Cisco Nexus 7000 Hardware Architecture

BRKARC-3470

Session Goal

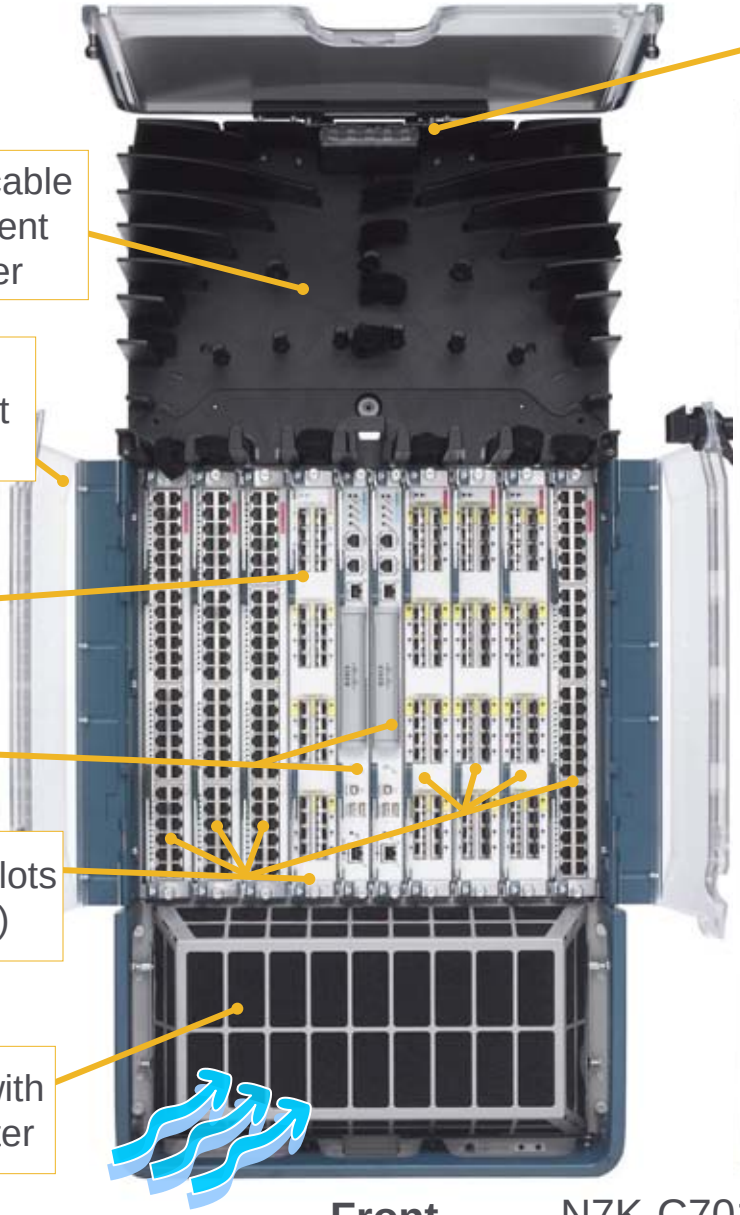
- To provide you with a thorough understanding of the Cisco Nexus™ 7000 switching architecture, supervisor, fabric, and I/O module design, packet flows, and key forwarding engine functions
- This session will **not** examine Unified I/O, DCB, FCoE, NX-OS software architecture, or other Nexus platforms
- Related sessions:

  BRKARC-3471: Cisco NXOS Software Architecture

Agenda

- Chassis Architecture
- Supervisor Engine Architecture
- I/O Module Architecture
- Forwarding Engine Architecture
- Fabric Architecture
- Layer 2 Forwarding
- IP Forwarding
- IP Multicast Forwarding
- ACLs
- QoS
- NetFlow

Nexus 7010 Chassis



System status LEDs

ID LEDs on all FRUs

Front-to-back airflow

Integrated cable management with cover

Air exhaust

Optional locking front doors

System fan trays

Locking ejector levers

Fabric fan trays

21RU

Two chassis per 7’ rack

Supervisor slots (5-6)

Crossbar fabric modules

I/O module slots (1-4, 7-10)

Power supplies

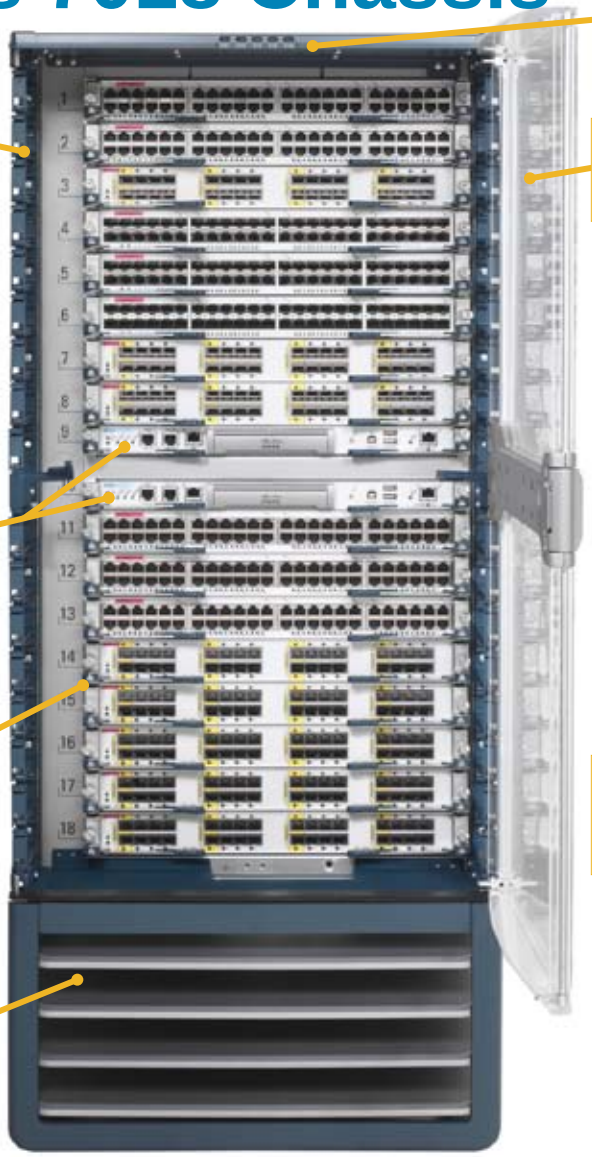
Air intake with optional filter

Common equipment removes from rear

Front N7K-C7010 **Rear**

Supported in NX-OS release 4.1(2) and later

Nexus 7018 Chassis



System status LEDs

System fan trays

Integrated cable management

Optional front door

Side-to-side airflow

Supervisor slots (9-10)

25RU

Crossbar fabric modules

I/O module slots (1-8, 11-18)

Common equipment removes from rear

Power supply air intake

Power supplies

Front

N7K-C7018

Rear

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Supervisor Engine

- Performs control plane and management functions
- Dual-core 1.66GHz Intel Xeon processor with 4GB DRAM
- 2MB NVRAM, 2GB internal bootdisk, compact flash slots
- Out-of-band 10/100/1000 management interface
- Always-on Connectivity Management Processor (CMP) for lights-out management
- Console and auxiliary serial ports
- USB ports for file transfer

