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Cisco Nexus 7000 Switch Architecture

BRKARC-3470

Ron Fuller, CCIE#5851 (R&S/Storage)
Technical Marketing Engineer

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Session Abstract

This session presents an in-depth study of the architecture of the latest generation of Nexus 7000 and Nexus 7700 data centre switches. Topics include supervisors, fabrics, I/O modules, forwarding engines, and physical design elements, as well as a discussion of key hardware-enabled features that combine to implement high-performance data centre network services.

Session Goal

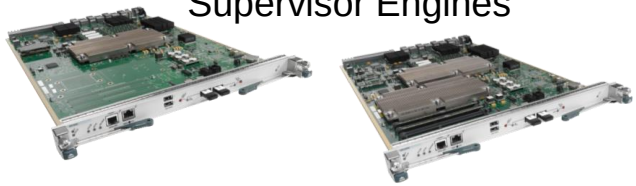
- To provide a thorough understanding of the Nexus 7000 / Nexus 7700 switching architecture, supervisor, fabric, and I/O module design, packet flows, and key forwarding engine functions
- This session will examine the Nexus 7700 system, as well as the latest additions to the Nexus 7000
- This session will not examine NX-OS software architecture or other Nexus platform architectures

What Is Nexus 7000?

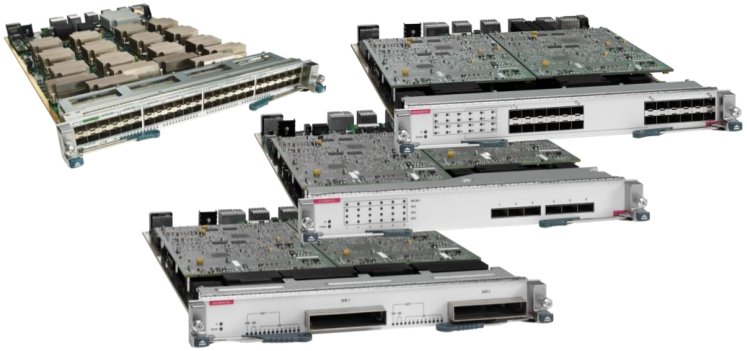
Data-centre class Ethernet switch designed to deliver high performance, high availability, system scale, and investment protection

Nexus 7000 designed for **general-purpose Data Centre** deployments, focused on 10G density plus 40G/100G

Supervisor Engines



I/O Modules



Chassis

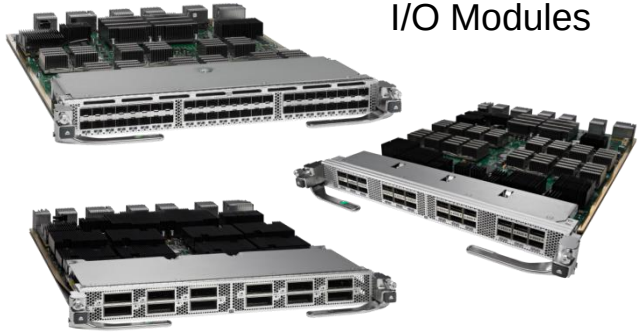
Fabrics

What Is Nexus 7700?

Data-centre class Ethernet switch designed to deliver high performance, high availability, system scale, and investment protection

Nexus 7700 designed for **SP and MSDC Data Centre** deployments, focused on high-density 40G/100G

I/O Modules

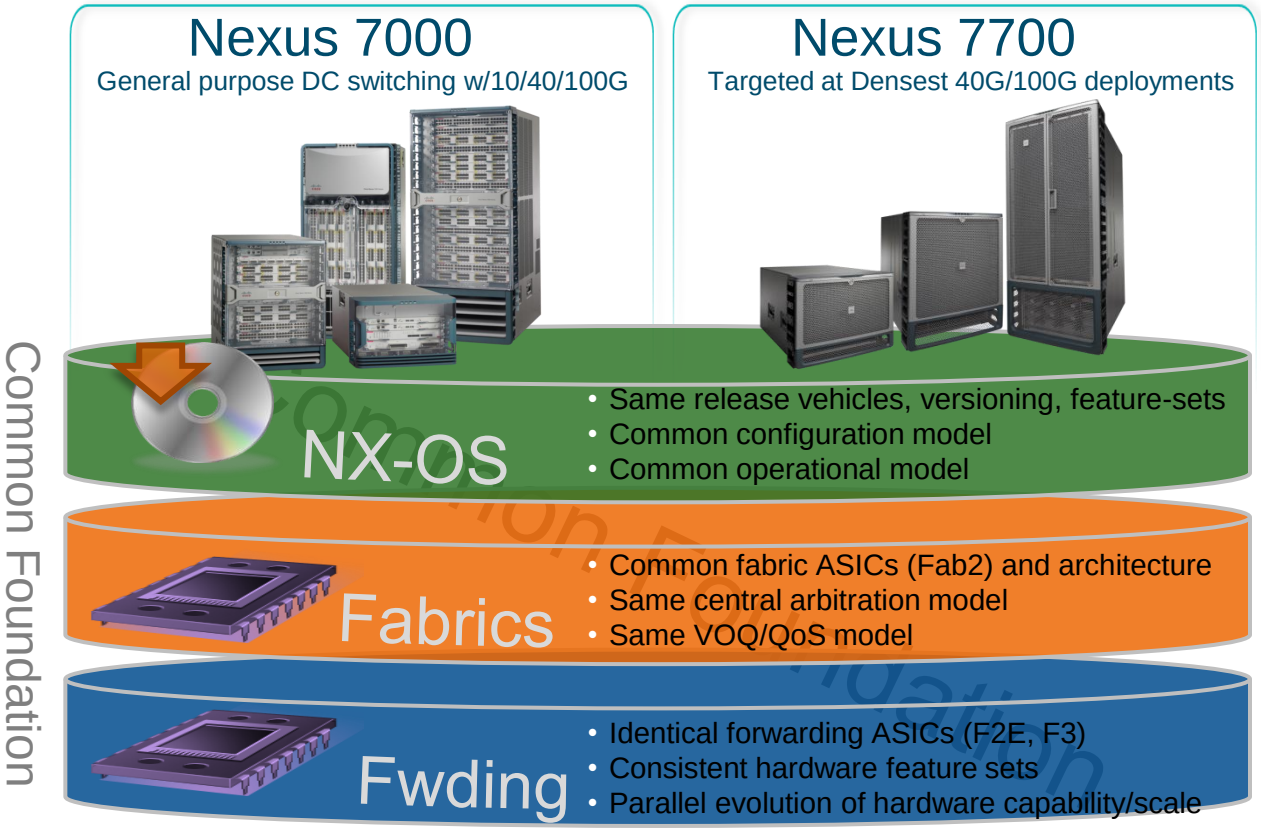


Chassis

Supervisor Engine

Fabrics

Nexus 7000 / Nexus 7700 – Common Foundation



Agenda

- Chassis Architecture
- Supervisor Engine and I/O Module Architecture
- Forwarding Engine Architecture
- Fabric Architecture
- I/O Module Queuing
- Layer 2 Forwarding
- Layer 3 Forwarding
- Classification
- NetFlow
- Conclusion

Nexus 7000 Chassis Family

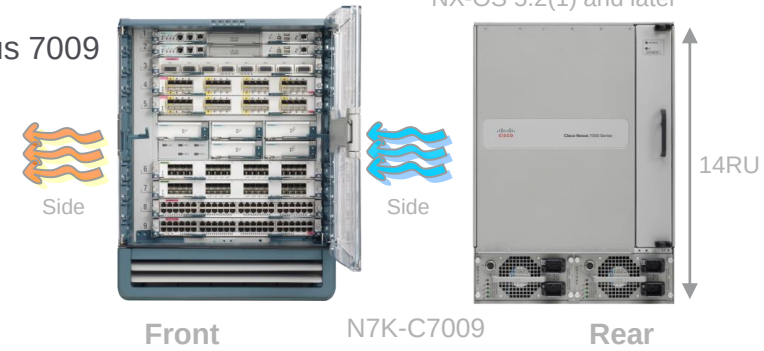
Nexus 7010

Nexus 7018

NX-OS 4.1(2) and later

Nexus 7009

NX-OS 5.2(1) and later



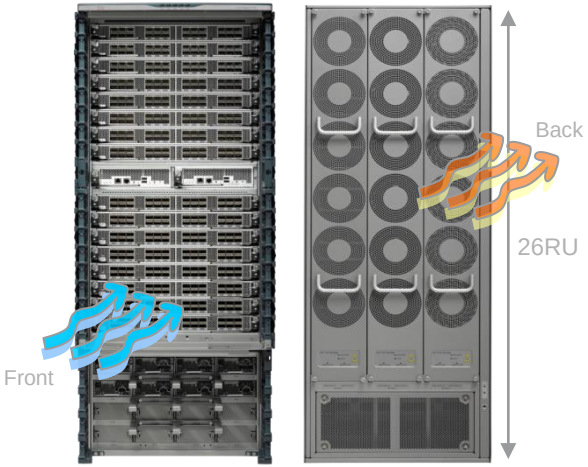
Nexus 7004

NX-OS 6.1(2) and later

Nexus 7700 Chassis Family

NX-OS 6.2(2) and later

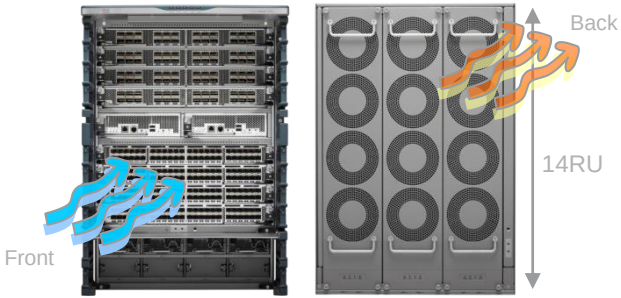
Nexus 7718



N77-C7718

NX-OS 6.2(2) and later

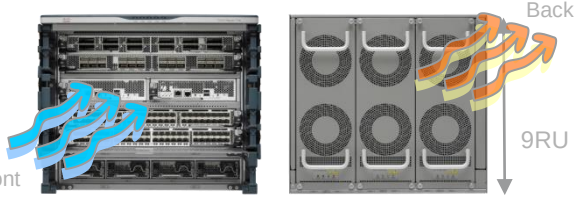
Nexus 7710



N77-C7710

NX-OS 6.2(6) and later

Nexus 7706



N77-C7706

Key Chassis Components

Nexus 7000

- Common components:
  - Supervisor engines
  - I/O modules
  - Power supplies (except 7004)
- Chassis-specific components:
  - Fabric modules
  - Fan trays

Nexus 7700

- Common components:
  - Supervisor engines
  - I/O modules
  - Power supplies
- Chassis-specific components:
  - Fabric modules
  - Fan trays

Common hardware components between Nexus 7000 and Nexus 7700:
NONE

No interchangeable hardware components between Nexus 7000 and Nexus 7700

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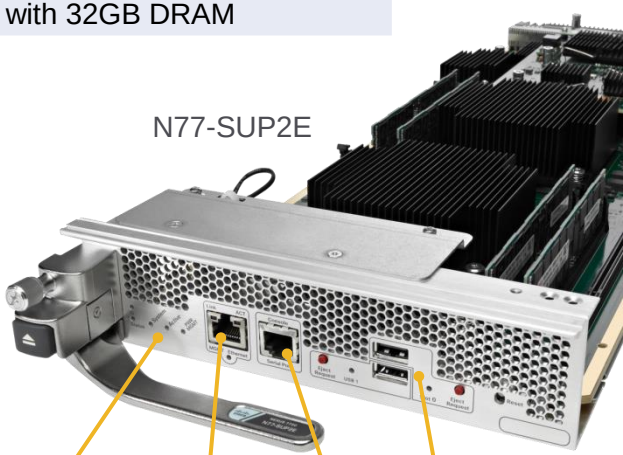
Supervisor Engine 2 / 2E

- Next generation supervisors providing control plane and management functions

Supervisor Engine 2 (Nexus 7000)	Supervisor Engine 2E (Nexus 7000 / Nexus 7700)
Base performance	High performance
One quad-core 2.1GHz CPU with 12GB DRAM	Two quad-core 2.1GHz CPU with 32GB DRAM

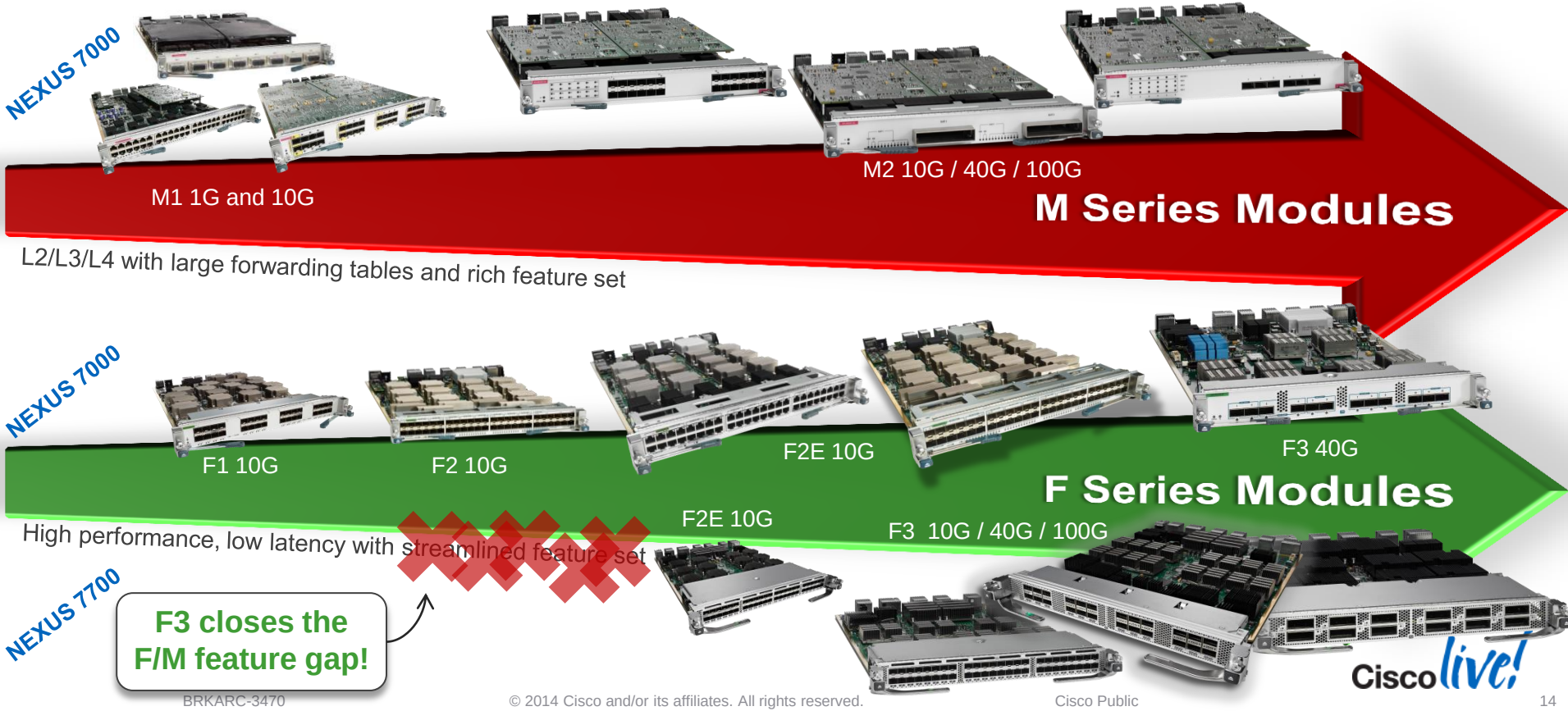
- Connects to fabric via 1G inband interface
- Interfaces with I/O modules via 1G switched EOBC
- Second-generation dedicated central arbiter ASIC
  - Controls access to fabric bandwidth via dedicated arbitration path to I/O modules

N77-SUP2E



N7K-SUP2/N7K-SUP2E

Nexus 7000 / 7700 I/O Module Families



Nexus 7000 M2 I/O Modules

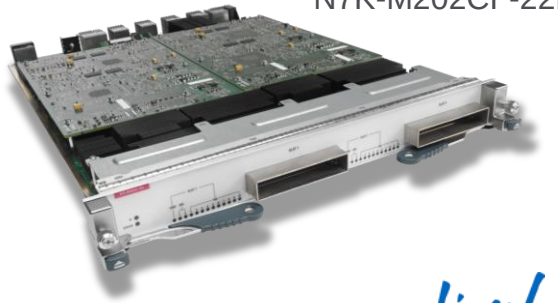
N7K-M224XP-23L / N7K-M206FQ-23L / N7K-M202CF-22L

- 10G / 40G / 100G M2 I/O modules
- Share common hardware architecture
- Two integrated forwarding engines (120Mpps)
  - Support for “XL” forwarding tables (licensed)
- Distributed L3 multicast replication
- 802.1AE LinkSec on all ports

N7K-M224XP-23L

N7K-M206FQ-23L

N7K-M202CF-22L

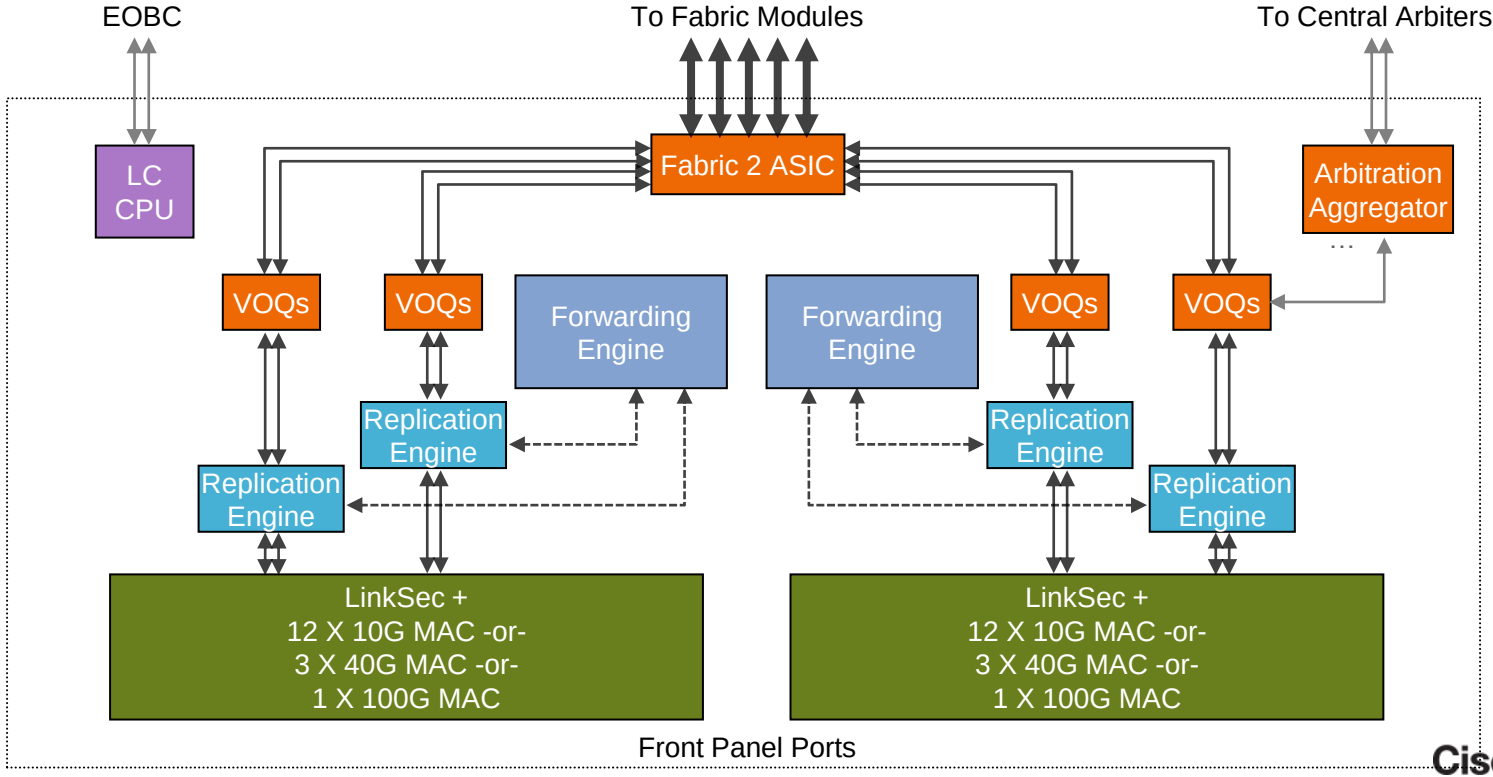


Module	Port Density	Optics	Bandwidth
M2 10G	24 x 10G (plus Nexus 2000 FEX support)	SFP+	240G
M2 40G	6 x 40G (or up to 24 x 10G via breakout)	QSFP+	240G
M2 100G	2 x 100G	CFP	200G

