



SERVICE PROVIDER

Brocade-RAD-Symmetricon Mobile Backhaul Solution

Presents a brief overview of the mobile backhaul market, illustrating the unique challenges facing mobile operators and backhaul transport providers and describing strategies for commercially viable transport of multi-generation mobile technologies; stresses the performance criteria mobile operators expect if they are to trust their backhaul network to third parties.



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INTRODUCTION

With rising demand for mobile broadband services due to the ever-increasing proliferation of cellular phones, PDAs, and other mobile communication devices, operators are seeing a sharp increase in bandwidth requirements. To keep pace with demand, operators must migrate to new packet backhaul networks that offer increased capacity at lower cost, while providing the necessary service, reliability, and quality of experience. However, migrating from TDM to Ethernet backhaul does not come without challenges, one of which is how to maintain precise timing and frequency for applications such as Gigabit Passive Optical Network (GPON), mobile backhaul, and LTE.

The Brocade®-RAD-Symmetricon mobile backhaul solution is a validated end-to-end (E2E) solution delivering a graceful evolution to packet backhaul in support of all mobile generations, including 4G. It provides flexible access/aggregation transport options, including native Ethernet/MPLS, and enables the cost effective delivery of new IP-based services requiring high bandwidth and superior Quality of Service (QoS). This joint solution from Brocade and partners meets and exceeds the requirements for backhauling applications.

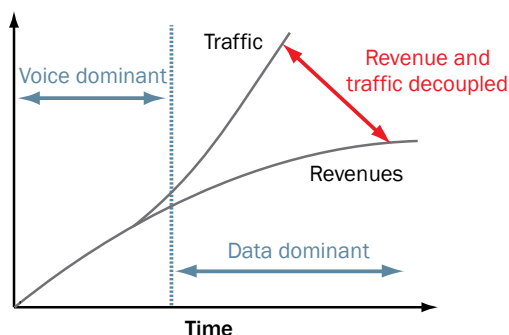
This paper presents a brief overview of the mobile backhaul market, illustrates the unique challenges facing mobile operators and backhaul transport providers, and describes strategies for commercially viable transport of multi-generation mobile technologies. In particular, it stresses the performance criteria that mobile operators expect if they are to trust their backhaul network to third parties, focusing on the business and technical challenges that transport providers face as their networks evolve to Ethernet, IP, and Multiprotocol Label Switching (MPLS) in support of traffic from mobile operators.

MOBILE BACKHAUL TRENDS UPDATE

Following are industry trends in the mobile backhaul space:

- Mobile backhaul equipment spending increased 21 percent in 2009, to \$7.2 billion worldwide*
- Mobile backhaul equipment market to growth to \$10.4 billion by 2014*
- Almost 1.5 billion new mobile subscribers and approximately 1.2 billion new mobile broadband subscribers between 2010 and 2014, which will require more base stations and cell site connections, higher backhaul capacities, and equipment for each cell site connection*
- Most wireless operators have backhaul plans in place in the major markets, so most backhaul growth in the future will be in building out second- and third-tier markets for 3G and 4G coverage**
- “Ethernet Quickly Eclipsing T1s for Backhaul” (Source: Light Reading)
- Two of every three towers already has more than one mobile operator on it
- Growing dependence on mobile connection for business applications

*Infonetics Research, “Mobile Backhaul Equipment, Installed Base & Services Market Outlook,” 2009



Mobile operators typically use expensive leased lines, which were never designed to handle the volume of data traffic required today, to backhaul traffic in mobile networks. As shown in the graph (Source: Infonetics Research, 2009), emerging 3G/4G service offerings require significantly more bandwidth at a much lower cost per bit. For mobile operators to reach profitability targets, while providing untarnished performance, wireless service providers must increase the capacity of the backhaul, and reduce the cost per bit delivered to keep pace.

This is where transport providers have a significant opportunity to generate incremental revenue by focusing on the rapidly growing backhaul market. To be successful, they must offer mobile operators less expensive and more scalable backhaul options than today's typical T1 or E1 connections. Importantly, the wholesale services must meet or exceed the performance criteria required by mobile operators for timing, packet loss, delay, jitter, and availability to support 2G, 3G, and 4G cellular protocols. In addition their solutions must include circuit validation and diagnostic capabilities to reduce OpEx and powerful Operations, Administration, and Maintenance (OAM) mechanisms to defend their guaranteed Service-Level Agreement (SLA).

ADDRESSING BACKHAUL CHALLENGES

The following are challenges for mobile operators around backhaul operations:

