Tellabs® 8800 Multiservice Router (MSR) Series — Enabling New Services and Network Convergence

The Tellabs® 8800 Multiservice Router (MSR) series offers high-performance, carrier-class multiservice edge routers.

Overview

The Tellabs® 8800 MSR series supports any-to-any Layer 2 and Layer 3 network and/or service interworking reliably and concurrently. It provides service providers a graceful migration path to a converged Multiprotocol Label Switching (MPLS)-enabled IP network. The Tellabs 8800 MSR series enables connection-oriented network characteristics such as Quality of Service (QoS) and security with powerful MPLS traffic engineering capabilities, while maintaining the superior scalability and flexibility of pure IP networks.

The Tellabs 8800 MSR series is available in three chassis sizes — six slots (Tellabs® 8830 Multiservice Router), 15 slots (Tellabs® 8840 Multiservice Router) and 19 slots (Tellabs® 8860 Multiservice Router) — all of which share a wide range of interfaces with unmatched service flexibility. It enables service providers the ability to deliver business-class IP and carrier Ethernet services, Frame Relay (FR), Asynchronous Transfer Mode (ATM) and Time Division Multiplexing (TDM) private leased line services at speeds from N x DS-0 to OC-192c/STM-64 and Ethernet services from 10 Mbps to 10 Gbps. The Tellabs 8800 MSR series scales from 80 to 320 Gbps in a fully redundant, nonblocking shelf.

Feature Highlights

Comprehensive Standards-based Signaling and Routing Support
The Tellabs 8800 MSR series supports full IP, ATM, FR and MPLS control planes and pseudowire service interface all within the same chassis. It has one of the industry's first ATM/MPLS control plane interworking implementations. Tellabs was the driver and active contributor behide the ATM and MPLS control plane interworking technical specification at the MFA Forum. In addition to UNI and NNI support for ATM, FR and UNI for carrier Ethernet, the Tellabs 8800 series uses LDP and RSVP-TE for MPLS signaling and traffic engineering. Moreover, it supports hierarchical and distributed PNNI for ATM routing and highly scalable MPLS and IP routing protocols such as BGP, MP-BGP, OSPF, IS-IS and PIM-SM.

Any-to-Any True Service Interworking at Line Rate
Based on pseudowire architecture, a unified MPLS core for Layer 2 services and TDM transport enables any customer with any Layer 1 or Layer 2 access technologies such as ATM, FR, Ethernet/VLAN, metro Ethernet, TDM, PPP and HDLC to communicate with each other, regardless of access media. All I/O slots can support complex any-to-any service interworking at 10 Gbps packet forwarding and switching speed while performing lookup and filtering tasks.

Any Service, Any Channel, Any Port
The Tellabs 8800 series can support Layer 1 to Layer 3 services on a single platform with the flexibility of any service, over any channel and any port with the industry's most comprehensive and flexible multi-service interfaces supporting: IP, MPLS, PPP/POS, HDLC, ATM, FR, EoS (X.86) and GFP, TDM, pseudowire circuits and link aggregation. Any Universal Line Card (ULC) card can simultaneously support packets, cells, TDM circuits, and mixing and matching of any Ethernet and SONET/SDH Physical Line Modules (PLM).

Per-Flow Guaranteed QoS
State-of-the-art, custom Application-Specific Integrated Circuit (ASIC) technology optimizes performance and traffic management. Per-Flow Queuing (PFQ) with Connection Admission Control (CAC) consistently ensures end-to-end ATM-like, deterministic, hard QoS across different service types, including traditionally best-effort IP and Ethernet services. Each ULC supports up to 32,000 PFQs (unidirectional) and 4,096 per-group queues. For example, the Tellabs® 8860 will support 512,000 PFQs per chassis.

Carrier-Class Reliability
The Tellabs 8800 series is a fully redundant platform providing carrier-class reliability. It offers immediate forwarding and hitless service preservation for all Layer 2 and Layer 3 services. The Tellabs 8800 series supports a non-service affecting upgrade, called Tellabs® ServiceAssured™ Upgrade. Based on real-time, the modular architecture, the Tellabs® Multiservice Operating System (TMOS) software, is field-proven and time tested in more than a dozen carrier networks worldwide.

Next Generation Ethernet Support
Industry leading metro Ethernet implementation is first certified by the Metro Ethernet Forum (MEF). The Tellabs 8800 series provides true access network convergence, supporting E-line, E-LAN, Ethernet over MPLS, Ethernet over ATM, Ethernet over FR and Ethernet over SONET (EoS) for both VPLS and Q-in-Q implementations in a multi-vendor environment. In addition, the Tellabs 8800 series supports per-flow guaranteed QoS with CAC for all types of Ethernet services. It has been proven and hardened in one of the world's largest metro-Ethernet deployments since 2003.

Customer Benefits

Enhanced Service Level Agreements (SLA)
The Tellabs 8800 series opens up new revenue streams by offering meaningful SLAs. These SLAs extend QoS contracts previously available only for ATM circuits to new and advanced broadband data services such as Ethernet and IP. Mission-critical services can now exist on technologies previously limited to traditional best-effort performance.

Superior Traffic Management
The Tellabs 8800 series ensures that policies defining SLAs for each service contract are honored. The state-of-the-art custom ASIC technology provides deterministic and granular per-flow and per-service SLA bandwidth management. Service-aware queuing techniques and traffic shaping help ensure predictability through varying levels of network utilization.

