SERVICE PROVIDER

Technical Brief: Next-Generation Wireless Backhaul Solutions

Many services, such as mobile Internet and mobile TV, require high bandwidth, and current backhaul infrastructures are not optimized to handle this traffic. Advanced routers and switches from Brocade enable highly scalable designs for the eventual convergence of voice and data infrastructure that can deliver new multimedia services.

BROCADE

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Executive Summary

Mobile operators are currently experiencing rapid growth in data services along with a steady growth in voice traffic. However, the voice market is extremely competitive and revenue growth is slow. They face the dual challenge of increasing average revenue per user and reducing customer churn. Service providers are seeking revenue and profit growth through new differentiated packet-based services. Many of these services, such as mobile Internet and mobile TV, require high bandwidth—and the current backhaul infrastructure is not optimized for handling such traffic. Hence, providers have to add backhaul capacity while keeping operational costs under control, a situation that is forcing carriers to migrate their access and core networks to the new 3G and 4G infrastructure. Further they must prepare for the eventual convergence of the voice and data infrastructures to deliver new multimedia services. Internet Protocol (IP)-based backhaul infrastructure solutions, using advanced routers and switches from Brocade, enable highly scalable designs for these converged networks.

Introduction

The Radio Access Network (RAN), the network between mobile devices and the core network, is evolving to accommodate rapid growth in data services and steady growth in voice traffic and to prepare for the next generation of services. *Wireless backhaul is the part of the network that carries voice and data traffic in the RAN from the mobile base xtation to the mobile operators' core network.* The costs of backhaul form a significant part of service providers' revenue. Since most infrastructures were initially designed for second-generation (2G) wireless networks to carry voice traffic, most consist of leased Time Division Multiplexing (TDM) and point-to-point microwave links. As more third-generation (3G) and fourth-generation (4G) services are offered, the bandwidth required for backhaul links increases quickly, and there is a need for network technologies that can efficiently handle voice and data traffic cost effectively. This leads to consideration of IP-based backhaul as a promising technology for 3G/4G networks.

Mobile operators are in a very competitive market with voice component of average revenue per user (ARPU) stagnant or even declining. In order to increase ARPU and reduce customer churn operators are offering newer services. Many of these new multimedia services such as mobile Internet and mobile TV are becoming popular and demand significantly higher bandwidth. Further, the old infrastructure was optimized for voice and was not designed for bursty nature of data traffic. As the mobile operators increase bandwidth in the backhaul networks, operation costs increase faster than revenues, and in some cases the backhaul infrastructure maintenance costs are as high as 25% of operating expenses (Infonetics Research, Radio Access Network Equipment Report 2006). Figure 1 shows the trend of revenue and traffic growth for a mobile operator. As the traffic mix changes from voice dominant to data dominant, the rate of traffic growth is much higher than the corresponding growth in revenue. Hence, to create a compelling business case for High-Speed Downlink Packet Access (HSDPA) and Evolution-Data Optimized (EV-DO) services, bandwidth must be increased in a cost-effective manner to preserve margins.

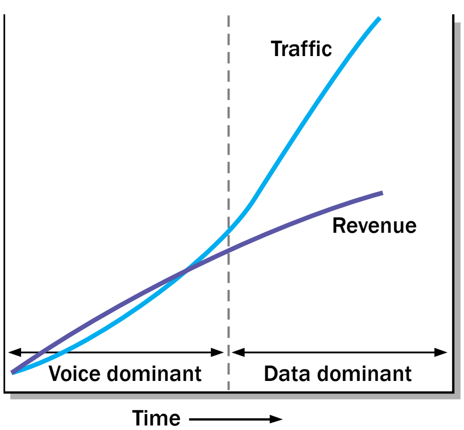

Figure 1. Growth trends in revenue and traffic requirements

IP-based backhaul using a converged voice and data infrastructure can help deliver the new multimedia services at an affordable cost. The IP network takes advantage of the bursty nature of traffic and can scale effectively, and the standards to support this backhaul infrastructure are in place. According to Infonetics Research, migration to an all-IP backhaul is underway but carriers are moving slowly. They predict a significant ramp from 2008 to 2011 primarily driven by the need to offer increased bandwidth at a beneficial cost point.

Reference Architecture

Figure 2 provides reference architecture for a mobile operator's network. The figure highlights the evolution in the UMTS RAN from TDM to ATM to all-IP, CDMA2000 network as well as Access Services Network in WiMax (IEEE 802.16e) networks. The rest of this paper focuses on the current backhaul options in the RAN as well as future migration to an all-IP RAN.

