer. The link layer (e.g., Ethernet, SONET, DWDM) that transports the PSN tunnel is similar to the SONET section layer. Figure 4 shows the analogy.

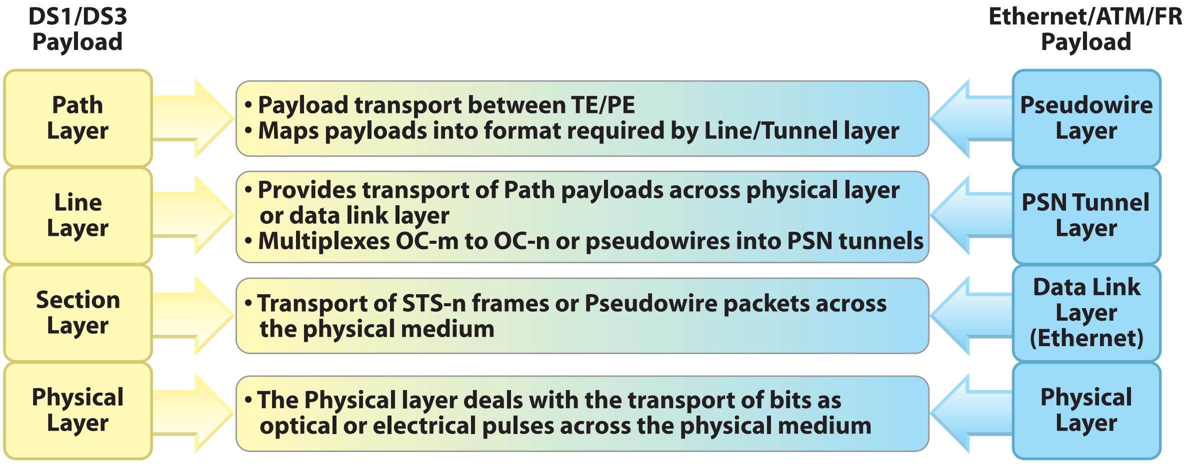

Figure 4: Pseudowire and SONET Layer Analogy

Pseudowire Benefits

An economic study [1] has shown that for an all data demand scenario, the packet-based transport network provides a 48% equipment cost advantage over the circuit-based transport network. In addition, it has a 68% collector ring and 36% IOF transport capacity advantage. This capacity advantage can be leveraged to route additional customer demands. These results were only based on a conservative 3:1 statistical multiplexing factor, so in reality, the gain shall be even better.

There are major savings and benefits of integrating pseudowire into the transport and access network:

- It allows statistical gain by multiplexing the traffic at the earliest point of the network. There is no stranded bandwidth as in a circuit-based network, which tends to underutilize the STS-1 when carrying DS1 traffic.
- It moves from the use of expensive, channelized TDM interfaces on MSEs into lower cost GigE interfaces.
- It allows grooming and switching with higher granularity in the packet level.

Figure 5 shows the converged packet-based transport network.