- Expand service offering and capture share of rapidly growing backhaul market
 - ✓ Offer less expensive backhaul options than today's typical T1 or E1 connections
 - ✓ Scalable bandwidth for unpredictable needs
 - ✓ Performance monitoring with threshold notifications
 - ✓ SLA assurance (delay, jitter, packet loss and availability)
 - ✓ Accurate frequency reference: better than 16ppb, SyncE, 1588-2008, GPS
 - ✓ Network redundancy: LAG (802.3ad), Multi-Chassis Trunking (MCT), dual homing, RING (G.8032), EVC protection (G.8031)
 - ✓ Redundant power options (24/48/AC) for connection to A/B sources at cell towers
- Cost-effectively upgrading best-effort metro Ethernet network to carrier Ethernet
 - ✓ Powerful traffic engineering capabilities, including traffic classification, policing, hierarchical scheduling, and per-EVC shaping to ensure end-to-end QoS.
 - ✓ Support color-sensitive P-bit remarking to ensure metering continuity in color-blind networks, as well as in color-aware networks with no "discard eligible" support
 - ✓ Standards-based Ethernet OAM for connection fault management, performance monitoring, and SLA assurance.
 - ✓ Mapping priority from base station to Ethernet Access to MPLS
- Extend facilities and services to more cell sites
 - ✓ Flexible interface options (fiber, TDM, SONET, Ethernet)
 - ✓ Support multiple mobile operators per tower using common facilities
- Minimize CapEx with all-in-one capabilities
 - ✓ Integrated demarcation, service assurance, packet ring, timing, and circuit emulation functionality
 - ✓ Cost-effective ordering options
- Minimize OpEx with integrated management and diagnostic tools
 - ✓ All-in-one reduces homologation, inventory, maintenance, provisioning, and training expenses
 - ✓ Simple turn-up including circuit validation (RFC-2544 and in-band facility loopbacks)
 - ✓ Reducing truck rolls with the help of fault detection and analysis tools

CARRIER ETHERNET SERVICE DELIVERY: FOCUS ON WHOLESALE MOBILE BACKHAUL

Wholesale backhaul is typically the catalyst for service providers offering best-effort Ethernet services to enhance their offering and provide carrier Ethernet services to retail carriers and enterprise customers. While this solution focuses on wholesale mobile backhaul, it can be easily adapted to cover other wholesale and retail service delivery. It includes features such as stringent QoS, powerful OAM, SLA assurance, circuit validation, and diagnostics critical for carrier Ethernet service delivery. The solution also features Time-Division Multiplexing (TDM) pseudowire and precise clock recovery features, which are targeted more at the mobile backhaul market.

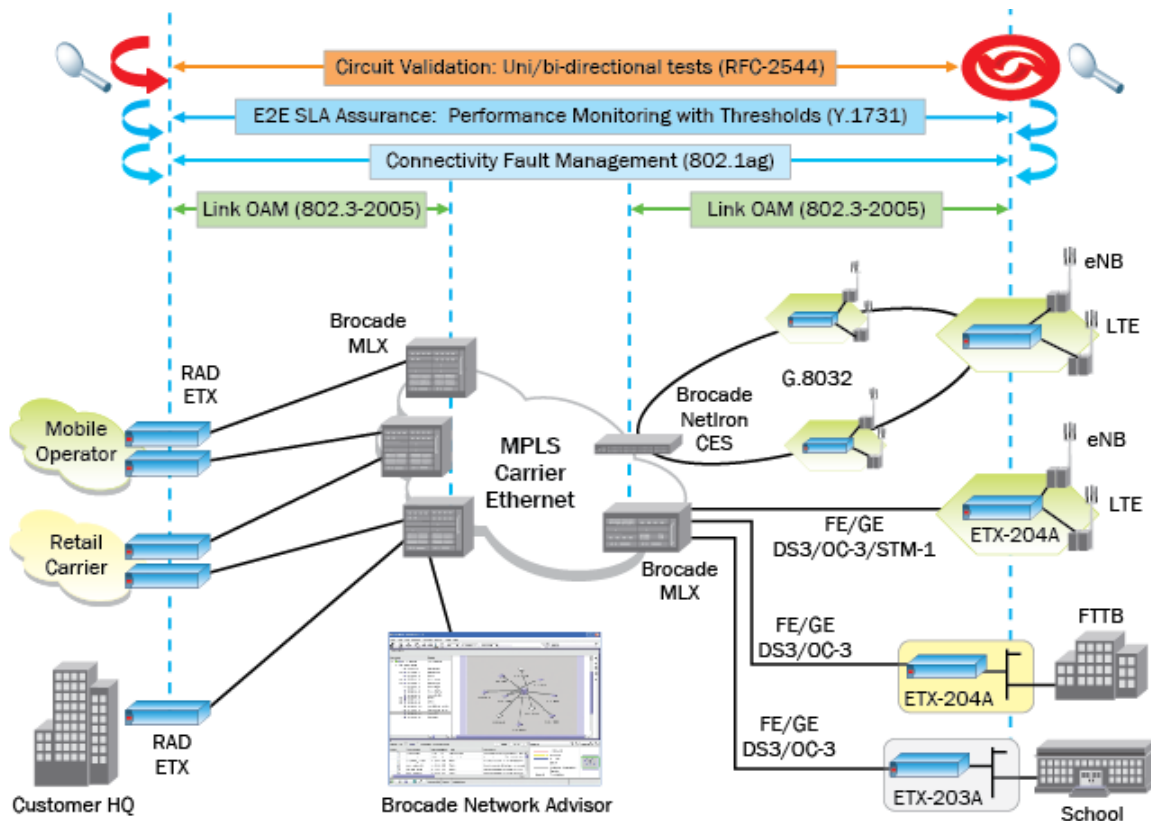


Figure 1. Mobile backhaul solution configuration

In the solution configuration, shown in Figure 1, RAD ETX and Brocade MLX and Netron® CES products were validated in the areas described in the following sections.