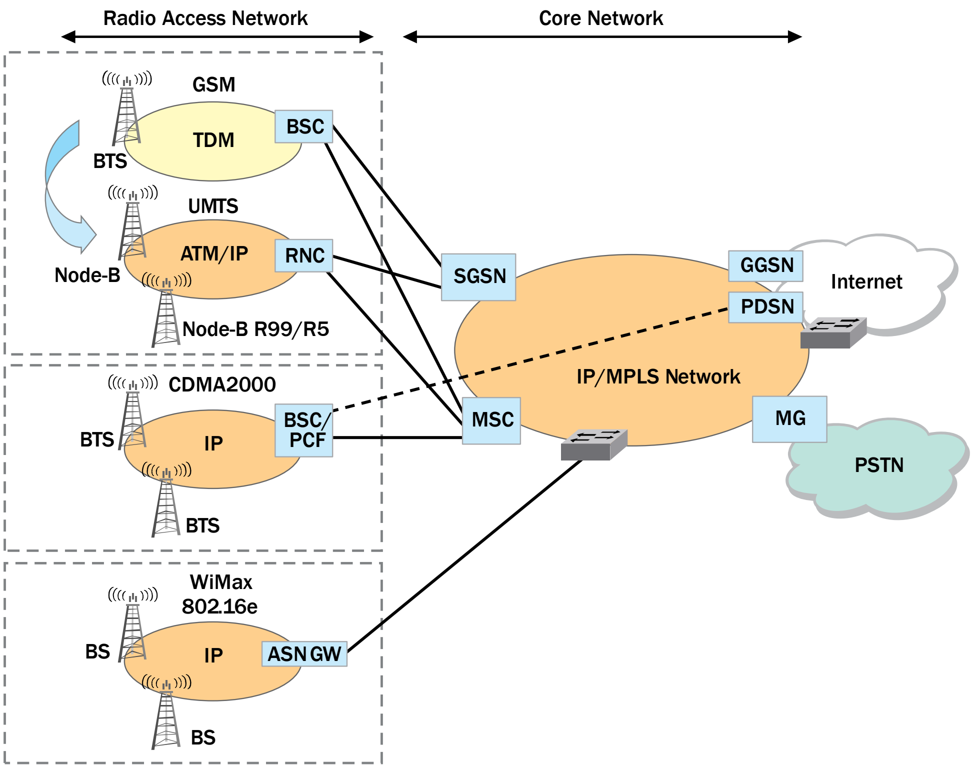

Figure 2. Reference architecture for wireless carrier network

Components of a Wireless Carrier Network

Base Station

A base station contains radio signal transmitting and receiving equipment. A base station is called a Base Transceiver Stations (BTS) in GSM and CDMA networks, and Node-B in Wideband-Code Division Multiple Access (W-CDMA)/UMTS networks. Base stations are connected to the central controller using the wireless backhaul network. Each base station can serve multiple cells.

Central Controller

Multiple base stations are connected to a central controller, which allocates radio channels, handles handoffs, and provides central control to all the base station elements. In GSM and CDMA networks the controller is referred to as the Base Station Controller (BSC), which in W-CDMA/UMTS systems is called the Radio Network Controller (RNC).

Serving GPRS Support Node

The Serving GPRS Support Node (SGSN) is the gateway between the central controller and the GPRS/UMTS backbone network and it mediates access to the network resources. It delivers data packets to and from the mobile station, mobility management for mobile station, and billing user data.

In CDMA networks, the Policy Control Function (PCF) routes IP traffic between the mobile station and the Packet Data Serving Node (PDSN). PCF and PDSNs together perform similar functions as the SGSN and Gateway GPRS Support Node (GGSN).

Mobile Switching Centre

The Mobile Switching Centre (MSC) is the gateway between the controller and the GPRS/UMTS backbone network and is responsible for handling voice calls and related services such as SMS, FAX, and so on. MSC also provides mobility management, user registration, and authentication services for mobile stations.

Gateway GPRS Support Node

The Gateway GPRS Support Node (GGSN) is the gateway between the GPRS/UMTS backbone network and the external IP network. It performs packet conversions required for transporting packets from the GRPS/UMTS core network to the IP network. GGSN is also responsible for IP address assignment and acts as the default router for the mobile station.