Evolutionary Migration of Legacy Networks
The Tellabs 8800 series supports open, standards-based software and hardware to interface with legacy equipment and protocols. Deployed legacy multiservice networks can be integrated with the Tellabs 8800 series-based network as part of a nondisruptive migration.

Enabling New Revenue Streams
With the enhanced SLA and superior MPLS traffic engineering, the Tellabs 8800 series enables service providers to offer high-growth Ethernet services using VPLS or Q-in-Q and MPLS VPN services based on RFC 2547bis/4364 today, while supporting legacy ATM and FR services from the same platform.

Guaranteed Service Availability
The Tellabs® ServiceAssured™ Upgrade package of unique software and hardware assures no single point of failure, non-service affecting product upgrades, Layer 2 and Layer 3 redundancy, in-service network expansion and distributed processing to maximize fault tolerance and performance. Carrier-class design provides full redundancy in common equipment and software resiliency features enable maximum service and network uptime.

Investment Protection
While increasing the breadth of the service portfolio, the Tellabs 8800 series extends service providers' investment in legacy network equipment by scaling its capacity as customer demands grow, without forklift upgrades. With significant high-density and high-speed capabilities, the Tellabs 8800 series accommodates growth in both end-user traffic and services. The switch fabric is highly scalable, providing up to 320 Gbps of nonblocking performance in a single chassis.

CapEx Reduction
Service providers frequently maintain multiple core service networks based on the individual end-customer services being offered. The Tellabs 8800 series provides a consolidated network infrastructure, collapsing multiple overlay networks to reduce the total number of network elements. Capital expenditures are further reduced with industry-leading technology, density and performance improvement.

OpEx Reduction
The Tellabs 8800 series reduces truck rolls, lowers spares inventory and minimizes operational costs for service providers with any service, any channel, any port functionality:

- A single ULC that accepts a flexible set of mix and matched PLMs spanning T1/E1 to OC-192/ STM-64 or 10/100 Ethernet to 10 GigE.
- Software-defined service edge enables any physical or logical port, channel or flow to be software configured to provide IP, FR, ATM, MLPPP, PPP, HDLC, MPLS or TDM.

In addition, the effective use of rack space further reduces operational complexity of managing multiple networks or network layers in the service provider network. Reduced operations costs are facilitated to bring greater profits and revenues.

Applications and Services
The Tellabs 8800 series enables service providers to offer the following services on converged network architecture, benefiting from new revenue opportunities while maintaining their legacy investments:

- Layer 1/Layer 2 Legacy Services
  - Private line service via TDM circuit emulation
  - ATM service (Layer 2 VPN)
  - FR service (Layer 2 VPN)
  - Ethernet Transparent LAN Services (L2 VPN)
  - 802.1Q
  - 802.1ad Provider Bridge/VLAN Stacking
  - VPLS and H-VPLS for large-scale multipoint-to-multipoint connectivity
- Layer 2 Network Interworking
  - Virtual Private Wire Services (VPWS) for point-to-point ATM, FR and Ethernet/VLAN (Layer 2 VPN)
  - FR to ATM
- Layer 2 Service Interworking
  - Bridged and routed with ARP mediation
  - FR to ATM
  - ATM to Ethernet
  - FR to Ethernet
  - Layer 3 VPNs
  - High-performance Layer 3 IP VPNs
  - IP VPN using GRE

- Broadband Aggregation
  - DSLAM aggregation and backhaul using Ethernet or ATM
  - Metro Ethernet aggregation
  - ATM VPI/VCI mapping to Q-in-Q
- High-Speed Access
  - EoS (X.86) and GFP
  - Broadband Internet access
  - IP-enabled FR service
  - IP-enabled ATM service
- Wireless Transport
  - 3G migration
  - Wireless backhaul
  - RAN aggregation
  - Wireless core
  - TDM circuit emulation for 2G transport
- Triple Play Services
  - IP telephony
  - IPTV
  - Broadcast TV
  - VoIP

Tellabs 8800 Series Architecture

Switch and Control Cards (SCC)
The SCCs are the central resource of the Tellabs 8800 MSR series for both data-plane switching and the control and management functionality. The highly scalable, efficient and redundant switch fabric is distributed across the SCCs. The SCCs provide N:1 automatic, hot-standby redundancy for the entire Tellabs 8800 series and data plane load sharing.

The switch fabric has the following switching and fault tolerant features:

- Fully nonblocking switching architecture
- Highly efficient and deterministic performance
- Instantaneous routing/switching around internal failures
- Scalable single-stage, low-latency design to achieve up to 320 Gbps in a single chassis

Universal Line Card (ULC)
All ULCs are hot-swappable. In contrast to legacy systems with cell- or packet-specific processing cards, the ULC provides both native cell and packet switching at the same time. Therefore, the ULC significantly reduces service provider card types, sparing inventory and operations complexity.

The ULC also contains the highly integrated Tellabs® custom ASIC, supporting low-latency and line-rate performance at all packet sizes.

