Cisco Catalyst 9500 Architecture
Introduction

Enterprise campus networks are undergoing profound changes to support ever-increasing bandwidth demands on the access layer with the introduction of 802.11ax and rapid growth of powerful endpoints. With access layer bandwidth moving from 1-Gbps to 2.5-Gbps and 5-Gbps speeds, higher bandwidth like 25 Gbps and 100 Gbps will become the de facto speeds to maintain a similar oversubscription ratio.

Cisco Catalyst® 9500 Series Switches are the foundation of the Cisco® next-generation, enterprise-class backbone solutions. These switches are industry’s first purpose-built, fixed 1-rack-unit (RU) core and aggregation layer switches targeted for the enterprise campus. These switches deliver exceptional table scales (MAC, route, and access control list [ACL]) and buffering capabilities for enterprise applications. This platform delivers up to 6.4 Terabits per second (Tbps) of switching capacity and up to 2 billion packets per second (Bpps) of forwarding performance. The platform offers non-blocking 100-Gigabit-Ethernet Quad Small Form-factor Pluggable 28 (QSFP28) and 40-Gigabit-Ethernet Quad Small Form-factor Pluggable (QSFP+) as well as 25-Gigabit-Ethernet Small Form-factor Pluggable (SFP28) and 10/1-Gigabit-Ethernet Small Form-factor Pluggable (SFP+/SFP) switches with granular port densities that meet diverse campus needs.

This white paper provides an architectural overview of the new Cisco Catalyst 9500 series, including system design, power, cooling, and storage options.

Platform overview

The Cisco Catalyst 9500 platform consists of fixed-configuration, front-to-back airflow switches built on the Cisco Unified Access™ Data Plane 2.0 XL and 3.0 (UADP) architecture, which not only protects your investment but also allows a larger scale and higher throughput. The platform runs on the modern Open Cisco IOS® XE operating system, which supports model-driven programmability and has the capacity to host containers and runs third-party applications natively within the switch (by virtue of an x86 CPU architecture, local storage, and a higher memory footprint). The platform also supports all the hardware high-availability capabilities, including Platinum-rated dual-redundant power supplies and variable-speed, highly efficient redundant fans. The Cisco Catalyst 9500 portfolio (Figure 1) offers switches with variable port speeds and port densities for the ever-increasing performance demands within enterprise campus environments.
The Catalyst 9500 portfolio provides an architectural foundation for next-generation hardware features and scalability. These high-performance switches are based on the UADP 3.0 ASIC, which supports a maximum forwarding capacity of 3.2 Tbps per ASIC and allowing larger table scale compared to the non-high-performance UADP 2.0XL C9500 SKU’s. Both Catalyst 9500 switches have a similar hardware architecture and offer stability with proven operating system software.

**100-Gigabit-Ethernet (GE) switches:**
- C9500-32C - Cisco Catalyst 9500 high-performance Series includes 2xUADP 3.0 ASIC with 32x 100GE Quad Small Form-Factor Pluggable 28 (QSFP28) ports
- C9500-32QC - Cisco Catalyst 9500 high-performance Series includes UADP 3.0 ASIC with 32x 40GE or 16x 100GE QSFP28 ports

**40GE switches:**
- C9500-24Q - Cisco Catalyst 9500 Series includes 4xUADP 2.0 XL ASIC with 24x 40GE Quad Small Form-Factor Pluggable + (QSFP+) ports
- C9500-12Q - Cisco Catalyst 9500 Series includes 2xUADP 2.0 XL ASIC with 12x 40GE QSFP+ ports

**25GE switches:**
- C9500-48Y4C - Cisco Catalyst 9500 high-performance Series includes UADP 3.0 ASIC with 48x 25GE SFP28 and 4x100/40GE QSFP28 ports
- C9500-24Y4C - Cisco Catalyst 9500 high-performance Series includes UADP 3.0 ASIC with 24x 25GE SFP28 and 4x100/40GE QSFP28 ports

**10GE switches:**
- C9500-40X - Cisco Catalyst 9500 Series includes 2xUADP 2.0 XL ASIC with 40x10GE Small Form-Factor pluggable+(SFP+) + 2x40/8x10GE ports
- C9500-16X - Cisco Catalyst 9500 Series includes UADP 2.0 XL ASIC with 16x10GE Small Form-Factor pluggable+(SFP+) + 2x40/8x10GE ports

**NOTE:** Naming conventions on the Cisco Catalyst 9500 Series indicate supported port speeds:
- C9500 – represents Catalyst switch family
- X: Native 10-GE front-panel ports
- Y: Native 25-GE front-panel ports
- Q: Native 40-GE front-panel ports
- C: Native 100-GE front-panel ports
Switch overview

This section describes the high-level highlights of the Catalyst 9500 Series switches.