CDMA networks have Packet Data Serving Nodes (PDSNs) instead of GGSNs, which provide mobility management and packet routing functions. PDSNs manage the Point-to-Point Protocol (PPP) sessions with the mobile stations.

Media Gateway

The Media Gateway (MG) provides the interface between the service provider's backbone network to the Public Switched Telephone Network (PSTN). It performs necessary conversions for different transmission and coding techniques.

Wireless Backhaul

The wireless backhaul network is the part of the RAN that carries traffic from the base stations at the edge to the central controllers. It includes a variety of transport, aggregation, and switching elements. The transport mechanism can vary widely, however it is currently dominated by TDM leased lines and point-to-point microwave links. The next section describes backhaul options in more detail.

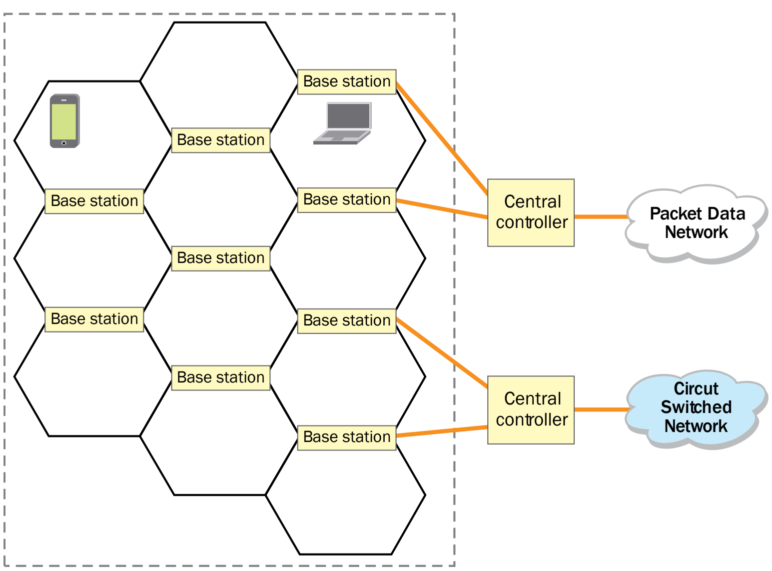

Figure 3. RAN architecture

Wireless Backhaul Options

Mobile carriers use various approaches for a backhaul infrastructure. Some of the most common approaches are described below.

TDM Leased Lines

Most US carriers and many international carriers use T1 leased lines for backhaul networks. TDM-based backhaul has been well utilized in primarily voice networks requiring fixed bandwidth per call. As the growth in packet-based services has increased, the overall bandwidth requirement has increased faster than the rate of revenue growth. The cost of the network increases linearly with the added bandwidth, as it involves leasing more T1 lines. These networks provide fixed bandwidth and cannot offer statistical multiplexing, which would be highly efficient for the transport of bursty data traffic.

Microwave and Free Space Optics

A popular option, particularly in Europe, the Middle East and Africa (EMEA) is fixed wireless transmission using microwaves. This involves point-to-point microwave links for connecting to the central controller. The use of microwave links capable of carrying Ethernet traffic is increasing in popularity and many carriers plan backhaul network expansion based on this approach.

Free Space Optics (FSO) is based on laser optics and provides a means for transport without the need to reserve a radio spectrum. The technology is particularly useful in areas where line-of-sight connectivity is available but laying out fiber is not economical or feasible. FSO is sensitive to weather changes and signal quality can degrade sharply in rain or fog. Although the links can go up to 10 km in distance, the practical range is limited to a few kilometers. The main attractions of this are fast installation due to use of light and unlicensed microwaves.

Worldwide Interoperability for Microwave Access (WiMAX) is growing in importance for fixed wireless networks. A number of carriers are evaluating this for their future network needs.

Asynchronous Transfer Mode (ATM)

ATM backhaul is an improvement over a TDM-based approach. It provides a packet-based network that is better for bursty data traffic. The network also has higher resiliency in the event of failure of certain network elements. It also provides a way to migrate to 3G traffic while leveraging the existing TDM infrastructure. It provides a better way to carry Ethernet/IP-based data traffic over the T1 links. UMTS Rel 99 defines ATM as the transport layer. ATM can also allow carriers to use SONET/SDH rings that are already in the metro networks.