Nexus 7000 M2 I/O Module Architecture

N7K-M224XP-23L / N7K-M206FQ-23L / N7K-M202CF-22L

M Series



7000: Supported in NX-OS release 6.1(2) and later
7700: Supported in NX-OS release 6.2(2) and later

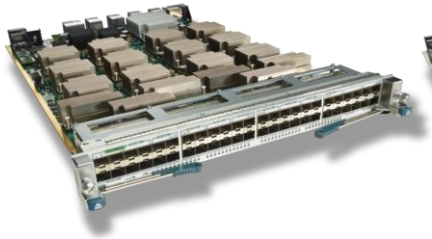
F Series

Nexus 7000 / 7700 F2E I/O Modules

N7K-F248XP-25E / N7K-F248XT-25E / N77-F248XP-23E

- 48-port 1G/10G with SFP/SFP+ transceivers
- 480G full-duplex fabric connectivity
- System-on-chip (SoC) forwarding engine design
  - 12 independent SoC ASICs
- Layer 2/Layer 3 forwarding with L3/L4 services (ACL/QoS)
- Interoperability with M1/M2, in Layer 2 mode on Nexus 7000
  - Proxy routing for inter-VLAN/L3 traffic
- LinkSec support*
  - Last 8 ports (SFP+)
  - All 48 ports (Copper)
- Supports Nexus 2000 (FEX) connections

N7K-F248XP-25E



N7K-F248XT-25E

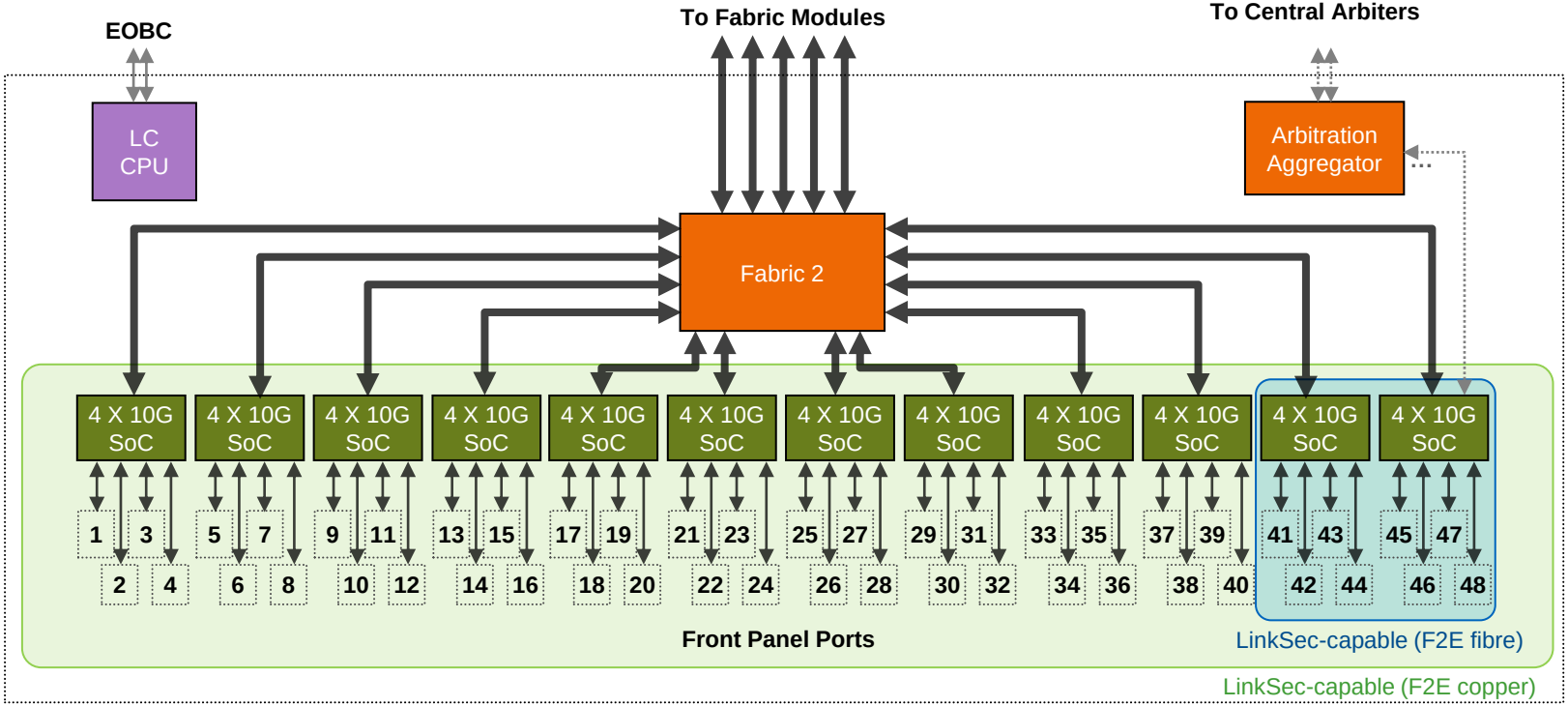
N77-F248XP-23E

* Roadmap item

Nexus 7000 F2E Module Architecture

N7K-F248XP-25E / N7K-F248XT-25E

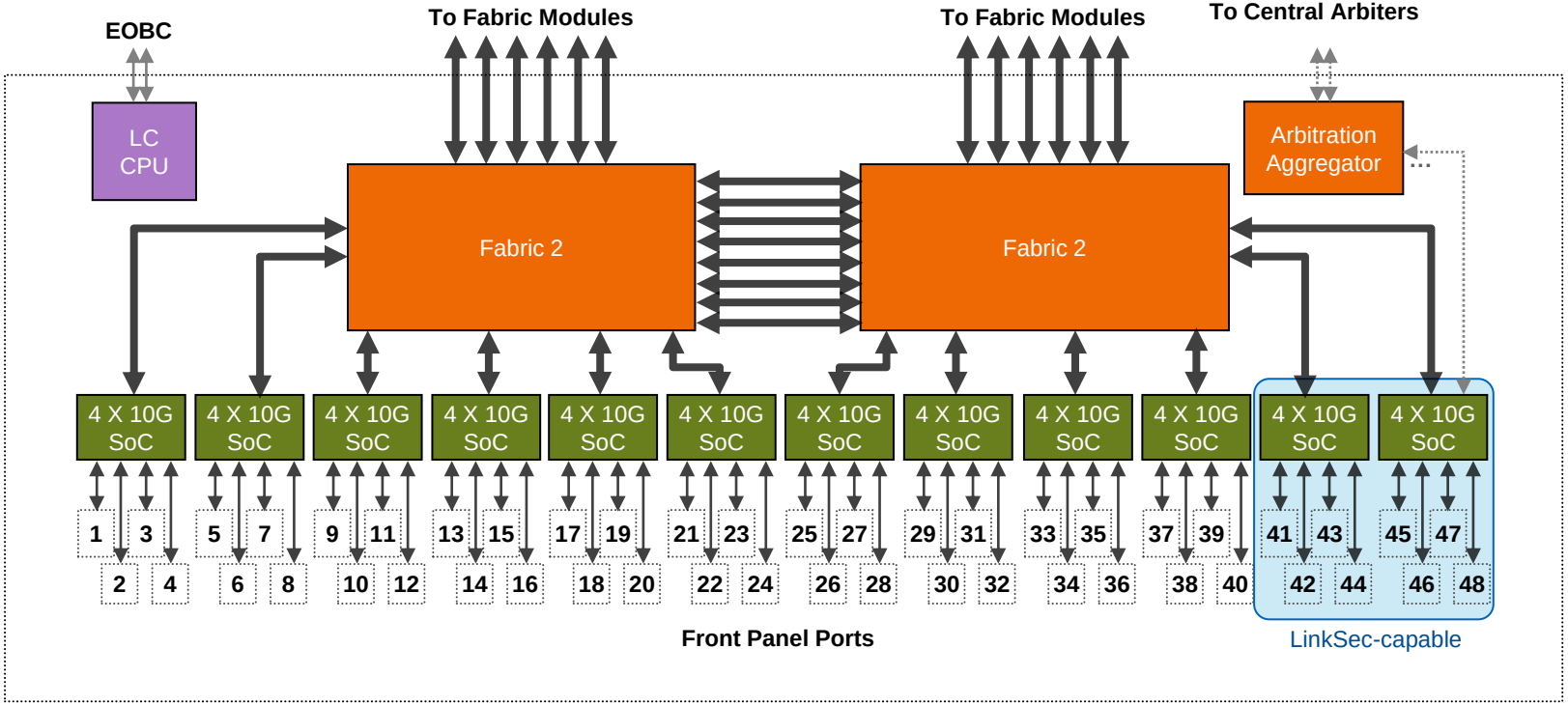
F Series



Nexus 7700 F2E Module Architecture

N77-F248XP-23E

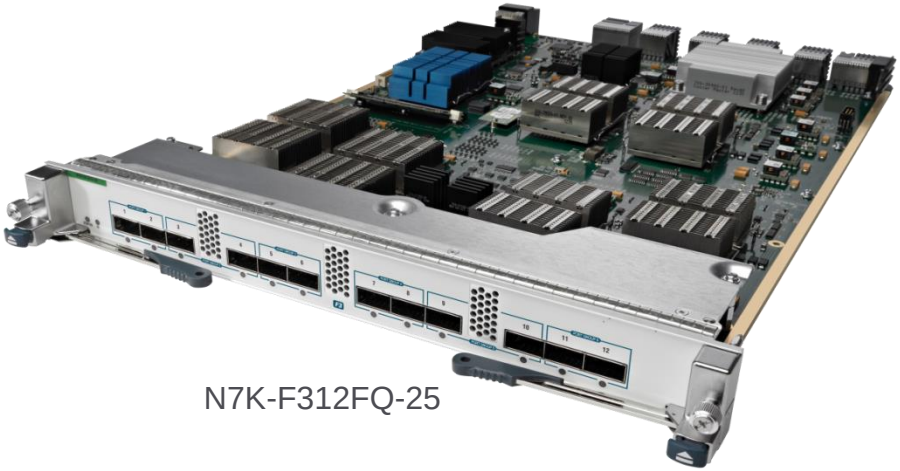
F Series



Nexus 7000 F3 40G Module

F Series

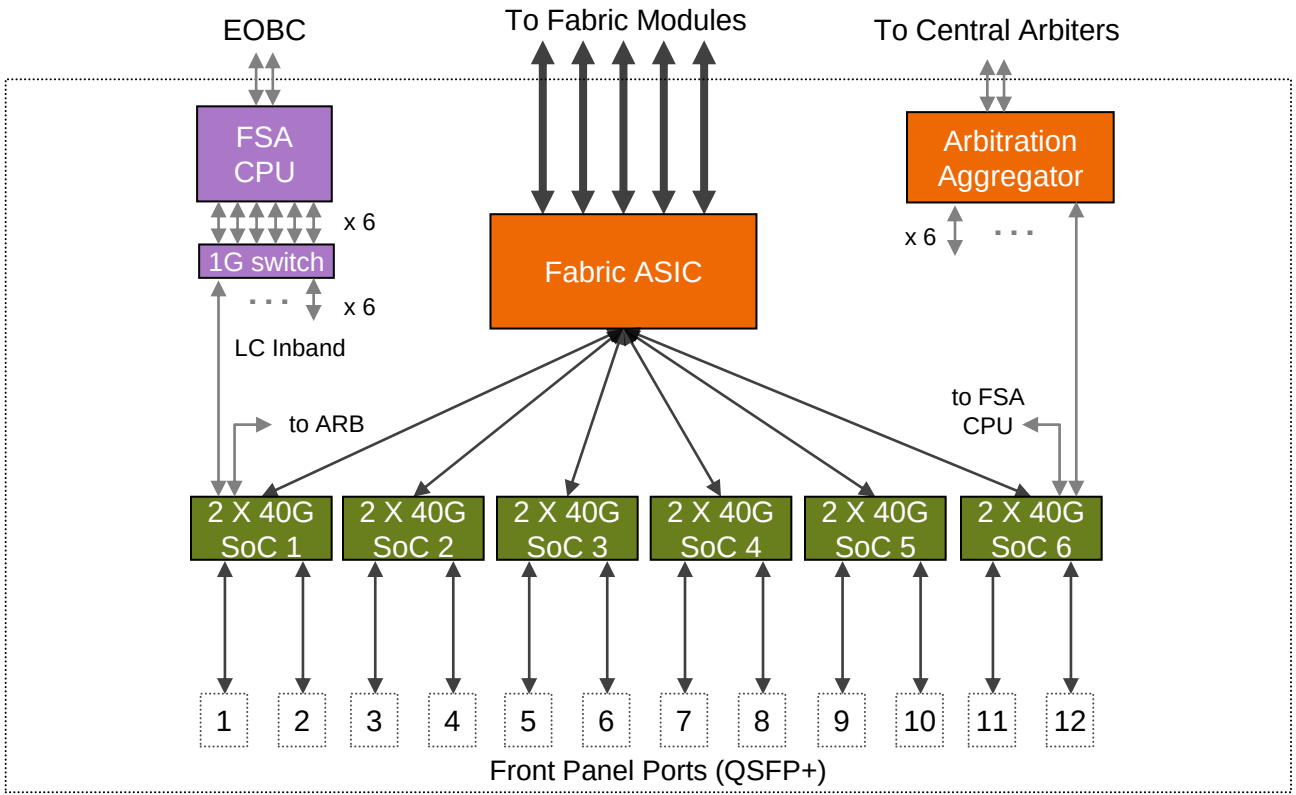
- 12-port 40G QSFP+ module
- 480G full-duplex fabric connectivity
- SoC forwarding engine design
  - 6 independent SoC ASICs
- Layer 2/Layer 3 forwarding with L3/L4 services (ACL/QoS) and advanced features
- Fabric Services Accelerator (FSA) CPU
- Breakout cable support
- ***Requires Supervisor Engine 2 / 2E***



N7K-F312FQ-25

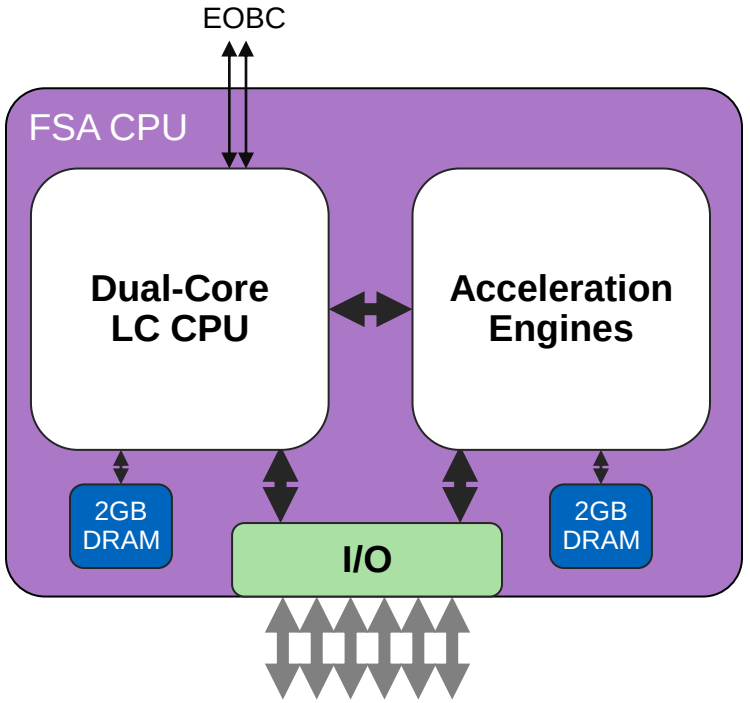
Nexus 7000 12-Port 40G Module Architecture

F Series



Fabric Services Accelerator (FSA)

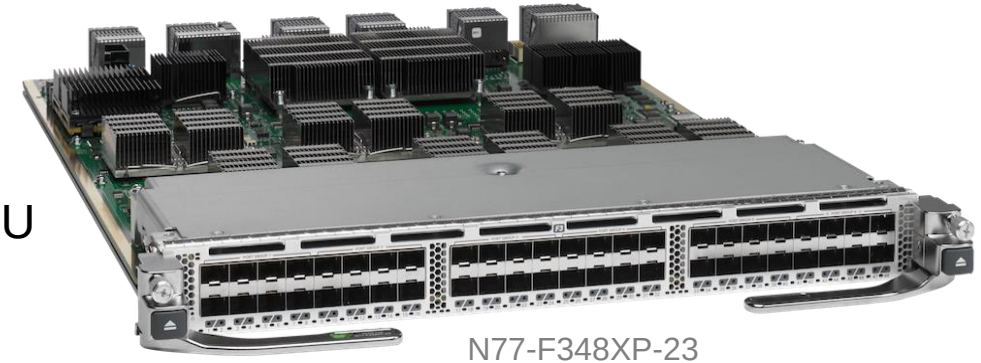
- High-performance module CPU with on-board acceleration engines
  - 6Gbps inband connectivity from SOCs to FSA
  - Multi-Mpps packet processing
  - 2GB dedicated DRAM
- Performance/scale boost for distributed fabric services, including BFD and sampled NetFlow (roadmap)
- Other potential applications include distributed ARP/ping processing, data plane packet analysis (wireshark), network probing, etc.