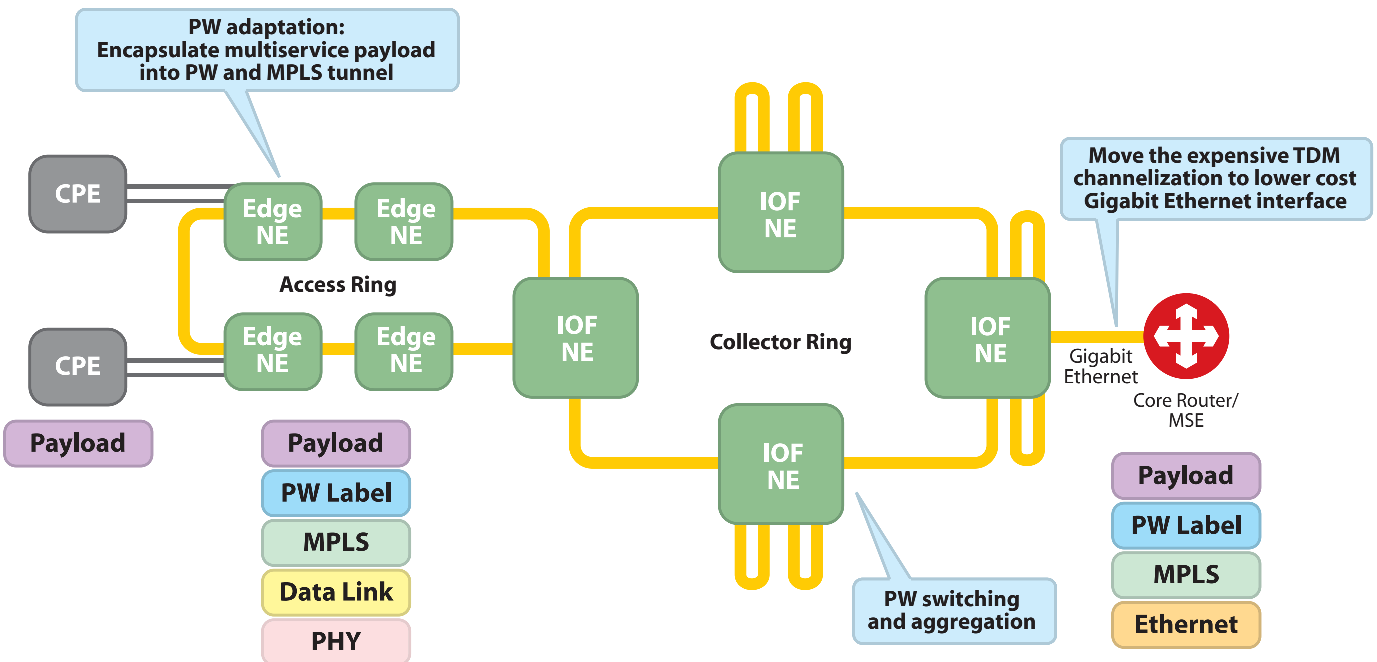

Figure 5: Converged Packet-Based Transport Network Architecture

What are the current trends in wireless networking?

Wireless operators are looking for ways to reduce cost and to generate new revenue. Migrating voice services to VoIP is on the move, although voice service alone will not justify the move to the packet-based network. New IP broadband services such as IM, video conferencing, Internet browsing, online gaming, VOD and others will help the migration.

What is 802.16 and WiMAX?

The IEEE has developed a broadband wireless access standard, 802.16, for systems in the frequency range below 66 GHz. The standard covers both the MAC and the PHY layers.

The IEEE 802.16a standard focuses on fixed broadband access, while the IEEE 802.16e standard is planned to be an extension to the approved IEEE 802.16-2004 standard. The purpose of 802.16e is to add data mobility to the current standard, which is designed mainly for fixed operation.

The WiMAX Forum is an organization of leading operators and communications component and equipment companies. Their charter is to promote and certify the compatibility and interoperability of broadband wireless access equipment that conforms to the IEEE 802.16 standard.

The IEEE 802.16 PHY layer governs non line-of-sight services and reduces the effect of multi-path. It allows wider channels, typically greater than 10 MHz in bandwidth. This gives the ability to provide high-capacity links on both the uplink and the downlink. The standard is designed to accommodate either TDD or FDD deployments, allowing for both full- and half-duplex terminals in the FDD case.

The IEEE 802.16 MAC layer is designed for very high bit rates of the broadband physical layer, while delivering ATM-compatible QoS; UGS, rtPS, nrtPS, and best effort. The MAC supports higher layer or transport protocols such as ATM, Ethernet or IP, and is designed to accommodate future protocols that have not yet been considered.

The 802.16 standard is designed to provide wireless last-mile broadband access in the metro, with performance comparable to DSL, cable and even T1 offerings. It can provide for fast service activation in remote areas that do not have a wired infrastructure, fill the gap in cable and DSL coverage and become critical in disaster recovery efforts.

How is Pseudowire used in Broadband Wireless Applications?