N7K-SUP1

ID LED

Status LEDs

Console Port

AUX Port

Management Ethernet

Compact Flash Slots

Reset Button

USB Ports

CMP Ethernet

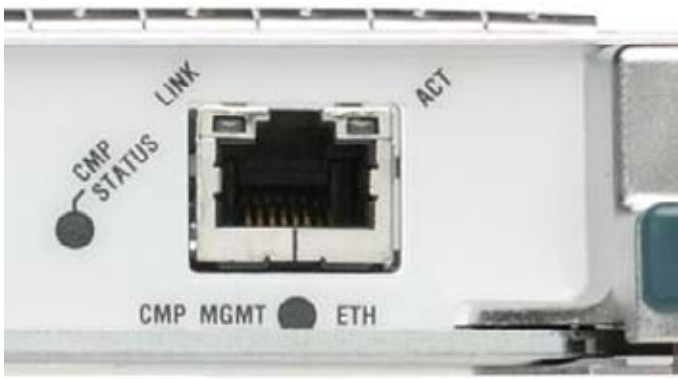
Management Interfaces

Management Ethernet

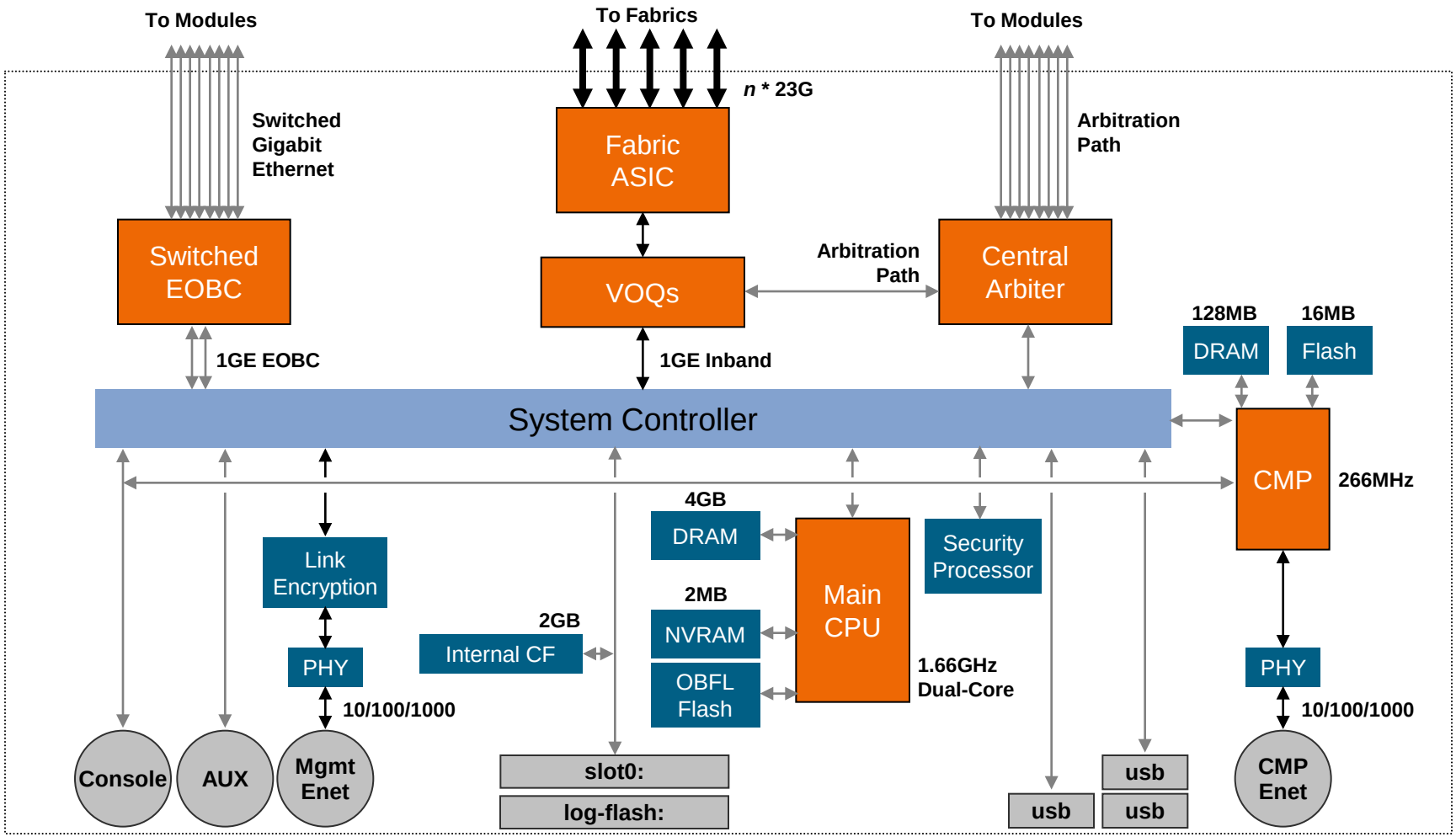
- 10/100/1000 interface used exclusively for system management
- Belongs to dedicated “management” VRF
  - Prevents data plane traffic from entering/exiting from mgmt0 interface
  - Cannot move mgmt0 interface to another VRF
  - Cannot assign other system ports to management VRF

Connectivity Management Processor (CMP) Ethernet

- Connects to standalone, always-on microprocessor on supervisor engine
  - Runs lightweight software with network stack
  - Completely independent of NX-OS on main CPU
- Provides ‘lights out’ remote management and disaster recovery via 10/100/1000 interface
  - Removes need for terminal servers



Supervisor Engine Architecture



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8-Port 10GE I/O Module

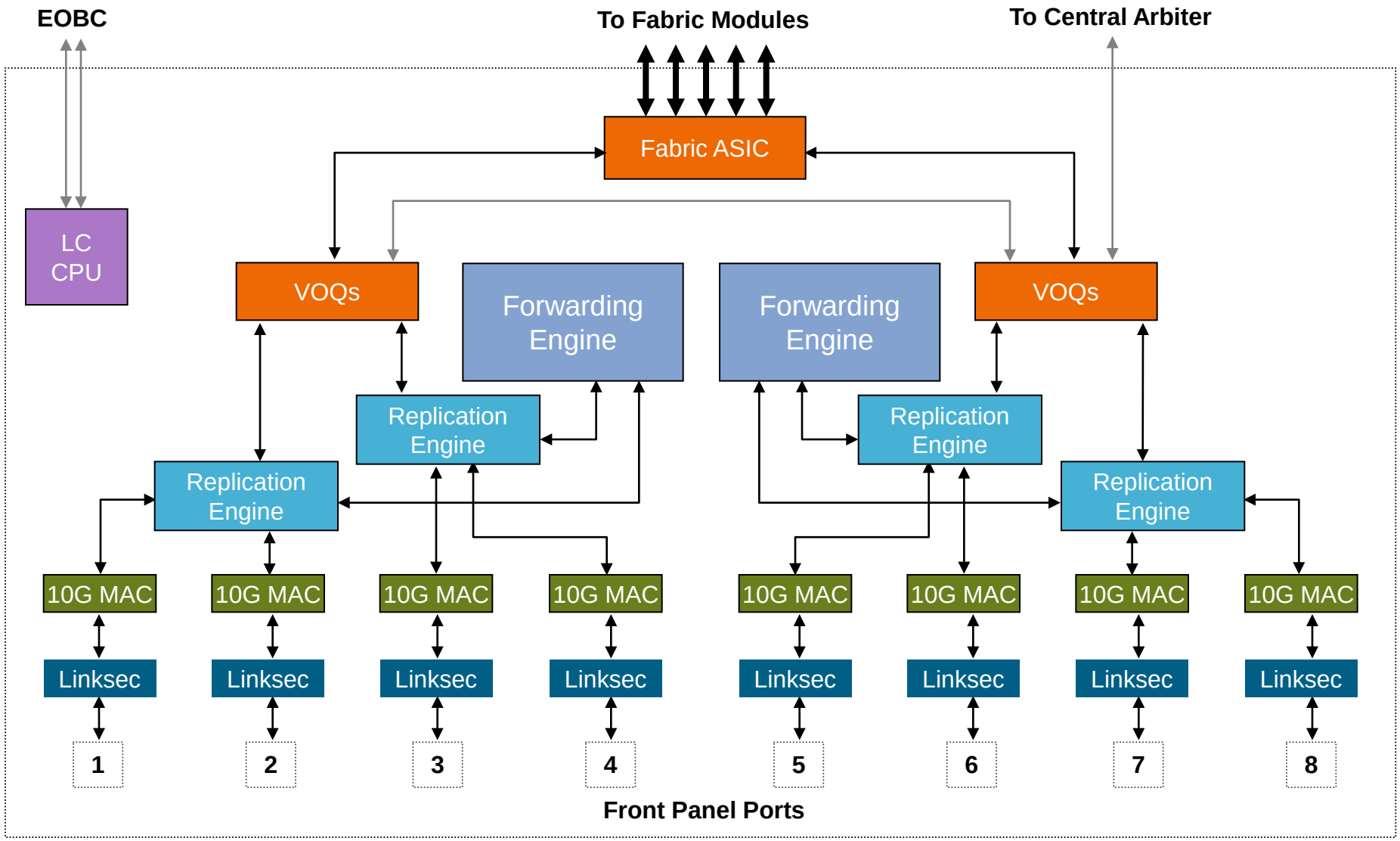
N7K-M108X2-12L

- 8-port 10G with X2 transceivers
- 80G full-duplex fabric connectivity
- Two integrated forwarding engines (120Mpps)
  - Support for “XL” forwarding tables (licensed feature)
- 8 ports wire-rate L3 multicast replication
- 802.1AE LinkSec

N7K-M108X2-12L

8-Port 10G XL I/O Module Architecture

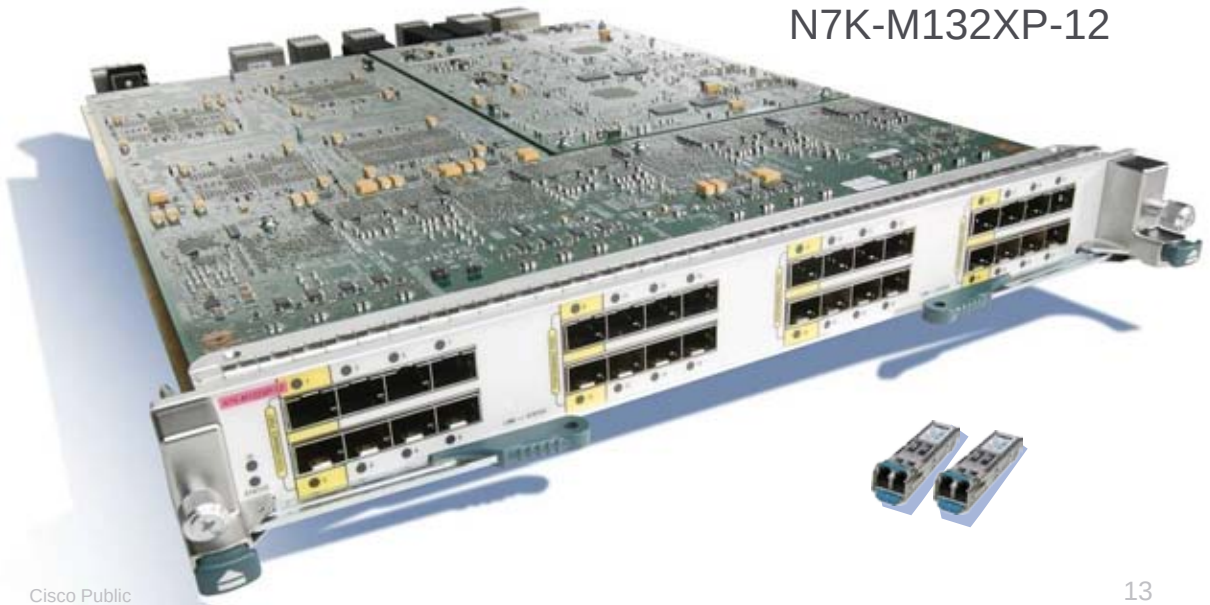
N7K-M108X2-12L



32-Port 10GE I/O Module

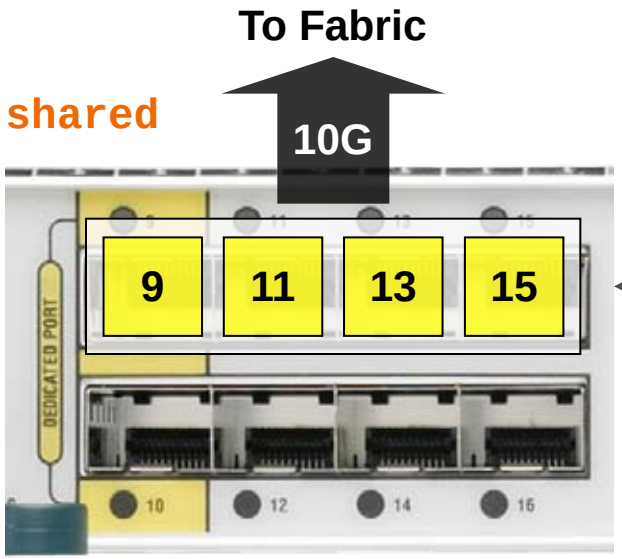
N7K-M132XP-12

- 32-port 10G with SFP+ transceivers
- 80G full-duplex fabric connectivity
- Integrated 60Mpps forwarding engine
- Oversubscription option for higher density (up to 4:1)
- 8 ports wire-rate L3 multicast replication
- 802.1AE LinkSec