Quality of Service (QoS)

QoS enables better service to certain flows over others. This is achieved by mapping traffic types, such as sync, control, signaling, streaming, interactive, and background traffic, into Classes of Service (CoS) and then prioritizing traffic to ensure QoS/CoS is maintained.

RAD and Brocade validated end-to-end QoS starting with comprehensive traffic management at the demarcation device and continuing across network. This included:

- RAD ETX performing the following functions:
 - ✓ Classifying traffic from the base station according to DSCP, VLAN P-bit, IP address, and so on
 - ✓ Policing to ensure CIR/EIR/CBS/EBS bandwidth profiles are maintained per flow
 - ✓ P-bit remarking according to “color” to ensure service consistency and QoS continuity across network
 - ✓ Hierarchical scheduling to ensure that high-priority traffic is not dropped.
 - ✓ Per-EVC shaping to conform egress traffic to a specific line rate
- Brocade MLX/Netron CES mapped priority correctly from Ethernet to MPLS and back again by mapping VLAN .p to EXP bits and EXP to VLAN .p bits, as shown in Figure 2.

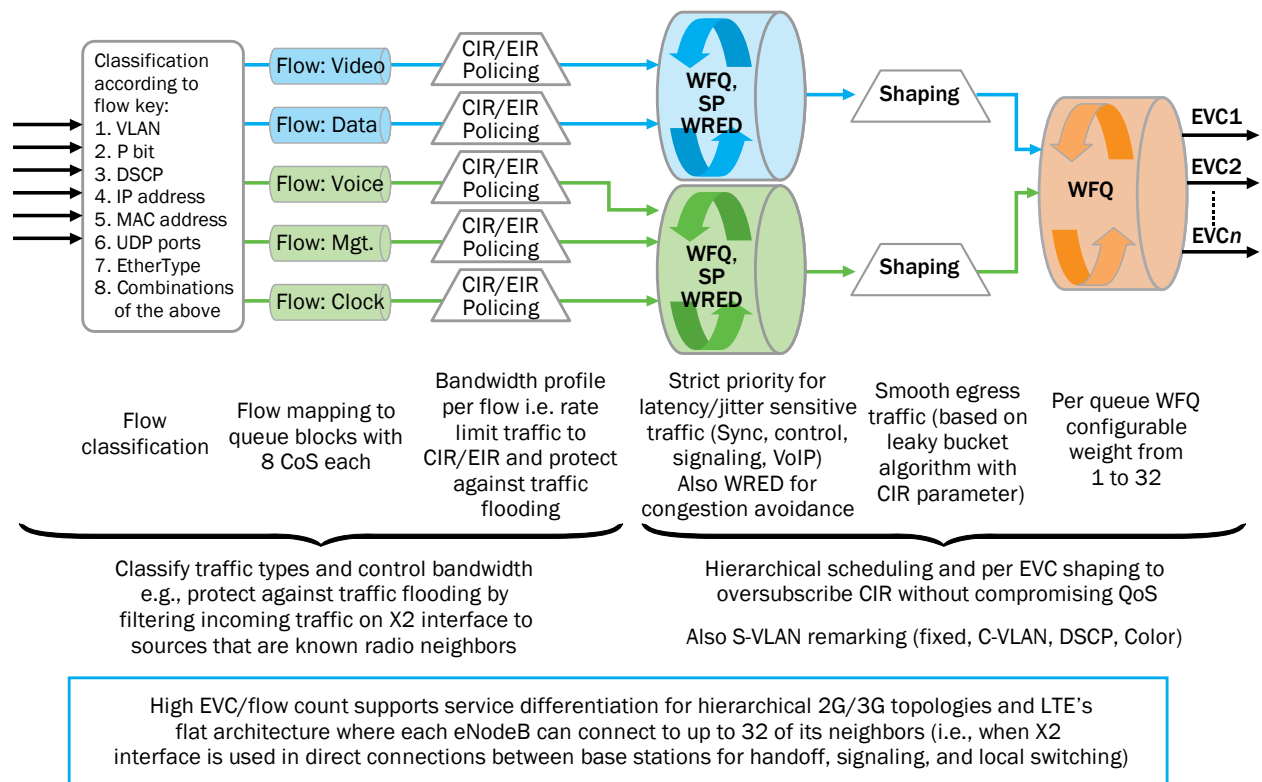


Figure 2. Priority traffic mapping

Operations and Maintenance (OAM)

OAM is used to monitor the health of a network and diagnose problems without maintenance truck rolls. OAM is required for connectivity verification, especially for connectionless protocols such as Ethernet (otherwise when there is no traffic, there is no verification of connectivity). The Ethernet OAM standard IEEE 802.3-2005 is important for link monitoring procedures, including auto-discovery, heartbeat, and fault notification messages; link statistics; MIB variable retrieval; and remote loopbacks. IEEE 802.1ag and ITU-T Y.1731 provide mechanisms for Connectivity Fault Management (CFM) and Performance Management (PM) over any path, whether single link or end-to-end, allowing the service provider to manage each EVC separately regardless of the underlying transport.

IEEE 802.3-2005

Single segment: IEEE 802.3-2005 (formerly 802.3ah Ethernet in first mile) interoperability between the Brocade MLX/Netron CES configured for active and the RAD ETX configured for passive was validated in tests and includes the functions in Table 1.