Multi-Service Systems Using Pseudowires

Some carriers are evaluating multi-service systems that can aggregate legacy T1/E1s and ATM, as well as Ethernet using pseudowires. These pseudowires can connect through leased lines or metro Ethernet network to the central controller. Many solutions exist that can aggregate Inverse Multiplexing over ATM (IMA) and 2G TDM, and carry over pseudowires. Pseudowires technology has been used and is proven in wireline networks and offers a viable migration path to a pure IP-based solution.

xDSL/Cable Based

The widespread deployment of broadband networks in the last few years has made DSL access networks and cable networks an effective alternative to traditional methods of mobile backhaul. Mobile operators benefit by getting a viable alternative to costly leased lines and MSOs and CLECs can diversify and increase their revenue stream.

Satellite

Satellite links can be used to transport traffic and provide a suitable alternative in environments in which fast or short-term network deployment is required. These networks are primarily used to provide additional bandwidth for special events or to serve remote locations.

All-IP RAN

This appears to be the most viable and scalable approach for offering new and higher bandwidth services along with voice. The solution involves carrying IP traffic over legacy, native Ethernet, or Ethernet over microwave links. New standards, including 3G (UMTS R5/R6 and CDMA2000) and WiMax, already define interfaces for IP over Ethernet. Also more and more RAN equipment is available with Ethernet interfaces and this, coupled with the growth in the metro Ethernet networks, make the IP-RAN option more viable.

Advantages of All-IP RAN and Backhaul

An All-IP RAN addresses many of the issues of traditional backhaul alternatives and provides additional benefits.

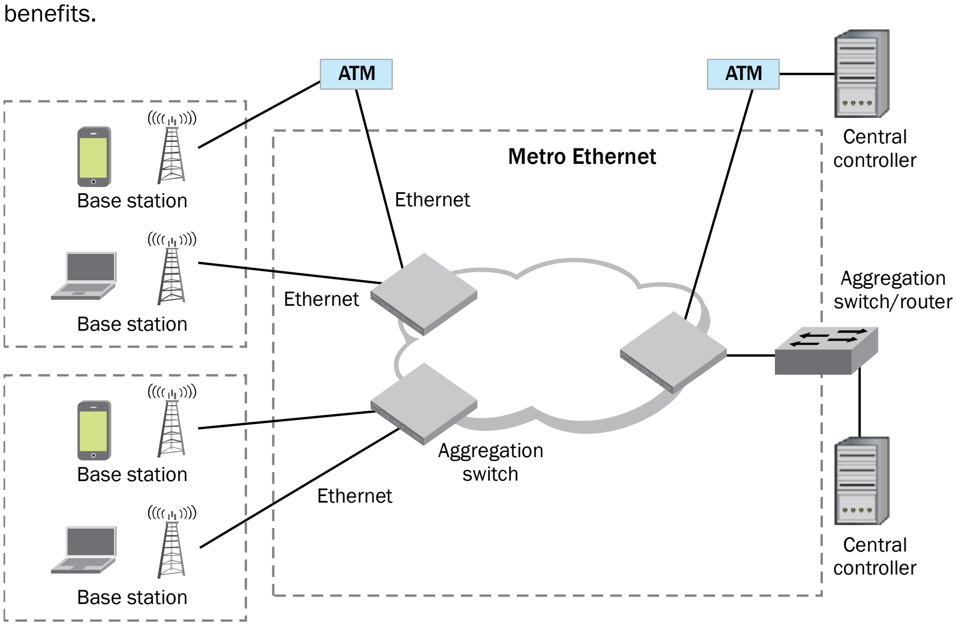

Figure 4. Reference architecture for an All-IP RAN

Following are some of the key advantages of this approach.

- It simplifies the network by providing a single technology that can run over a variety of transport technologies including legacy transport, native Ethernet, or Ethernet over microwave links. IP/Ethernet networks can be used for service convergence, providing the ability to deliver next-generation voice, data, and multimedia services over a single infrastructure.
- As subscriber traffic is increasingly becoming more data dominant, legacy TDM infrastructures prove to be suboptimal. An IP RAN provides the benefits of statistical multiplexing, thereby making efficient use of the available bandwidth.
- An IP over Ethernet infrastructure has the advantage of the bandwidth growth curve of Ethernet moving from 10 Megabits per second (Mbps) to 10 Gigabits per second (Gbps) today and 100 Gbps in future. This coupled with the decreasing cost of Ethernet ports provides growth opportunities with increasing economies of scale.

- The rapid deployment of metro Ethernet networks in the last few years provides mobile operators with access to carrier class and higher bandwidth networks. These networks have better scaling characteristics than fixed-speed T1/E1 links.
- Newer, and in many cases higher bandwidth services, are easier that provide differentiation opportunities to mobile operators are easier to deploy.