Shared vs. Dedicated Mode

`rate-mode shared`
(default)

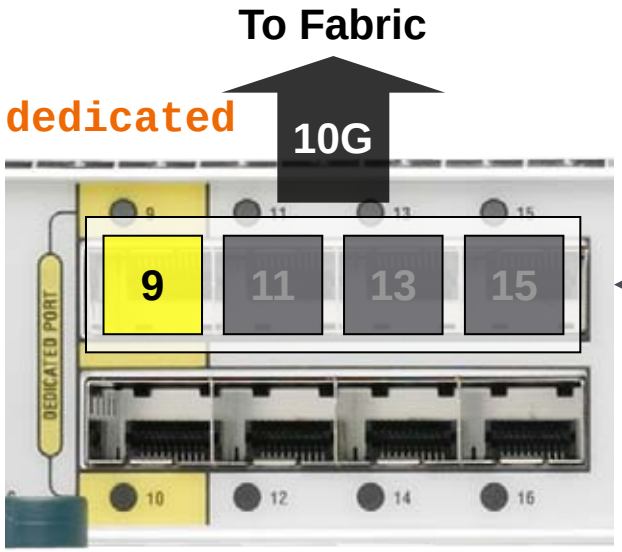


Shared mode

- Four interfaces in port group share 10G bandwidth

"Port group"–group of contiguous even or odd ports that share 10G of bandwidth (e.g., ports 1,3,5,7)

`rate-mode dedicated`

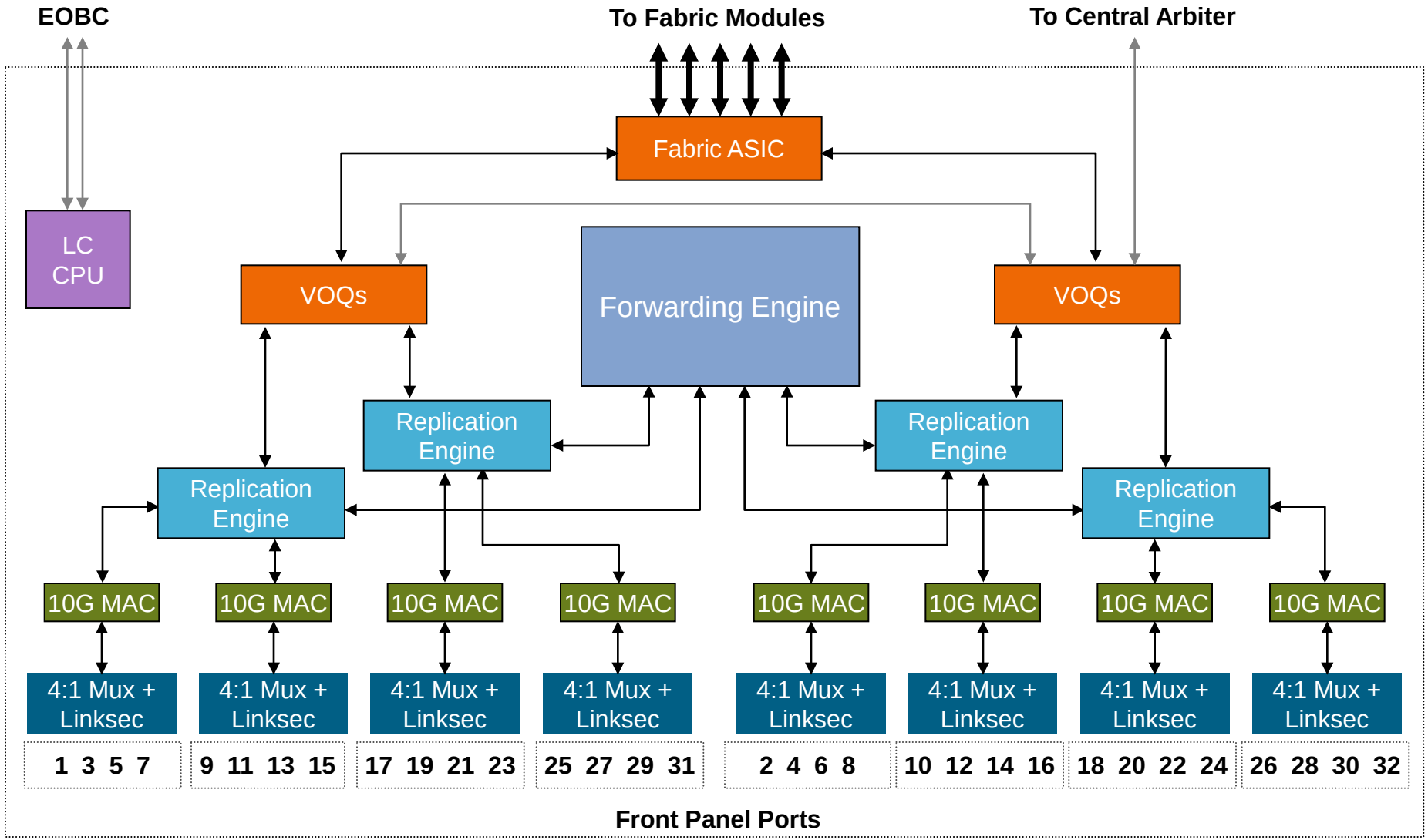


Dedicated mode

- First interface in port group gets 10G bandwidth
- Other three interfaces in port group disabled

32-Port 10G I/O Module Architecture

N7K-M132XP-12



48-Port 1G I/O Modules

N7K-M148GT-11, N7K-M148GS-11, N7K-M148GS-11L

- Three 1G I/O module options:
  - 48 10/100/1000 RJ-45 ports (N7K-M148GT-11)
  - 48 1G SFP ports (N7K-M148GS-11)
  - 48 1G SFP ports with XL forwarding engine (N7K-M148GS-11L)
- Integrated 60Mpps forwarding engine
- 46G full duplex fabric connectivity
  - Line rate on 48-ports with some local switching
- 48 ports wire-rate L3 multicast replication
- 802.1AE LinkSec