Nexus 7700 F3 48-Port 1G/10G Module

F Series

- 48-port 1G/10G with SFP/SFP+ transceivers
- 480G full-duplex fabric connectivity
- SoC-based forwarding engine design
  - 6 independent SoC ASICs
- Layer 2/Layer 3 forwarding with L3/L4 services (ACL/QoS) and advanced features
- Fabric Services Accelerator (FSA) CPU
- LinkSec support (last 8 ports)*
- Supports Nexus 2000 (FEX) connections

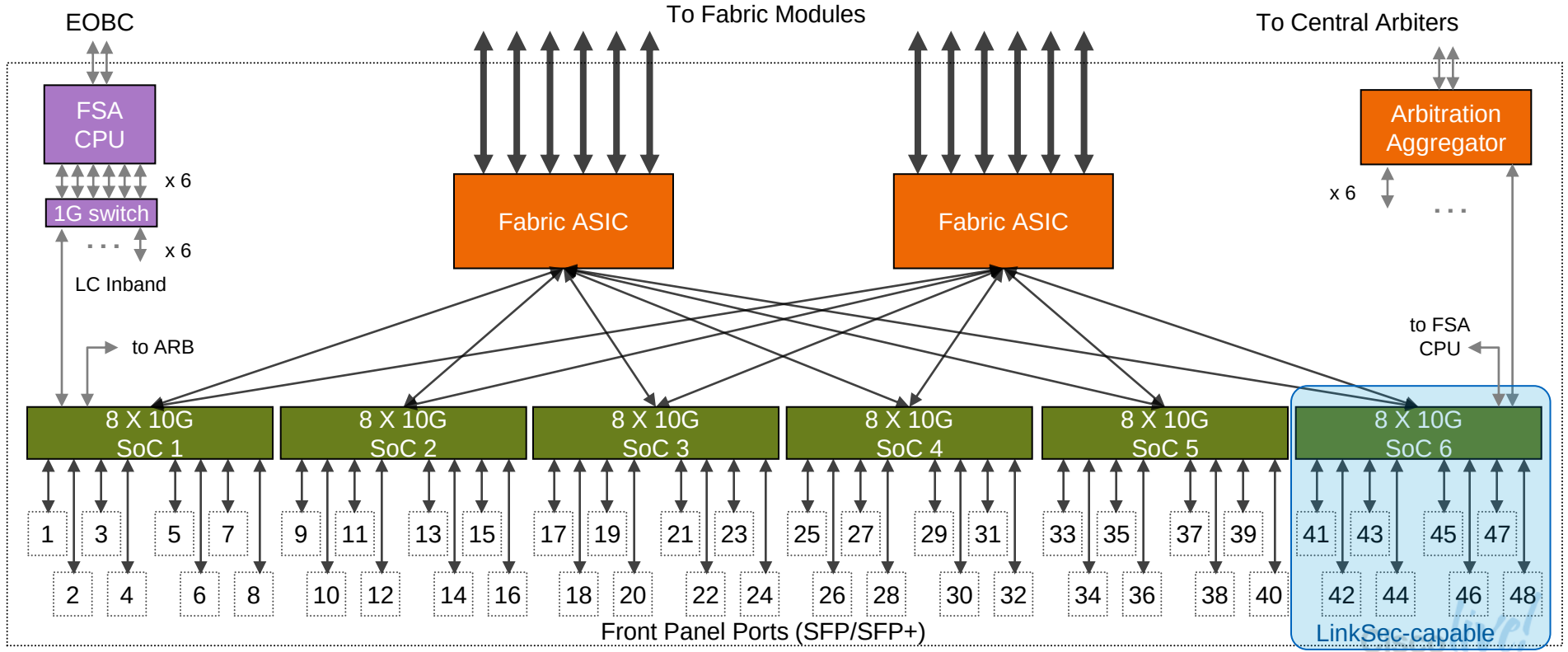


N77-F348XP-23

* Roadmap item

Nexus 7700 F3 48-Port 1G/10G Module Architecture

F Series

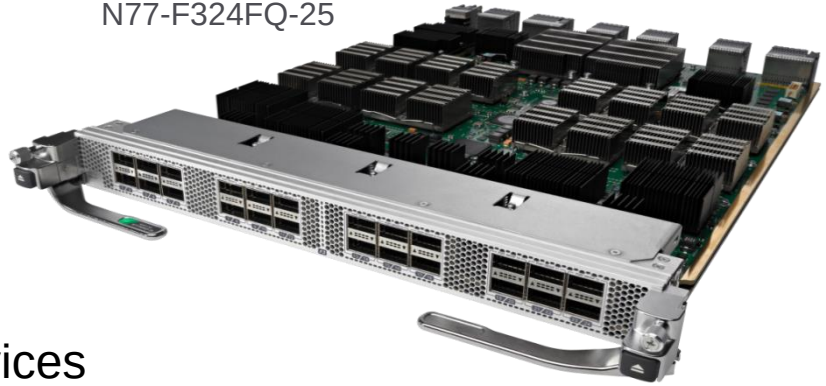


Nexus 7700 F3 40G and 100G Modules

F Series

- 24-port 40G QSFP+ module / 12-port 100G CPAK module
- 960G/1.2T full-duplex fabric connectivity
- SoC forwarding engine design
  - 12 independent SoC ASICs
- Layer 2/Layer 3 forwarding with L3/L4 services (ACL/QoS) and advanced features
- Fabric Services Accelerator (FSA) CPU
- 40G breakout cable support*

N77-F324FQ-25

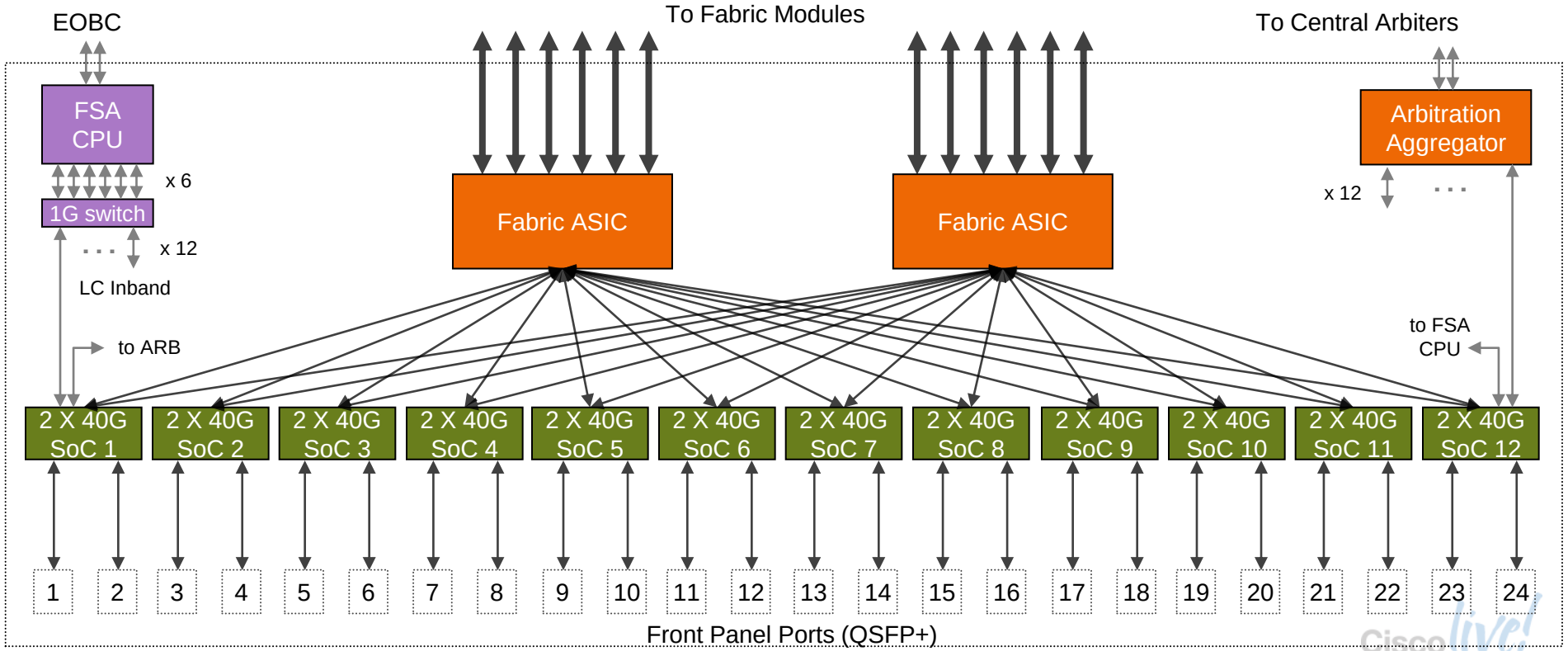


N77-F312CK-26

* Roadmap item

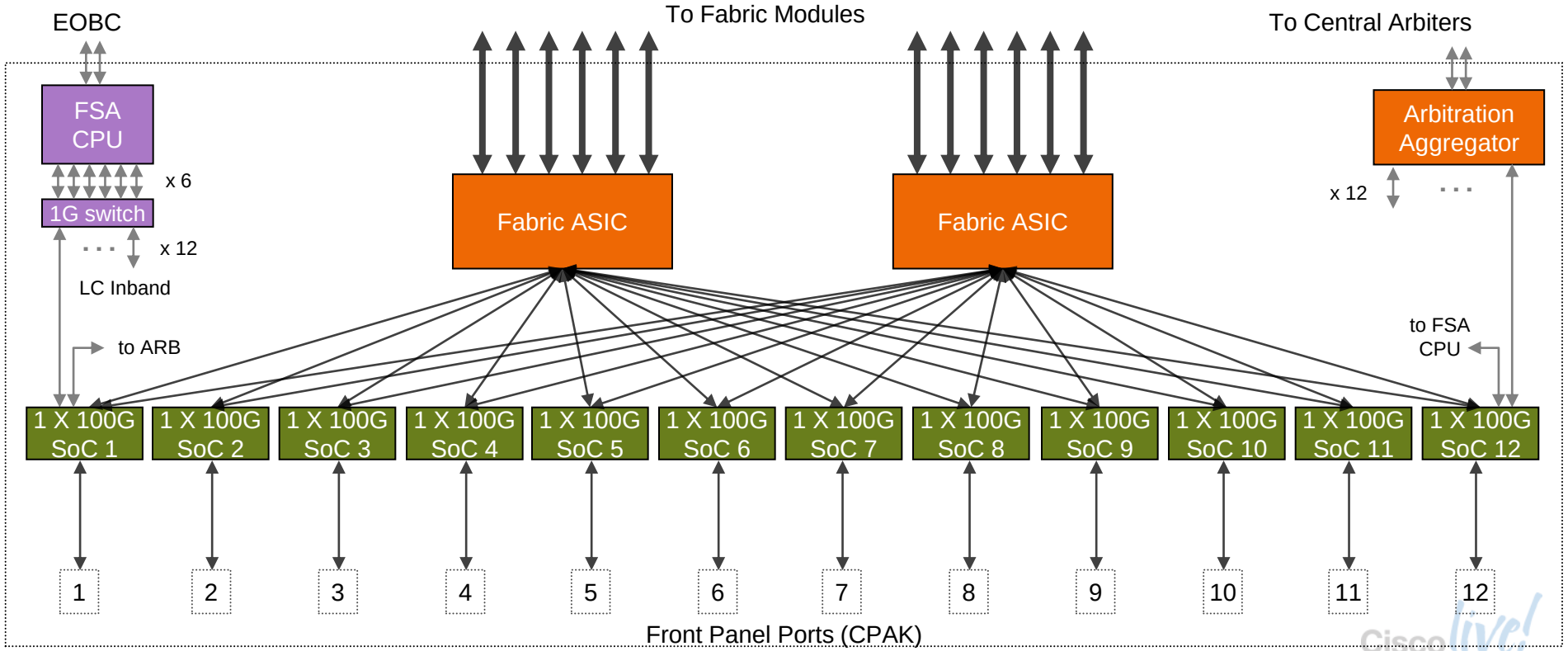
Nexus 7700 F3 24-Port 40G Module Architecture

F Series



Nexus 7700 F3 12-Port 100G Module Architecture

F Series



Agenda

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- Forwarding Engine Architecture
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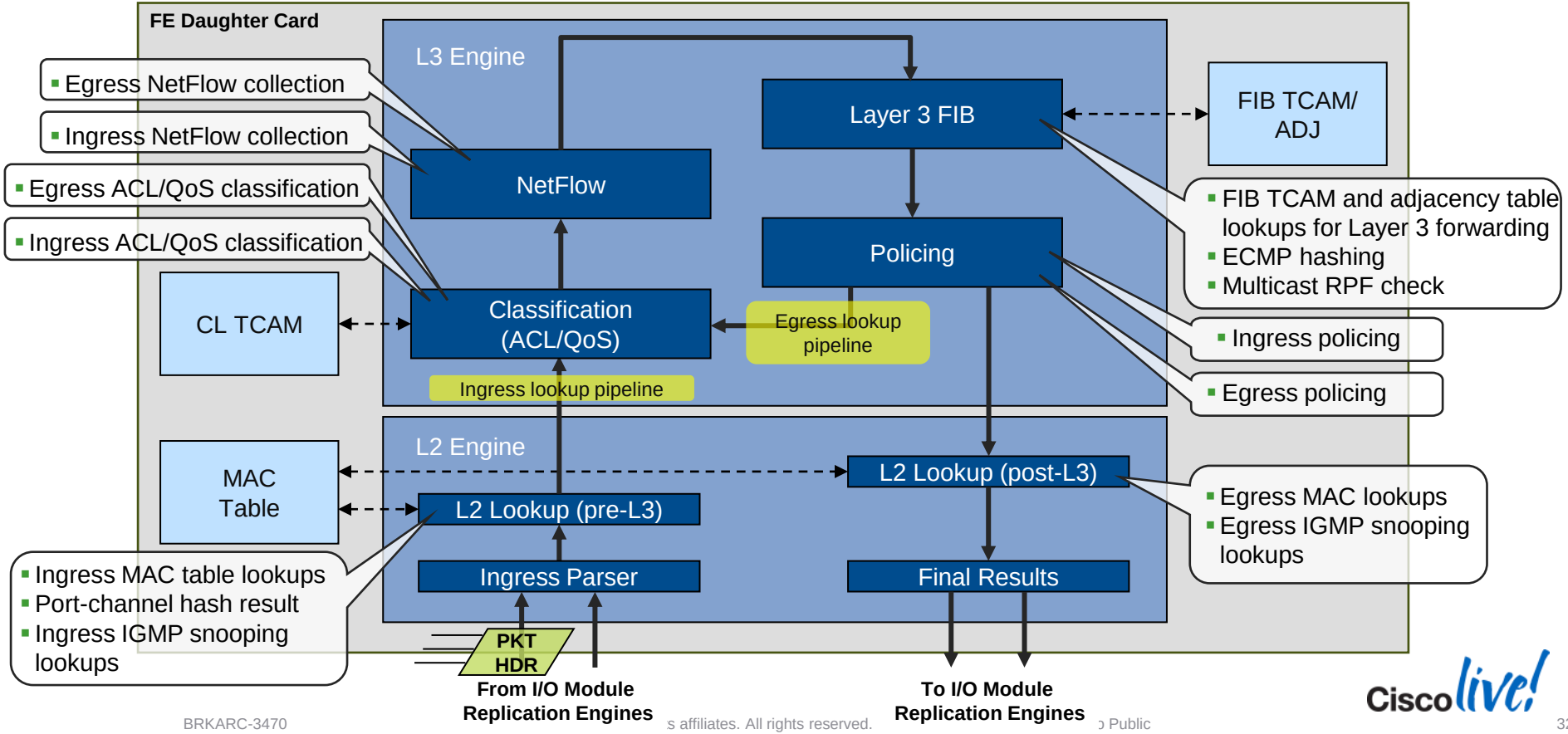
- I/O Module Queuing
- Layer 2 Forwarding
- Layer 3 Forwarding
- Classification
- NetFlow
- Conclusion

M-Series Forwarding Engine Hardware

- Two hardware forwarding engines integrated on every M2 I/O module
- 120Mpps (60Mpps per forwarding engine) Layer 2 bridging with hardware MAC learning
- 120 Mpps (60Mpps per forwarding engine) Layer 3 IPv4
- 60Mpps (30Mpps per forwarding engine) Layer 3 IPv6 unicast
- Layer 3 IPv4 and IPv6 multicast support (SM, SSM, Bidir)
- MPLS/VPLS/EoMPLS
- OTV
- RACL/VACL/PACL
- QoS remarking and policing policies
- Policy-based routing (PBR)
- Unicast RPF check and IP source guard
- IGMP snooping
- Ingress and egress NetFlow (full

Hardware Table	M-Series Modules without Scale License	M-Series Modules with Scale License
MAC Address Table	128K	128K
FIB TCAM	128K IPv4 / 64K IPv6	**900K IPv4 / 350K IPv6**
Classification TCAM (ACL/QoS)	64K	**128K**
NetFlow Table	1M	1M

M-Series Forwarding Engine Architecture



F2E Forwarding Engine Hardware

F Series

- Each SoC forwarding engine services 4 front-panel 10G ports (12 SoCs per module)
- 60Mpps per SoC Layer 2 bridging with hardware MAC learning
- 60Mpps per forwarding engine Layer 3 IPv4/ IPv6 unicast
- Layer 3 IPv4 and IPv6 multicast support (SM, SSM, Bidir*)
- RACL/VACL/PACL
- QoS remarking and policing policies
- Policy-based routing (PBR)
- Unicast RPF check and IP source guard
- IGMP snooping
- FabricPath forwarding
- FCoE (with Sup2 / Sup2E)
  - Roadmap on Nexus 7700
- Ingress sampled NetFlow

Hardware Table	Per F2E SoC	Per F2E Module
MAC Address Table	16K	192K*
FIB TCAM	32K IPv4/16K IPv6	32K IPv4/16K IPv6
Classification TCAM (ACL/QoS)	16K	192K*

* Assumes specific configuration to scale SoC resources

* Roadmap item

F3 Forwarding Engine Hardware

F Series

- Each SoC forwarding engine services:
  - 8 front-panel 10G ports
  - 2 front-panel 40G ports
  - 1 front-panel 100G port
- 148Mpps per SoC Layer 2 bridging with hardware MAC learning
- 148Mpps per forwarding engine Layer 3 IPv4/ IPv6 unicast
- Layer 3 IPv4 and IPv6 multicast support (SM, SSM, Bidir*)
- RACL/VACL/PACL
- QoS remarking and policing policies
- Policy-based routing (PBR)
- Unicast RPF check and IP source guard
- IGMP snooping
- FabricPath forwarding
- Overlay Transport Virtualisation (OTV)
- MPLS/VPLS/EoMPLS, LISP, VXLAN, GRE, FCoE*
- Ingress/egress* sampled NetFlow