One of the primary broadband wireless applications is to backhaul traffic from the base station into the core network. The present model for most of the wireless operators is to lease the T1 line from the LECs to backhaul the wireless traffic. The current cost of leasing the T1 circuit is rather expensive, especially in rural areas. High bandwidth broadband wireless services such as Internet access, gaming, and email can be deployed when UMTS/3G, Wi-Fi and WiMAX technologies can provide higher speed and bandwidth. Consequently, the backhaul pipe to the core network becomes the bottleneck. Multiple T1s or T3 are required to increase the bandwidth, but it will impact the profit margin of the cost-sensitive wireless services.

Wireless operators are looking for ways to reduce their OPEX. Using copper or optically-fed Carrier Ethernet to backhaul broadband wireless traffic is cheaper and more scalable. The bandwidth can be provisioned from 1 Mbps up to 10 Gbps with finer granularity. As more wireless applications become IP-based, wireless operators are planning to migrate their network infrastructure to IP. However, there are still a lot of legacy networks which are ATM and TDM-based. MPLS and pseudowires will provide a smooth migration to an all-IP infrastructure that can support ATM, TDM, IP and Ethernet at the same time.

Figure 6 illustrates the 802.16 implementation of Wi-Fi hot spot backhaul. This application may be implemented as a PTP topology or PMP topology depending on the backhaul capacity requirements of each hot spot location. The WiMAX access point located at the hot spot location aggregates the traffic from multiple Wi-Fi access points and provides an 802.16-backhaul uplink to the WiMAX base station. It also illustrates the 802.16e implementation of a mobile broadband service network.