N7K-M148GT-11
Release 4.0(1) and later

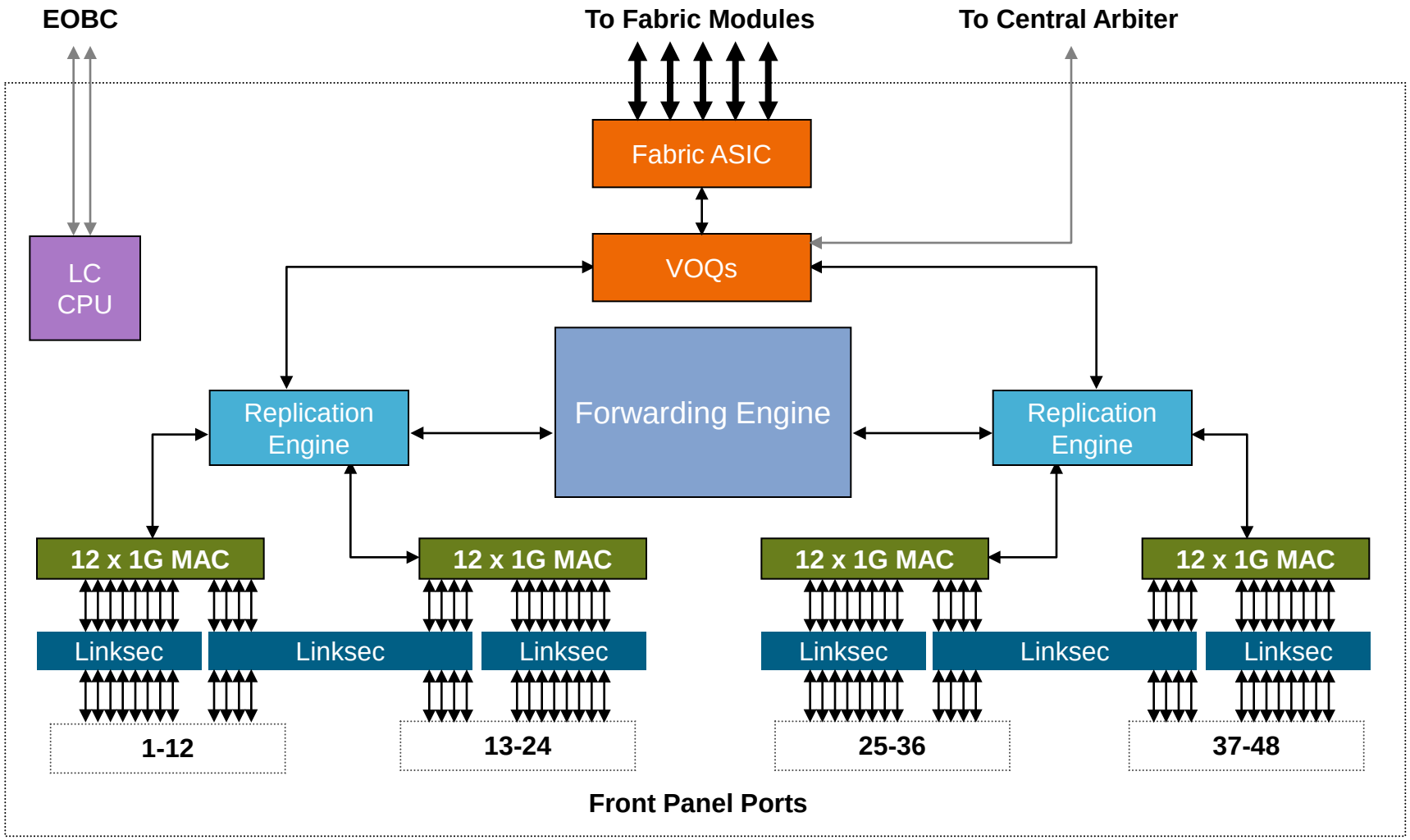
N7K-M148GS-11
Release 4.1(2) and later

N7K-M148GS-11L
Release 5.0(2) and later

Cisco Public

48-Port 1G I/O Modules Architecture

N7K-M148GT-11, N7K-M148GS-11, N7K-M148GS-11L



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Forwarding Engine Hardware

- Hardware forwarding engine(s) integrated on every I/O module
- 60Mpps per forwarding engine Layer 2 bridging with hardware MAC learning
- 60Mpps per forwarding engine IPv4 and 30Mpps IPv6 unicast
- IPv4 and IPv6 multicast support (SM, SSM, bidir)
- RACL/VACL/PACLs
- Policy-based routing (PBR)
- Unicast RPF check and IP source guard
- QoS remarking and policing policies
- Ingress and egress NetFlow (full and sampled)

Hardware Table	M1 Modules	M1-XL Modules without License	M1-XL Modules with License
FIB TCAM	128K	128K	**900K**
Classification TCAM (ACL/QoS)	64K	64K	**128K**
MAC Address Table	128K	128K	128K
NetFlow Table	512K	512K	512K

“Scalable Services” License

- Forwarding engines on M1-XL I/O modules always have “XL” capacity
- Access to additional capacity controlled by presence of “Scaleable Services” license

  License applies to entire system (per-chassis)

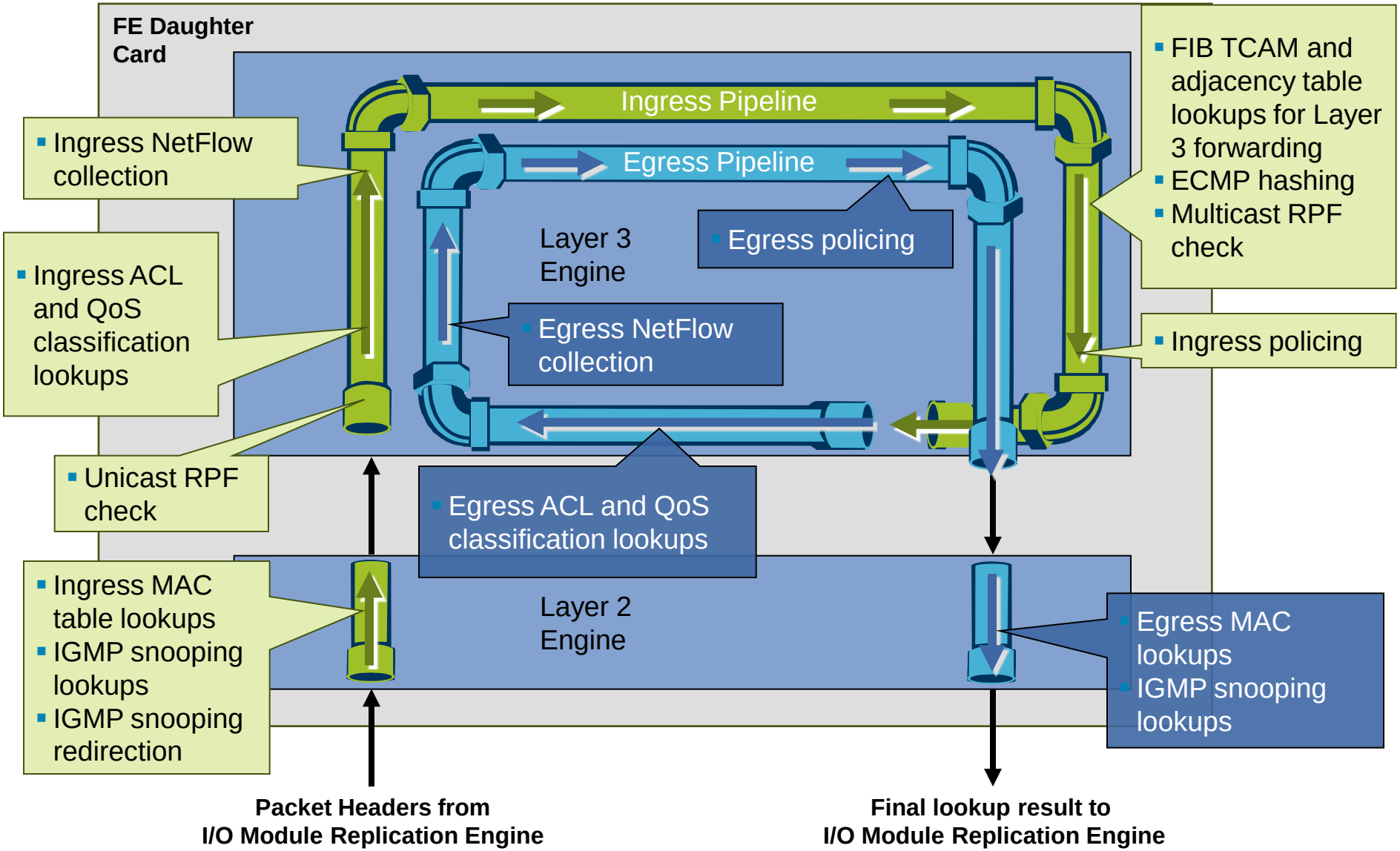
```
N7K# show license usage
Feature                      Ins  Lic   Status Expiry Date Comments
                                 Count
--------------------------------------------------------------------------------
SCALABLE_SERVICES_PKG         Yes   -   In use Never       -
LAN_ADVANCED_SERVICES_PKG     Yes   -   In use Never       -
LAN_ENTERPRISE_SERVICES_PKG   Yes   -   In use Never       -
--------------------------------------------------------------------------------
N7K#
```

Forwarding Engine Architecture

Forwarding engine chipset consists of two ASICs:

- Layer 2 Engine
  - Ingress and egress SMAC/DMAC lookups
  - Hardware MAC learning
  - IGMP snooping and IP-based Layer 2 multicast constraint
- Layer 3 Engine
  - IPv4/IPv6 Layer 3 lookups
  - ACL, QoS, NetFlow and other processing
  - Linear, pipelined architecture–every packet subjected to both ingress and egress pipeline
  - Enabling features does not affect forwarding engine performance

Forwarding Engine Pipelined Architecture



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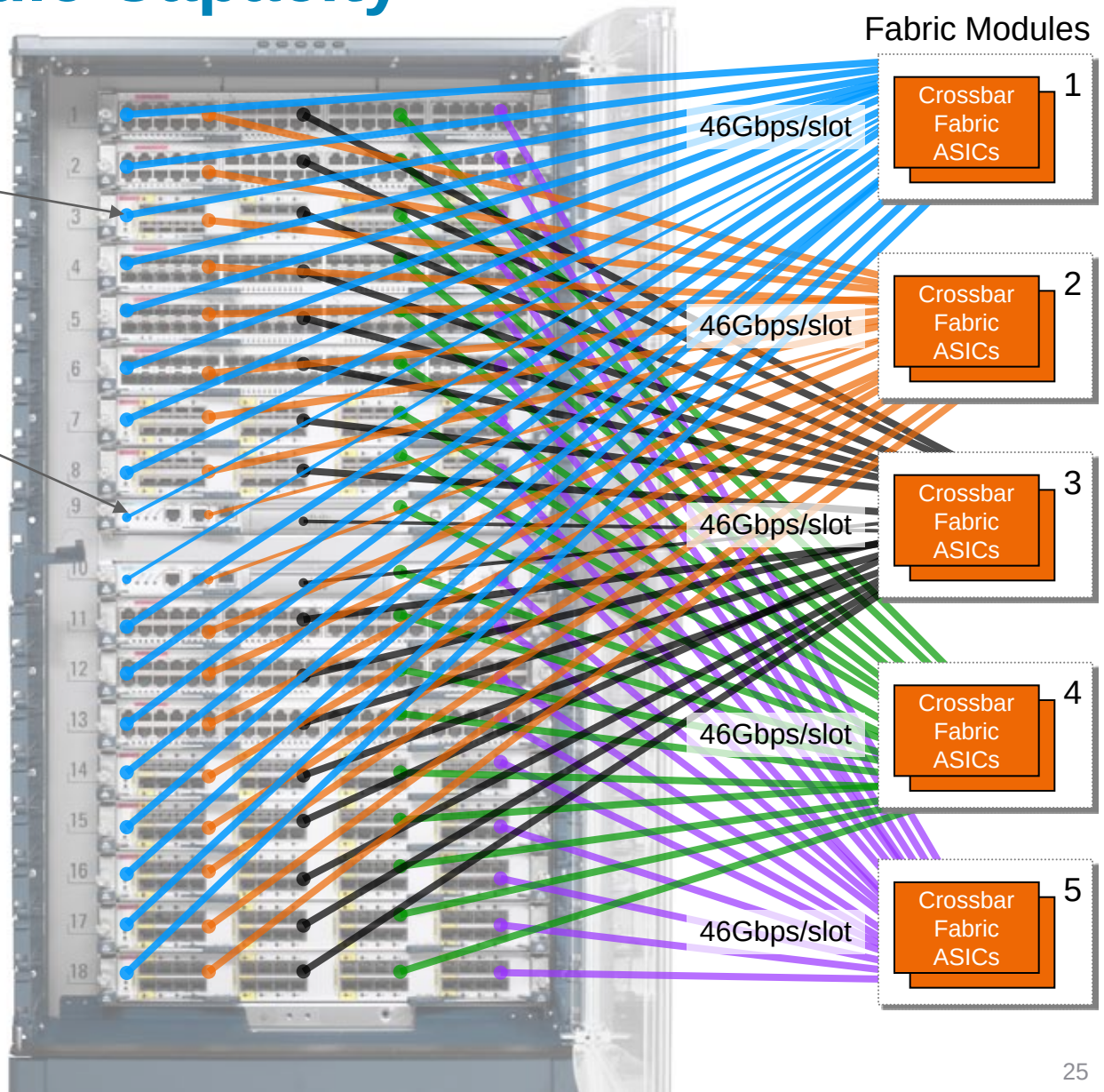
Crossbar Switch Fabric Module

