The Force10 E-Series Architecture

Overview
The Force10 E-Series provides the unmatched scalability, line-rate performance, and full L2 switching and L3 routing functionality essential for today's most demanding network applications. The Force10 E-Series architecture reliably delivers these capabilities to the E-Series at never-before-realized price/performance ratios. To provide this unprecedented combination of power and economy, the E-Series architecture leverages innovations in switch-fabric, backplane, Application-Specific Integrated Circuit (ASIC), and system-control-plane design.

Scalable, High-performance Ethernet
The Force10 E-Series provides unmatched scalability to 672 Gigabit Ethernet (GbE) or 56 10 Gigabit Ethernet (10 GbE) ports per chassis, line-rate forwarding with Access Control Lists (ACLs) on all ports, and comprehensive L2 switching and L3 routing. The E-Series architecture delivers these capabilities via a number of technology breakthroughs:

- The E-Series switch fabric, featuring 8:1 redundancy, advanced queuing, multicast, and jumbo frame support, delivers unmatched scalability with up to 1.68 Tbps of non-blocking connectivity.
- An industry first, a passive copper backplane reliably and cost-efficiently provides 56.25 Gbps between each line card slot — without the cost and complexity of optical or active backplanes.
- Distributed Force10 ASICs — purpose built for efficiently switching Ethernet frames and routing IP packets — provide full hardware support for line-rate packet processing, classification, buffer and traffic management, scheduling, and switching.
- A high-performance multiprocessor control plane enables line-rate L2 switching and L3 routing with full L2/L3 protocol and feature support.

The Force10 E-Series combines these elements of the architecture with high-availability features such as hot-swappability of all key components and system-wide environmental monitoring. This combination enables the E-Series to deliver maximum system uptime and serviceability along with unprecedented performance and scalability. As a result, the Force10 E-Series can bring the simplicity and economics of Ethernet to some of today’s most demanding network applications, including Server Aggregation, Cluster/Grid Computing, next-generation Internet Exchanges (IXs), Broadband Aggregation, and Enterprise Backbones.

Scalable Switching Capacity
Non-Blocking 1.68 Tbps Switch Fabric
The switch fabric provides 1.68 Tbps non-blocking switching capacity along with support for advanced queuing, multicast, and jumbo frames. The Switch Fabric Modules (SFMs) that comprise the switch fabric are 8:1 redundant and hot swappable, maximizing the E-Series’ system availability. The E-Series provides 56.25 Gbps of full-duplex bandwidth to each line card slot. This ensures line-rate performance on up to 672 GbE ports or 56 10 GbE ports in a single E-Series chassis and leaves customers with enough headroom to double the system's port density in the future without the hassle of a forklift upgrade. The switch fabric’s 8:1 redundant design enables the E-Series to provide redundancy without replicating the entire switch fabric complex — a costly strategy necessitated by other architectures.
The switch fabric is designed to forward full Ethernet and IP frames in hardware, switching them without any need for segmentation and reassembly. The Virtual Output Queue (VOQ)-based crossbar switching architecture overcomes the cost and complexity of multi-level or clustered switch fabrics.

In contrast to previous switch/router architectures, the scalable VOQ fabric model enables high-performance switching of complete packets across the backplane. This capability enables the E-Series switch/routers to scale well beyond software-based forwarding architectures, eliminate the throughput limitations of bus-based architectures, and avoid the non-deterministic characteristics of cell-based architectures (such as sequencing and reassembly issues).

**Passive Copper Backplane**

The reliable and cost-efficient backplane is the industry’s first high-speed non-optical backplane to achieve 5 Tbps in a single-rack switch/router chassis. Unlike optical backplane interconnect systems or active copper backplanes, the patent-pending backplane has no single points of failure and eliminates costly electrical-optical-electrical conversions. The resulting system simplicity means bulletproof reliability, system simplicity, and minimum cost.

**True Line-rate L2/L3 Forwarding**

**Distributed Forwarding with Deterministic Low Latency**

The Force10 ASICs are present on every line card, providing predictable, hardware-based distributed packet processing up to 1,000 Mpps. Unlike centralized architectures, the distributed processing architecture enables high throughput and deterministic performance even as more ports are added to the system and as more traffic load is added to the network. In contrast with low-performance processor or route-cache-based forwarding architectures, the E-Series has no "slow-path" or software-based forwarding.