Key Considerations for Wireless Backhaul

Access Technologies

Radio technologies supported by the base station play an important role in determining backhaul network technology. Networks deployed today use Time Division Multiple Access (TDMA), Global System for Mobile Communications (GSM), CDMA, W-CDMA/UMTS, and CDMA2000/EV-DO. For all-IP RANs to be successful, interfaces must be well defined with most of the current radio technologies, that is, GSM, W-CDMA, CDMA and CDMA2000. TDMA networks are slowly being phased out, for example, Cingular/AT&T phased them out completely in 2008. In preparation for future converged networks, standards bodies have already defined IP and/or Ethernet interfaces for most multiple access technologies.

Migration

Many base stations are currently equipped with TDM and ATM equipment. While they need to eventually migrate to a packet-based infrastructure, new installation must allow co-existence with older base stations. The challenge is to backhaul traffic from the legacy base stations over the IP network. A transition path involving pseudowires to transport TDM over IP is a possible option, which usually requires Circuit Emulation over Packet Switching Networks (CESoPSN) or similar technologies.

Most next-generation networks will eventually migrate to an all Ethernet infrastructure. Base stations will be aggregated and transported over a metro Ethernet network to connect to the central controller. Many metro Ethernet networks have been rolled out by carriers and are currently used to provide services to business and residential customer over the same network. These networks are capable of offering Layer 2 and 3 Virtual Private Network (VPN) services to customers. In some locations Ethernet over microwave links will turn out to be a very effective solution as well, as it provides the benefits of Ethernet transport, rapid provisioning, and long-term cost benefits of microwave networks.

Quality of Service

The backhaul network will simultaneously carry voice and data traffic. The voice component of traffic along with some multimedia applications is highly sensitive to latency and jitter, so it is important to be able to classify and prioritize traffic in the network. Each network element as well as the network itself must be designed to provide reliable performance guarantees to voice and video traffic.

High Availability

Reliability and high availability of the network is essential for the backhaul network that supports a large number of simultaneous customers. Customers rely on the network for voice as well as emergency and data services and are used to the reliability associated with legacy infrastructure. The new infrastructure must be designed to maintain high availability and to function well with the core backbone. The network must also be designed to recover from equipment failures quickly enough to avoid discernable disruption in service.

Future-proof Infrastructure

Improving the scalability of the network and creating an infrastructure that makes it easy to provision new services are the primary forces driving a network migration. The network must be designed to allow additional users as well as future migration to 3G and beyond. As the cost of additional bandwidth must be much lower to create a meaningful business case for new services, larger pipes through use of Ethernet will be helpful.

The metro Ethernet network infrastructure required for backhaul will be used for providing many additional services to business and residential customers. The services include wireless backhaul, residential broadband and IPTV, and business VPN services. Carriers continue to evolve and differentiate these services to increase revenue. The equipment must be flexible enough to provide Layer 2 and 3 services for different customer types.

Time Synchronization

In order to understand the importance of synchronization, it is important to understand the workings of various wireless technologies. Wireless technologies use either Frequency Division Duplex (FDD) or Time Division Duplex (TDD) to divide the spectrum into various channels. Guard bands, that is, gaps left vacant between uplink and downlink traffic, are used to avoid interference. If the base stations are not time and/or frequency synchronized, they could interfere with nearby base stations due to clock drift. Networks have to be synchronized to a reference clock within a specified tight range to ensure mobile set handoff when it moves from one network to another. In backhaul networks using TDM, timing synchronization is available through the network. In an all-IP network an alternative approach is needed.

A Global Positioning System (GPS)-based receiver is one such alternative that can get accurate timing information. GPS is highly reliable and does not require a change in the network. However, it needs a clear view of the sky and that may present difficulty in some cases. Another approach is IEEE 1588 Precision Timing Protocol (PTP). This timing can be synchronized over the IP/Ethernet backhaul network. Reference clocks can be present in aggregation sites to synchronize clocks at base stations. PTP can be used independently and as a backup for a GPS receiver. Currently there does not seem to be a clear winner and both approaches satisfy the synchronization requirements for major networks.