The Catalyst 9500 switches supports:

- **8 SKU options**: Select the system that best fits your needs based on port speeds, port density, and network scale.
- **Up to two Platinum-rated PSU**: 1.6KW AC/DC or 950W/930W AC/DC power supplies supporting 1:1 power redundancy.
- **New high-efficient variable speed fans**: Supports N+1 or 1+1 Fan/Fan-Tray redundancy with maximum fan speed up to 24000 RPM.
- **Multi-rate optics**: Every QSFP28 port can support different speeds of 100/40/25/10/1G and every QSFP+ port can support different speeds of 40/10/1G.
- **120G USB3.0 or up to 960G M2 SATA external SSD storage**: Primarily for hosting third-party applications.

Switch design

With enterprise networks moving toward higher speeds like 25 Gbps and 100 Gbps, reports indicate that modular port shipments are declining as fixed switches offer significant density, cost, and power benefits. This section briefly covers the high-level system design of the new Cisco Catalyst 9500 Series switches. Additional details can be found in the later sections. Figures 2, 3, 4, and 5 show the different board layouts.

Figure 2. C9500-32C board layout
Figure 3. C9500-32QC/48Y4C/24Y4C board layout

Figure 4. C9500-24Q/12Q board layout
The Catalyst 9500 switches also includes a front-panel RJ45 console port, USB mini type B console port, an RJ45 management port and a USB type A 2.0/3.0 host port for flash drives. All switches come with built-in passive RFID for inventory management, Blue Beacon LED for switch-level identification and Tri-Color LED for system status.

The rear panel on the Catalyst 9500 switches has two field-replaceable power supply unit (PSU) slots and five field replaceable redundant variable speed fans or dual fan trays units, and an M2 SATA drive or USB 3.0 drive for storage.

**Switch power**

The Cisco Catalyst 9500 high-performance switches supports up to two 1.6KW/650W AC or 1.6KW/930W DC small form factor power supply units (PSUs) for a total system capacity of 1.6KW or 650W (Figure 6). The Catalyst 9500 UADP 2.0 XL SKUs support up to two 950W AC/DC PSUs for a total system capacity of 950W. Each PSU is Platinum-rated for greater than 90 percent power efficiency at 100 percent load. The system supports either one PSU operating in non-redundant mode, which is sufficient to power up the switch in its maximum configuration, or two PSUs operating in redundant load-sharing mode, where 50% power is withdrawn from each PSU. Power supplies support both AC, DC, and a combination of AC and DC units, and support full online insertion and removal (OIR) capabilities.
Power supply unit

The maximum output power per power supply in the Catalyst 9500 switches is:

- 1.6KW AC PSU is 1.6KW at 220V input and 1000W at 110V input
- 950W AC PSU is 950W at 110V-220V
- 930W AC PSU is 930W at 110-220V

Each PSU has a power holdup time of approximately 20 milliseconds at 100 percent load. Each PSU comes with front-to-back variable-speed cooling fans and has a push-release lock for simple and secure OIR. Figure 7 shows the PSU features of the switches.

Figure 7. Cisco Catalyst 9500 AC PSUs

Each PSU supports a bi-color (green/amber) LED to determine the status of the power supply, as shown in Table 1.