Table 1. 802.3-2005 functions tested on Brocade and RAD devices

802.3ah Capability	Brocade MLX and Netron CES	RAD ETX-204A
OAM capability discovery	✓	✓
Active and passive modes	✓	✓
OAM events: link fault/dying/gasp/critical	✓	✓
OAM loopback control	✓	✓

ITU-T Y.1731 and IEEE 802.1ag

The solution supports hardware-powered OAM for end-to-end connection fault management and performance monitoring. Some of the benefits of software- and hardware-based OAM are shown in Table 2.

Table 2. Comparison of the benefits of software- and hardware-powered OAM

Feature	SW-powered OAM	HW-powered OAM	OAM Benefits of HW-Powered
OAM scalability	✗	✓	OAM rate is limited only by physical line speed
Multi-flow monitoring	✗	✓	Monitor multiple concurrent flows simultaneously
Fast detection of connectivity failure	✗	✓	Fast failure restoration < 50 ms
Accurate frame loss measurements	✗	✓	Detects even one lost frame
Accurate frame delay/frame delay variation	✗	✓	Ensures accurate FD/FDV results (microsecond resolution)
OAM loopback at line rate	✗	✓	Test throughput using RFC-2544 at any rate and MTU sizes
MIP support	✗	✓	Fully participate as a Maintenance Intermediate Point (MIP) between MEPs

E2E SLA ASSURANCE: PERFORMANCE MONITORING AND THRESHOLDS

End-to-end SLA monitoring, based on ITU-T Y.1731 can be defined across the network to allow service providers to measure parameters such as frame loss, frame delay, frame delay variation, and availability on a per-service basis (EVC + CoS). In addition to providing real-time and interval-based statistics, service providers can now also define performance objectives that conform to SLAs and proactively monitor end-to-end SLA with traps sent when SLA thresholds are crossed.

Circuit Validation and Diagnostics

Remote diagnostic loopback tests are performed on demand at service turn-up and, once the service is running, to enable quick isolation of problems and minimize false repair calls. The solution supports the RFC-2544 standard for test generation and reporting using OAM frames of various sizes as well as multiple, simultaneous, always-on MAC/IP swap loopbacks that allow transport providers to offer retail and mobile customers the ability to test their own Ethernet circuits non-intrusively.

RFC-2544

When turning up a new Ethernet service, it is vital to provide performance metrics for the Ethernet network under test. RAD ETX-A demarcation devices incorporate RFC-2544 generator for E2E circuit validation over Brocade-powered network (VLL or VPLS) including the following capabilities:

- Unidirectional or bidirectional tests (using OAM frames)
- Measurements of throughput, latency, and frame loss
- Creation of throughput, packet loss, and latency test reports

Diagnostic loopbacks

Support for always-on MAC/IP swap loopbacks is analogous to T1 in-band facility loopbacks, because they allow customers to test their circuit or diagnose problems without coordinating effort with the transport provider. It is superior to T1 in-band facility loopbacks because the loopback criteria are configurable and supported non-intrusively across switched/routed networks.

Redundancy Tools

The solution ensures high service availability with a rich assortment of network redundancy capabilities including LAG (802.3ad), dual homing, Multi-Chassis Trunking, RING (G.8032), linear/EVC protection (G.8031) as well as equipment redundancy with dual power supply options in the demarcation equipment and full module redundancy in the core. Sometimes customers prefer to buy dual VLANs from the transport provider and take care of the redundancy themselves. This scenario is also fully supported including allowing the customers primary and backup VLANs to share a single bandwidth profile to ensure they only get the bandwidth they pay for.

Fault Propagation

In the event of a network fault, it is important that the demarcation device notify the subscriber so that critical traffic can be rerouted. This is achieved with the help of Continuity Check (CC) messages sent across the network. Network failure causes LOS at the remote sites, which in turn shut down user ports or provide ETH AIS.

Access Interface Options

In addition to Ethernet over fiber access options, the RAD/Brocade solution supports RAD MiRiCi-T3E3 and MiRiCi-155 SFPs to provide DS3, E3, OC3 and STM-1 backhaul options.

TDM Pseudowire

Despite the trend toward LTE, mobile operators still have extensive 2G/3G networks and typically require T1/E1 and Ethernet backhaul services. Therefore TDM pseudowire or circuit emulation is an important complement to Ethernet backhaul because it helps support legacy 2G/3G backhaul over a single converged access infrastructure. We tested the RAD IPmux, Gmux, and MiTOP and the Brocade MLX, and NetIron CES products and validated that the Brocade-RAD network provides the QoS and performance required to support not only Ethernet with QoS and SLA assurance, but also TDM circuits with the low latency and accurate clock recovery required for 2G/3G backhaul.

NOTE: Due to product availability, feature validation was performed using RAD IPmux device that supports pseudowire, Ethernet, G.8032, and other features mentioned below.