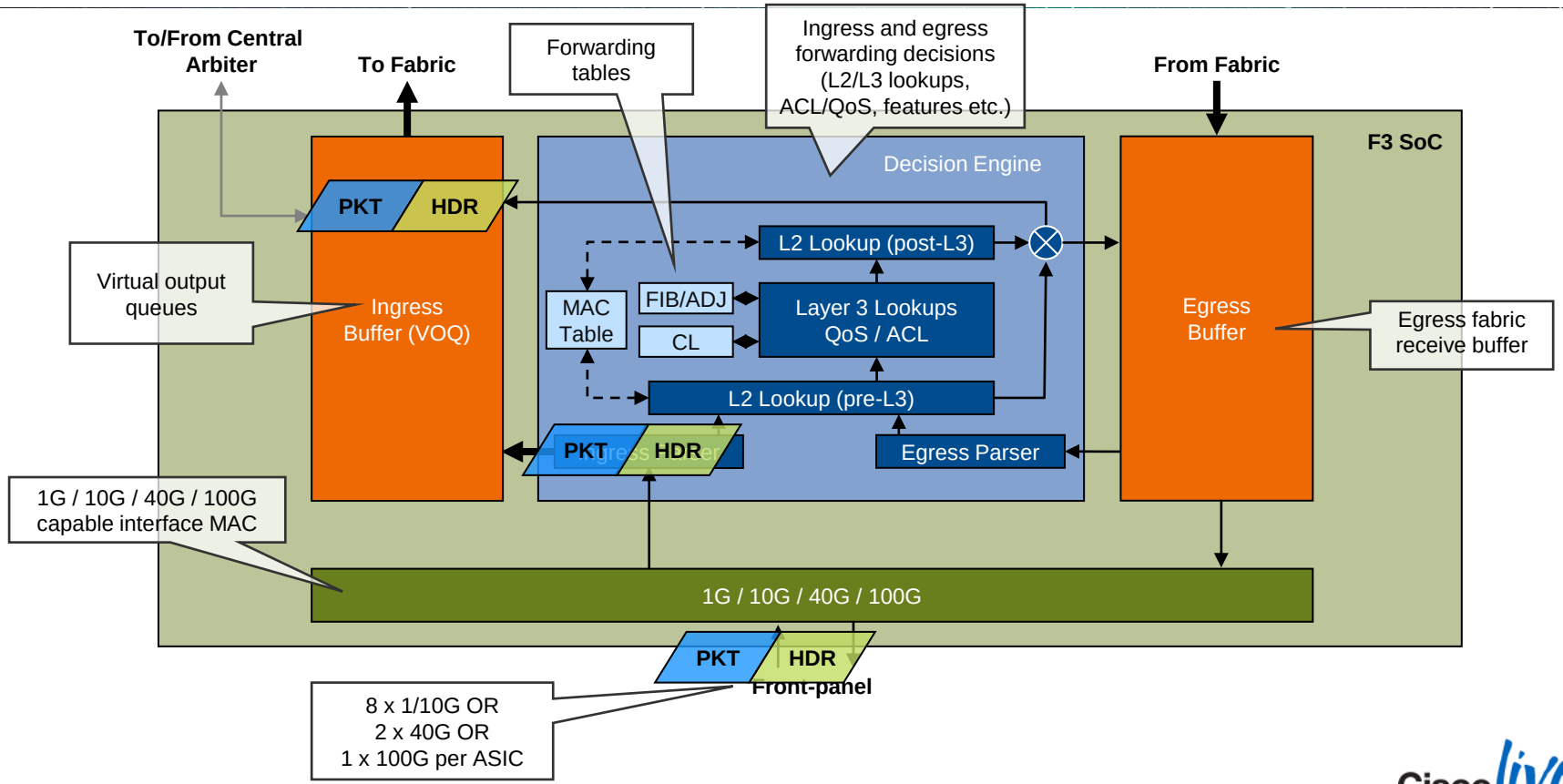
Hardware Table	Per F3 SoC	Per F3 Module
MAC Address Table	64K	384K/768K**
FIB TCAM	64K IPv4/32K IPv6	64K IPv4/32K IPv6
Classification TCAM (ACL/QoS)	16K	96K/192K**

** Assumes specific configuration to scale SoC resources

* Roadmap items

F3 Forwarding Engine

F Series



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Crossbar Switch Fabric Modules

- Provide interconnection of I/O modules
- Each installed fabric increases available per-payload slot bandwidth
- Nexus 7000 and Nexus 7700 fabrics based on Fabric 2 ASIC

Fabric Module	Supported Chassis	Per-fabric module bandwidth	Max fabric modules	Total bandwidth per slot
Nexus **7000** Fabric 2	7009 / 7010 / 7018	110Gbps per slot	5	550Gbps per slot
Nexus **7700** Fabric 2	7706 / 7710 / 7718	220Gbps per slot	6	1.32Tbps per slot

N77-C7718-FAB-2
N77-C7710-FAB-2
N77-C7706-FAB-2

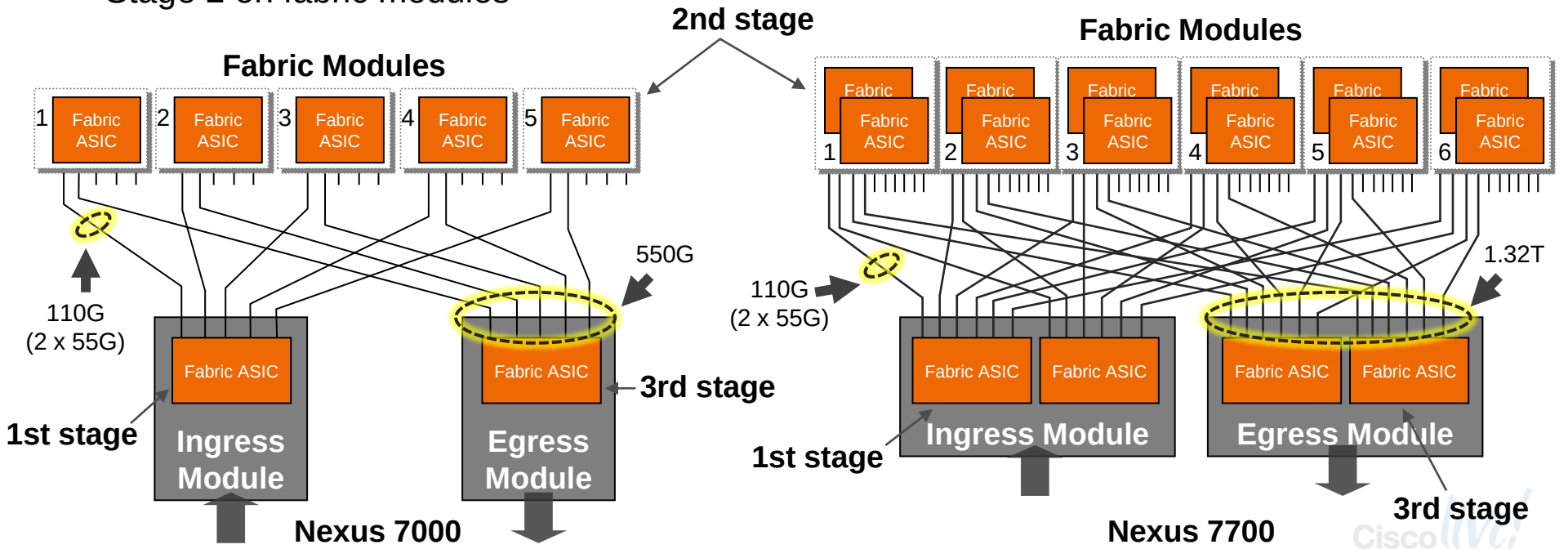
- Different I/O modules leverage different amount of available fabric bandwidth
- Access to fabric bandwidth controlled using QoS-aware central arbitration with VOQ

N7K-C7018-FAB-2
N7K-C7010-FAB-2
N7K-C7009-FAB-2

Multistage Crossbar

Nexus 7000 / Nexus 7700 implement 3-stage crossbar switch fabric

- Stages 1 and 3 on I/O modules
- Stage 2 on fabric modules



I/O Module Capacity – Nexus 7000

550Gbps
per slot bandwidth

One fabric:

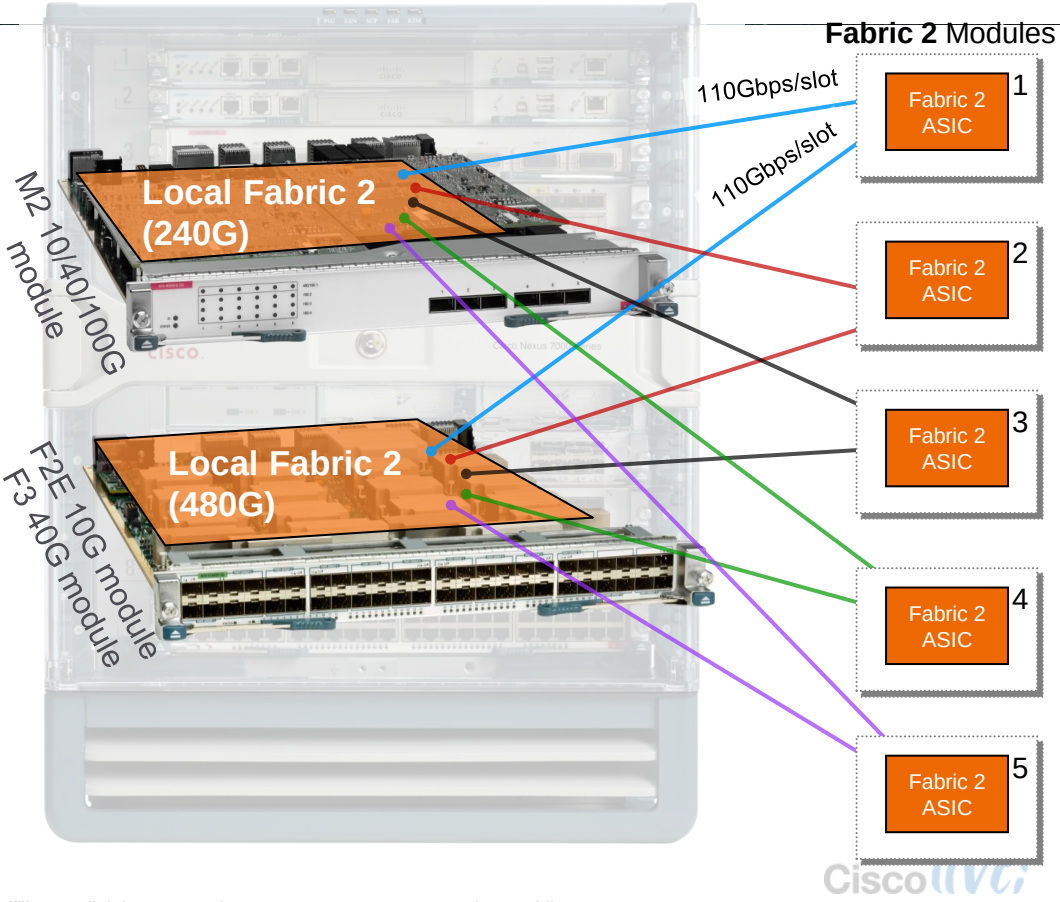
- **Any port** can pass traffic to **any other port** in VDC

Three fabrics:

- 240G M2 module has maximum bandwidth

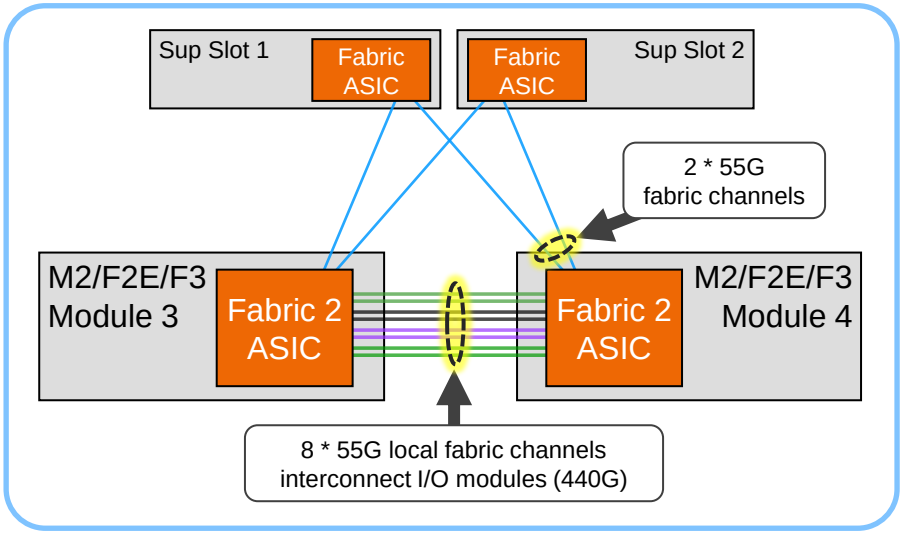
Five fabrics:

- 480G F2E/F3 module has maximum bandwidth



What About Nexus 7004?

- Nexus 7004 has no fabric modules
- I/O modules have local fabric with 10 available fabric channels
  - I/O modules connect “back-to-back” via 8 fabric channels
  - Two fabric channels “borrowed” to connect supervisor engines



I/O Module Capacity – Nexus 7700

1320Gbps

per slot bandwidth

One fabric:

- **Any port** can pass traffic to **any other port** in VDC

Three fabrics:

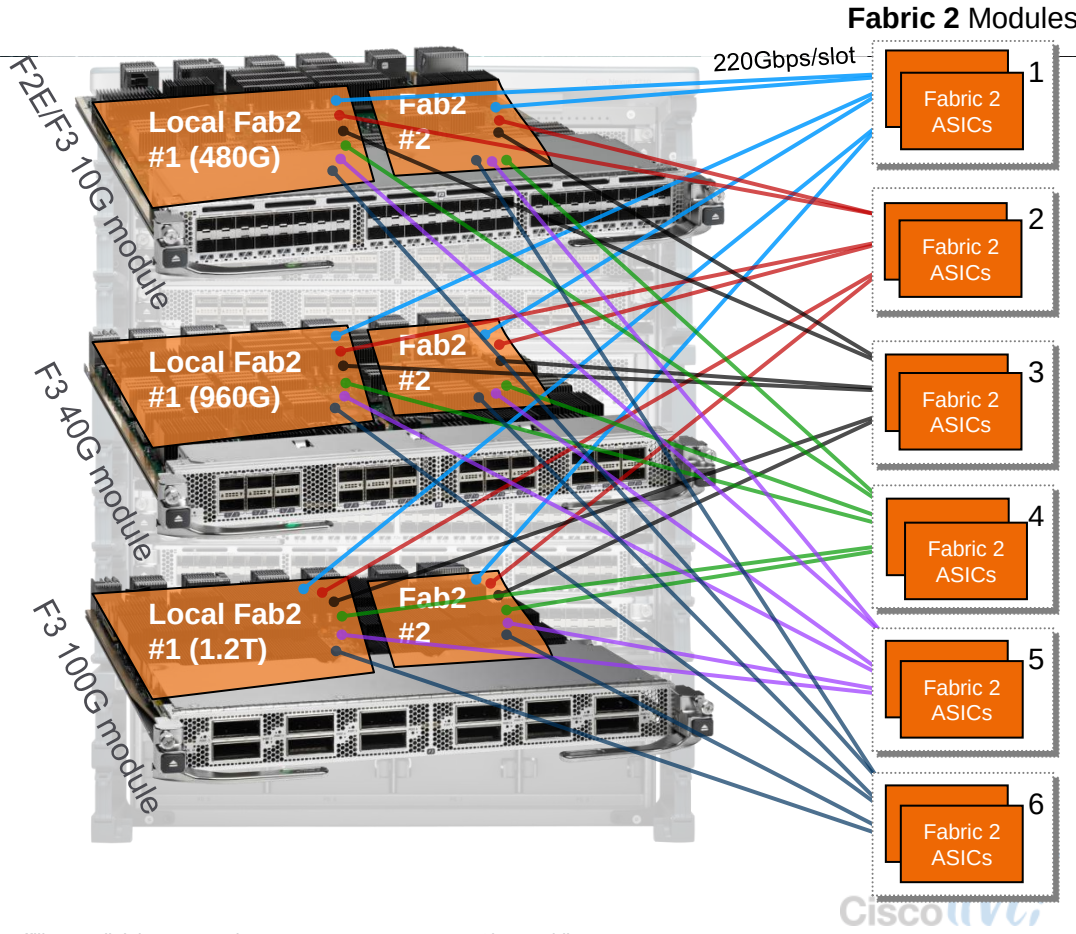
- 480G F2E/F3 10G module has maximum bandwidth

Five fabrics:

- 960G F3 40G module has maximum bandwidth

Six fabrics:

- 1.2T F3 100G module has maximum bandwidth



Fabric, VOQ, and Arbitration

- **Crossbar fabric** – Provides dedicated, high-bandwidth interconnects between ingress and egress I/O modules
- **Virtual Output Queues (VOQs)** – Provide buffering and queuing for ingress-buffered switch architecture
- **Central arbitration** – Controls scheduling of traffic into fabric based on fairness, priority, and bandwidth availability at egress ports

- Fabric, VOQ, and arbitration combine to provide all necessary infrastructure for packet transport inside switch

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Buffering, Queuing, and Scheduling

- Buffering – storing packets in memory
  - Needed to absorb bursts, manage congestion
- Queuing – buffering packets according to traffic class
  - Provides dedicated buffer for packets of different priority
- Scheduling – controlling the order of transmission of buffered packets
  - Ensures preferential treatment for packets of higher priority and fair treatment for packets of equal priority

- Nexus 7000 / Nexus 7700 use queuing policies and network-QoS policies to define buffering, queuing, and scheduling behaviour
- Default queuing and network-QoS policies always in effect in absence of any user configuration

I/O Module Buffering Models

- Buffering model varies by I/O module family
  - **M-series modules**: hybrid model combining ingress VOQ-buffered architecture with egress port-buffered architecture
  - **F-series modules**: pure ingress VOQ-buffered architecture

M2 – Hybrid Ingress/Egress Buffered

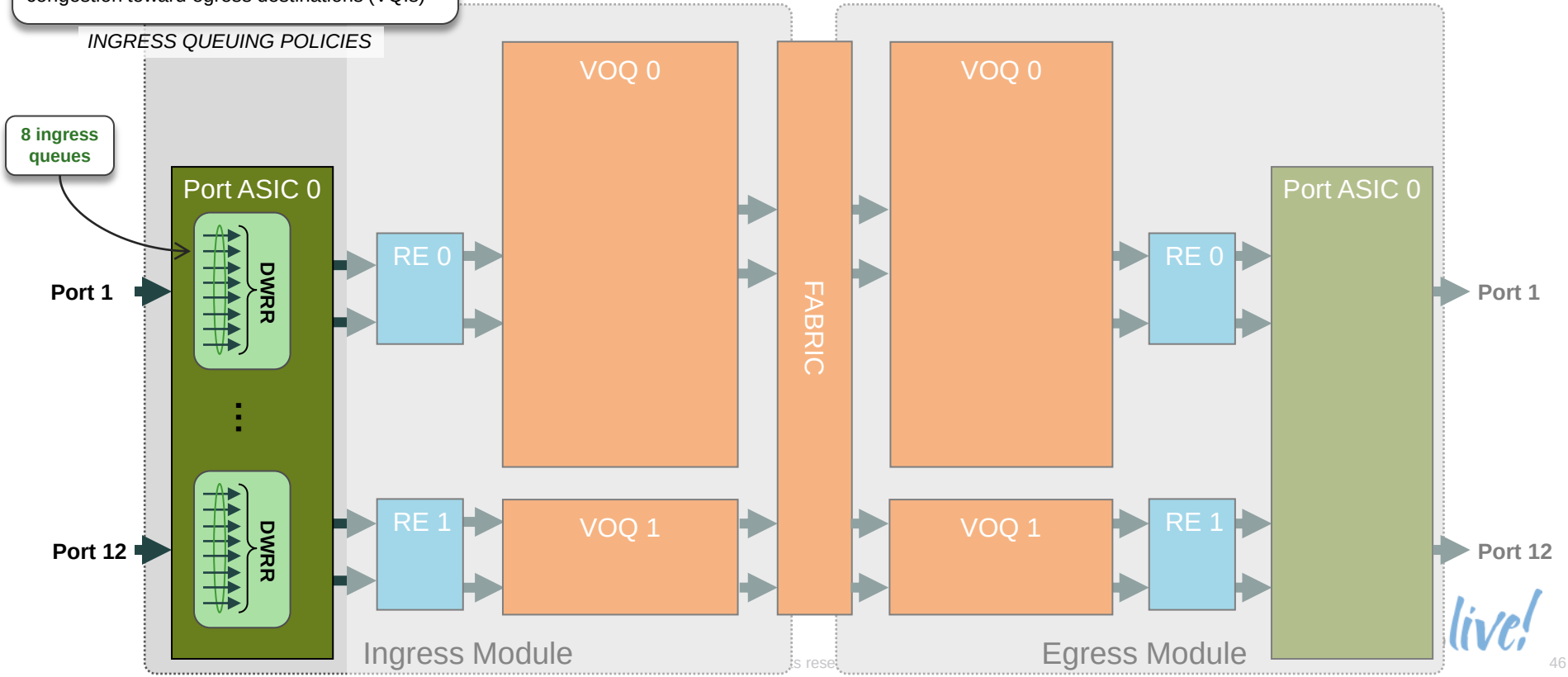
10G module used as example

Diagram represents half of each I/O module

M Series

Buffering / queuing / scheduling

Ingress port buffer – Manages congestion of ingress forwarding/replication engines, and congestion toward egress destinations (VQIs)