Brocade's Wireless Backhaul Solutions

Brocade provides a wide variety of network infrastructure options for wireless backhaul networks that require high availability, low latency, low jitter, and Operations, Administration and Maintenance (OAM) capabilities. The products offer network level resiliency, hardware-based Quality of Service (QoS), easy manageability, and flexible network processor-based architecture. Some of these products include:

- The **NetIron® XMR Series** of high-end, carrier-class, MPLS backbone routers. Available in four form factors (NetIron XMR 4000, XMR 8000, XMR 16000 and XMR 32000), routers are designed from the ground up for high performance and scalability to address the needs of the most demanding converged networks. They offer full Layer 2, Layer 3, and advanced MPLS capabilities. The XMR routers offer wire-speed performance on all ports, full IPv6 routing today, and 100 Gbps of user bandwidth per full slot.

- The **NetIron MLX Series** of metro switching routers, with full Layer 2, Layer 3, and advanced MPLS capabilities. Available in four form factors, the NetIron MLX Series is the only MPLS-enabled metro switching router that offers wire-speed performance on all ports, full IPv6 unicast and multicast routing today, and 100 Gbps of user bandwidth per full slot. The NetIron MLX Series offers unparalleled flexibility to providers choosing the right network design and is specifically designed for advanced capabilities needed for voice, video, and data edge networks.

- The **NetIron CES 2000 Series** of compact edge/aggregation switches are purpose-built for Carrier Ethernet service delivery. The switches offer 24 – 48 ports of 1 GbE and optionally, 2 x 10 GbE ports in a 1U compact form factor. Built for compliance with MEF9 and MEF14 specifications, the NetIron CES 2000 Series of switches support both Provider Backbone Bridging (PBB) and Provider Bridging (PB) technologies. When used in combination with the NetIron XMR/MLX product families, scalable Carrier Ethernet services can be delivered by combining VPLS/VLL technologies in the core with PB/PBB technologies at the edge of the network.

- The **FastIron® Edge X (FESX) Series** of compact switches offer 24 – 48 ports of 1 GbE and optionally, 2 x 10 GbE ports in a 1.5U compact form factor. Availability of both copper and fiber interface options for the 1 GbE ports makes it an appealing choice for aggregating traffic from several access nodes that are either co-located or geographically distributed.

- The **FastIron Edge Switch (FES) Series** of compact switches deliver a highly adaptable feature set combined with the highest 10/100 Base-TX and GbE port densities in its class. FES switches provide feature-rich switching and Layer 3 multi-protocol routing capabilities, comprehensive hardware and software redundancy, complete QoS controls (including prioritization and rate limiting), and integrated copper GbE ports. This makes it a great choice for a range of applications from aggregation to converged voice, video, and data.

Figure 5 shows a sample topology along with the products available for each part of the network.

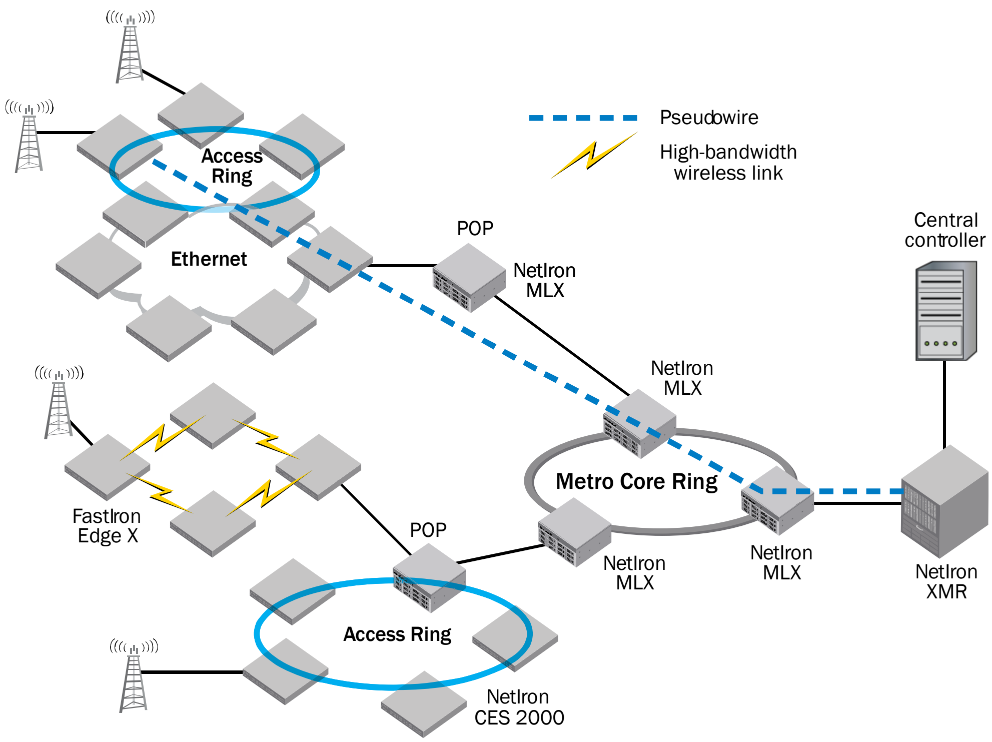

Figure 5. Example architecture for wireless B=backhaul using Brocade routers and switches