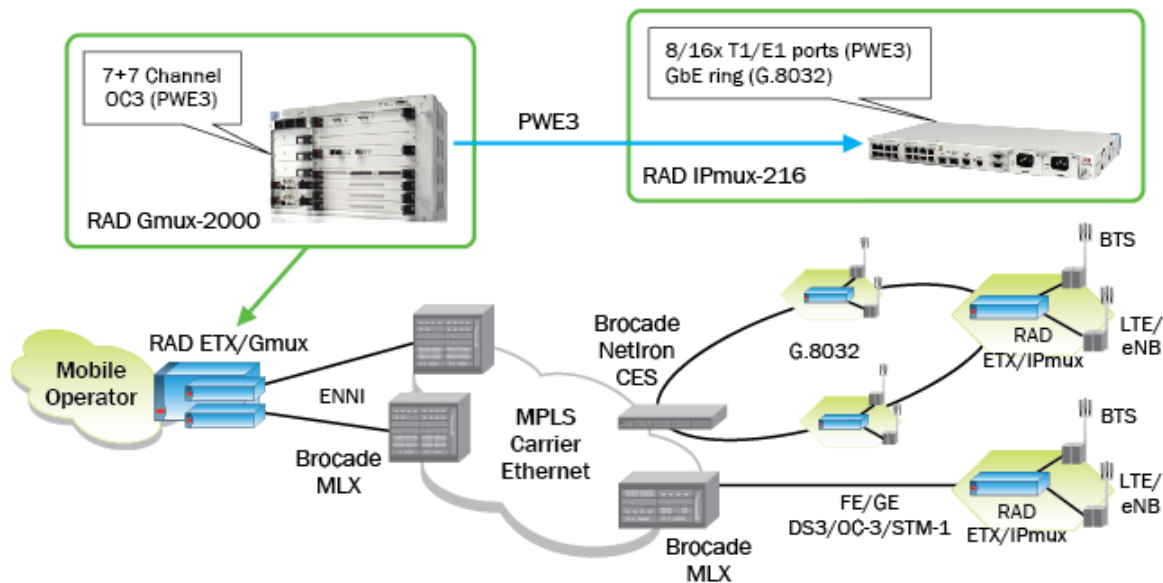


Figure 3. TDM pseudowire configuration

TDM pseudowire highlights include:

- T1 and DS3 circuit emulation with channelized DS3 and OC3 aggregation.
- In-band facility loopback based on ANSI T1 403 eliminates need for “smartjack”
- SATOP, CESoPSN, TDMoIP, or HDLCoPSN frame formats with MEF 8 or UDP/IP addressing
- E2E latency starting at under 1ms (configurable jitter buffer from 0.5 to 180 ms)
- DS0-level grooming (TDM and HDLC)
- Packet reordering at wire speed (even if the jitter buffer is configured to < 1ms)
- Industry-leading clock recovery conforms to G.823/G.824 Traffic or Sync Interface
- Multiple timing domains and better than 16 ppb clock accuracy
- Internal, loopback, adaptive, external (input or output,) and system timing
- Adaptive/adaptive timing (allows SP to be agnostic to user clocking scheme)
- OAM to verify connectivity, measures round-trip delay and prevents configuration mismatch
- Fault propagation—network and service alarms propagated to remotes

SYNCHRONIZATION OVER PACKET-SWITCHED NETWORKS

As shown in Table 3, synchronization is a critical factor in any wireless network, but particularly in mobile backhaul, and probably the most challenging capability to be supported over packet-switched networks. In a TDM network, clock is transported natively over the network. But with a packet-based transport network that is asynchronous in nature, a dedicated mechanism must be developed to transport the clock in an accurate and reliable manner with minimum bandwidth consumption and to overcome packet-based network issues such as varying delay, jitter, and packet loss.

Table 3. Wireless network synchronization requirements

Application	Frequency	Time
CDMA2000	50 ppb	Goal: < 3 μ s Must meet: < 10 μ s
GSM	50 ppb	N/A
WCDMA	50 ppb	N/A
TD-SCDMA	50 ppb	3 μ s inter-cell phase difference
LTE (FDD)	50 ppb	N/A
LTE (TDD)	50 ppb	*3 μ s inter-cell phase difference
LTE MBMS	50 ppb	*5 μ s inter-cell phase difference
FemtoCell	250 ppb	N/A
WiMAX (TDD)	2 ppm absolute, ~50 ppb between base stations	1.0 to 1.5 μ s
Backhaul Network	16 ppb	N/A

The Brocade-RAD-Symmetricon backhaul solution described in this paper includes timing support. Deploying RAD ETX, Symmetricon TP-5000, and Brocade MLX/NetIron CES products, the solution validated the option to add precise clock synchronization based on IEEE 1588- PTP support from the Symmetricon grandmaster out to the RAD ETX-A series demarcation devices. The RAD ETX not only recovered the timing, but also acted as a timing gateway to deliver 1588-PTP, SyncE (ITU G.8261), and E1/T1/2Mhz on RJ-45, BNC, and DB9 interfaces to the base stations. Integrated timing support in the Ethernet demarcation devices eliminates the need for dedicated hardware or GPS installations. Note that if TDM pseudowire is deployed, precise timing can also be achieved via adaptive clock recovery between pseudowire entities.