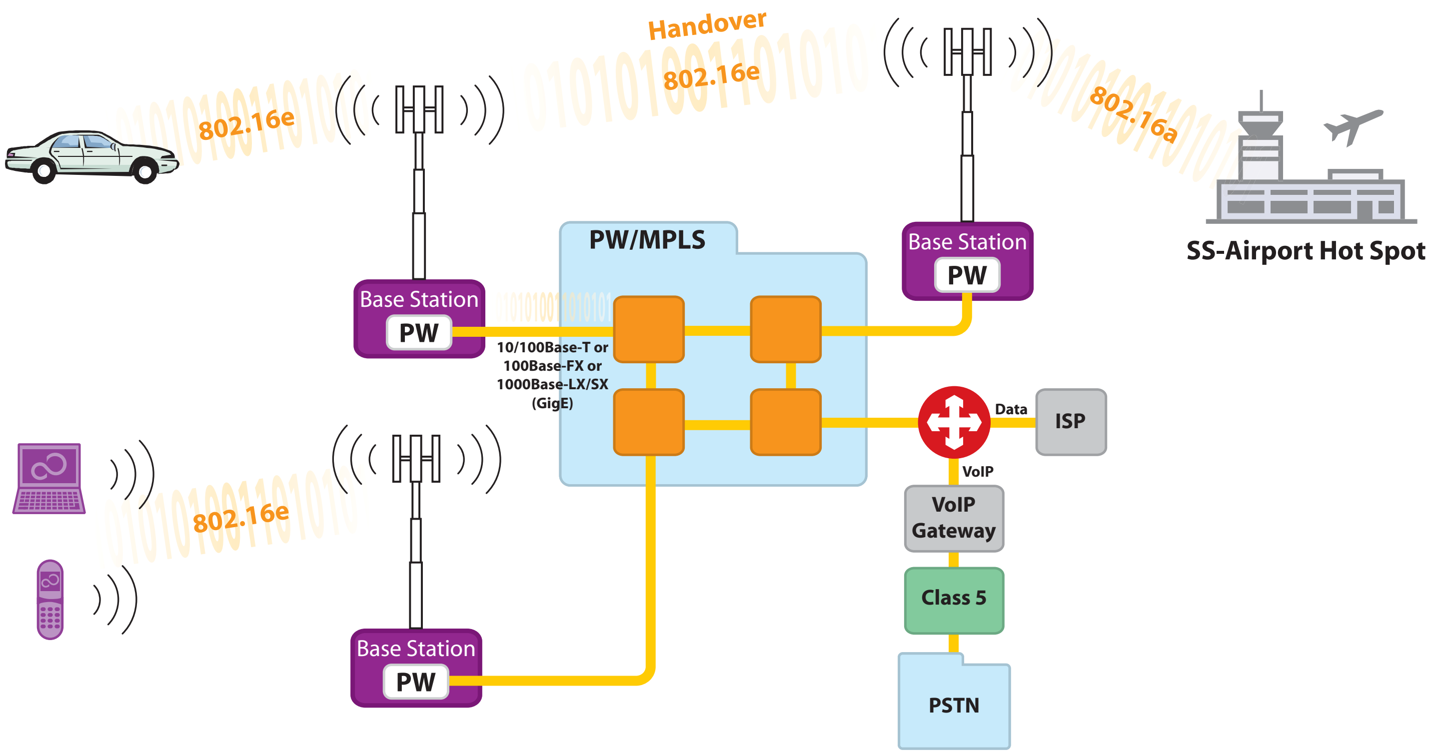

Figure 6: 802.16 Broadband Wireless Packet-Based Network

Challenges Ahead for a Converged Packet-Based Network

The next-generation converged packet-based transport market is still in its infancy. Management of the network will be a key issue. Service providers are comfortable with the current mode of operations, and any change will require new training and education.

Proper traffic management for multiple service classes in a large packet-based network will be challenging. Investing in too much silicon will increase the cost, but not investing enough will not be sufficient to provide QoS assurance to support SLAs.

Conclusion

The vision of network convergence is driven by packet-based services and the need for CAPEX and OPEX savings. The evolution of technology and applications is beginning to erase the barrier between different networks. Service providers tried to regain customers by bundling voice, data, video and even wireless services together. The need for a low cost, operationally efficient, and service performance guaranteed network creates a lot of challenges for service providers and equipment vendors. The next-generation, packet-based transport market is still in its early stages. However, the increased penetration of the new packet-based broadband wireline and wireless technologies such as DSL, PON, UMTS, and WiMAX can help push the reality of network convergence even closer.

Pseudowire will play a key role in the rollout of next-generation networks since it can preserve profitable legacy services and is flexible to accommodate new services. The core network will migrate to MPLS/IP, and in the future, it will extend to the access network as well.

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Acronym	Descriptor
ATM	Asynchronous Transfer Mode
CAPEX	Capital Expenditure
CE	Customer Edge
DSL	Digital Subscriber Line
DVB-ASI	Digital Video Broadcast-Alternate Space Inversion
DWDM	Dense Wavelength Division Multiplexing
EPL	Ethernet Private Line
FDD	Frequency Division Duplexing
FR	Frame Relay
FTTx	Fiber to the (curb, home, premise, etc.)
GigE	Gigabit Ethernet
GFP	Generic Framing Procedure
HDTV	High Definition Television
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IM	Instant Messaging
IOF	Inter Office Facility
IP	Internet Protocol
IPTV	Internet Protocol Television
LCAS	Link Capacity Adjustment Scheme
LEC	Local Exchange Carrier
MAC	Media Access Control
MPEG	Moving Picture Experts Group
MPLS	Multiprotocol Layer Switching
MSE	Multiservice Edge Switch
MSO	Multiple System Operator

Acronym	Descriptor
MSPP	Multiservice Provisioning Platform
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operating Expense
PE	Provider Edge
PHY	Physical
PON	Passive Optical Network
POS	Point of Service
PSN	Packet Switched Network
PTM	Point-to-Multipoint
PTP	Point-to-Point
PW	Pseudowire
PWE3	Pseudowire Emulation Edge to Edge
QoS	Quality of Service
RBOC	Regional Bell Operating Company
RPR	Resilient Packet Ring
SLA	Service Level Agreement
SONET	Synchronous Optical Network
TDD	Time Division Duplexing
TDM	Time Division Multiplexing
UMTS	Universal Mobile Telecommunications System
VCAT	Virtual Concatenation
VOD	Video on Demand
VoIP	Voice over IP
VPN	Virtual Private Networking
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access

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