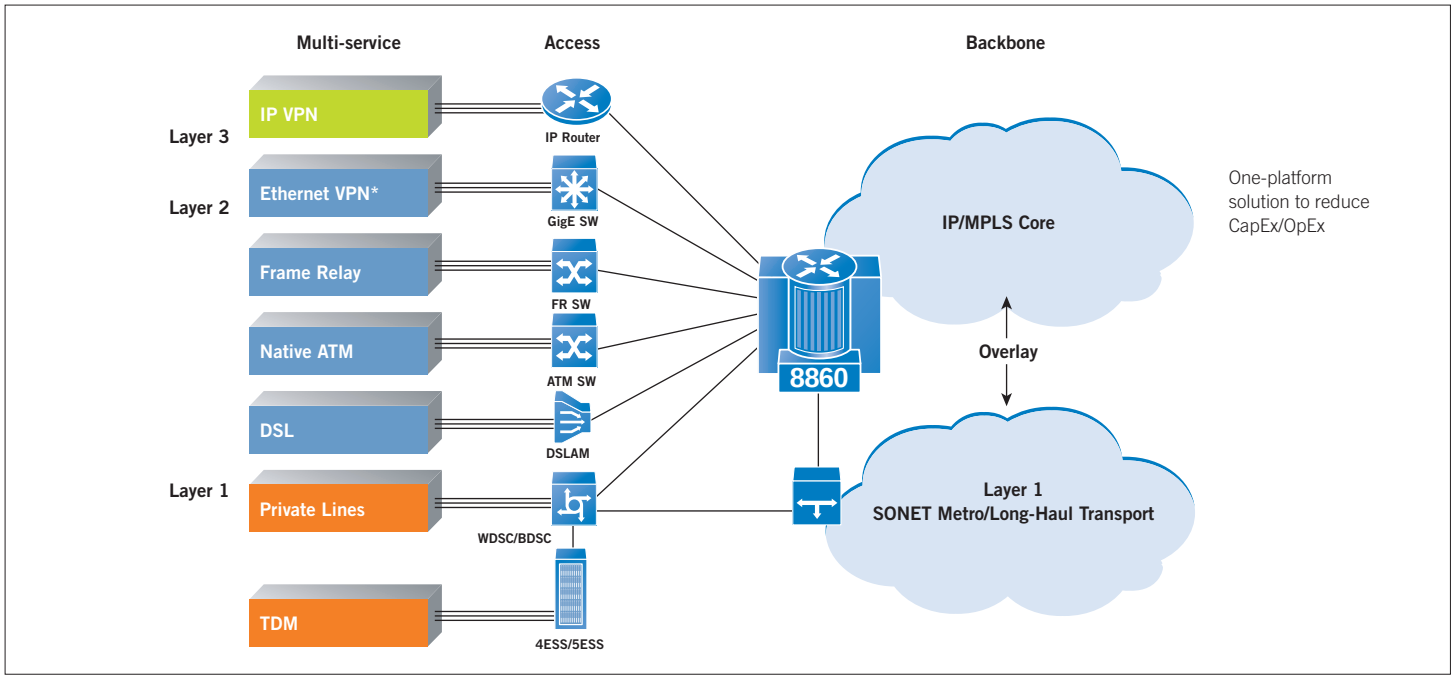


Figure 1. Tellabs® 8800 Multiservice Router Series sample services

Innovative SLAs can be provisioned and managed on the ULC with:

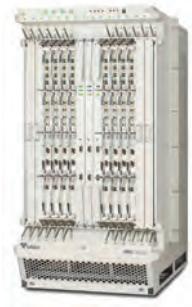
- Ingress per-flow policing
- Ingress and egress per-flow queuing and shaping
- Per-flow congestion detection and avoidance
- Support of all ATM QoS classes regardless of service types
- Support of IP QoS based on Differentiated Services (DiffServ) classes of service
- Support of Ethernet CoS based on IEEE 802.1p
- Wire-speed IP forwarding and processing with complex lookup and filtering mechanisms
- Support of 32,000 flows per ULC and 512,000 flows per chassis

Combined with the switch fabric, the ULC provides the Tellabs 8800 series the ability to offer integrated and highly efficient data forwarding across multiple services.

PLM Flexibility
All PLM types can be interchanged and interworked with each other in the Tellabs 8800 series. The Tellabs 8800 series delivers one of the industry's best SONET/SDH channelization. SONET/SDH PLMs are available in rates ranging from OC-3/STM-1 through OC-192/STM-64. The OC-192/SDH-64 and the 10 GigE PLMs require one ULC and hence displace four standard PLMs. All channelized SONET/SDH interfaces are completely flexible in terms of channel (STS-1 through STS-48c) assignment or concatenated operations. With the software-defined service edge feature, service providers can define any protocol (FR, ATM, EoS, PPP, MPLS and TDM) on a per-channel basis via software configuration.

	Tellabs® 8860 MSR	Tellabs® 8840 MSR	Tellabs® 8830 MSR
Switching Capacity	320 Gbps	240 Gbps	80 Gbps
Bandwidth per Slot	20 Gbps	20 Gbps	20 Gbps
Chassis Design	Backplane	Backplane	Midplane
No. of SCC per Chassis	3	3	2
No. of ULCs / PLMs	16/64	12/48	4/16
Redundancy	Fully redundant platforms to provide carrier-class reliability	Fully redundant platforms to provide carrier-class reliability	Fully redundant platforms to provide carrier-class reliability
	N:1 Redundancy on all common system elements: power supplies, cooling, BITS inputs, Stratum 3 internal clocks, etc.	N:1 Redundancy on all common system elements: power supplies, cooling, BITS inputs, Stratum 3 internal clocks, etc.	1:1 Redundancy on all common system elements: power supplies, cooling, BITS inputs, Stratum 3 internal clocks, etc.