<table>
<thead>
<tr>
<th>LED</th>
<th>Color</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>⬤</td>
<td>Off</td>
<td>No input power</td>
</tr>
<tr>
<td>Green</td>
<td>⬤</td>
<td>Blinking</td>
<td>12V main off, 12V standby power ON</td>
</tr>
<tr>
<td>Green</td>
<td>⬤</td>
<td>Solid</td>
<td>12V main ON</td>
</tr>
<tr>
<td>Amber</td>
<td>⬤</td>
<td>Blinking</td>
<td>Warning detected, 12V main</td>
</tr>
<tr>
<td>Amber</td>
<td>⬤</td>
<td>Solid</td>
<td>Critical error detected</td>
</tr>
</tbody>
</table>
Switch cooling

Cisco Catalyst 9500 High-Performance SKU’s support hot-swappable and field-replaceable variable-speed modular fans ((five individual fan modules) in the rear of the switch. Cisco Catalyst 9500 UADP 2.0 XL based SKU’s supports hot-swappable and field-replaceable variable-speed fan trays (two fan trays with dual-stacked fan modules) in the rear of the switch with front-to-back airflow. These fan and fan-tray units support Online Insertion and Removal (OIR) and can support a maximum fan speed of 24000 rpm. The fan unit is responsible for cooling the entire switch and interfacing with environmental monitors to trigger alarms when conditions exceed thresholds. Switches are equipped with on-board thermal sensors to monitor the ambient temperature at various points and report thermal events to the system to adjust the fan speeds. Switches supports a hardware failure of up to one individual fan or fan tray, where remaining fans will automatically increase their rpm to compensate and maintain sufficient cooling. If the switch fails to meet the minimum number of required fans, the switch shuts down automatically to prevent the system from overheating.

Figure 8. Cisco Catalyst 9500 fan and fan tray

Insertion and removal of the fan modules are made easy with fan assembly ejectors levers. Press the fan ejector levers and use the fan handle to insert or remove the module. Table 2 highlights the LED signal for each fan and fan tray state.

Table 2. Cisco Catalyst 9500 fan and fan tray LEDs

<table>
<thead>
<tr>
<th>LED</th>
<th>Color</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan</td>
<td>Off</td>
<td>No input power</td>
<td>No input power</td>
</tr>
<tr>
<td>Fan</td>
<td>Blinking</td>
<td>12V main off, 12V standby power ON</td>
<td>12V main off, 12V standby power ON</td>
</tr>
<tr>
<td>Fan</td>
<td>Solid</td>
<td>Critical error detected</td>
<td>Critical error detected</td>
</tr>
</tbody>
</table>

Switch airflow

The Cisco Catalyst 9500 fans and fan trays support front-to-back airflow. Airflow vents are illustrated in Figure 9.

Figure 9. Cisco Catalyst 9500 airflow
The 9500 switches support port-side intake airflow on all C9500 SKUs, where coolant air enters the switch through the port side (cold aisle) and exhausts through the fan and power supply modules in the rear (hot aisle). QSFP/SFP cages are thermally enhanced with the mid-portion allowing airflow through the cage.

**Baseboard components**

Catalyst 9500 switches are line rate switches offering configurable system resources to optimize support for specific features, depending on how the switch is used in the network. The switch architecture consists of four main components:

- UADP ASIC complex
- X86 CPU complex
- ASIC interconnect
- Front-panel interfaces

Figure 10 shows a high-level diagram of the switch’s components.

Figure 10. Catalyst 9500 high-performance SKU high-level block diagram
UADP ASIC complex

Catalyst 9500 Series Switches are built on two variants of the UADP ASIC: UADP 2.0 XL and UADP 3.0. Both are based on a system-on-chip (SOC) architecture. The architecture of both ASICs is similar, but the versions differ in switching capacity, port density, port speeds, buffering capability, and forwarding scalability.

UADP 2.0 XL is a third-generation, 240G, dual core ASIC optimized for next-generation Catalyst fixed or modular switches. The architecture and functionality of UADP 2.0 XL is largely unchanged from previous generation of the UADP ASIC. The UADP 2.0 XL ASIC is built using 28-nanometer technology with dual core architecture. Figure 11 shows the components of the UADP 2.0 XL ASIC.