- Each fabric module provides 46Gbps per I/O module slot
  - Up to 230Gbps per slot with 5 fabric modules
- Currently shipping I/O modules do not leverage full fabric bandwidth
  - Maximum 80G per slot with 10G module
  - Future modules leverage additional available fabric bandwidth
- Access to fabric controlled using QoS-aware central arbitration with VOQ

N7K-C7010-FAB-1

N7K-C7018-FAB-1

Fabric Module Capacity



230Gbps

per slot bandwidth

Nexus 7018

I/O Module Capacity

1G modules

- Require 1 fabric for full bandwidth
- Require 2 fabrics for N+1 redundancy

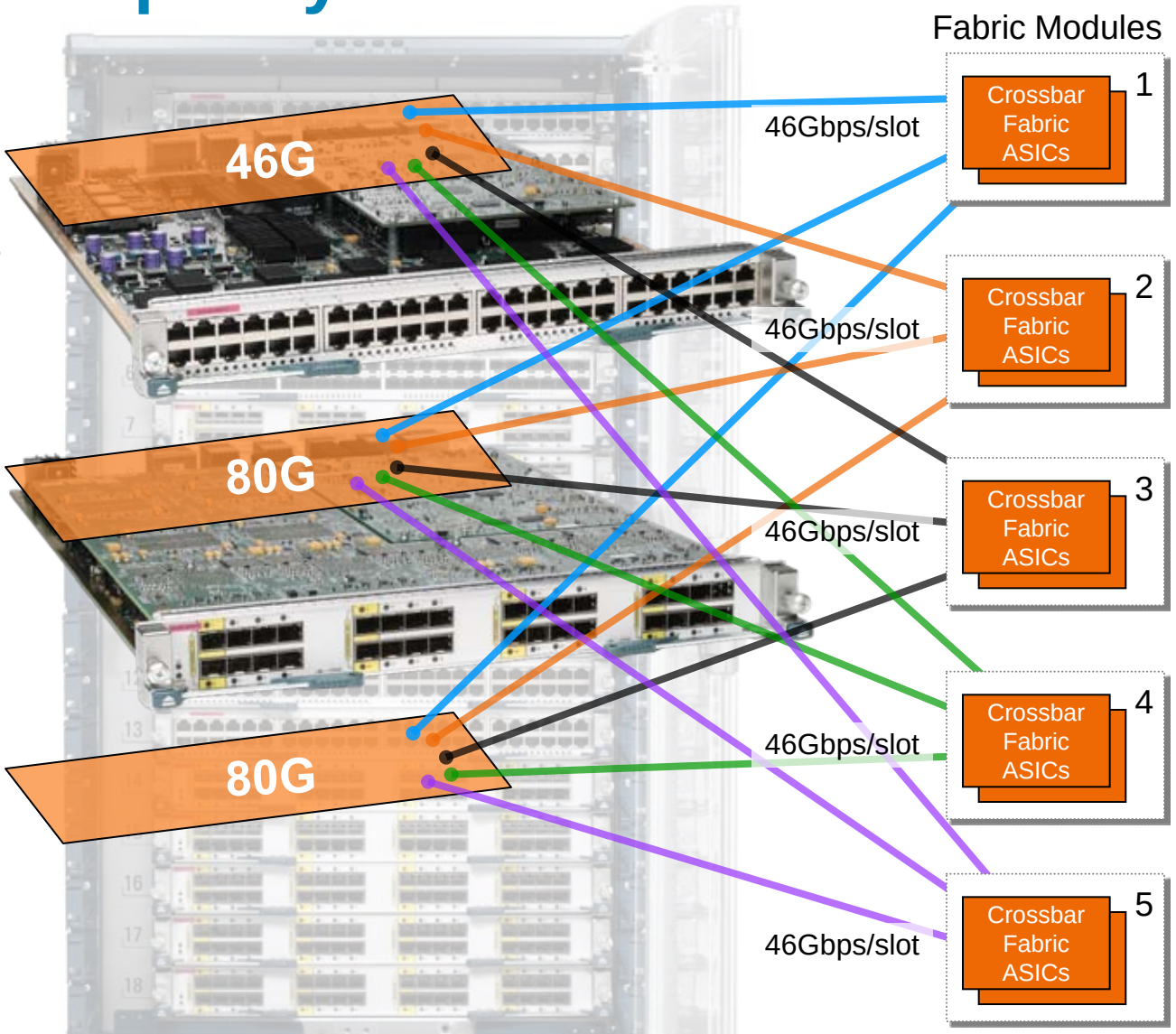
230Gbps

per slot bandwidth

- 4th and 5th fabric modules provide additional redundancy and future-proofing

10G modules

- Require 2 fabrics for full bandwidth
- Require 3 fabrics for N+1 redundancy



Access to Fabric Bandwidth

- Access to fabric controlled using central arbitration
  - Arbiter ASIC on supervisor engine provides fabric arbitration
- Bandwidth capacity on egress modules represented by Virtual Output Queues (VOQs) at ingress to fabric
  - I/O modules interface with arbiter to gain access to VOQs

What Are VOQs?

- Virtual Output Queues (VOQs) on ingress modules represent bandwidth capacity on egress modules
- If VOQ available on ingress to fabric, capacity exists at egress module to receive traffic from fabric
  - Central arbiter determines whether VOQ is available for a given packet
  - Bandwidth capacity represented by “credits”
  - Credits are requested by I/O modules and granted by arbiter
- VOQ is “virtual” because it represents EGRESS capacity but resides on INGRESS modules
  - It is still PHYSICAL buffer where packets are stored
- Note: VOQ is **not** equivalent to ingress or egress port buffer or queues
  - Relates ONLY to ASICs at ingress and egress to fabric

Benefits of Central Arbitration with VOQ

- Ensures priority traffic takes precedence over best-effort traffic across fabric
  - Four levels of priority for each VOQ destination
- Ensures fair access to bandwidth for multiple ingress ports transmitting to one egress port
  - Central arbiter ensures all traffic sources get appropriate access to fabric bandwidth, even with traffic sources on different modules
- Prevents congested egress ports from blocking ingress traffic destined to other ports
  - Mitigates head-of-line blocking by providing independent queues for individual destinations across the fabric
- In future, will provide lossless service for FCoE traffic across the fabric
  - Can provide strict priority and backpressure (blocking instead of dropping) for certain traffic classes, such as SAN traffic

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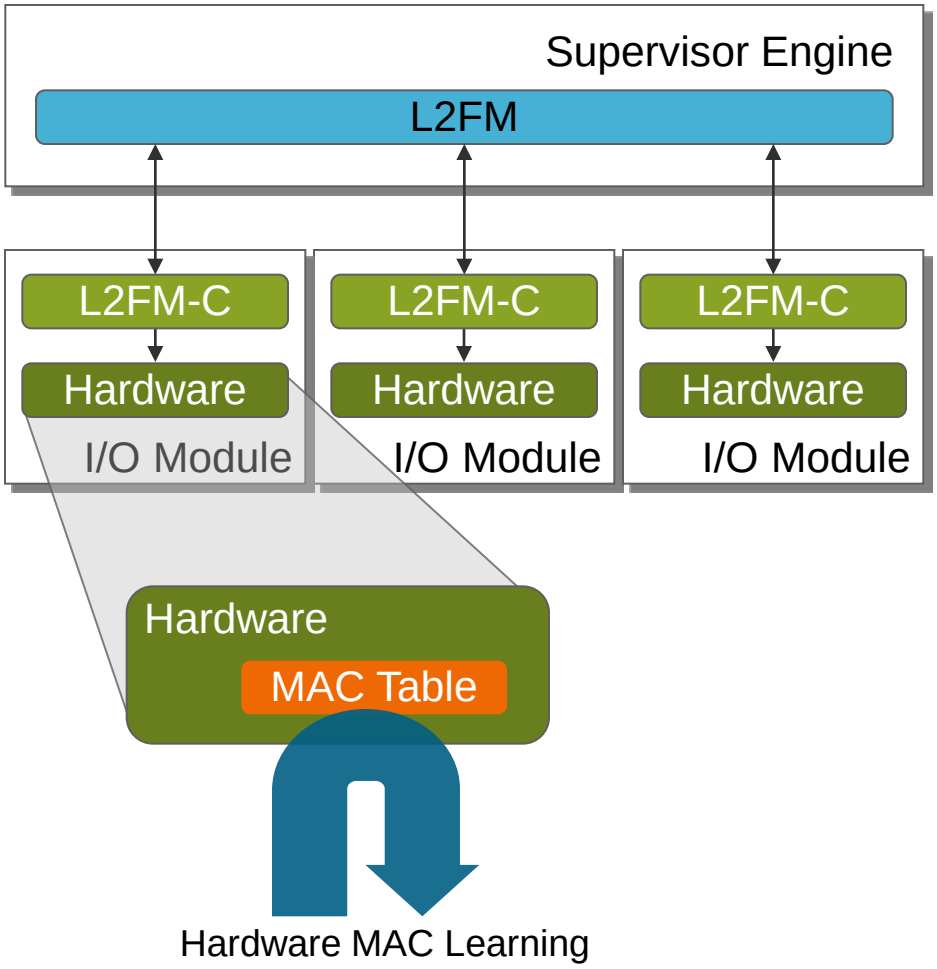
Layer 2 Forwarding