	Tellabs® 8860 MSR	Tellabs® 8840 MSR	Tellabs® 8830 MSR
Redundancy	1+1 Control Plane provides non-stop reliability, mirror state from primary to secondary SCC	1+1 Control Plane Redundancy: provides non-stop reliability, mirror state from primary to secondary SCC	1+1 Control Plane Redundancy: rovides non-stop reliability, mirror state from primary to secondary SCC
	N:1 Forwarding Plane Redundancy: switch fabric will load share across all three SCCs	N:1 Forwarding Plane Redundancy: switch fabric will load share across all three SCCs	1:1 Forwarding Plane Redundancy: 100% available internal bandwidth in case of unlikely switch fabric failure
	1:12 switch fabric component redundancy for graceful degradation	1:12 switch fabric component redundancy for graceful degradation	1:8 switch fabric component redundancy for graceful degradation
	In-service insertion and removal of system components and physical interfaces	In-service insertion and removal of system components and physical interfaces	In-service insertion and removal of system components and physical interfaces
Mechanical Dimensions	Height: 35 in / 88.9 cm Width: 21.6 in / 54.9 cm Depth: 29.5 in / 74.9 cm	Height: 35 in / 88.9 cm Width: 17.3 in / 43.9 cm Depth: 29 in / 73.7 cm	Height: 14 in / 35.6 cm Width: 17.5 in / 44.4 cm Depth: 23.5 in / 59.7 cm
No. of chassis per 7 ft rack	2	2	5
Weight (fully configured)	385 lbs (175 kg)	325 lb (147 kg)	160 lb (72 kg)
Cooling	– 1 large fan tray with 16 dual-speed fan – Top to bottom air flow	– 3 small fan trays with 4 fans each – Top to bottom air flow	– Dual fan trays with 7 fans each – Side to side air flow
Electrical Power	Three redundant power inputs — each has A&B power inputs	Four power input filters — each has A&B power inputs	Powered AC or DC. 1:1 redundancy from separate, independent power sources
Maximum Power	4500 W	3500 W	1300 W
DC	Maximum current per power input: 60 Amps at -40V DC	Maximum current per power input: 30 Amps at -40V DC	Maximum current 32.5 Amps at -40V DC
	Input voltage range: -40V DC to 56.7V DC	Input voltage range: -40V DC to -56.7V DC	Input voltage range: -40V DC to -56.7V DC



	Tellabs® 8860 MSR	Tellabs® 8840 MSR	Tellabs® 8830 MSR
AC			Maximum current per power input: 8 Amps at 180 V
			Input voltage range: 180–240 V
Maximum Thermal Output	15,354 BTU/hr	11,945 BTU/hr	4,437 BTU/hr
Temperature	32° F – 113° F/0° C – 45° C	32° F – 113° F/0° C – 45° C	32° F – 113° F/0° C – 45° C
Maximum Altitude	Up to 4,000 m (13,123 ft)	Up to 4,000 m (13,123 ft)	Up to 4,000 m (13,123 ft)
Operational Relative Humidity	5–90% no condensing	5–90% no condensing	5–90% no condensing

Tellabs 8800 Series Port Densities

The Tellabs 8800 series supports industry-leading port densities while efficiently using central office/point-of-presence rack space. The following table provides the system and rack densities offered by a selection of PLMs:

		Tellabs® 8860 MSR	Tellabs® 8840 MSR	Tellabs® 8830 MSR
Module	**Ports Per PLM/ULC**	**Ports Per Shelf / 7 ft Rack**	**Ports Per Shelf / 7 ft Rack**	**Ports Per Shelf / 7 ft Rack**
OC-192c/STM-64	1 / 1	16 / 32	12 / 24	4 / 20
Channelized OC-48/STM-16 (down to DS-3/E-3)	1 / 4	64 / 128	48 / 96	16 / 80
OC-48c/STM-16c	1 / 4	64 / 128	48 / 96	16 / 80
Channelized OC-12/STM-4 (down to DS-3/E-3)	4 / 16	256 / 512	192 / 384	64 / 320
Channelized OC-48/STM-16 GFP (down to STS-1/VC-3)	4 / 16	256 / 512	192 / 384	64 / 320
OC-12c/STM-4c	4 / 16	256 / 512	192 / 384	64 / 320
OC-3c/STM-1c	4 / 16	256 / 512	192 / 384	64 / 320
Channelized OC-3/STM-1 (down to DS-0)	2 / 8	128 / 256	96 / 192	32 / 160
Channelized OC-3 STM-1 IMA (down to T-1/E-1)	2 / 8	128 / 256	96 / 192	32 / 160
Channelized OC-3 STM-1 SAToP (down to T-1/E-1)	2 / 8	128 / 256	96 / 192	32 / 160
Channelized OC-3 STM-1 MS ML-PPP (down to DS-0)	2 / 8	128 / 256	96 / 192	32 / 160
DS-3/E-3	6 / 24	384 / 768	288 / 576	96 / 480
Channelized DS-3/E-3 (3/1/0) (down to DS-0)	6 / 24	384 / 768	288 / 576	96 / 480
10 GigE	1 / 1	16 / 32	12 / 24	4 / 20
GigE	4 / 16	256 / 512	192 / 384	64 / 320
10/100BaseT	24 / 96	1536 / 3072	1152	384 / 1920
T1/E1/J1	24 / 96	1536 / 3072	1152	384 / 1920