Key UADP 2.0 XL capacities and capabilities include:

- **Packet bandwidth/switching throughput:** 240 GE (120 GE per core)
- **Forwarding performance:** 375 Mpps
- **Stack bandwidth:** 720G (2x360G rings)
- **FIB table:** 128K/64K IPv4 and IPv6 Host routes and 64K/32K IPv4 and IPv6 longest-prefix-match entries
- **Shared packet buffer:** 32 MB (16 MB per core)
- **Dedicated NetFlow block:** Up to 128K(IPv4)/64K(IPv6) (64K/32K per core)
- **TCAM ACL:** 54K total capacity

The UADP 3.0 ASIC is based on the next-generation UADP 2.0 architecture, using a 16-nanometer technology that offers significantly larger tables and bandwidth compared to all other UADP ASICS. Figure 12 shows the components of the UADP 3.0 ASIC.
Key UADP 3.0 capacities and capabilities include:

- **Packet bandwidth/switching throughput**: 1600 GE (800 GE per core)
- **Forwarding performance**: 1Bpps (500 Mpps per core)
- **ASIC interconnects**: Two point to point links with total of 800G bandwidth
- **FIB entries**: 416K double width tables optimized for IPV6 deployments
- **Unified packet buffer**: 36M shared between both cores
- **NetFlow**: Up to 128K IPv4 and IPv6 double-width shared tables
- **TCAM ACL**: 54K total capacity

**NOTE**: UADP 3.0 achieves linerate forwarding performance for packet sizes greater than 187 bytes and above.

Table 3 highlights the high-level differences between the UADP 2.0 XL and UADP 3.0 ASICs.

<table>
<thead>
<tr>
<th>Capabilities (per ASIC)</th>
<th>Cisco Catalyst 9500 Series (UADP 2.0 XL)</th>
<th>Cisco Catalyst 9500 High Performance (UADP 3.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching and forwarding capacity</td>
<td>480 Gbps/360 Mpps</td>
<td>3.2 Tbps/1 Bpps</td>
</tr>
<tr>
<td>Stack bandwidth</td>
<td>2x 360 Gbps</td>
<td>2x 400 Gbps</td>
</tr>
<tr>
<td>Buffer capability</td>
<td>2x 16 MB</td>
<td>36 MB shared buffer</td>
</tr>
<tr>
<td>Switch Database Management (SDM) template</td>
<td>Fixed templates</td>
<td>Customizable templates</td>
</tr>
<tr>
<td>NetFlow capabilities</td>
<td>Dedicated NetFlow table</td>
<td>Shared NetFlow table</td>
</tr>
<tr>
<td>v4 FIB scale</td>
<td>Total 224K*</td>
<td>Total 416K*</td>
</tr>
<tr>
<td>v4 and v6 scale</td>
<td>v6 reduced by half</td>
<td>v4 and v6 same scale</td>
</tr>
</tbody>
</table>

*Maximum ASIC Capacity
X86 CPU complex

Catalyst 9500 Series Switches are equipped with the same CPU, system memory and flash storage. Figure 13 outlines the X86 CPU complex.

Some highlights include:

• New 2.4 Ghz x86 quad-core CPU (Intel® Xeon®-D CPU running at 2.4 Ghz)
• Single 16 GB of DDR4 2400MT/s RAM
• Support for a USB Type A file system (front-serviceable) for external storage and Bluetooth dongle
• Support for a USB Type B serial console in addition to a RJ-45 serial console
• 16 GB of internal enhanced USB (eUSB) flash
• USB 3.0 (400 MB/s read and 140 MB/s write) or M.2 (300 MB/s read or 290 MB/s write) form-factor SSD module (rear-serviceable) for application hosting or general-purpose storage
• System reset switch for manually power cycle

Figure 13. X86 CPU complex
ASIC interconnect

Catalyst 9500 switches are fixed core and aggregation switches without any rear stack ports, hence ASIC interconnect links are used for inter-ASIC communications. Communication within a core or between cores is locally switched within the ASIC, so packets destined to local ports within the ASIC do not use ASIC interconnects link. The purpose of the ASIC interconnects are to move data between multiple UADP ASICSs.

UADP 3.0 has two ASIC interconnect links, allowing a total packet bandwidth of 800 Gbps.

ASIC interconnects are a combination of up to 16 SERDES (serializer/deserializer) operating at a 25G NRZ format with a total packet bandwidth of 400 Gbps. Because the UADP 3.0 has two ASIC interconnect links, it allows for a total packet bandwidth of 800 Gbps.

Major UADP 3.0 ASIC interconnect features:

- No packet size limitations
- Packet type-agnostic
- Packet data is spread across the SERDES channels
- Header compression capabilities
- No fragmentation or reordering
- No buffering on ASIC interconnects links

Figure 14 offers a block diagram of the ASIC interconnect.