ADVANTAGES OF BROCADE BACKHAUL SOLUTIONS

Brocade offers a broad range of high performance routing and switching products for next-generation wireless backhaul and core networks. The products are offered in multiple form factors to suit the needs of most network infrastructures. The products support full featured Layer 2, Layer 3, and advanced MPLS capabilities to provide operators flexibility in choosing a network design to offer complete solutions for converged networks.

High Availability

High availability is achieved through a combination of hardware and software architecture. Brocade NetIron XMR and MLX architectures feature a fully redundant design with no single point of failure. All system modules are hot pluggable and removal of any system module does not impact the performance of the rest of the platform. These platforms are designed for NEBS and ETSI compliance. The modular architecture of

Multi-Service IronWare® operating system has several high availability features that distinguish it from legacy operating systems running on other routers:

- Industry-leading cold restart time of less than a minute
- Support for hitless software upgrade
- Hitless Layer 2 and Layer 3 failovers with graceful restart for BGP and OSPF
- Sub-second switchover to the standby management module if a communication failure occurs between active and standby management modules

The capabilities increase network-level reliability by minimizing the impact of a node failure. The MPLS feature set includes path protection and Fast Reroute (RFC 4090) to ensure 50 ms failover around failed links or nodes. The combination of hardware and software architecture, as well as network-level reliability makes this an ideal platform for wireless backhaul networks.

Quality of Service

The Brocade NetIron XMR/MLX platforms offer hardware-based QoS to prioritize the use of available bandwidth and to manage congestion in the aggregation and core layers. Weighted Random Early Discard (WRED) can be used for congestion avoidance. WRED enables the system to detect signs of congestion and take corrective action, so that the system can selectively discard higher-drop precedence traffic when the system becomes congested.

When QoS features are enabled, arriving traffic is classified and processed based on packet priorities. Packet prioritization can be based on:

- Layer 2 Class of Service (CoS) as defined in IEEE 802.1p
- Layer 3 IP precedence as defined in RFC 791
- Layer 3 Diff-Serv Code Point (DSCP)
- MPLS EXP

The platform has extensive packet marking capabilities to allow changing of QoS information for treatment in next hop. This is useful when the packet is traversing from one network to another. The platform also supports remarking of packet priority based on the result of 2-rate 3-color policer. Additionally, tiered QoS guarantees can be obtained by using scheduling mechanisms such as strict priority, weighted fair queuing, or a combination at the output port.

A unique characteristic of the NetIron XMR/MLX routers is the use of a distributed buffering scheme that maximizes the utilization of buffers across the whole system during congestion. This scheme marries the benefits of input-side buffering (virtual output queuing) with those of an output port-driven scheduling mechanism. Input buffering using virtual output queues ensures that bursty traffic from one port does not take up too many buffers on an output port. An output-port-driven scheduling scheme ensures that packets are sent to the output port only when the port is ready to transmit a packet. Additional details on the system architecture are available in the Brocade NetIron XMR Architecture white paper, available on www.brocade.com.

For the network edge, the Brocade NetIron CES 2000 and FES/FESX platforms provide a rich set of QoS controls. The FES/FESX platforms support packet prioritization based on 802.1p, Type of Service (ToS), DSCP, and Access Control Lists (ACL). They offer flexibility in queuing methods supporting Weighted Round Robin (WRR), strict priority queuing, or a combination. In addition, the NetIron CES 2000 supports up to 8 queues per port, each with a distinct priority level. Advanced QoS capabilities such as the use of 2-rate, 3-color traffic policers, egress shaping, and priority remarking can also be applied to offer a deterministic “hard QoS” capability to customers of the service.

The Brocade NetIron XMR/MLX routers, CES 2000 switch, and FES/FESX switches provide full line-rate forwarding throughput for all ports. These hardware-based QoS features, low latency platforms, and efficient bandwidth management can be used to design networks without packet loss and with very low latency and jitter.