Tellabs® 8890 Management System
The Tellabs 8800 series can be managed locally via Command Line Interface (CLI) or remotely by the Tellabs® 8890 Management System. The Tellabs 8890 system is a full FCAPS network and element management system that provides:

- Integration with existing OSS systems via CORBA and SNMP-based northbound interfaces
- Graphical network maps with element drill-down views
- Per-network, per-circuit management view
- Point-and-click configuration and provisioning
- Integrated fault management
- Accounting, performance and security management
- Statistics collection for SLA reporting and network planning

Technical Specifications

Tellabs Multiservice Operating System Software
The Tellabs Multiservice Operating System (TMOS) software provides a standards-based set of open protocols and control planes for the Tellabs 8800 series network. It facilitates new SLAs for existing services that require no change of the end-user customer or customer premise equipment.

- **SCC**
  - 1 GB PC100 SDRAM
  - 4 M flash boot ROM
  - 60 GB hard drive
  - 256 MB flash

  Tellabs 8840 MSR and Tellabs 8860 MSR:
  - Two separate processors — Memory Processor (MP) and Route Processor (RP)
  - 1 Gb PC100 SDRAM per processor

  Tellabs 8830 MSR:
  - One processor for both MP and RP
  - 2 GB PC 3200 DDR SDRAM

- **ULC**
  - 1 GB PC100 SDRAM
  - 4 Mbit flash boot ROM
  - 256 MB flash
  - Line rate performance for all packet sizes
  - CAM:
    - ULC1 — 9 M ingress; 9 M egress
    - ULC2 — 36 M ingress; 9 M egress

- **System Management and Alarm Interfaces**
  - RS-232 (DB-9) serial ports for remote and console connections
  - 10/100 Mbps Ethernet (RJ-45) ports for out-of-band management
  - Premise alarm connector (DB-25)
  - Alarm Cut-Off (ACO) switch
  - LEDs for power, temp, fan, status and alarm (critical, major and minor)

- **Regulatory Compliance**
  - Safety
    - UL 60950-1
    - EN 60950-1:2001
    - CSA C22.2 No. 60950-1
    - AS/NZS 60950.1:2003
    - EN 60825-1:1994, A11, A2
  - EMC/Immunity
    - FCC Part 15 Class A
    - ICES-003 Class A (Canada)
    - EN 55022 (1998) Class A (Europe)
    - VCCI (April 2000) Class A (Japan)
  - Tellabs® 8860 MSR
    - AS/NZS 3458 (W/A1 & A2 1997 Class A) (Australia, New Zealand)
    - ETSI EN300 386 V1.3.1 (2001-09)
  - Tellabs® 8840 MSR
    - ACA, AS/NZS (CISPR22: 2004 Class A) (Australia, New Zealand)
    - ETSI EN300 386 V1.3.1 (2001-09)
  - Tellabs® 8830 MSR
    - ACA, AS/NZS (CISPR22: 2004 Class A) (Australia, New Zealand)
    - BSMI CLASS A (TAIWAN) - 8830
    - ETSI EN300 386 V1.3.2 (2003-05)

- **NEBS**
  - GR-63-CORE: ISSUE 2 (APR 2002) NEBS PHYSICAL PROTECTION
  - GR-1089-CORE Issue 3 (2002): EMC and Electrical Safety
  - ETS 300 019-2-1
  - ETS 300 019-2-2
  - ETS 300 019-2-3
  - ETS 300 019-2-4
  - ETS 300 753
  - AT&T NEDS (MLID#4069, V4.01, 1/16/2004)
  - SBC-TP-96200 ISSUE 5A, FEB 2004
  - ANSI T1.315-2001 (Tellabs 8830 MSR ONLY)

Software Specifications

- **Layer 3 Protocol Supported**
  - Routing: BGP4, IS-IS, OSPF, PIM-SM
  - Advanced Routing features: BGP Confederation and BGP graceful restart
  - IS-IS: Graceful Restart, Jumbo Frames, Domain-wide Prefix Distribution, Mesh Groups, IGP Shortcuts
  - OSPF: Stateful Redundancy, NSSA, IGP Shortcuts, Multiple Instances, graceful restart
  - MPLS: LDP, RSVP-TE
  - Advanced MPLS Features: MPLS traffic engineering, RSVP-TE, IS-IS-TE, OSPF-TE, Constraint-based Shortest Path First (CSPF)
  - RSVP-TE: stateful redundancy, fast reroute (FRR) with sub 10ms failover, Diffserv encoding, backup LSPs, open-bandwidth LSPs and auto-bandwidth LSPs
  - LDP: LDP QoS, graceful restart, fault tolerant, LDP over RSVP tunnels
  - IP VPN: RFC2547bis/4364 MP-BGP, OSPF multi-instance, overlapping VPNs, Full mesh and hub/spoke VPN topologies
  - IP Multicast: IGMPv2, PIM-SMv2
  - Policies: Access lists, prefix lists, route maps, AS-path lists, extended community lists
  - DHCP relay