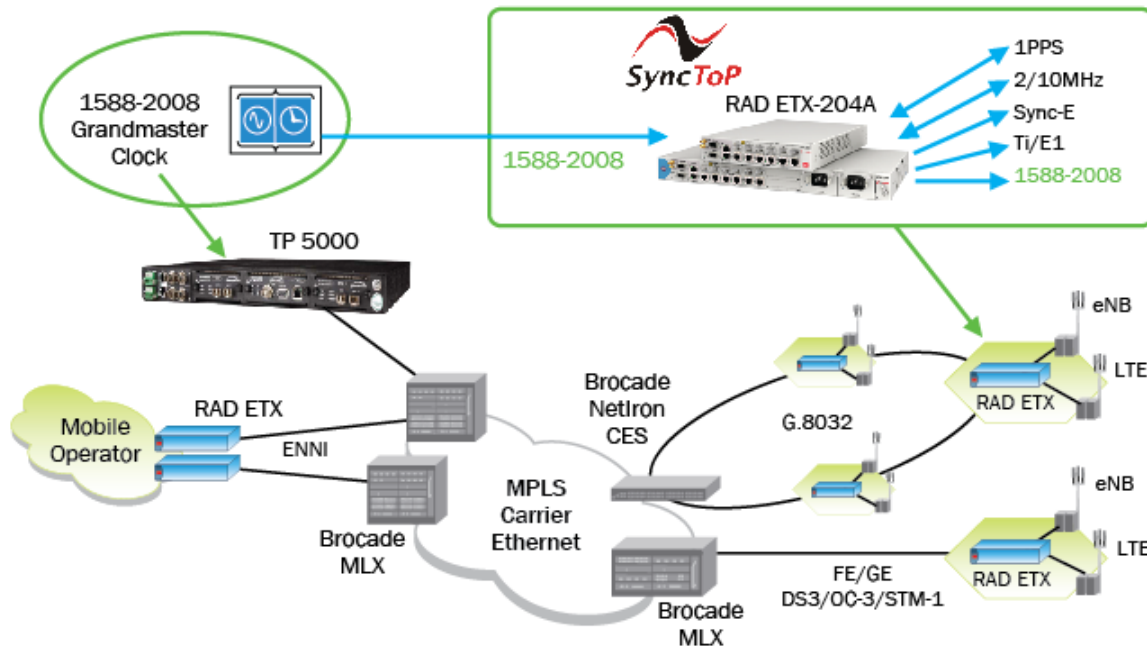


Figure 4. Solution configuration for timing support

The test results clearly illustrate that the stringent frequency and timing required for mobile backhaul applications can be achieved with IEEE 1588 and proper network engineering and configuration. All test results were captured using the Symmetricom TimeMonitor test and measurement software. The Maximum Timing Interval Error (MTIE) graph, for example, is shown in Figure 5.

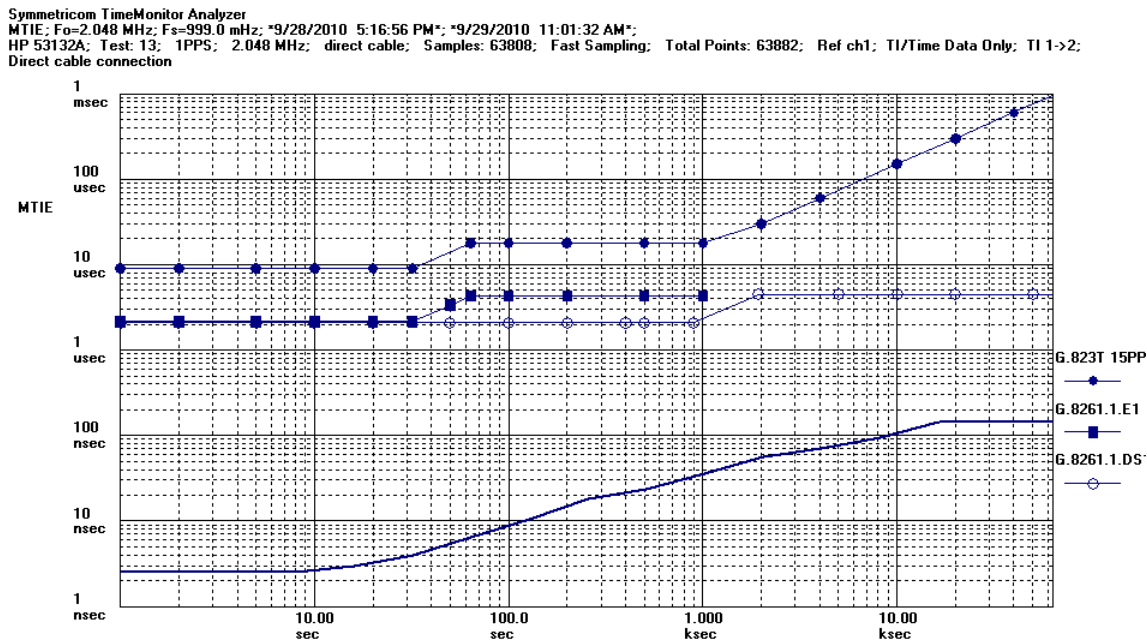


Figure 5. MTIE results as recorded by Symmetricom TimeMonitor in Brocade labs

BROCADE NETWORK ADVISOR

Most service providers today face tighter budgets, ever-increasing network traffic and complexity. Managing Service Level Agreements (SLAs) in this dynamic network environment requires seamless coordination among a wide range of elements. While every network has its own specific management requirements, organizations face the same type of management challenges. These challenges include minimizing network downtime, reducing operational expenses, managing application SLAs, and providing robust security. Brocade Network Advisor is the industry's first unified network management solution.