M2 – Hybrid Ingress/Egress Buffered

10G module used as example

Diagram represents half of each I/O module

M Series

Buffering / queuing / scheduling

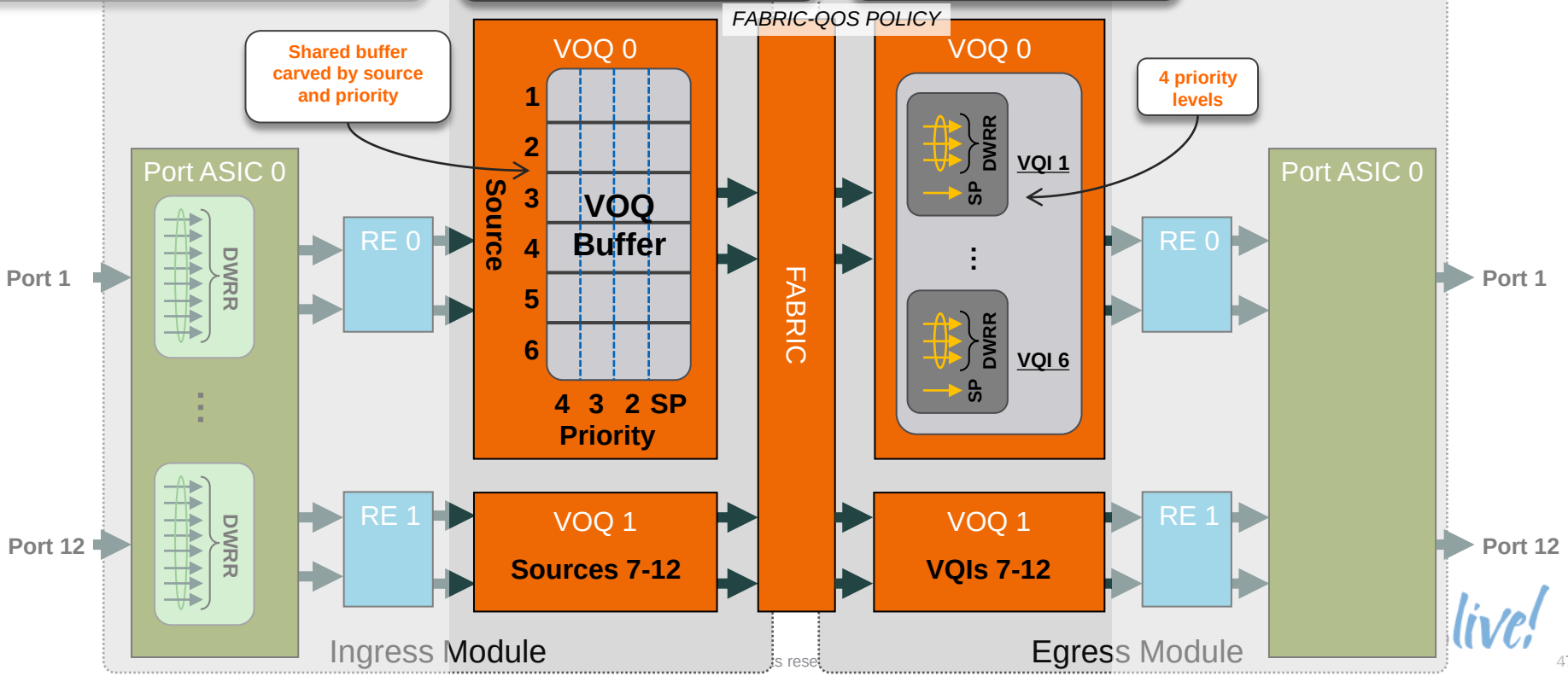
Ingress port buffer – Manages congestion of ingress forwarding/replication engines, and congestion toward egress destinations (VQIs)

Buffering / queuing

Ingress VOQ buffer – Manages congestion toward egress destinations (VQIs)

Scheduling

Egress VOQ buffer – Receives frames from fabric



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10G module used as example

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M Series

Buffering / queuing / scheduling

Ingress port buffer – Manages congestion of ingress forwarding/replication engines, and congestion toward egress destinations (VQIs)

Buffering / queuing

Ingress VOQ buffer – Manages congestion toward egress destinations (VQIs)

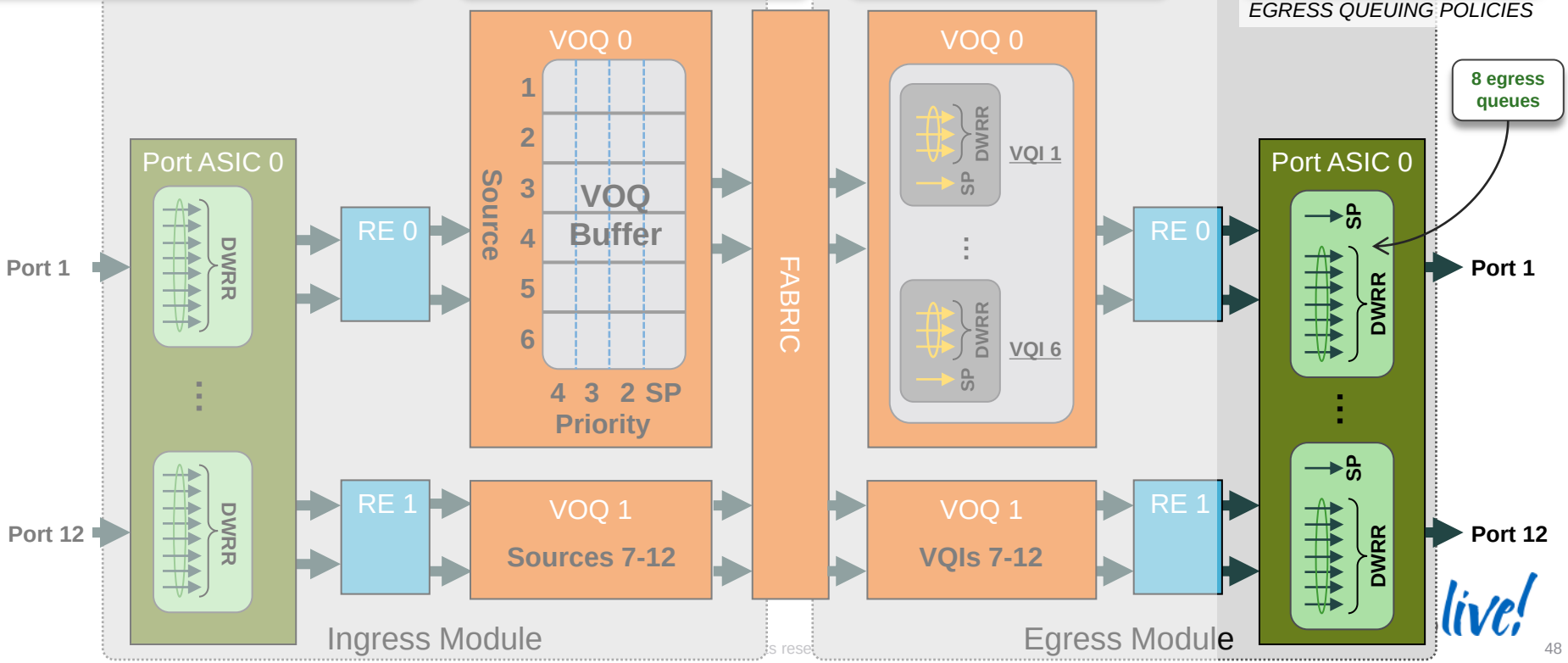
Scheduling

Egress VOQ buffer – Receives frames from fabric

Buffering / queuing / scheduling

Egress port buffer – Manages congestion at egress physical interface

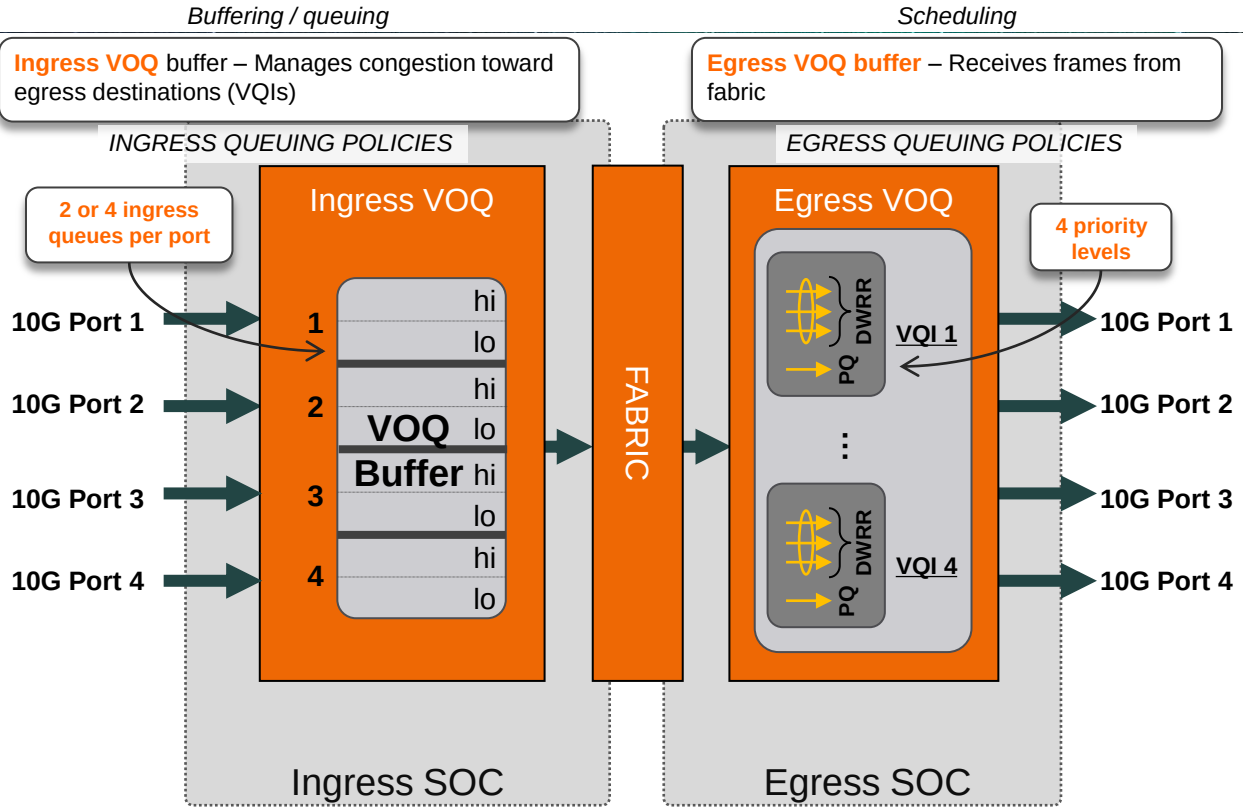
EGRESS QUEUING POLICIES



F2E – Ingress Buffered (Nexus 7000)

F Series

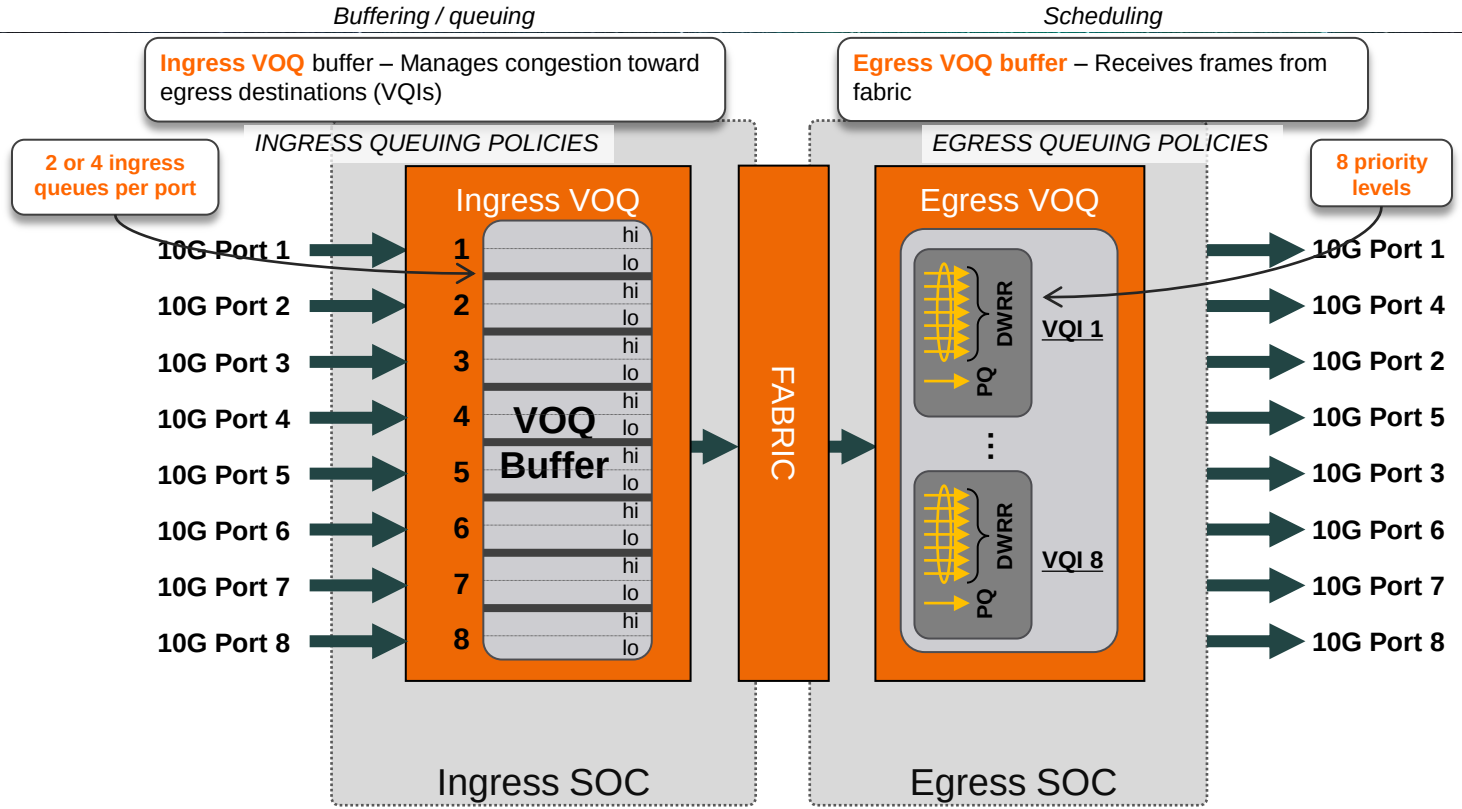
Diagram represents one SoC on each I/O module



F3 10G – Ingress Buffered (Nexus 7700)

F Series

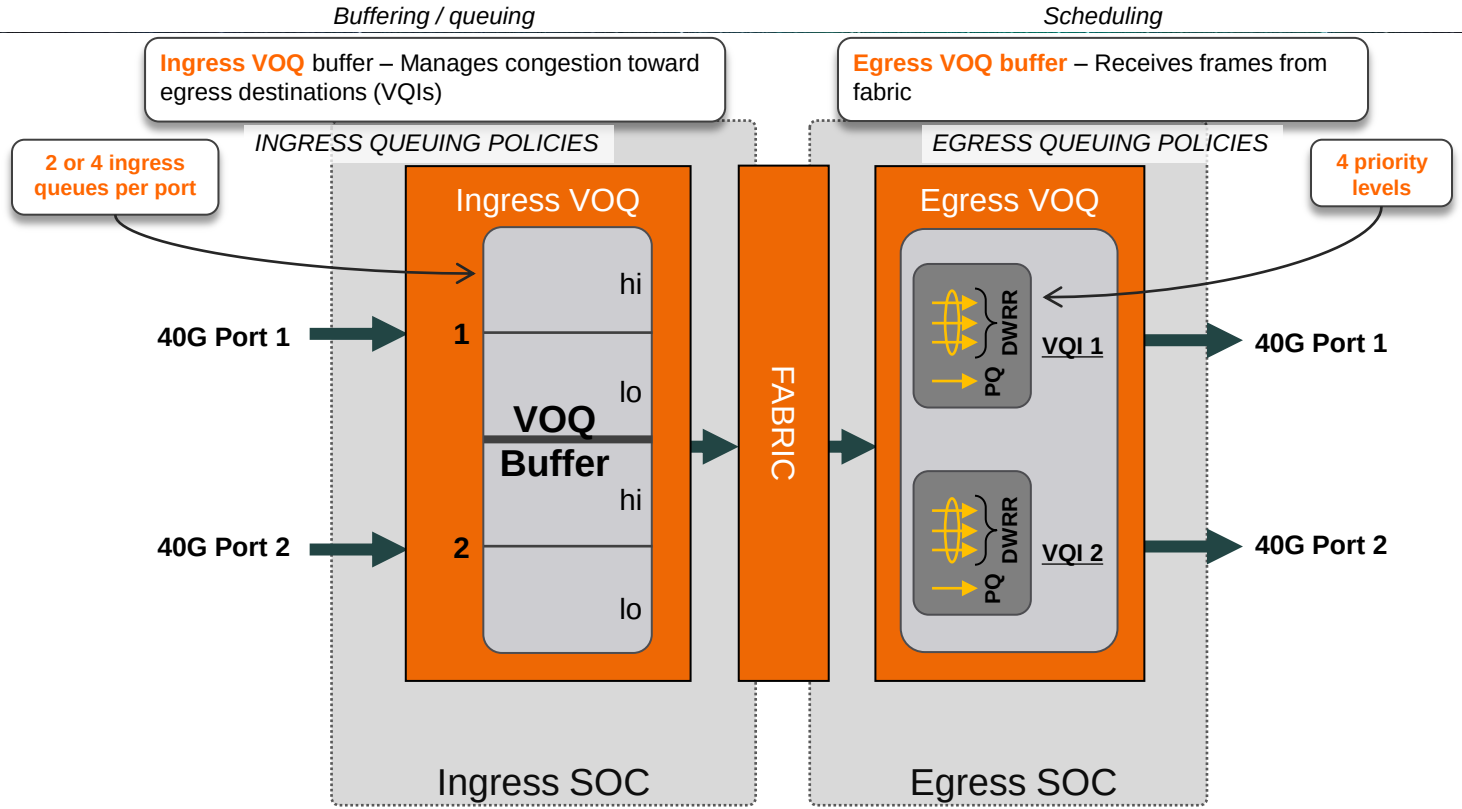
Diagram represents one SoC on each I/O module



F3 40G – Ingress Buffered (Nexus 7000)