- **Layer 1 and 2 Protocol Supported**
  - ATM : UNI 3.0 and 3.1, PNNI 1.0 and 1.1, ILMI 4.0, IISP 1.0, AINI 1.2, ITU TI.617, IMA 1.0 and 1.1
  - Frame Relay: FRF 1.1 UNI, FRF 2.1 NNI, FRF.5 Network Interworking, and FRF.8 Service Interworking, ITU Q.933 FR LMI
  - Ethernet/VLAN, link aggregation, E-line and E-LAN, VPLS, H-VPLS, Q-in-Q STP, RSTP, MSTP
  - EoS (X.86) and GFP
  - TDM: SAToP
  - HDLC
  - PPP (POS)
  - ML-PPP
  - Pseudowires based on Martini Draft for ATM, Frame Relay, Ethernet/VLAN, PPP, HDLC and TDM traffic encapsulation
  - MFA: The Use of Virtual Trunks for ATM/MPLS Control Plane Interworking

- **Traffic Management**
  - MPLS traffic engineering using OSPF-TE, ISIS-TE, RSVP-TE, LDP over RSVP tunnel
  - CSPF routing
  - E-LSP (EXP inferred)
  - L-LSP (Label inferred)
  - 2-Stage CAC at Layer 2, Layer 3 and LSP level
  - Strict Priority Queuing: CBR, VBR-rt, VBR-nrt, UBR, UBR+ and UBR+max
  - Weighted Fair Queuing (WFQ) based on Deficit Round Robin (DRR) scheme
  - Policing at the ingress (Dual leaking bucket algorithm with 3 color marking + explicit drop)
  - Shaping at the egress and ingress
  - Weighted Random Early Detection (WRED) and/or Weighted Tail Drop (WTD)
  - Hierarchical queuing
  - 32,000 Per-Flow Queues (unidirectional) per ULC or 512,000 per 8860 Chassis
  - 4,000 Per-Group Queues per ULC or 64,000 per 8860 Chassis
  - Virtual output queues
  - SLAs are applied (both policing and shaping) on Per-Flow Queues via state-of-the-art ASICs
  - Multi-class pseudowires
  - Weighted QoS

- **Carrier Class Resiliency**
  - Tellabs® ServiceAssured™ Upgrade without affecting services and minimal customer traffic loss
  - Fully redundant platforms to provide carrier-class reliability
  - Hot-swappable switch fabric and line cards
  - N:1 redundancy on all common systems elements: Switch fabric, management processor, routing processor, power supplies, dual DC feeds, cooling, external BITS inputs, Stratum 3 internal clocks, disks, OAM ports, etc.
  - 1:N switch fabric component redundancy for graceful degradation
  - N:1 forwarding plane redundancy when using 3 SCCs
  - Nonstop forwarding for all traffic during control plane switchover
  - 1+1 control plane redundancy: Provides nonstop reliability, mirrored states from primary to secondary SCC
  - Routing resiliency: OSPF and RSVP-TE stateful redundancy, OSPF, ISIS, BGP and LDP graceful restart
  - Database redundancy: RIB and FIB routing and forwarding table, OSPF-TE and ISIS-TE traffic engineering database, CAC, statistics, VPLS MAC address, circuit states
  - PPP states, ARP Cache, SVC states are maintained during control plane switchover
  - Data path protection: Supports redundant LSPs and LSP fast reroute in sub-10 ms, ECMP, link aggregation and SONET/SDH APS/MSP protection, ATM IMA, MLPPP, VRRP, STP, RSTP, MSTP, H-VPLS, backup pseudowires and VRRP, loop detection blocking
  - Pseudowire redundancy: dual-homing for H-VPLS
  - BFD support for OSPF, IS-IS, BGP, LDP and RSVP LSP
  - Distributed PNNI signaling

OAM

Extensive network diagnostics capabilities to detect and diagnose abnormalities in the network. The feature set includes, but not limited to:

- ATM services disruption detection and diagnostic capabilities: fault notification, fault detection, fault isolation and fault recovery, as per recommended standards: F4/F5 ATM AIS, RDI, and loopback
- Frame Relay Link Management Interface (LMI): ITU-T Q.933 Annex A, ANSI T1.617 Annex D and Cisco ILMI
- Ethernet services disruption detection and diagnostics: port mirroring, continuity check (includes VPLS) link trace and loopback, as per IEEE 802.1ag (Draft) service OAM
- MPLS services disruption detection and diagnostics: LSP ping and trace, pseudowire Virtual Circuit Connectivity Verification (VCCV) and Bidirectional Forwarding Detection (BFD)
- Performance monitoring and management role provided via integrated OSS support

Security

Well-defined secure network element access, extensive monitoring and disaster recovery methods based on layered, reliable and scalable security architecture:

- Operating system security using protected memory and modular processes
- Management plane security using multi-level security matrix for secure EMS/NMS access, SNMPv3 security support, SFTP, RADIUS, TACACS+, forensics capability for security audit or threat diagnostics, network database backup for disaster recovery
- Control plane security against DDoS and TCP SYN attacks and MD5 authentication for IP, ATM/FR and MPLS
- Data plane security for flexible class based traffic protection, E911 regulation for public safety, deep packet inspection, flexible access control list, lawful interception, resource protection, spoofing