- MAC table is 128K entries (115K effective)
- Hardware MAC learning
  - CPU not directly involved in learning
- All modules have copy of MAC table
  - New learns communicated to other modules via hardware “flood to fabric” mechanism
  - Software process ensures continuous MAC table sync
- Spanning tree (PVRST or MST) or Virtual Port Channel (VPC) ensures loop-free Layer 2 topology

Layer 2 Forwarding Architecture

- Layer 2 Forwarding Manager (L2FM) maintains central database of MAC tables
- L2FM keeps MAC table on all forwarding engines in sync
- L2FM-Client process on I/O modules interfaces between L2FM and hardware MAC table



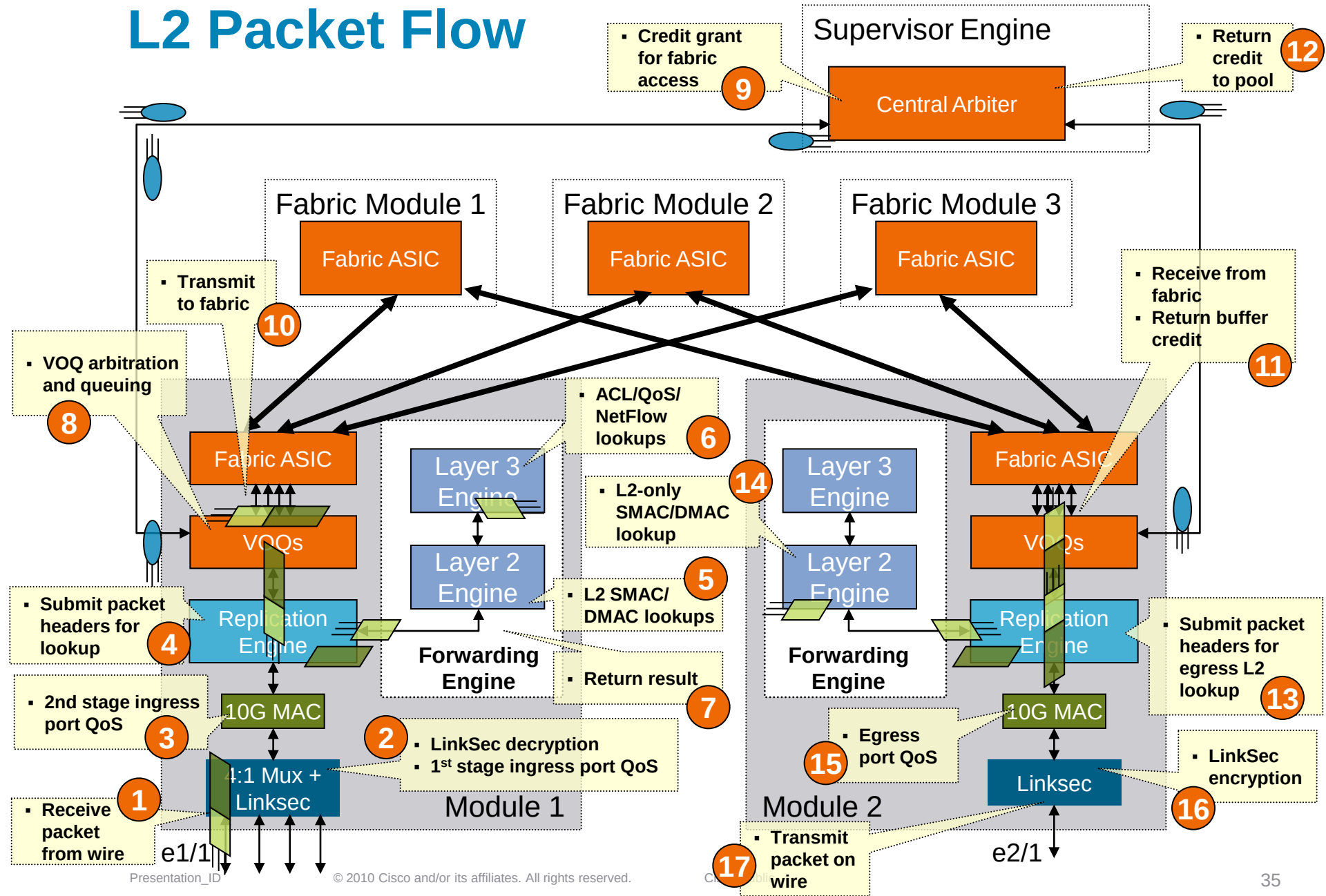

```
n7010# sh processes cpu | egrep PID|l2fm
PID    Runtime(ms)  Invoked   uSecs  1Sec   Process
 3848         1106  743970580      0      0  l2fm
n7010# attach mod 9
Attaching to module 9 ...
To exit type 'exit', to abort type '$.'
Last login: Mon Apr 21 15:58:12 2009 from sup02 on
pts/0
Linux lc9 2.6.10_mvl401-pc_target #1 Fri Mar 21
23:26:28 PDT 2009 ppc GNU/Linux
module-9# sh processes cpu | egrep l2fm
 1544         6396    388173     16    0.0  l2fmc
module-9#
```

Hardware Layer 2 Forwarding Process

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

HDR = Packet Headers DATA = Packet Data CTRL = Internal Signaling

L2 Packet Flow



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IP Forwarding

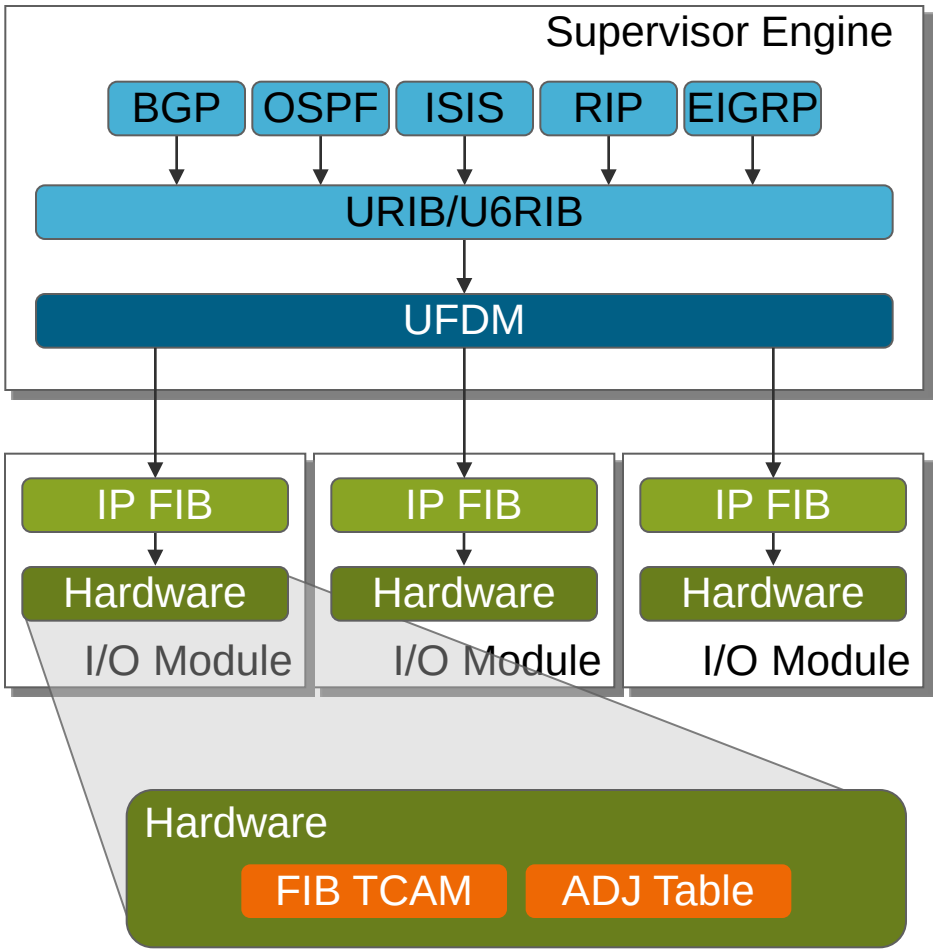
- Nexus 7000 decouples control plane and data plane
- Forwarding tables built on control plane using routing protocols or static configuration

  OSPF, EIGRP, IS-IS, RIP, BGP for dynamic routing

- Tables downloaded to forwarding engine hardware for data plane forwarding

IP Forwarding Architecture

- Routing protocol processes learn routing information from neighbors
- IPv4 and IPv6 unicast RIBs calculate routing/next-hop information
- Unicast Forwarding Distribution Manager (UFDM) interfaces between URIBs on supervisor and IP FIB on I/O modules
- IP FIB process programs forwarding engine hardware on I/O modules
  - FIB TCAM contains IP prefixes
  - Adjacency table contains next-hop information