Figure 14. C9500 high-performance switch ASIC interconnect block diagram

UADP 2.0 XL has effective bandwidth of 720G, with each core ASIC interconnect burst up to 360G. 360G is composed of dual-independent six-60-Gbps rings (see Figure 15).
Front-panel interfaces

The Ethernet physical layer (PHY) connects a link-layer device (often a MAC) to a physical medium such as a transceiver. The PHY on Catalyst 9500 switches is a fully integrated Ethernet transceiver supporting steering and mapping of lanes back to the ASIC to support multiple speeds (10, 25, 40, and 100GE) depending on the optics inserted into the front-panel ports. Figure 16 provides a high-level overview of the C9500-32C switch components.
Highlights of the C9500-32C Switch include:

- 16 columns of QSFP28 cage in 2x1 configuration mode
- Each QSFP28 cage has 8 northbound SERDES connections back to the ASIC
  - Each SERDES connection operates at either 4x10G speed for 40G QSFP+ optics, or 4x25G speed for 100G QSFP28 optics
  - Interface speeds are based on the transceiver module inserted
- 32 QSFP28 Ethernet ports
  - 40G or 100G with a QSFP+/QSFP28 transceiver module or 10G/1G with a CVR adaptor
- Port mapping
  - Ports 1-8 are mapped to ASIC0/Core1 and ports 9-16 are mapped to ASIC0/Core0
  - Ports 17-24 are mapped to ASIC1/Core1 and ports 9-16 are mapped to ASIC1/Core0
- Power to the optics are enabled by the onboard controller, which turns on as the module are inserted into the front-panel cage
- The advanced-forwarding ASIC supports 100-Gbps single-flow traffic processing on all ports

Figure 17 provides a high-level overview of the C9500-32QC switch components.

Figure 17. C9500-32QC high-level block diagram
Key highlights of the C9500-32QC switch include:

- 16 columns QSFP28 cage in 2x1 configuration mode
- Each QSFP cage has 4 northbound SERDES connections back to the ASIC
  - Each SERDES connection operates at either 2x20G speed for 40G QSFP+ optics, or 4x25G speed for 100G QSFP28 optics
  - Interface speeds are CLI-based
- 32 QSFP28 Ethernet ports
  - 40G or 100G with a QSFP+/QSFP28 transceiver module or 10G/1G with a CVR adaptor
- Port mapping
  - Ports 1-16 are mapped to ASIC0/Core1 and ports 17-32 are mapped to ASIC0/Core0
- Power to the optics is enabled by the onboard controller, which turns on as the module is inserted
- Default port configuration,
  - Ports 1 to 24 are enabled and active as 40G interfaces
  - Ports 25 to 32 are 40G interfaces but inactive
  - Ports 33 to 44 are 100G but inactive
  - Ports 45 to 48 are 100G interfaces and active
- Enable or disable of 100G ports using the “enable/no enable” interface command
- The advanced-forwarding ASIC supports 100-Gbps single-flow traffic processing on 100G capable ports and 20G single-flow traffic processing on all 40G Ports

Figure 18 shows the port configuration modes supported on the C9500-32QC switch.

Figure 18. C9500-32QC port configuration modes

Note: Other configuration options are supported, including mix and match of speeds
Figure 19 provides a high-level overview of the C9500-48Y4C switch components.

Figure 19. C9500-48Y4C high-level block diagram

Key highlights of the C9500-48Y4C include:

- 12 Columns of SFP28 cage in 2x1 configuration mode and 2 columns of QSFP28 cage in 2x1 configuration mode
- Each SFP28 cage has 24 northbound SERDES connections back to the ASIC
  - Each SERDES connection operates at 25G speed for SFP28 Optic and 10G speed for SFP+ Optic
  - Interface speeds are based on the transceiver module inserted
- Each QSFP28 cage has 8 northbound SERDES connections back to the ASIC
  - Each SERDES connection operates at 4x10G speed for 40G, or 4x25G speed for 100G optics
- 48 SFP28 Ethernet ports and 4 QSFP28 Ethernet ports
  - 25G/10G/1G with a SFP28/SFP+ transceiver module and 40G or 100G with a QSFP+/QSFP28 transceiver module
- Port mapping
  - Ports 1-24 and 49-50 are mapped to ASIC0/Core1
  - Ports 25-48 and 51-52 are mapped to ASIC0/Core0
- Power to the optics is enabled by an onboard controller, which turns on as the module is inserted
- The advanced-forwarding ASIC supports 100-Gbps single-flow traffic processing on the uplinks ports and 25-Gbps single-flow traffic processing on the downlinks ports

Note: C9500-24Y4C Switch has exact same architecture as C9500-48Y4C with 1xUADP 3.0 ASIC and total of 24 x 25G/10G/1G ports + 4 QSFP28 Ethernet uplink ports with similar port mapping.
Figure 20 provides a high-level overview of the C9500-24Q switch components.