Standards Compliance

TCP/IP
- RFC 768 User Datagram Protocol (UDP)
- RFC 791 Internetwork Protocol (IP)
- RFC 792 Internet Control Message Protocol (ICMP)
- RFC 793 Transmission Control Protocol (TCP)
- RFC 813 Window and Acknowledgement Strategy in TCP/IP
- RFC 815 IP Datagram Reassembly Algorithms
- RFC 826 Address Resolution Protocol (ARP)
- RFC 854 Telnet Protocol Specification
- RFC 879 The TCP Maximum Segment Size and Related Topics
- RFC 894 Standard for Transmission of IP Datagrams over Ethernet
- RFC 919 Broadcasting Internet Datagrams
- RFC 950 Internet Standard Subletting Procedure
- RFC 1042 Standard for the Transmission of IP Datagrams over IEEE 802 Network
- RFC 1122 Requirements for Internet Hosts — Communication Layers
- RFC 1141 Incremental Updating of the Internet Checksum
- RFC 1191 Path MTU Discovery
- RFC 1256 ICMP Router Discovery Messages
- RFC 1305 Network Time Protocol (NTP) Version 3
- RFC 1323 TCP Extensions for High Performance
- RFC 1349 Type of Service in the Internet Protocol Suite
- RFC 1350 TFTP Version 2 (revision of RFC 783)
- RFC 1812 Requirements for IP Version 4 Routers
- RFC 1918 Address Allocation for Private Internets
- RFC 2018 TCP Selective Acknowledgment
- RFC 2390 Inverse Address Resolution Protocol
- RFC 2581 TCP Congestion Control
- RFC 3768 Virtual Router Redundancy Protocol (VRRP)

IP Multicast
- RFC 1112 Host Extensions for IP Multicasting
- RFC 2236 Internet Group Mangement Protocol, Version 2
- RFC 3046 DHCP Relay Agent Information Option
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- RFC 2210 The USE of RSVP with IETF Integrated Service
- RFC 2961 RSVP Refresh Overhead Reduction Extension
- RFC 3097 RSVP Cryptographic Authentication (revision of RFC 2747)
- RFC 3209 RSVP-TE: Extensions to RSVP for LSP Tunnels
- RFC 3210 Applicability Statements for Extensions to RSVP for LSP Tunnels
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- RFC 1403 BGP OSPF Interaction
- RFC 1745 BGP4/IDRP for IP/OSPF Interaction
- RFC 1850 OSPF Version2 Management Information Base
- RFC 2307 The OSPF Opaque LSA Option
- RFC 2328 OSPF Version 2
- RFC 2740 OSPF for IPv6 (upgradable)
- RFC 3101 The OSPF Not So Stubby Area Option
- RFC 3137 OSPF Stub Router Advertisement
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- Draft-IETF-L3VPN-OSPF-2547: OSPF Multi-instance in BGP/MPLS VPNs
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- RFC 2763 Dynamic Hostname Exchange Mechanism for IS-IS
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- RFC 3784 ISIS-TE
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- RFC 2439 BGP Route Flap Damping
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- RFC 2858 Multi-Protocol Extensions for BGP-4 (Revision of RFC 2283)
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- RFC 2598 An Expedited Forwarding PHB
- RFC 2702 Requirements for Traffic Engineering Over MPLS
- RFC 3031 MPLS Architecture
- RFC 3032 MPLS Label Stack Encoding
- RFC 3036 LDP Specification
- RFC 3037 LDP Applicability
- RFC 3063 MPLS Loop Prevention Mechanism
- RFC 3107 Carrying Label Information in BGP-4
- RFC 3215 LDP State Machines
- RFC 3270 MPLS Support for Differentiated Services
- RFC 3346 Applicability Statement for Traffic Engineering with MPLS
- RFC 3443 Time to Live (TTL) Processing in Multi-Protocol Label Switching (MPLS) Networks
- RFC 3468 The Multiprotocol Label Switching (MPLS) Working Group Decision on MPLS Signaling Protocols
- RFC 3469 Framework for Multi-Protocol Label Switching (MPLS) based Recovery
- RFC 3478 Graceful Restart Mechanism for Label Distribution Protocol
- RFC 3479 Fault Tolerance for LDP
- RFC 3564 Requirements for Support of Differentiated Services-aware MPLS Traffic Engineering
- RFC 3612 Applicability Statement for Restart Mechanisms for the Label Distribution Protocol (LDP)
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- RFC 4762 Virtual Private LAN Services over MPLS
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- IEEE 802.1ag (Draft) service OAM
- IEEE 802.3 10Base-T
- IEEE 802.3u 100Base-TX
- IEEE 802.3x Flow Control
- IEEE 802.3z 1000Base-SX/LX
- IEEE 802.3ad Link Aggregation
- IEEE 802.3ae 10 Gbps Ethernet
- IEEE 802.3x Ethernet Flow Control
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- RFC 2684 Multiprotocol Encapsulation over ATM Adaptation Layer 5 (revision of RFC 1483)

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- Draft-IETF-BFD-v4v6: BFD for IPv4 and IPv6
- Draft-IETF-BFD-MPLS: Bidirectional Forwarding Detection for MPLS LSPs