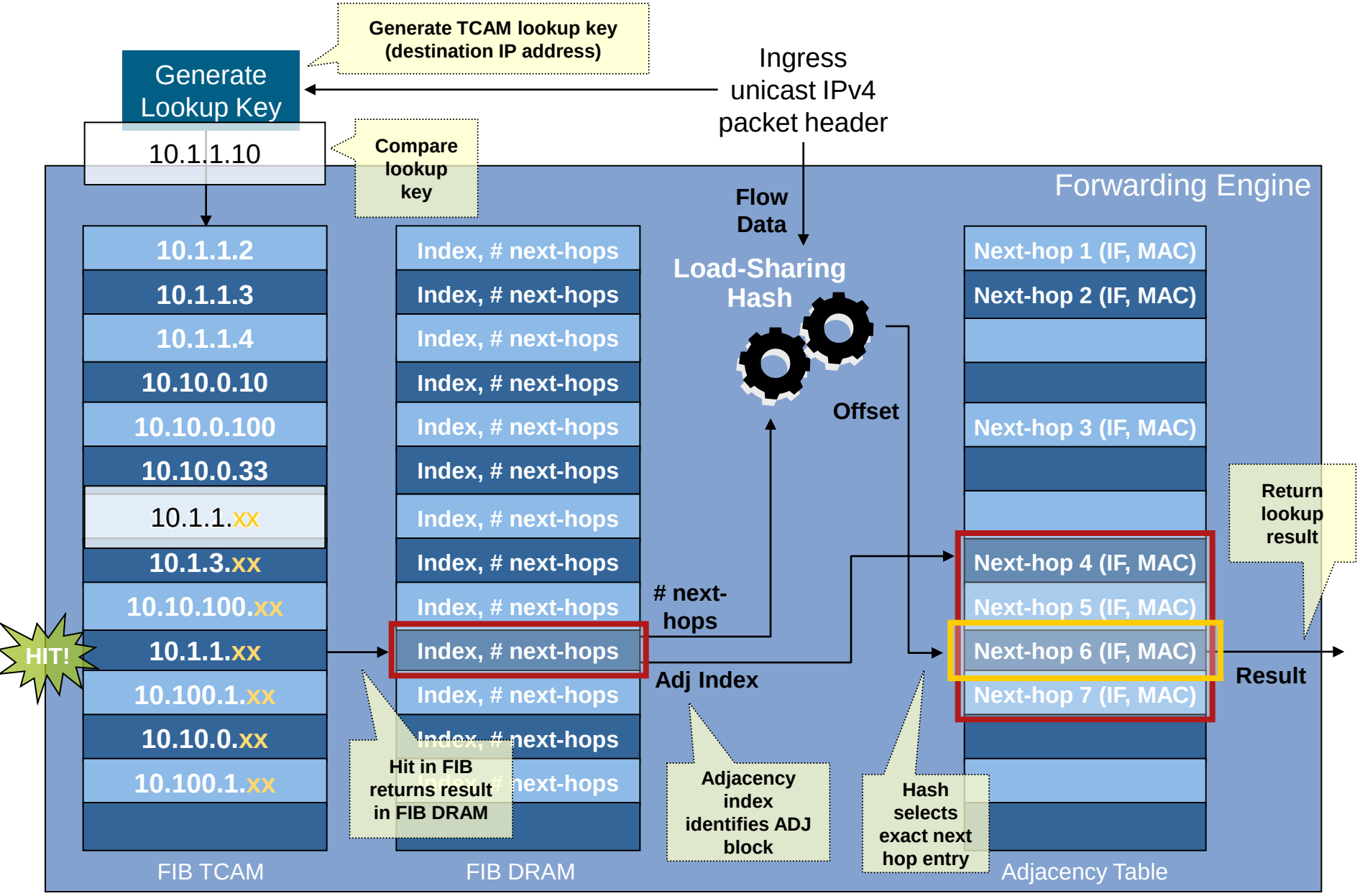



```
n7010# sh processes cpu | egrep ospf|PID
PID    Runtime(ms)  Invoked    uSecs  1Sec    Process
20944           93  33386880       0     0   ospf
n7010# sh processes cpu | egrep u.?rib
 3573          117  44722390       0     0   u6rib
 3574          150  34200830       0     0   urib
n7010# sh processes cpu | egrep ufdm
 3836         1272  743933460       0      0  ufdm

module-9# sh processes cpu | egrep fib
 1534        80042    330725    242    0.0  ipfib
module-9#
```

Hardware IP Forwarding Process

- FIB TCAM lookup based on destination prefix (longest-match)
- 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

IPv4 FIB TCAM Lookup



“Routing” vs. “Forwarding”

- “Routing” information refers to unicast RIB contents in supervisor control plane
- “Forwarding” information refers to FIB contents at I/O module

Displaying Routing and Forwarding Information

- **`show routing [ipv4|ipv6] [<prefix>] [vrf <vrf>]`**

  Displays software routing (URIB) information

  Can also use traditional **`show ip route`** command

- **`show forwarding [ipv4|ipv6] route module <mod> [vrf <vrf>]`**

  Displays hardware forwarding (FIB) information on per-module basis

- **`show forwarding adjacency module <mod>`**

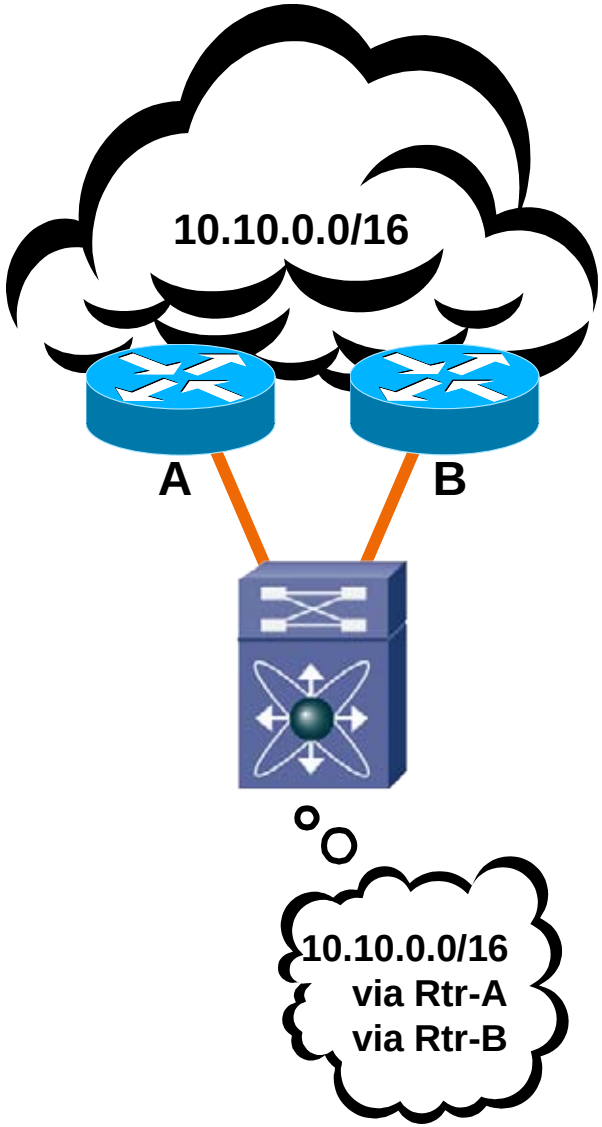
  Displays hardware adjacency table information on per-module basis

Displaying Routing and Forwarding Information (Cont.)

```
n7010# sh routing ipv4 10.100.7.0/24
IP Route Table for VRF "default"
10.100.7.0/24, 1 ucast next-hops, 0 mcast next-hops
   *via 10.1.2.2, Ethernet9/2, [110/5], 00:02:30, ospf-1, type-1
n7010# show forwarding ipv4 route 10.100.7.0/24 module 9
IPv4 routes for table default/base
------------------+------------------+--------------------
Prefix            | Next-hop         | Interface
------------------+------------------+--------------------
10.100.7.0/24       10.1.2.2           Ethernet9/2
n7010# show forwarding adjacency 10.1.2.2 module 9
IPv4 adjacency information, adjacency count 1
next-hop         rewrite info    interface
---------------  --------------  ----------
```

ECMP Load Sharing

- Up to 16 hardware load-sharing paths per prefix
- Use **`maximum-paths`** command in routing protocols to control number of load-sharing paths
- Load-sharing is per-IP flow or per-packet
  - Use caution with per-packet load-balancing!
- Configure load-sharing hash options with global **`ip load-sharing`** command:
  - Source and Destination IP addresses
  - Source and Destination IP addresses plus L4 ports (default)
  - Destination IP address and L4 port
- Additional randomized number added to hash prevents polarization
  - Automatically generated or user configurable value
- Configure per-packet load-sharing with interface **`ip load-sharing per-packet`** command
  - Ingress interface determines if load-sharing is per-flow or per-packet!