Brocade Network Advisor provides time-saving tools that help automate repetitive tasks by using intuitive wizards. As a result, organizations can automatically discover and manage Brocade IP switches and MPLS routers. In addition, they can easily configure and deploy group policies—significantly reducing administration overhead and simplifying management.

Specifically, Brocade Network Advisor has the ability to discover and manage third-party devices and perform the following tasks (see the main window in Figure 6):

- Role-based administration
- Topology management
- Perform CLI commands for third-party devices in telnet session launched from the Brocade Network Advisor GUI
- Launch third-party element managers
- SNMP monitoring
- Trap forwarding
- Dynamically react to traps
- Report generation

Acknowledged	Area	Source Name	Source Addr	Origin	Category	Description	Last Event
<input checked="" type="checkbox"/>		snmpstat	192.168.1.21	Application Event	User Action Event	Backed up 317 files and database successfully	Mon Oct 0...
<input checked="" type="checkbox"/>		snmpstat	192.168.1.21	Application Event	User Action Event	Start backup D:\Backup	Mon Oct 0...
<input type="checkbox"/>	P	ETK-204-1	10.17.95.121	SNMP Trap	Security Event	Authentication failure	Tue Oct 0...
<input type="checkbox"/>	P	ETK-204-1	10.17.95.121	SNMP Trap	Security Event	Authentication failure	Tue Oct 0...
<input type="checkbox"/>	P	ETK-204-1	10.17.95.121	SNMP Trap	Security Event	Authentication failure	Tue Oct 0...
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<input type="checkbox"/>	P	ETK-204-1	10.17.95.121	SNMP Trap	Security Event	Authentication failure	Tue Oct 0...
<input type="checkbox"/>	P	ETK-204-1	10.17.95.121	SNMP Trap	Security Event	Authentication failure	Tue Oct 0...
<input type="checkbox"/>	P	ETK-204-1	10.17.95.121	SNMP Trap	Security Event	Authentication failure	Tue Oct 0...

Figure 6. Brocade Network Advisor main window

Using Brocade Network Advisor for Fault Management

Brocade Network Advisor collects and manages events from all the network elements, including RAD ETX-204A demarcation devices, Brocade NetIron CES aggregations switches and Brocade MLX Series core routers. Not only does it manage the way events are displayed in the event browser, but it also manages the system response to specific events according to policies. For examples, it may mask low priority or duplicated traps but generate notifications when it receives high-priority traps, such as “dying gasp” or link “flapping” notification or when a critical threshold is crossed. Alerts from network elements are displayed in the bottom left corner of the main window (see panel outlined in a dashed red line in Figure 6).

Using Brocade Network Advisor to “Defend” SLAs

Wholesale providers are often called upon to prove that SLAs were respected by providing mobile operators or retail carriers with service reports for the period of time in question. The demarcation devices at the cell sites and MTSO perform proactive performance measurements for the EVPL service on an ongoing basis. By analyzing the measured data, the devices calculate and report standard performance metrics per class of service flow, including Y.1731-defined latency, jitter, and packet loss. They record minimum, maximum, and average values for delay and delay variation, together with the rate of frame loss and the number of seconds during which the service was unavailable—all for a specified time interval.

The continuous monitoring of key performance indicators for multiple management end-points and flows simultaneously allows the service provider to detect degradation in service quality and to take remedial actions to quickly restore appropriate performance levels.

When the counters of any of the tested parameters rise above or drop below pre-set thresholds within the specified sampling period, the demarcation devices send SNMP traps to the Brocade Network Advisor, where they are collected into an event log to provide a historical view of network and service behavior, without over-taxing the network with excessive management traffic. Brocade Network Advisor uses these rising and falling threshold notifications to create reports so the service provider can easily evaluate actual performance over time and compare it to SLA guarantees.

In this example shown in Figure 7, Brocade Network Advisor dynamically records all the details of the incoming traffic. Here a customer has violated the bandwidth contract and bandwidth rates are recorded and filtered into a Microsoft Excel spreadsheet, where they can be aggregated and provided to the customer to justify additional fees. The demarcation devices help Brocade Network Advisor identify baseline and out-of-range traffic behavior.

The screenshot shows a web browser window displaying the 'Events Report Report' interface. The report covers the time period from Oct 07, 2010 04:00:00 PM, PDT to Oct 08, 2010 03:10:09 PM, PDT. It shows 6 records, with the first one displayed. The table below represents the data shown in the screenshot.

Source Name	Port	Product Address	Severity	Description	Category
ETX-204-1		10.17.95.121	Notice	failed login	Product Event
ETX-204-1		10.17.95.121	Info	Successful login	Product Event
ETX-204-1	1	10.17.95.121	Warning	Link down for :ETH 1	Product Event
ETX-204-1	1	10.17.95.121	Warning	Link up for :ETH 1	Product Event
ETX-204-1		10.17.95.121	Info	Authentication failure	Security Event
ETX-204-1		10.17.95.121	Info	Authentication failure	Security Event

Figure 7. Alerts from RAD ETX-204-1 displayed in the Events Report

MPLS Provisioning in the Core

The Multiprotocol Label Switching (MPLS) Manager in Brocade Network Advisor allows you to configure and monitor VLL and VPLS services. It contains the following managers:

- Virtual Leased Line (VLL) Manager to configure and modify VLL services.
- VLL Monitor to monitor traffic on VLL instances.
- Virtual Private LAN Services (VPLS) Manager to configure and modify VPLS services.
- VPLS Monitor to monitor traffic on VPLS instances.
- VCID Pool to create a pool of VCIDs, which are used when new VLL and VPL instances are created
- LSP manager to create any switch path across the network on Brocade devices with MPLS capability.