F Series

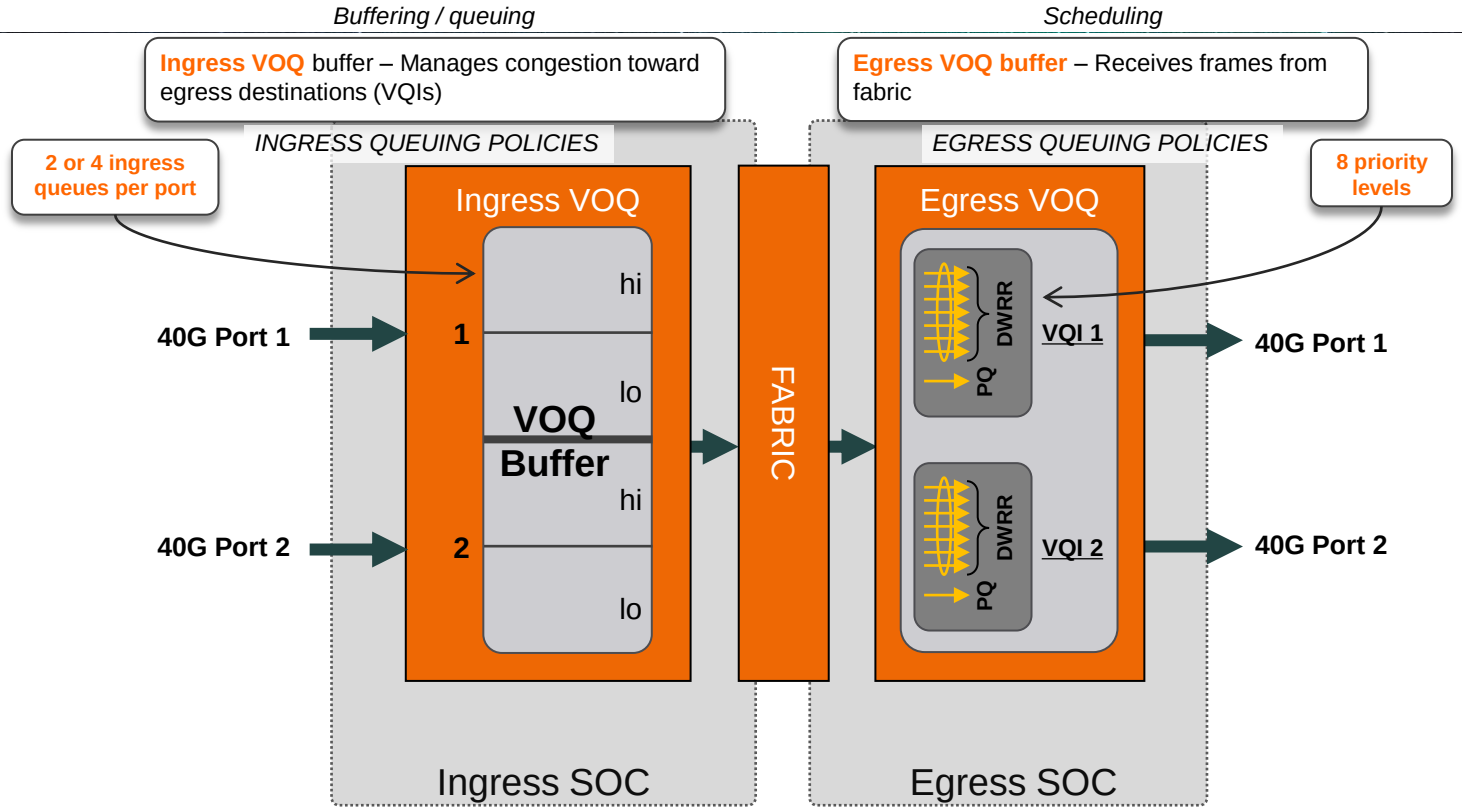
Diagram represents one SoC on each I/O module



F3 40G – Ingress Buffered (Nexus 7700)

F Series

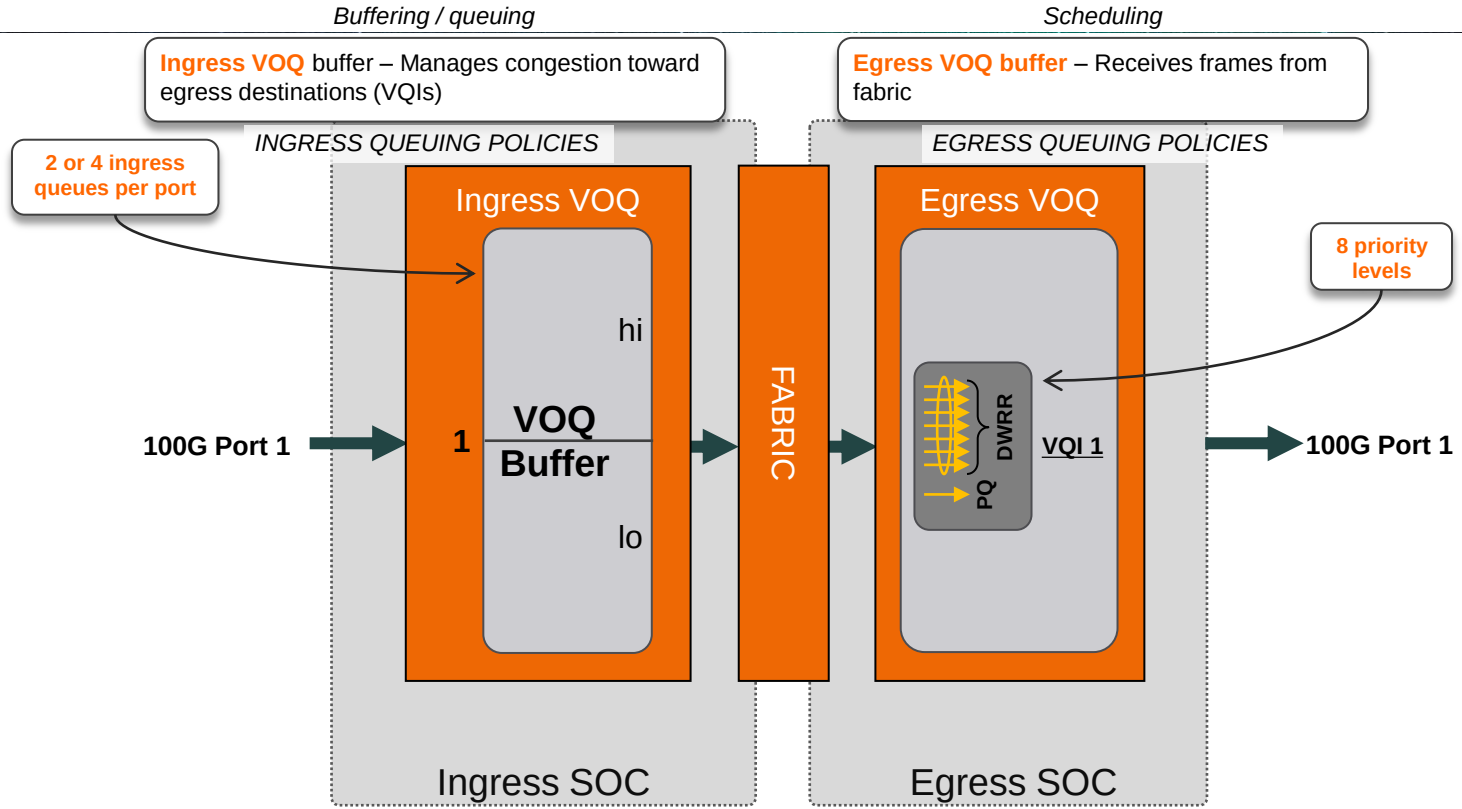
Diagram represents one SoC on each I/O module



F3 100G – Ingress Buffered (Nexus 7700)

F Series

Diagram represents one SoC on each I/O module



FAQ: What Is a VQI?

- VQI = Virtual Queuing Index
- “A Destination Across the Fabric”

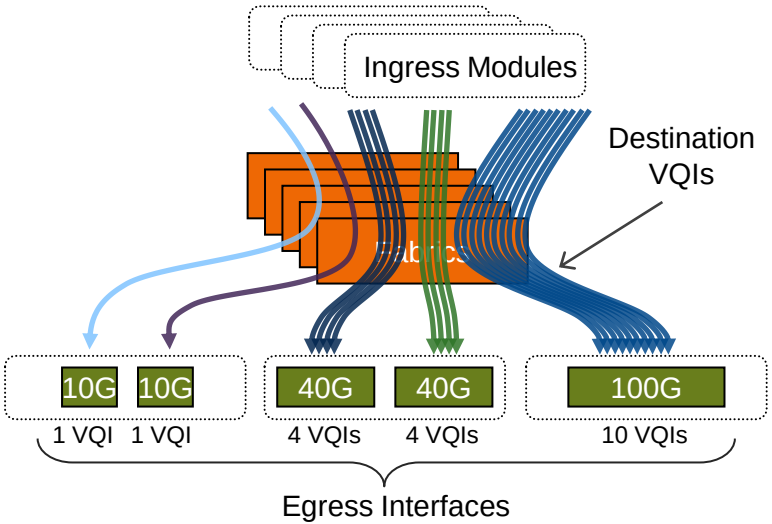
- For M2 / F2E / F3 10G modules, VQI == 10G interface

- For M2 40/100G ports, uses multiple 10G VQIs

- For F3 40/100G ports, uses single 40/100G VQI

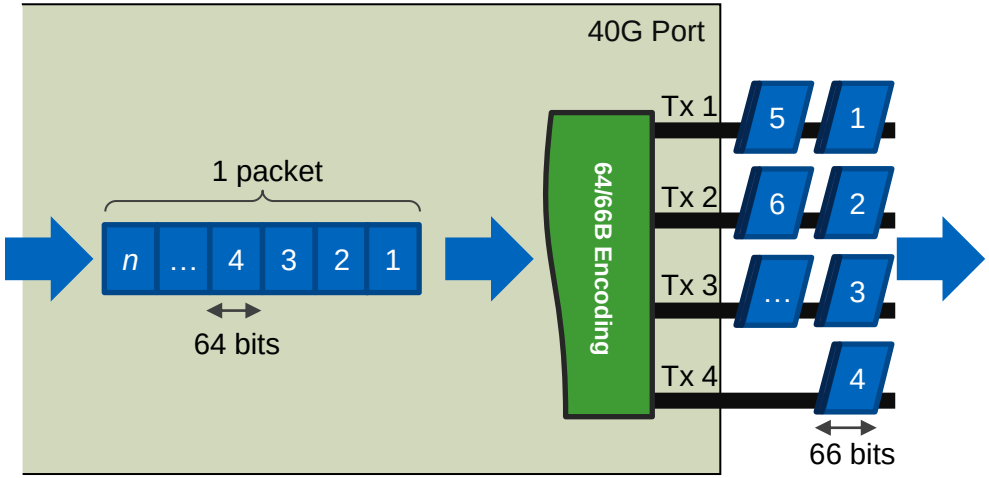
M2 Module 40G and 100G Flow Limits

Internal to Nexus 7000 System



- Each Virtual Queuing Index (VQI) sustains 10G traffic flow
- All packets in given 5-tuple flow hash to single VQI
- Single-flow limit is 10G

On the Wire (40G)

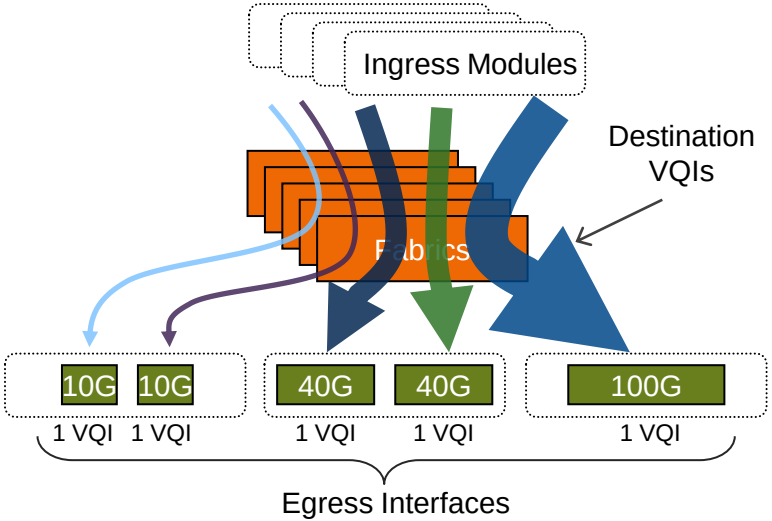


- Packets split into 66-bit “code words”
- Four code words transmitted in parallel, one on each physical Tx fibre
- No per-flow limit imposed – splitting occurs at physical layer

F3 Module 40G and 100G Flow Limits

F Series

Internal to Nexus 7000 / 7700 System



- Virtual Queuing Index (VQI) sustains 10G, 40G, or 100G traffic flow based on destination interface type
- No single-flow limit – full 40G/100G flow support

Agenda

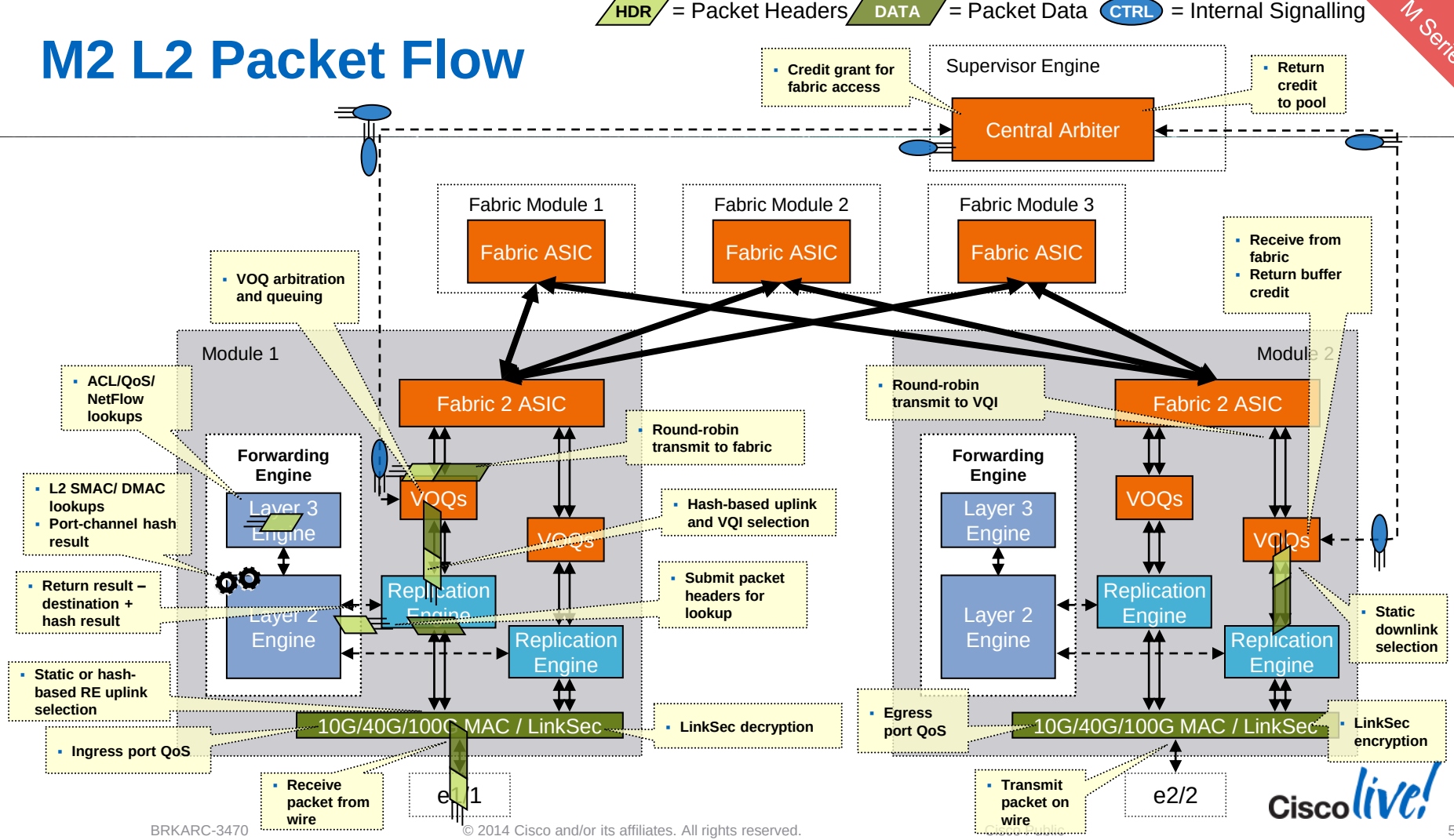
- Chassis Architecture
- Supervisor Engine and I/O Module Architecture
- Forwarding Engine Architecture
- Fabric Architecture
- I/O Module Queuing
- Layer 2 Forwarding
- Layer 3 Forwarding
- Classification
- NetFlow
- Conclusion

Hardware Layer 2 Forwarding Process

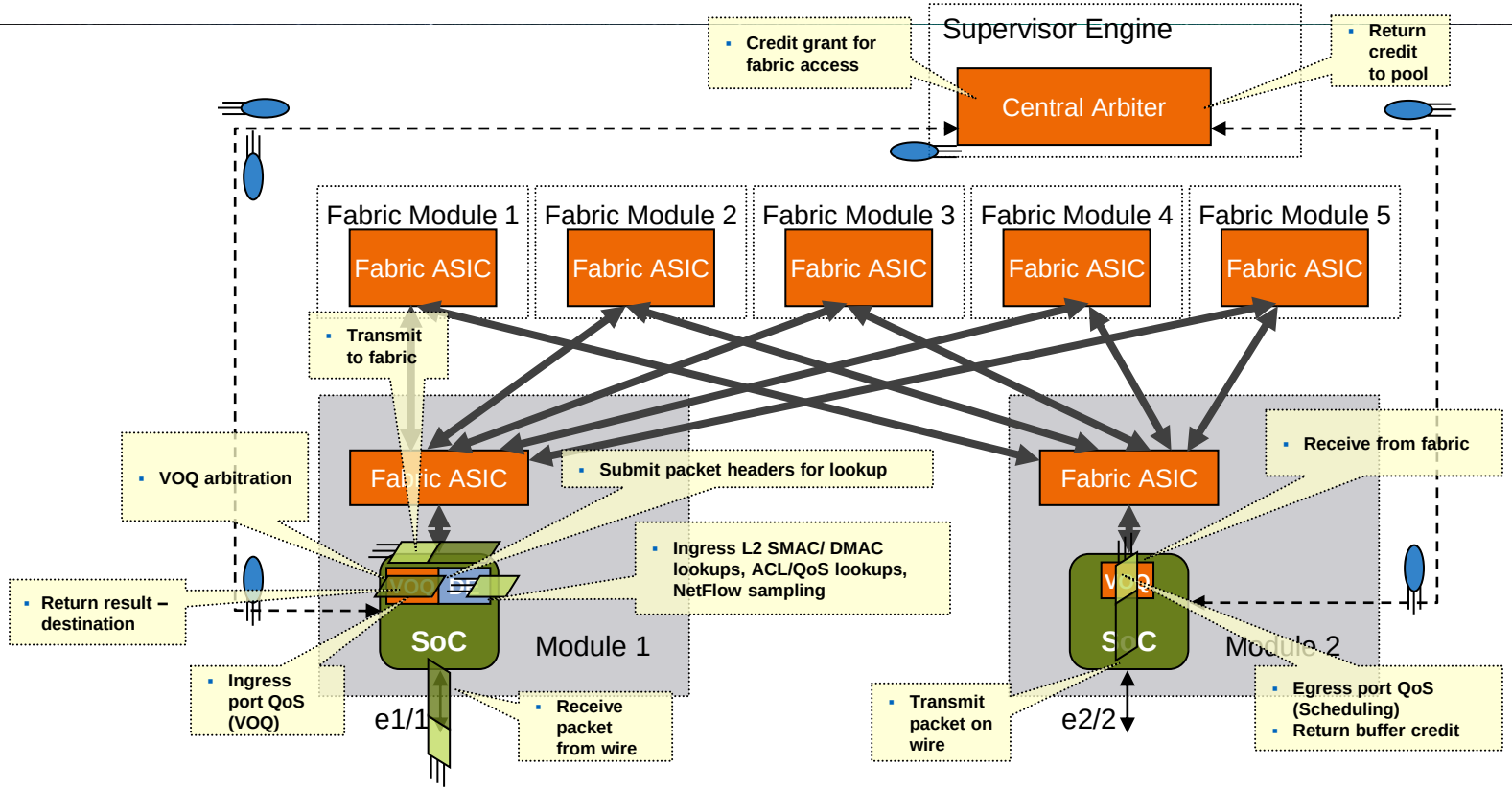
Layer 2 forwarding – traffic steering based on destination MAC address