**Figure 20. C9500-24Q high-level block diagram**

Key highlights of the C9500-24Q:

- 3 columns of QSFP+ cage in 2x1 configuration mode
- Each QSFP+ cage has 8 northbound SERDES connections back to the ASIC
  - Each SERDES connection operates at 10G speed
  - Interface speeds are based on the transceiver module inserted
- 24 QSFP Ethernet ports
  - 40G with a QSFP+ transceiver module or 10G/1G with a CVR adaptor
- Port mapping for 24Q SKU
  - Ports 1-3 are mapped to ASIC3/Core1 and ports 4-6 are mapped to ASIC3/Core0
  - Ports 7-9 are mapped to ASIC2/Core1 and ports 10-12 are mapped to ASIC2/Core0
  - Ports 13-15 are mapped to ASIC1/Core1 and ports 16-18 are mapped to ASIC1/Core0
  - Ports 19-21 are mapped to ASIC0/Core1 and ports 22-24 are mapped to ASIC0/Core0
- Power to the optics is enabled by an onboard controller, which turns on as the module is plugged in
- ASIC supports 10-Gbps single-flow traffic processing on all ports

**Note:** C9500-12Q Switch has exact same architecture as C9500-24Q with two UADP 2.0 XL ASIC and total of 12 x 40G ports and similar port mapping.
Figure 21 provides a high-level overview of the C9500-40X switch components.

Figure 21. C9500-40X high-level block diagram

Key highlights of the C9500-40X:

- 12/8 columns of SFP+ cage in 2x1 configuration mode
- Each SFP+ cage has 24 northbound SERDES connections back to the ASIC
  - Each SERDES connection operates at 10G Speed
  - Interface speeds are based on the transceiver module that is plugged in
- 40 SFP+ Ethernet ports
  - 10G /1G with an SFP/SFP+ transceiver module
- Port mapping
  - Ports 1-12 are mapped to ASIC1/Core1 and ports 13-24 are mapped to ASIC1/Core0
  - Ports 25-36 are mapped to ASIC0/Core1 and ports 37-40 are mapped to ASIC0/Core0
  - Uplink ports 41/42 or 1-8 are mapped to ASIC0/Core0
- Power to the optics is enabled by an onboard controller, which turns on as the module is plugged in
- ASIC supports 10-Gbps single-flow traffic processing on all ports

Note: C9500-16X Switch has exact same architecture as C9500-40X with one UADP 2.0 XL ASIC and total of 16 x 10G ports and similar port mapping.
Network modules

The Cisco Catalyst 9500 Series supports two optional network modules (Figure 22) for uplink ports on C9500-40X and C9500-16X switches. The default switch configuration does not include the network modules. All ports on the network module are line rate and all software features supported on switch downlink ports are also supported on network module ports.

Figure 22. Catalyst 9500 network modules

Key network modules highlights:

- Uplink modules are supported on the C950-40X and C9500-16X SKUs only
- Modules are automatically powered upon insertion
- OIR-capable
- ACT2 authenticated
- Line-rate on every port with 10G single-flow traffic processing
- Speed is auto-negotiated depending on the optics inserted

Storage

Applications are used in enterprise networks for a variety of business-relevant use cases. Examples of enterprise applications include administrative tools such as performance monitors and protocol analyzers, as well as security toolsets such as intrusion detection services, which traditionally operate on an external physical or virtual server.

This section specifies the SSD modules supported on Catalyst 9500 switches with primary application for hosting third-party applications. The modules also serve as general-purpose storage for packet captures, operating system trace logs, and graceful insertion and removal (GIR) snapshots. Catalyst 9500 switches use a Cisco application framework, also known as Cisco IOx (the application framework combines Cisco IOS and Linux) to support applications containerized in KVM-based virtual machines, Linux containers (LXC), or Docker containers.