In Figure 8, an MPLS tunnel has been created between the edge routers, Brocade NetIron CES and Brocade NetIron CER.

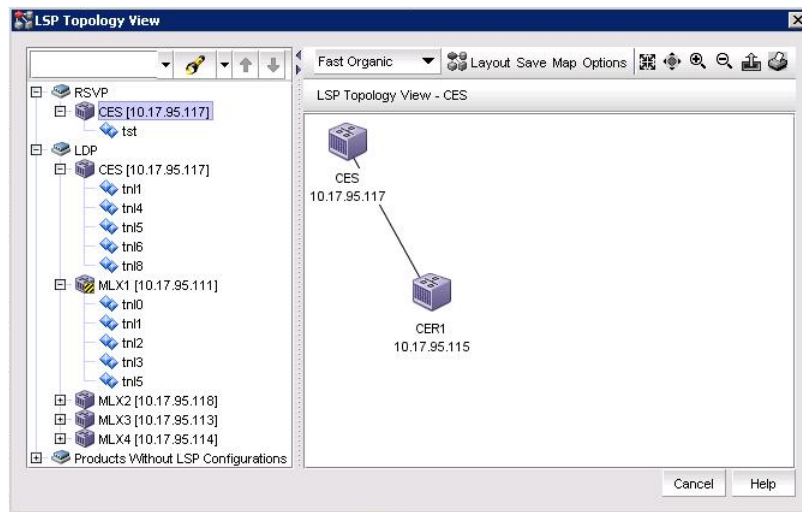


Figure 8. Brocade Network Advisor LSP Topology View

SUMMARY

A Brocade-RAD-Symmetricon solution was validated in Brocade labs to enable mobile backhaul customers to meet the stringent requirements for SLA guarantees, bridge multi-generational backhaul technologies, and meet clocking and synchronization requirements—while providing the lowest Total Cost of Ownership (TCO) for these networks. Key differentiators of this solution are:

- Enables wholesale operators to respond to Tier 1 mobile carrier's RFP successfully by providing
 - ✓ Architecture blueprints
 - ✓ Pre-tested configurations
 - ✓ Pre-validated performance, test reports, and results
 - ✓ Deployment guides
- Enables single-pane-of-glass network management for access, aggregation, and core via Brocade Network Advisor end-to-end management platform for configuration, performance management, and fault management
- Provides service providers with the freedom to choose best-of-breed devices and eliminate vendor lock by leveraging Industry-standard interoperable features
 - ✓ Ethernet OAM (IEEE 802.3-2005 ; IEEE 802.1ag and ITU-T Y.1731)
 - ✓ RFC-2544 support for end-to-end validation
 - ✓ Protection mechanisms: LAG (802.3ad), (G.8032), EVC protection (G.8031)
 - ✓ Precise timing with 1588 PTP
- One-stop- channel and technical support with expert help for design and consulting
- Lowest TCO solution

Contact Brocade for a detailed TCO White Paper.

ABOUT BROCADE

Brocade connects the world's most important information—delivering proven networking solutions for today's most data-intensive organizations. From the data center to high-performance Ethernet networks, Brocade is extending its near-15-year heritage as a leading partner for advanced storage and networking solutions.

The innovative Brocade approach to networking facilitates strategic partnerships by providing:

- Standards-based solutions that streamline qualification and help ensure interoperability
- Leading-edge technology that enables comprehensive, best-in-class solutions
- The best alternative choice to Cisco in terms of overall business value

The world's largest enterprise networks, government entities, and global service providers rely on Brocade to maximize the business return on their data. It's no wonder 90 percent of the world's most critical business information flows through Brocade solutions. Quite simply, Brocade enables today's complex businesses to run. Where other vendors produce networking that's ordinary, Brocade is committed to delivering the extraordinary.

ABOUT RAD

Established nearly 30 years ago, RAD Data Communications is an award-winning manufacturer of cost-effective access and backhaul solutions for mobile and fixed line carriers, service providers, enterprises, government agencies, transportation systems, and public utilities. RAD is a preferred solutions provider for more than 150 carriers around the world, from Tier 1 mobile operators to fixed line incumbents, wholesale service providers, city carriers, ISPs, and rural service telephone companies.

Beyond its strong ties with telecom providers, RAD maintains extensive relationships with enterprise network professionals in the banking, commercial, educational, energy, financial, government and defense, manufacturing, and transportation sectors.

ABOUT SYMMETRICOM

Symmetricon is the world's leading source of highly precise timekeeping technologies, instruments, and solutions. We provide timekeeping in GPS satellites, national time references, and national power grids as well as in critical military and civilian networks, including those that enable next-generation data, voice, mobile and video networks, and services. We assist customers in over 90 countries to generate, distribute, and apply time.

Our product offering—among the industry's broadest—includes atomic clocks, hydrogen masers, timescale systems, GPS instrumentation, synchronous supply units, standards-based clients and servers, performance measurement and management tools, and embedded subsystems that generate, distribute, and apply precise frequency and time.

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