- MAC table lookup drives Layer 2 forwarding
- Source MAC and destination MAC lookups performed for each frame, based on {VLAN,MAC} pairs
- Source MAC lookup drives new learns and refreshes aging timers
- Destination MAC lookup dictates outgoing switchport

M2 L2 Packet Flow



F2E / F3 L2 Packet Flow



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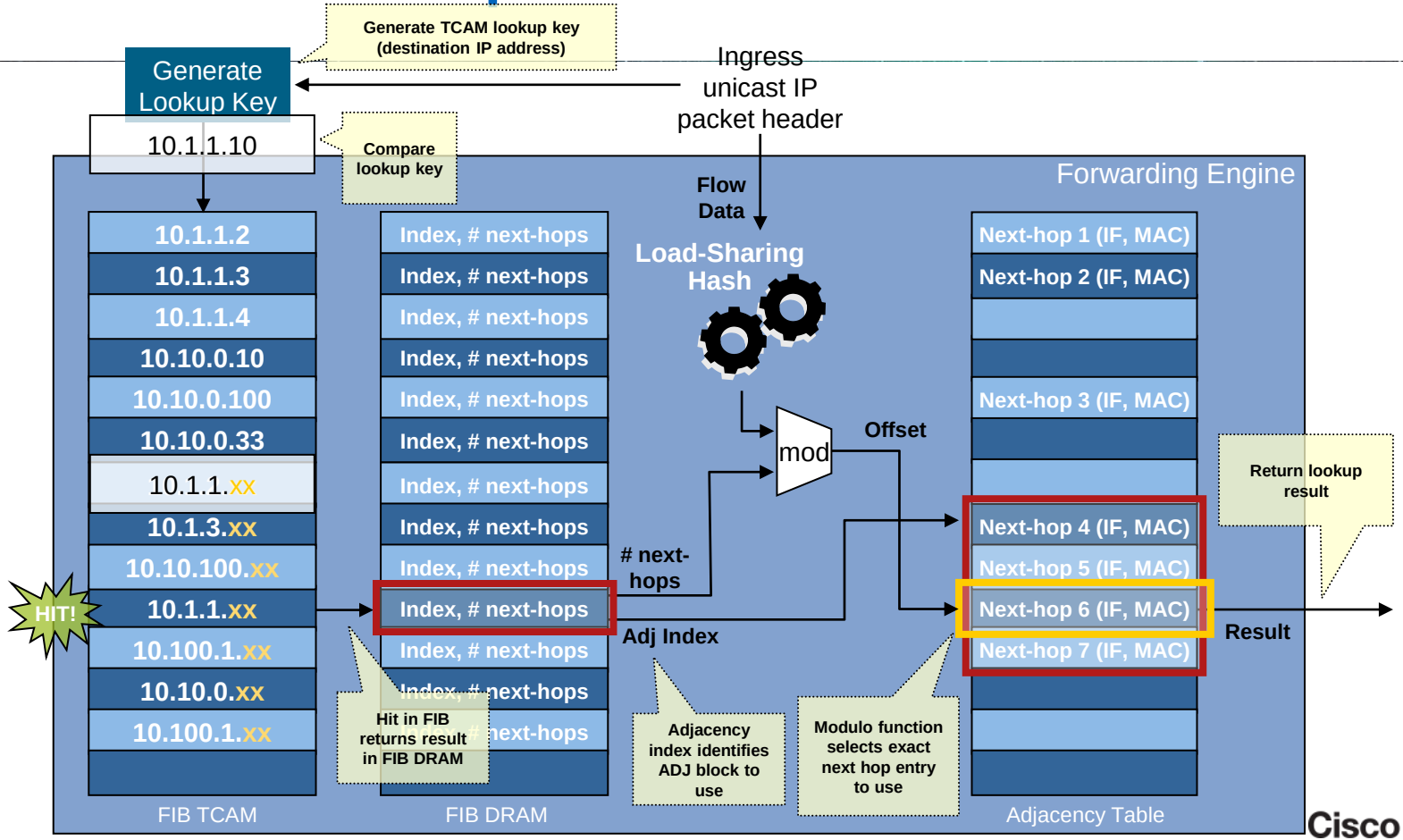
Layer 3 Forwarding

- Nexus 7000 decouples control plane and data plane
- Forwarding tables built on control plane using routing protocols or static configuration
  - OSPF, EIGRP, IS-IS, RIP, BGP for dynamic routing
- Tables downloaded to forwarding engine hardware for data plane forwarding
  - FIB TCAM contains IP prefixes
  - Adjacency table contains next-hop information

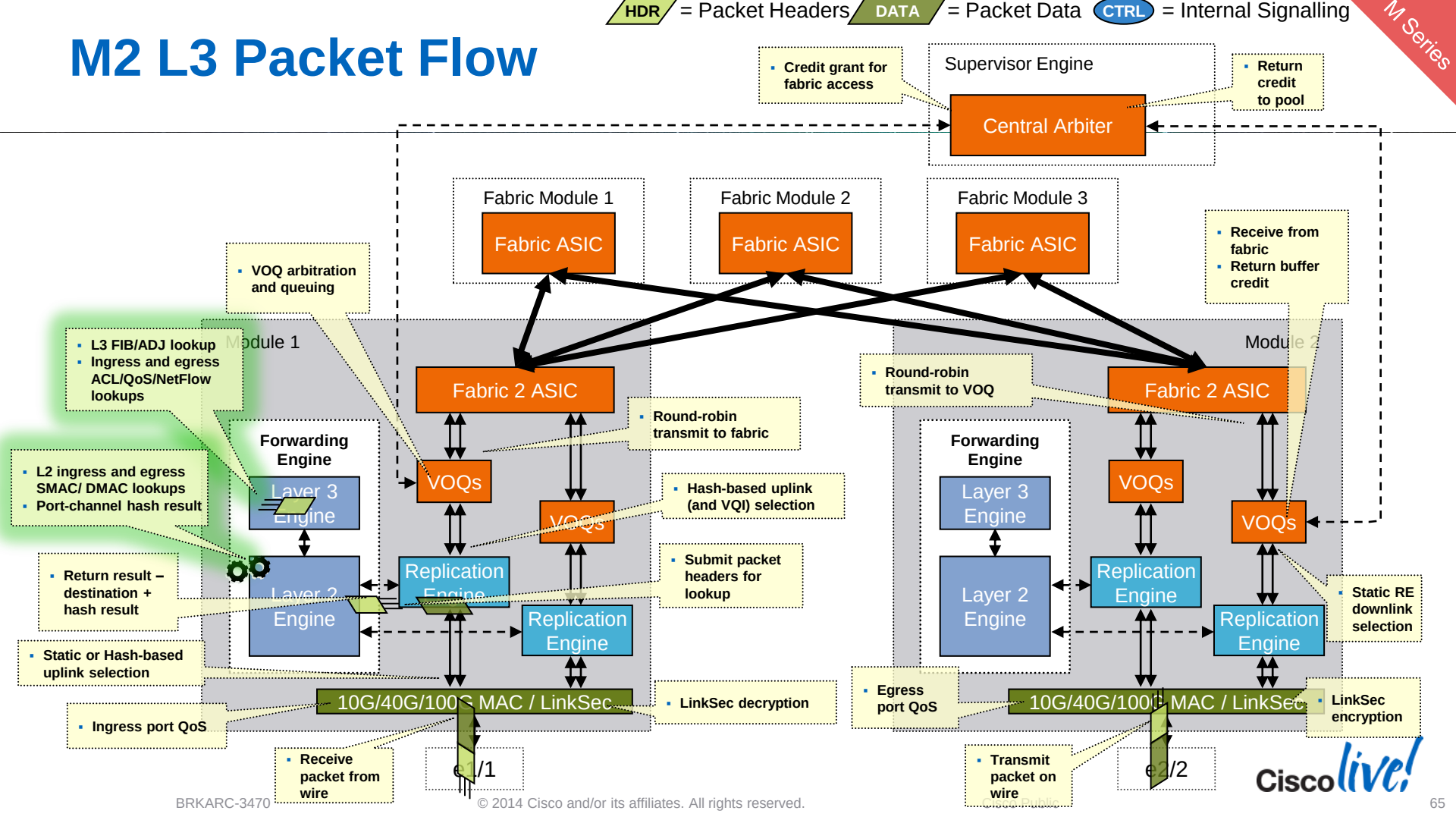
Hardware Layer 3 Forwarding Process

- FIB TCAM lookup based on longest-match destination prefix comparison
- FIB “hit” returns adjacency, adjacency contains rewrite information (next-hop)
- Pipelined forwarding engine architecture also performs ACL, QoS, and NetFlow lookups, affecting final forwarding result

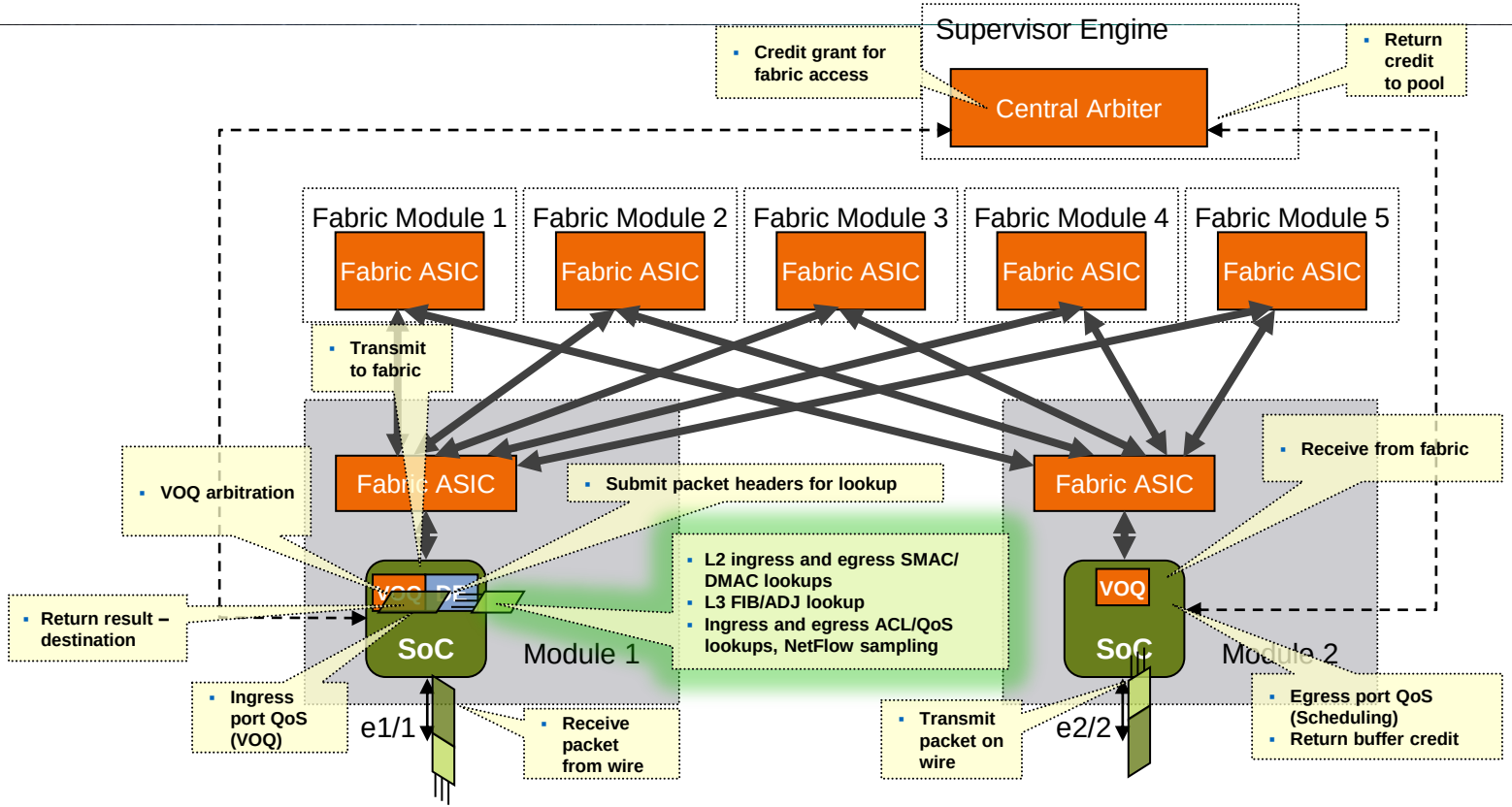
IP FIB TCAM Lookup



M2 L3 Packet Flow



F2E / F3 L3 Packet Flow



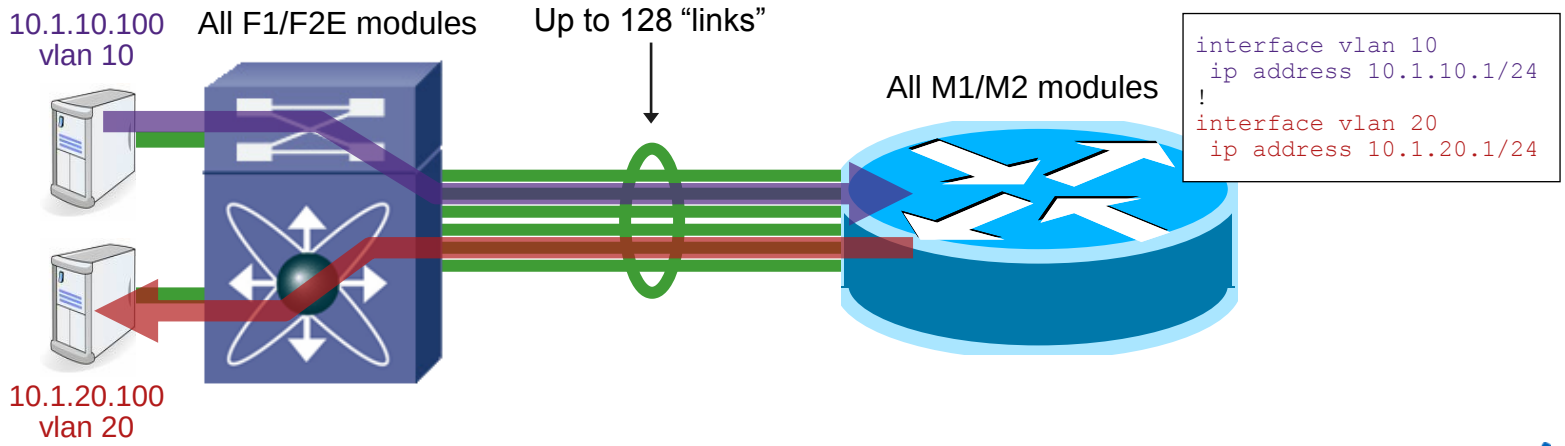
Layer 3 Forwarding – Module Interoperability Models

Two interoperability models for L3 forwarding:

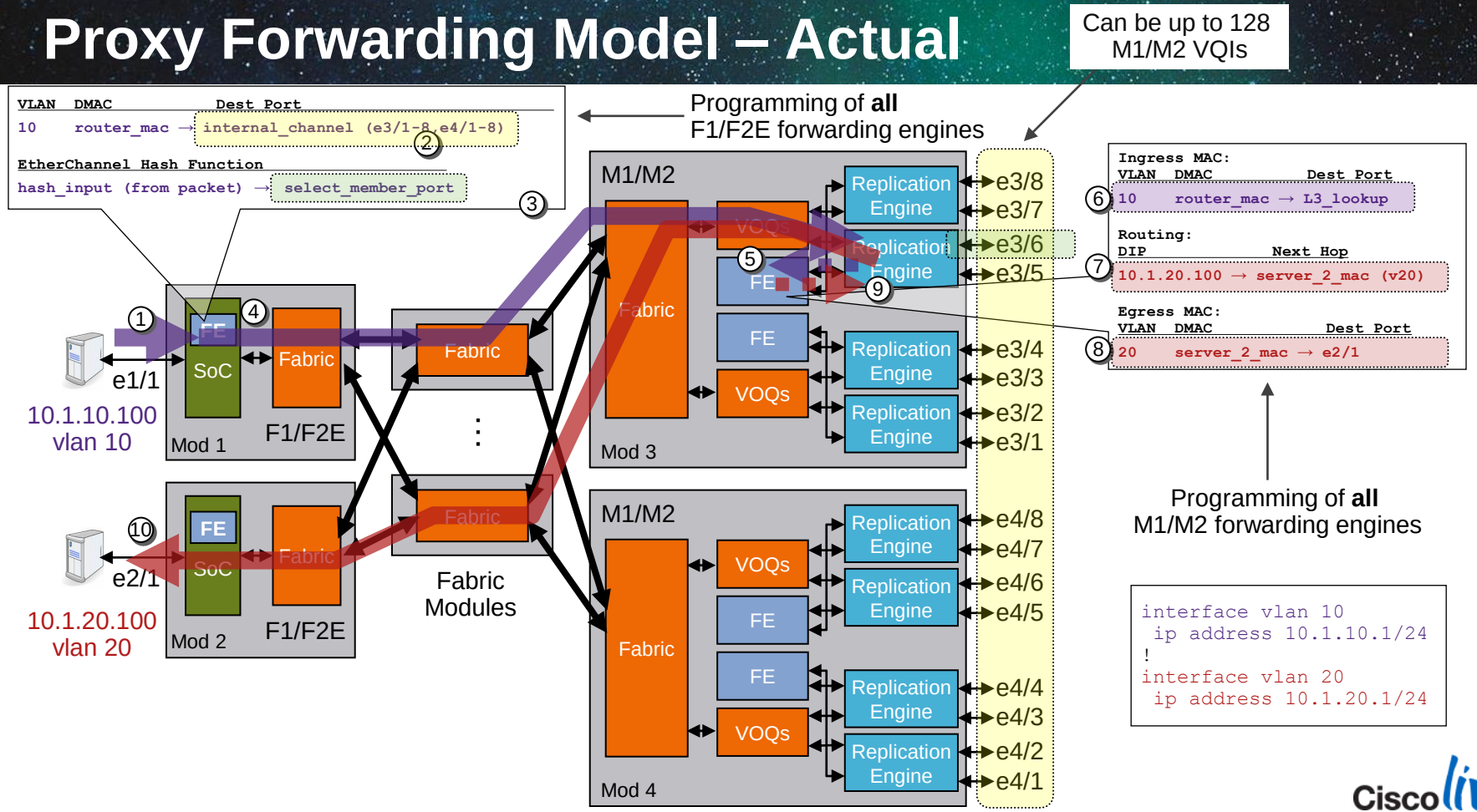
- “Proxy Forwarding”
- “Ingress Forwarding” with Lowest Common Denominator

Proxy Forwarding Model – Conceptual

- From F1/F2E perspective, Router MAC reachable through giant port-channel
- All packets destined to Router MAC forwarded through fabric toward one "member port" in that channel



Proxy Forwarding Model – Actual



Ingress Forwarding with Lowest Common Denominator Model

- F3 module interoperability always Ingress Forwarding – *NO* proxy forwarding with F3
  - Essentially equivalent to current M1 + M2 interoperability model
  - The *ingress* module makes all the forwarding decisions
- Supported feature set based on Lowest Common Denominator
  - Feature available if all modules support the feature

Not all features supported by software today

VDC Type	Layer 2	Layer 3	vPC	Fabric Path	VXLAN	FEX	MPLS	OTV	LISP	FCoE	Table Sizes
F3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	F3 size
M2 + F3	✓	✓	✓	✗	✗	✓	✓	✓	✗	✗	F3 size
F2/F2E + F3	✓	✓	✓	✓	✗	✓	✗	✗	✗	✓	F2E size