The classification ASICs, along with advanced Ternary Content Addressable Memories (TCAM), allow line-rate lookups within L2 and L3 forwarding tables. Similarly, as packets enter the system, the classification ASICs enable on-the-fly line-rate lookups of ACL entries for destination, policy and Quality of Service (QoS) mappings. This simultaneous packet processing and classification allows the E-Series to provide line-rate L2/L3 forwarding performance independent of table lengths, IP address prefix lengths, or packet size — even when all ACLs and QoS features are enabled. The hardware forwarding afforded by the Force10 ASICs gives the E-Series the ability to combine the true line-rate performance and low, deterministic latency and jitter required to build server aggregation networks in next-generation streaming media applications.

**Line-Rate with All L2/L3 Features**

Perhaps the biggest problem with today’s switch/routers is the performance degradation they suffer when L2/L3 features are turned on. As opposed to these traditional architectures, the E-Series does not compromise on features to provide line-rate forwarding performance. The Force10 ASICs have line-rate support for filtering, statistics collection, QoS, rate policing, and limiting. Force10 ASICs also deliver protocol-specific hardware support at line-rate for L2 switching and L3 routing.

The E-Series’ line-rate features include:
- Filtering with standard and extended ACLs
- QoS (DiffServ, IEEE 802.1p)
- Rate policing and limiting
- L2 switching features
  - Source address learning and limiting
  - Link Aggregation
  - VLAN stacking
- L3 routing features
  - ECMP
  - Inter-VLAN routing
  - IP multicast
- Statistics collection

**Service-Aware QoS Architecture**

The E-Series provides extensive QoS and traffic management capabilities designed according to DiffServ and IEEE 802.1p requirements.

The Force10 ASICs provide robust packet marking capabilities, including the ability to re-map packet priorities between IP and Ethernet schemes. Traffic conditioning is based upon two-rate, three-color token bucket-based metering and marking. Eight queues per destination port map directly to class-based DiffServ and IEEE 802.1p queuing models. Congestion avoidance is enabled by configurable drop precedence probability curves of Weighted Random Early Discard (WRED). The combination of these features enables Committed Access Rate (CAR)-based service offerings with rate policing and limiting.

QoS is also built into the switch fabric. Both ingress and egress buffering are provided, including backpressure mechanisms that ward off the possibility of head-of-line blocking. Separate unicast and multicast queues with
between 85 and 200 milliseconds of buffering enable minimal packet loss even in oversubscribed network conditions. The E-Series switch fabric uses Interleaved Weighted Fair Queuing (IWFQ) to schedule traffic out of the ingress and egress queues, and programmable queue sizes allow seamless handling of both real-time and bursty traffic patterns.

With the service-aware QoS capabilities of the E-Series architecture, service providers can honor customer-defined traffic priorities, or assign their own class of service policies to enforce simple and manageable Service Level Agreements (SLAs).

**Robust System Control Plane**

**Distributed Multiprocessor Control Plane**

With three processors on each Route Processor Module (RPM) and one processor on every line card, the E-Series system control plane is purpose-built to deliver high-performance and fault-tolerance to the full Force10 Operating System (FTOS™) suite of L2 switching features and L3 routing protocols. Designed to meet the needs of Internet-scale networks, the system control plane supports millions of routing table entries, up to 512K forwarding table entries, and tens of thousands of ACLs on every line card.

Software processes are distributed among the processors, allowing true real-time multiprocessing. This enables process isolation with memory protection. These features are absolutely necessary for fault tolerance and rapid convergence in large-scale enterprise and service provider networks.

**Resilience and Security**

The RPMs provide innovative traffic control, rate limiting, and filtering. These capabilities empower network administrators to suppress harmful Denial of Service (DoS) attacks and prevent flooding of unwanted traffic onto the network — an event that places an unnecessary burden on control processors. Dedicated 100 Mbps switched paths from the RPMs to every line card eliminate sluggish forwarding table updates that could otherwise jeopardize network stability.