Cisco IOS XE running on the Catalyst 9500 switches reserves dedicated memory and CPU resources for application hosting (Table 4). By reserving memory and CPU resources, the switch provides a separate execution space for user applications, it protects the switch’s IOS XE run-time processes, ensuring both its integrity and performance.
Table 4. Catalyst 9500 application hosting resources

<table>
<thead>
<tr>
<th>Platform</th>
<th>Memory (GB)</th>
<th>CPU (cores)</th>
<th>USB 3.0 (GB)</th>
<th>M2 SATA (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalyst 9500 (UADP 2.0)</td>
<td>8</td>
<td>1 x 2.4Ghz</td>
<td>120</td>
<td>NA</td>
</tr>
<tr>
<td>Catalyst 9500 High Performance (UADP 3.0)</td>
<td>8</td>
<td>1 x 2.4Ghz</td>
<td>NA</td>
<td>240/480/960</td>
</tr>
</tbody>
</table>

Cisco Catalyst 9500 (UADP 2.0) switch support for a field-replaceable unit (FRU) USB 3.0 SSD on the rear of the switch provides extra 120GB storage for application hosting (only for Cisco IOS XE Release 16.9.1 and above). The USB 3.0 Solid State Drive (SSD) is enabled with Self-Monitoring, Analysis, and Reporting Technology (S.M.A.R.T.) to monitor the reliability of the drive, predict drive failures, and carry out different types of drive self-tests. The USB 3.0 SSD module has one partition of 120GB. Cisco IOS Software creates a partition with EXT4 as the default file system.

Storage needs on Catalyst 9500 high-performance switches are supported by a pluggable Serial Advanced Technology Attachment (SATA) SSD module located on the rear panel of the switch. This module is a field-replaceable unit and has a hot-swap button on the storage panel of the switch for graceful removal. The SSD module storage capacity ranges are 240GB, 480GB, and 960GB and the default file system supported is EXT4. The SATA module also supports the ability to monitor the health of the device through S.M.A.R.T. Figure 23 outlines the 9500 Series’ storage options.

Figure 23. Catalyst 9500 storage options
Packet walks

This section provides a high-level overview of how packet forwarding is performed on a Catalyst 9500 high-performance switch. UADP 2.0 XL and UADP 3.0 are architecturally equivalent, hence a single unicast packet walk is described.

**Ingress and egress Unicast Forwarding with the ASIC**

Figure 24 shows a visual representation of the Unicast packet forwarding within the ASIC.

**Figure 24. Catalyst 9500 high-performance packet walk within the ASIC**

Following is the basic sequence of events when packets enter the Catalyst 9500 front-panel ports:

1. The packet arrives at the ingress port and the Physical Layer (PHY) converts the signal and serializes the bits, then sends the packet to the Network Interface (NIF) on the ASIC.

2. The NIF packages the frame into 256-bytes chunks and moves it to the ingress MACsec engine. The NIF also implements 1588 timestamping and EEE if enabled.

3. The MACsec engine is a cut-through, fixed-Latency, cryptography engine that supports 802.1AE MAC security and core cryptography of L2-CTS and output frames to go to the ingress, First-In-First-Out (FIFO).

4. The ingress FIFO collects the frames in segments of 256 bytes and transmits them to PBC.

5. The Ingress Forwarding Controller (IFC) snoops packets between the ingress FIFO and PBC and performs frame processing and a series of table lookups to deliver the resulting frame descriptor to PBC.

6. PBC is the primary packet store on the UADP ASIC, which uses the 64-bytes frame descriptor to determine the egress port and Quality-of-Service (QoS) treatment of the frame. As egress port is on the same ASIC, PBC performs local switching by allowing frames to be enqueued directly into Egress Queues (EQS).

7. EQS (egress queues and scheduler) is responsible for queue management, replication, and scheduling packets. EQS enqueues packets arriving from the local ingress path into egress queue structures and then schedules them for transmission to the corresponding egress ports.

8. PBC receives the packet handle/results from the EQS bock and sends the packet to the egress FIFO through the rewrite engine.

9. The Egress Forwarding Controller (EFC) snoops the frames as it moves from PBC to the rewrite engine.
10. The EFC completes egress lookup functions (like egress SPAN, re-circulation) and writes the rewrite descriptor to the rewrite engine.