Scalability

Brocade NetIron XMR/MLX platforms are highly scalable and available in four different form factors (4, 8, 16, and 32 slot chasses), providing service providers with the flexibility to choose a platform that fits current and projected future needs. The XMR supports 4K VLANs and up to 2 million MAC addresses, 1 million IPv4 routes in hardware, 240K IPv6 routes, 10 million BGP routes, 16K VPLS instances, and 2K BGP/MPLS VPNs. The MLX platform supports 4K VLANs and up to 1 million MAC addresses, 512K IPv4 routes in hardware, 112K IPv6 routes, 2 million BGP routes, 4K VPLS instances, and 400 BGP/MPLS VPNs[1]. These platforms lead the industry in port density and line-rate throughput.

Service Flexibility

Brocade NetIron XMR/MLX platforms are feature rich and offer Layer 2, Layer 3, and advanced MPLS capabilities in a single platform. They are deployed in VLL, VPLS and BGP/MPLS VPN networks, making them ideal for offering converged business, residential, and mobile services. The FastIron Series offer high performance at the network edge with advanced Layer 2 and Layer 3 features.

MPLS and Pseudowires

Brocade NetIron XMR and MLX platforms support industry-leading MPLS and pseudowire features, and can function both as edge and transit nodes. The platforms support Ethernet pseudowires, and also work with devices that aggregated traffic onto pseudowires and feeds to NetIron products.

Flexible Interfaces

Brocade routers and switches support a wide variety of interfaces featuring one of the highest densities in the industry. The supported interfaces include 10/100/100 0Base-T, 100 Base-FX, Gigabit Ethernet, 10 Gigabit Ethernet, and SONET/SDH (OC-12c/STM-4, OC-48c/STM-16, OC-192c/STM-48).

SUMMARY

Mobile operators have been growing backhaul networks to address the new trend of shifting traffic from voice to packet-based services. However the current approach of adding T1 lines is turning out to be very expensive. To address growing bandwidth requirements, prepare for the convergence of voice and data to a single network. To reduce the cost of incremental bandwidth, operators are looking at IP-based RAN solutions. IP traffic over Carrier Ethernet Networks and microwave links appears to address the requirements well.

Brocade routers and switches enable a wide variety of solutions that make it easier for mobile operators to deploy a highly scalable, next-generation infrastructure. The products feature high-availability design, MPLS, pseudowires, robust Layer 2 and 3 protocols, IPv6 routing, Layer 2 and 3 VPNs, and a flexible architecture to adapt to changing standards. These features along with advanced Quality of Service (QoS), high platform capacity, and low latency and jitter make the products an ideal fit for scalable, cost effective 3G/4G wireless backhaul.

[1] Scalability limits dependent on configured system parameters, system profile selected, and routing database complexity.

APPENDIX A: ACRONYM LIST

The following acronyms are industry standard and provided here for your reference.

2G	Second-generation wireless networks
3G	Third-generation wireless networks
4G	Fourth-generation wireless networks
ARPU	Average revenue per user
ATM	Asynchronous Transfer Mode
ASN	Access Service Network
BSC	Base Station Controllers
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CLEC	Competitive Local Exchange Carrier
CoS	Class of Service
DSCP	Diff-Serve Code Point
EV-DO	Evolution-Data Optimized
FDD	Frequency Division Duplex
FRR	Fast Re-Route for MPLS
FSO	Free Space Optics
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Services
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HSDPA	High-Speed Downlink Packet Access
IMA	Inverse Multiplexing over ATM
IP	Internet Protocol
MG	Media Gateway
MPLS	Multi-Protocol Label Switching
MSC	Mobile Switching Center
MSO	Multiple Service Operator
OAM	Operations Administration Maintenance
PCF	Packet Control Function
PDSN	Packet Data Service Node
POP	Point of Presence
PSTN	Public Switched Telephone Network
PTP	Precision Timing Protocol
QoS	Quality of Service
RAN	Radio Access Network

RNC	Radio Network Controllers
SDH	Synchronous Digital Hierarchy
SGSN	Serving GPRS Support Node
SONET	Synchronous Optical Network
TDD	Time Division Duplex
TDM	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications Systems
UTRAN	UMTS Terrestrial Radio Access Network
VLAN	Virtual Local Area Network
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
W-CDMA	Wideband-Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
xDSL	Digital Subscriber Line (all variants)