**Fault Tolerance and High Availability**

To maximize network uptime, the E-Series architecture supports redundancy, availability, and serviceability features. All key components are redundant, including the RPMs, SFMs, power, and cooling components. All memory systems are ECC/parity protected. System-wide environmental monitoring and persistent configuration synchronization enable the FTOS to detect, report, and correct faults with minimum system interruption. In addition, serviceability features such as hot-swappability of all key components, cable management, and front-side access to all cabling and cards minimize mean time to repair.

**Full L2/L3 Functionality**

**Reliable Real-Time Operating System**

Force10 FTOS software is purpose-built for scalable, high-performance Ethernet applications that span the LAN, MAN, and WAN. FTOS harnesses the massive performance of the Force10 E-Series and provides end users with the functionality they need to utilize the power of the E-Series architecture.

A real-time operating system, FTOS is customized for an extensive range of high-performance L2 switching and L3 routing features. Process modularity and distribution in a protected multiprocessor environment ensures stability and fault tolerance. Critical FTOS features include robust IP routing control plane, hardware and software fault-tolerance, highly granular traffic management and accounting, industry standard Command Line Interface (CLI), and system diagnostics.

**Extensive L2/L3 Control Plane Features**

FTOS works in harmony with the hardware-assisted per-packet features provided by Force10 ASICs. As a result, FTOS provides the system’s L2/L3 control plane features and functionality, making it an integral part of the E-Series architecture.
In the case of L3, FTOS delivers robust routing protocols — including Border Gateway Protocol 4 (BGP4), IS-IS, Open Shortest Path First (OSPF), and Routing Information Protocol 2 (RIP) v2 — that scale to millions of routes and 384K forwarding entries. Virtual Router Redundancy Protocol (VRRP) and Equal Cost Multi-Path routing (ECMP) in FTOS enable reliable network design while support for IP Multicast — ranging from Internet Group Management Protocol (IGMP) and Protocol Independent Multicast-Sparse Mode (PIM-SM) to Multiprotocol Border Gateway Protocol (MBGP) and Multicast Source Discovery Protocol (MSDP) — make the E-Series the platform of choice in Campus and Metro Backbone applications.

In the case of L2, FTOS scales to thousands of MAC entries. It also supports 4096 VLANs, VLAN tagging and stacking, load sharing and fail-over with Link Aggregation (LAG), and Rapid Spanning Tree Protocol (RSTP).

**Flexible Services and Management**

Customers demand flexibility, and the Force10 E-Series gives them the tools they need. These features include congestion control with WRED and WFQ, QoS interworking between L2, and L3, CAR (policing), and detailed statistics for accounting and billing.

Integral to the E-Series architecture are its flexible and secure management capabilities. User access can be authenticated via RADIUS and TACACS+, while secure access methods include Secure Shell (SSH) and Secure Copy (SCP). Built in support for SNMP MIBs and a dedicated 100BaseT management port allows seamless integration in any in-band and out-of-band Network Management environment.

**Conclusion**

The Force10 E-Series architecture enables enterprises and service providers to build scalable, resilient, and high-performance Ethernet networks. Technological innovation across a range of areas enables the E-Series to deliver a scalable 1.68 Tbps switch fabric, high-performance ASIC-based distributed forwarding, a robust control plane, and the feature-rich FTOS operating system.

The Force10 E-Series has a per slot capacity of 56.25 Gbps across 14 slots. This allows massive GbE and 10 GbE port density today plus enough scalability to double that density tomorrow — without a forklift upgrade. Force10’s ASIC-based distributed forwarding provides true line-rate performance for all packet sizes, even with all L2/L3 features enabled. The multiprocessor control plane, fortified with DoS protection, supplies scalability and resilience to large networks. In addition, FTOS’s process modularity and isolation allow control plane stability with extensive L2/L3 features.

From Server Aggregation and Cluster/Grid Computing to next-generation Internet Exchanges and Metro-Ethernet Services, the breakthrough E-Series architecture supports the most demanding network applications and enables tomorrow’s ultra high-speed network applications. The Force10 E-Series provide an unprecedented combination of scalability, performance, and full-featured L2 switching and L3 routing.