11. The Rewrite Engine (RWE) performs packet rewrite with a new descriptor and fragmentation. Packets are rewritten first, and then, if necessary, are fragmented and sent to the egress port FIFO. The egress port FIFO provides storage for frames awaiting transmission to either NIF or to the re-circulation path.

12. Egress MACSEC performs in fixed latency and a wire rate encryption is required by the frame for 802.1AE or L2-CTS. It then passes the frame on to the NIF in a cut-through manner.

**Ingress and egress unicast forwarding across the ASIC**

Figure 25 shows a visual representation of the unicast packet forwarding across the ASIC.

Following is the basic sequence of events when packets enter the Catalyst 9500 front-panel ports:

1. The packet arrives at the ingress port and the PHY converts the signal and serializes the bits, then sends the packet to the Network Interface (NIF) on the ASIC.

2. The NIF packages frames into 256-bytes chunks and moves to the ingress MACsec engine. The NIF also implements 1588 timestamping and EEE, if enabled.

3. The MACsec engine is a cut-through, fixed-Latency, cryptography engine to support 802.1AE MAC security and core cryptography of L2-CTS and output frames to go to the ingress FIFO.

4. The ingress FIFO collects the frames in segments of 256 bytes and transmits to PBC.

5. The Ingress Forwarding Controller (IFC) snoops packets between the ingress FIFO and PBC, and performs frame processing and a series of table lookups to deliver the resulting frame descriptor to PBC.

6. The PBC is the primary packet store on the UADP ASIC, which uses the 64-bytes frame descriptor to determine the egress port and the QoS treatment of the frame. As the egress port is on the remote UADP ASIC, PBC sends the frame descriptor to the Ingress Queue and Scheduler (IQS).
7. The IQS provides queueing and scheduling functions along with congestion management (priority packets are enqueued first on to ASIC interconnect) before sending a packet to the remote UADPs.

8. The IQS notifies PBC to dequeue a frame out on the ASIC interconnect once the queues are available for transmission.

9. Packets arriving from the ASIC interconnect are buffered in PBC and descriptors are sent to EQS for further processing.

10. The Egress Queues and Scheduler (EQS) is responsible for queue management, replication, and scheduling packets. EQS enqueues packets arriving from the local ingress path into egress queue structures and then schedules them for transmission to the corresponding egress ports.

11. PBC receives the packet handle/results from the EQS block and sends the packet to the egress FIFO through the rewrite engine.

12. The Egress Forwarding Controller (EFC) snoops the frames as it moves from PBC to the rewrite engine.

13. The EFC completes egress lookup functions (like egress SPAN, re-circulation) and writes the rewrite descriptor to the rewrite engine.

14. The Rewrite Engine (RWE) performs packet rewrite with new descriptors and fragmentation. Packets are rewritten first and then, if necessary, fragmented and sent to the egress port FIFO. The egress port FIFO provides storage for frames awaiting transmission to either NIF or to the re-circulation path.

15. Egress MACsec performs in fixed latency and a wire rate encryption is required by the frame for 802.1AE or L2-CTS. It then passes the frame on to the NIF in a cut-through manner.

Conclusion

Cisco Catalyst 9500 Series Switches are the enterprise-class backbone of the Cisco Catalyst 9000 Family of switches, offering a comprehensive high-density portfolio and architectural flexibility with 100G, 40G, 25G, and 10G. This new platform is based on the Cisco next-generation programmable UADP ASIC for increased bandwidth, scale, security, and telemetry. The platform also supports infrastructure investment protection with non-disruptive migration from 10G to 25G and beyond. Cisco Catalyst 9500 Series Switches are built on a modular system architecture designed to provide high performance to meet the evolving needs of highly scalable and growing enterprise networks.

References

Additional websites that offer more information about the Cisco Catalyst 9500 Series and its capabilities:

- Cisco Catalyst 9500 Series Switches data sheet
- Cisco Catalyst 9500 Series Switches hardware installation guide
- Cisco Catalyst 9000 - Switching for a new era of intent-based networking
- 25GE and 100GE – Enabling higher speeds in the enterprise with investment protection white paper
- Cisco Catalyst 9500 High Performance series performance validation