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- RFC 3916 Requirements for Pseudo-wire Emulation Edge-to-Edge (PWE3)
- RFC 3985 PWE3 Architecture
- RFC 4379: Detecting MPLS Data Plane Failures
- RFC 4446: IANA Allocations for Pseudo Wire Edge to Edge Emulation
- RFC 4447: Pseudowire Setup and Maintenance using LDP
- RFC 4448: Encapsulation Methods for Transport of Ethernet Frames Over MPLS
- RFC 4553: Structure-Agnostic TDM over Packet (SAToP)
- RFC 4618: Encapsulation Methods for Transport of PPP/HDLC over MPLS
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- RFC 4717: Encapsulation Methods for Transport of ATM over MPLS Networks
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- Draft-IETF-PWE3-CW: PWE3 Control Word for Use Over an MPLS PSN
- Draft-IETF-BFD-MPLS: Bidirectional Forwarding Detection (BFD) for MPLS LSPs
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- RFC 1334 PPP Authentication Protocols
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- RFC 1662 PPP in HDLC-like Framing
- RFC 1990 PPP Multilink Protocol
- RFC 1994 PPP Challenge Handshake Authentication Protocol
- RFC 2433 Microsoft PPP CHAP Extensions
- RFC 3518 Point-to-point Protocol (PPP) Bridging Control Protocol (BCP)

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- RFC 1702 Generic Route Encapsulation over IPv4 networks
- RFC 2473 Generic Packet Tunneling in IPv6
- RFC 2784 Generic Routing Encapsulation (GRE) (revision of RFC 1701)

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- FRF.2.1 Frame Relay NNI
- FRF.5 Frame Relay / ATM PVC Network Interworking
- FRF.8.1 Frame Relay / ATM PVC Service Interworking
- ITU-T Q.933 Annex A DSS1 — Signaling Specification for Frame Mode Switched and Permanent Virtual Connection Control and Status Monitoring
- RFC 2427 Multiprotocol Interconnect over Frame Relay (revision of RFC 1490)
- RFC 2590 Transmission of IPv6 Packets over Frame Relay Networks Specification
- ANSI T1.617 Annex D DSS1 — Signaling Specification for Frame Relay Bearer Service

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- ITU-T Q.933 Annex A DSS1 — Signaling Specification for Frame Mode Switched and Permanent Virtual Connection Control and Status Monitoring
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- Draft-IETF-PWE3-VCCV: Pseudo Wire Virtual Circuit Connectivity Verification (VCCV)
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- ATM Forum Integrated Local Management Interface (ILMI) 4.0
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- ITU-T Q.2931 B-ISDN DSS2 User-Network Interface (UNI) Layer 3 Specification for Basic Call/Connection Control
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- RFC 1695 Definition of Management Objects for ATM Management Version 8.0 Using SMIv2
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- RFC 1905 Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2)
- RFC 1906 Transport Mappings for Version 2 of the Simple Network Management Protocol (SNMPv2)
- RFC 2012 SNMPv2 Management Information Basefor the Transmission Control Protocol using SMIv2
- RFC 2570 SNMP Version 3 Framework
- RFC 2578 Structure of Management Information Version (SIMv2)
- RFC 2579 Textual conventions for SMIv2
- RFC 3411 An Architecture for Describing Simple Network Management protocol (SNMP) Management Frameworks
- RFC 3412 Message Processing and Dispatching for the Simple Network Management Protocol (SNMP)
- RFC 3413 User-based Security Model (USM) for Version 3 of the Simple Network Management Protocol (SNMP) Applications
- RFC 3414 User-based Security Model (USM) for Version 3 of the Simple Network Management Protocol (SNMPv3)
- RFC 3415 View-based Security Model (USM) for Version 3 of the Simple Network Management Protocol (SNMP)
- RFC 3418 Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)
- RFC 3584 Coexistence between Version 1, Version 2, and Version 3 of the Internet-standard Network Management Framework

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- RFC 1213 Management Information Base for Network Management of TCP/IP-based Internets: MIB-II
- RFC 1398 Definitions of Managed Objects for Ethernet-like Interface Types
- RFC 1657 Definitions of Managed Objects for Version 4 of the Border Gateway Protocol (BGP-4) Using SMIv2
- RFC 1850 OSPF Version2 Management Information Base
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- RFC 1903 Textual Conventions for SNMP Version 2
- RFC 2011 SNMPv2 Management Information Base for IP using SMIv2
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- RFC 2465 MIB for IP Version 6: Textual Conventions and General Groups
- RFC 2493 Textual Conventions for MIB Modules using performance history based on 15 minute intervals
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- RFC 2496 Definitions of Managed Objects for the DS-3/E-3 Interface Types
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- RFC 2515 Definitions of Managed Objects for ATM Management
- RFC 2571 An Architecture for Describing SNMP Management Framework
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- Draft -ietf-diffserv-model DiffServ MIB
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- ATM Forum 0055 PNNI related MIBs
- ATM Forum 0066 ATM Soft PVC MIBs
- ATM Forum 0086 ATM Inverse Multiplexing
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- RFC 1321 The MD5 Message-Digest Algorithm
- RFC 1492 Access Control Protocol or TACACS
- RFC 1858 Security Considerations for IP Fragmnet Filtering
- RFC 1948 Defending Against Sequence Number Attacks
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- RFC 2759 Microsoft PPP CHAP Extensions, Version 2
- RFC 2827 Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address
- RFC 2865 Remote Authentication Dial-In User Service (RADIUS)
- RFC 3097 RSVP Cryptographic Authentication — Updated Message Type Value
- RFC 3101 The OSPF Not So Stubby Area (NSSA) Option
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- RFC 3414 User-based Security Model (USM) for Version 3 of the Simple Network Management Protocol (SNMPv3)
- RFC 3567 IS-IS Cryptographic Authentication
- Draft-ylonen-ssh-protocol The SSH (Secure Shell) Remote Login Protocol
- Cisco Proprietary TACACS+
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