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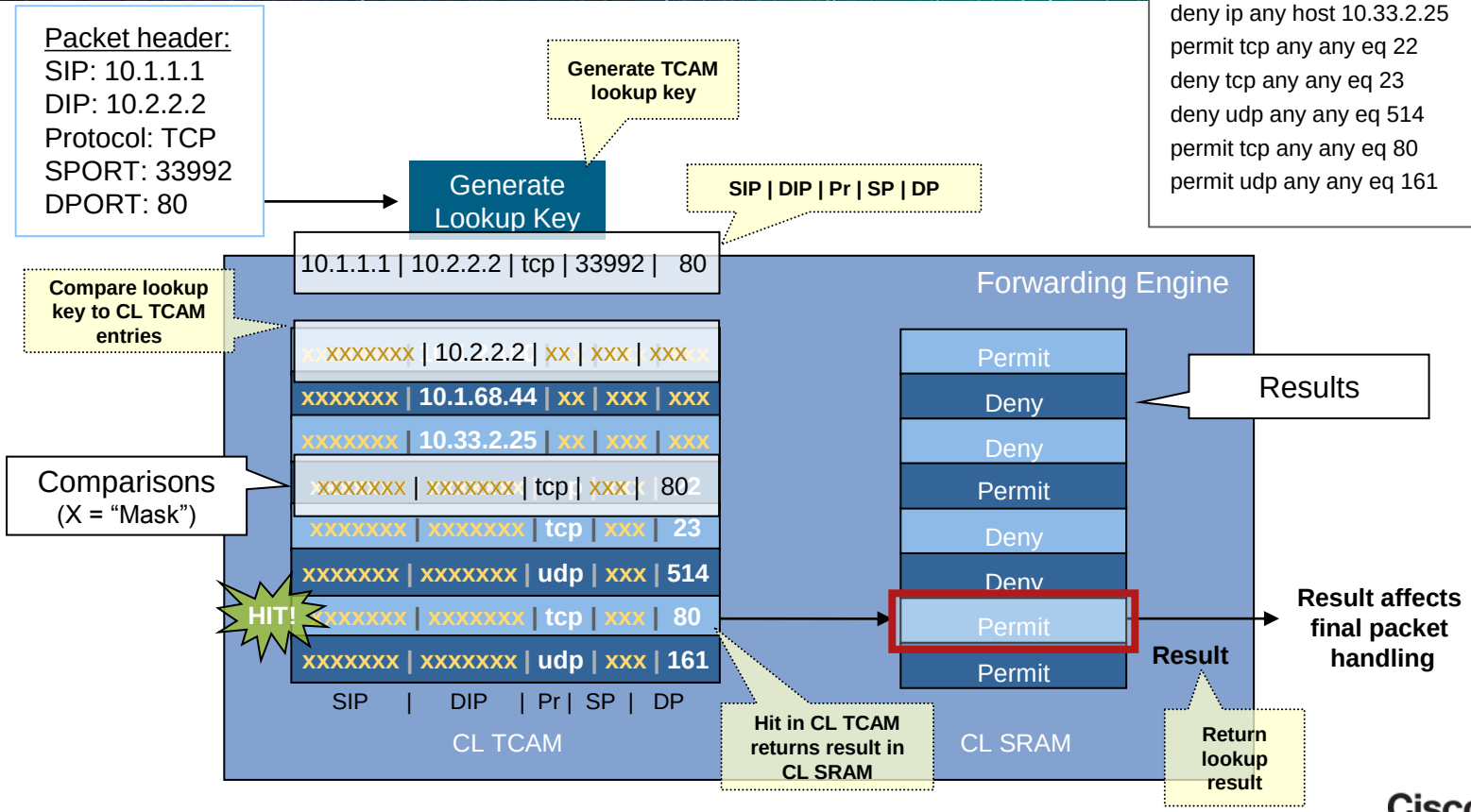
What Is Classification?

- Matching packets
  - Layer 2, Layer 3, and/or Layer 4 information
- Used to decide whether to apply a particular policy to a packet
  - Enforce security, QoS, or other policies
- Some examples:
  - Match TCP/UDP source/destination port numbers to enforce security policy
  - Match destination IP addresses to apply policy-based routing (PBR)
  - Match 5-tuple to apply marking policy
  - Match protocol-type to apply Control Plane Policing (CoPP)
  - etc.

CL TCAM Lookup – ACL

Security ACL

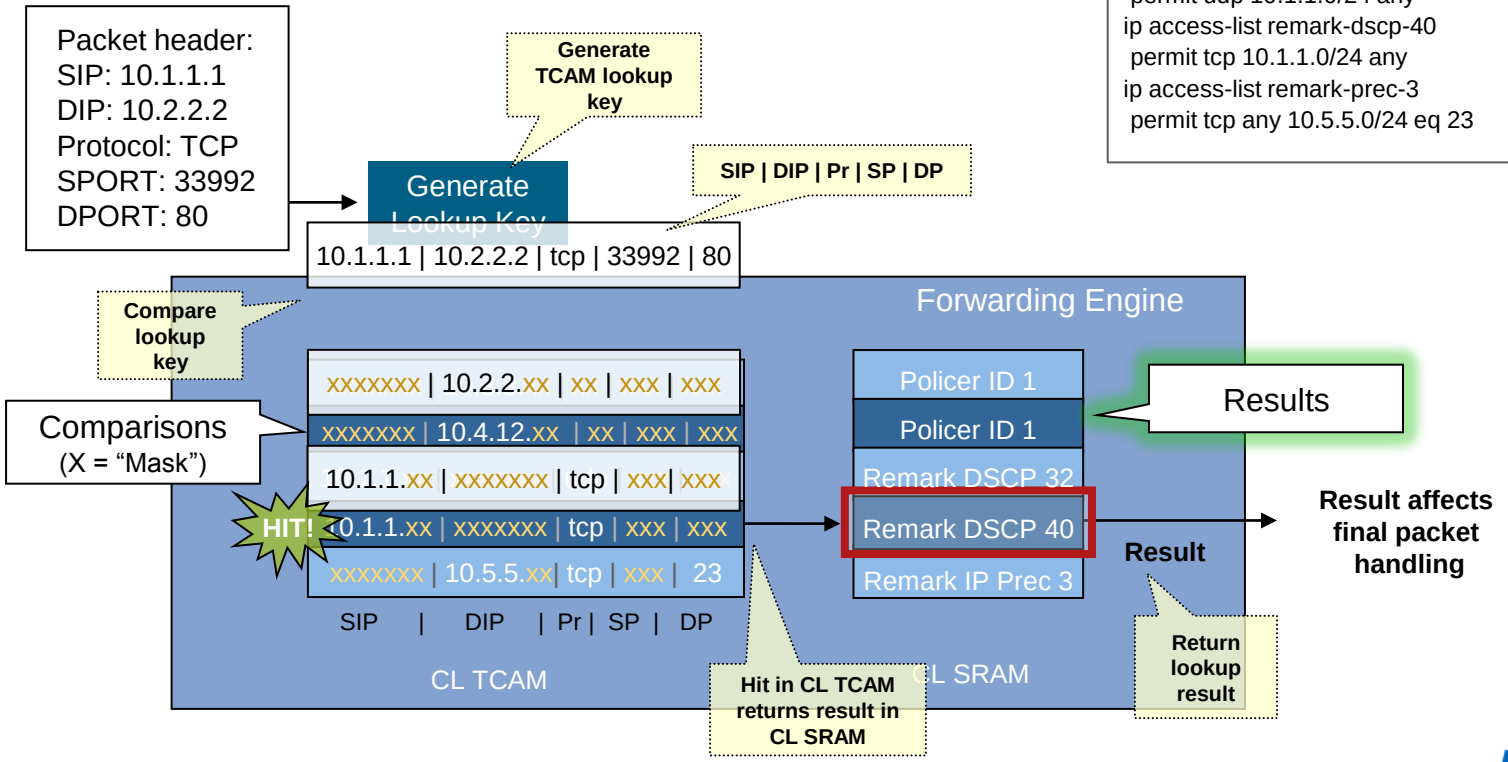
```
ip access-list example
 permit ip any host 10.1.2.100
 deny ip any host 10.1.68.44
 deny ip any host 10.33.2.25
 permit tcp any any eq 22
 deny tcp any any eq 23
 deny udp any any eq 514
 permit tcp any any eq 80
 permit udp any any eq 161
```



CL TCAM Lookup – QoS

QoS Classification ACLs

```
ip access-list police
 permit ip any 10.3.3.0/24
 permit ip any 10.4.12.0/24
ip access-list remark-dscp-32
 permit udp 10.1.1.0/24 any
ip access-list remark-dscp-40
 permit tcp 10.1.1.0/24 any
ip access-list remark-prec-3
 permit tcp any 10.5.5.0/24 eq 23
```



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NetFlow

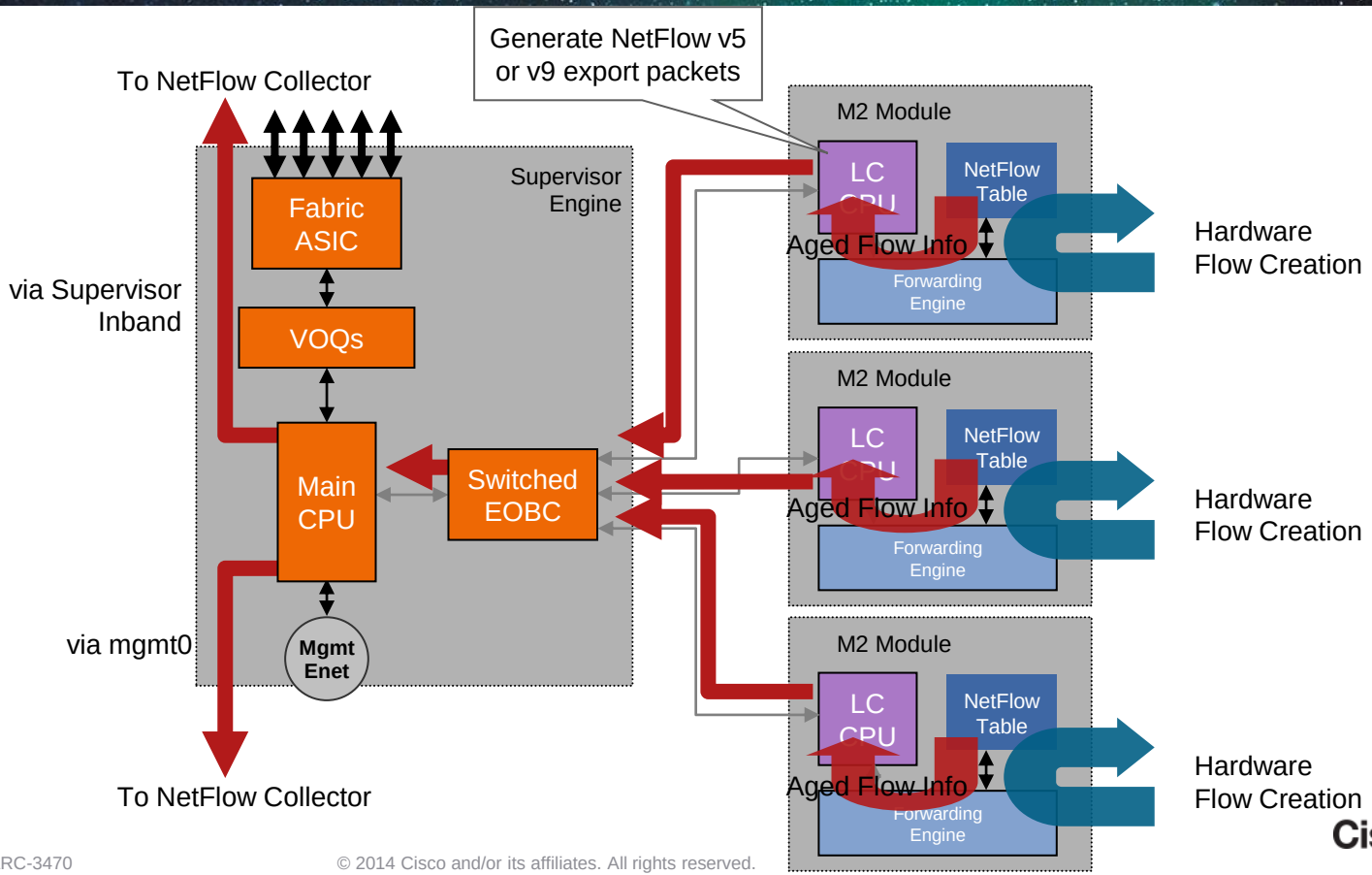
- NetFlow collects flow data for packets traversing the switch
- Each module maintains independent NetFlow table

	M2	F2E / F3
Per-interface NetFlow	Yes	Yes
NetFlow direction	Ingress/Egress	Ingress only
Full NetFlow	Yes	No
Sampled NetFlow	Yes	Yes
FSA Assist for Sampled NetFlow	No	F3 only (future)
Bridged NetFlow	Yes	Yes
Hardware Cache	Yes	No
Software Cache	No	Yes
Hardware Cache Size	512K entries per forwarding engine	N/A
NDE (v5/v9)	Yes	Yes

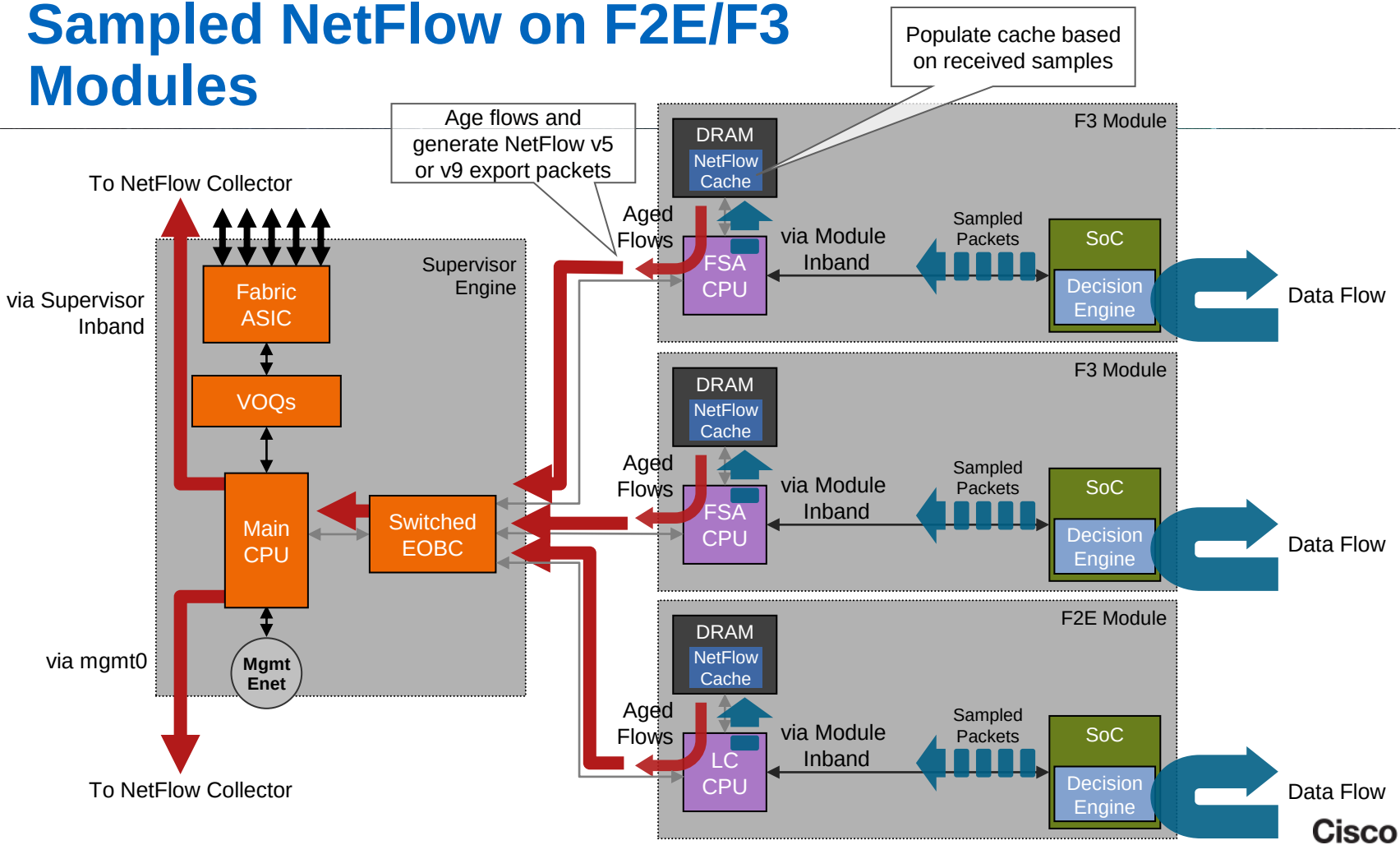
Full vs. Sampled NetFlow

- NetFlow collects full or sampled flow data
- Full NetFlow: Accounts for every packet of every flow on interface
  - Available on M-Series modules only
  - Flow data collection up to capacity of hardware NetFlow table
- Sampled NetFlow: Accounts for M in N packets on interface
  - Available on both M2 (ingress/egress) and F2E/F3 (ingress only)
  - M2: Flow data collection up to capacity of hardware NetFlow table
  - F2E/F3: Flow data collection for up to ~1000pps per module
  - F3 (future): Increased per-module sampling rate leveraging on-board Fabric Services Accelerator (FSA) complex

NetFlow on M2 Modules



Sampled NetFlow on F2E/F3 Modules



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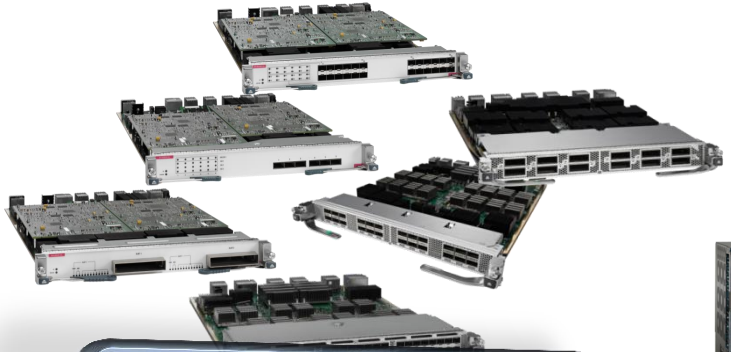
Nexus 7000 / Nexus 7700 Architecture Summary

I/O Modules



Variety of front-panel interface and transceiver types with feature-rich hardware-based forwarding and services

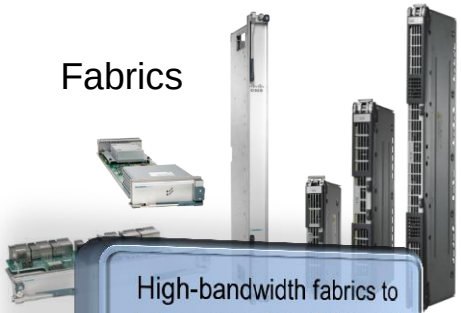
Scalable platform for control plane protocols, system and network management

Supervisor Engines

Chassis

Multiple chassis designs with density and airflow options to fit any deployment

Fabrics



High-bandwidth fabrics to interconnect modules and provide investment protection

Conclusion

- You should now have a thorough understanding of the Nexus 7000 / Nexus 7700 switching architecture, I/O module design, packet flows, and key forwarding engine functions…
- **Any questions?**

Q & A

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