ECMP Prefix Entry Example

```
n7010# sh routing ipv4 10.200.0.0
IP Route Table for VRF "default"
10.200.0.0/16, 2 ucast next-hops, 0 mcast next-hops
   *via 10.1.1.2, Ethernet9/1, [110/5], 00:03:33, ospf-1, inter
   *via 10.1.2.2, Ethernet9/2, [110/5], 00:00:13, ospf-1, inter
n7010# sh forwarding ipv4 route 10.200.0.0 module 9
IPv4 routes for table default/base
------------------+------------------+--------------------
Prefix            | Next-hop         | Interface
------------------+------------------+--------------------
10.200.0.0/16       10.1.1.2           Ethernet9/1
                    10.1.2.2           Ethernet9/2
n7010#
```

Identifying the ECMP Path for a Flow

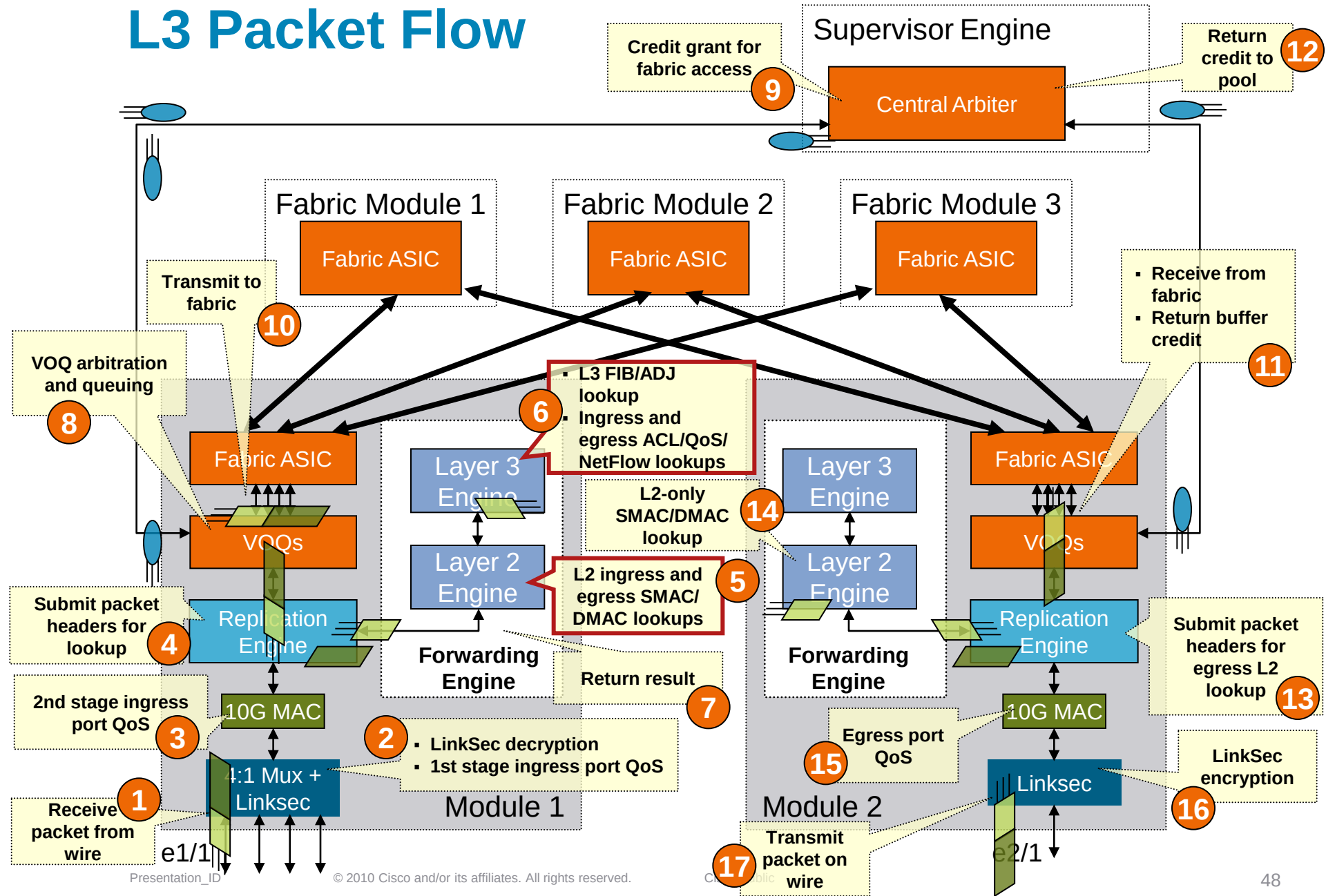
show routing [ipv4|ipv6] hash <sip> <dip> [<sport> <dport>] [vrf <vrf>]

```
n7010# sh routing hash 192.168.44.12 10.200.71.188

Load-share parameters used for software forwarding:

load-share type: 1

Randomizing seed (network order): 0xebae8b9a


Hash for VRF "default"

Hashing to path *10.1.2.2 (hash: 0x29), for route:


10.200.0.0/16, 2 ucast next-hops, 0 mcast next-hops

   *via 10.1.1.2, Ethernet9/1, [110/5], 00:14:18, ospf-1, inter

   *via 10.1.2.2, Ethernet9/2, [110/5], 00:10:58, ospf-1, inter

n7010#
```

Same hash algorithm applies to both hardware and software forwarding

HDR = Packet Headers DATA = Packet Data CTRL = Internal Signaling

L3 Packet Flow



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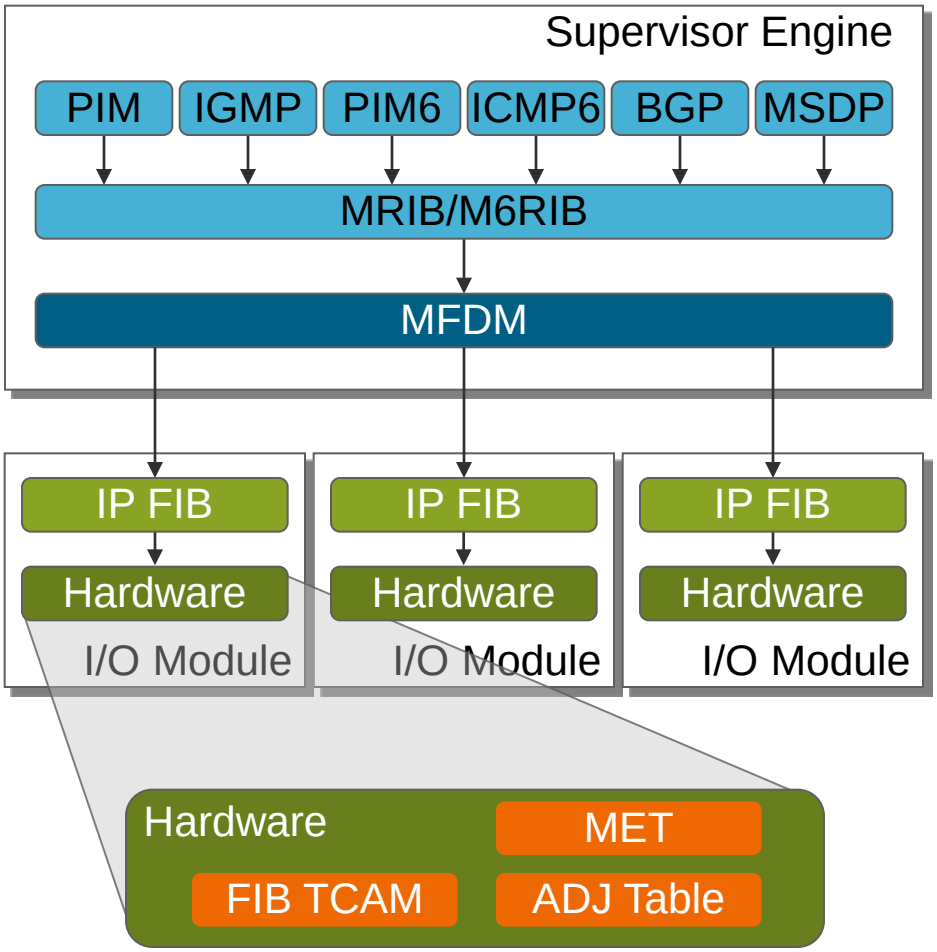
IP Multicast Forwarding

- Forwarding tables built on control plane using multicast protocols
  - PIM-SM, PIM-SSM, PIM-Bidir, IGMP, MLD
- Tables downloaded to:
  - Forwarding engine hardware for data plane forwarding
  - Replication engines for data plane packet replication

IP Multicast Forwarding Architecture

- Multicast routing processes learn routing information from neighbors/hosts
- IPv4 and IPv6 multicast RIBs calculate multicast routing/RP/RPF/OIL information
- Multicast Forwarding Distribution Manager (MFDM) interfaces between MRIBs on supervisor and IP FIB on I/O modules
- IP FIB process programs hardware:
  - FIB TCAM
  - Adjacency table
  - Multicast Expansion Table (MET)

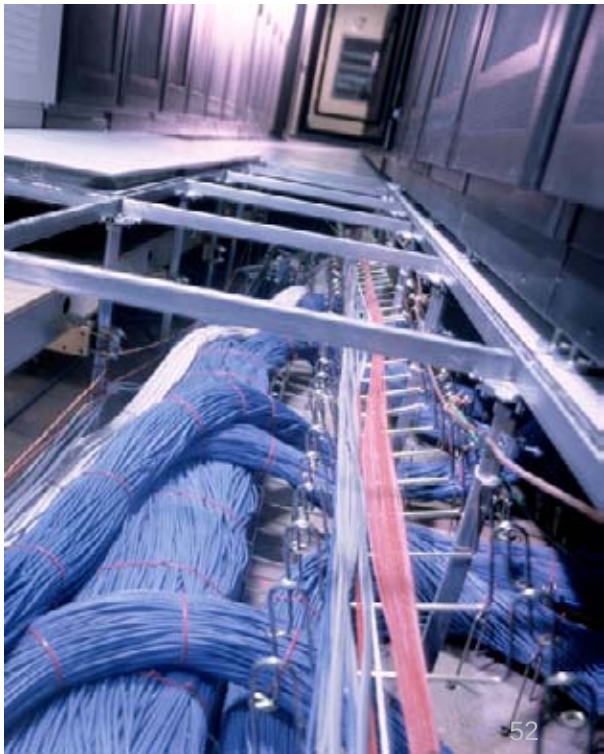



```
n7010# sh processes cpu | egrep pim|igmp|PID
PID    Runtime(ms)  Invoked   uSecs  1Sec   Process
 3842          109  32911620      0      0  pim
 3850          133  33279940      0      0  igmp
n7010# sh processes cpu | egrep m.?rib
 3843          177  33436550      0      0  mrib
 3847          115  47169180      0      0  m6rib
n7010# sh processes cpu | egrep mfdm
 3846         2442  743581240      0      0  mfdm

module-9# sh processes cpu | egrep fib
 1534        80153    330725    242    0.0  ipfib
module-9#
```

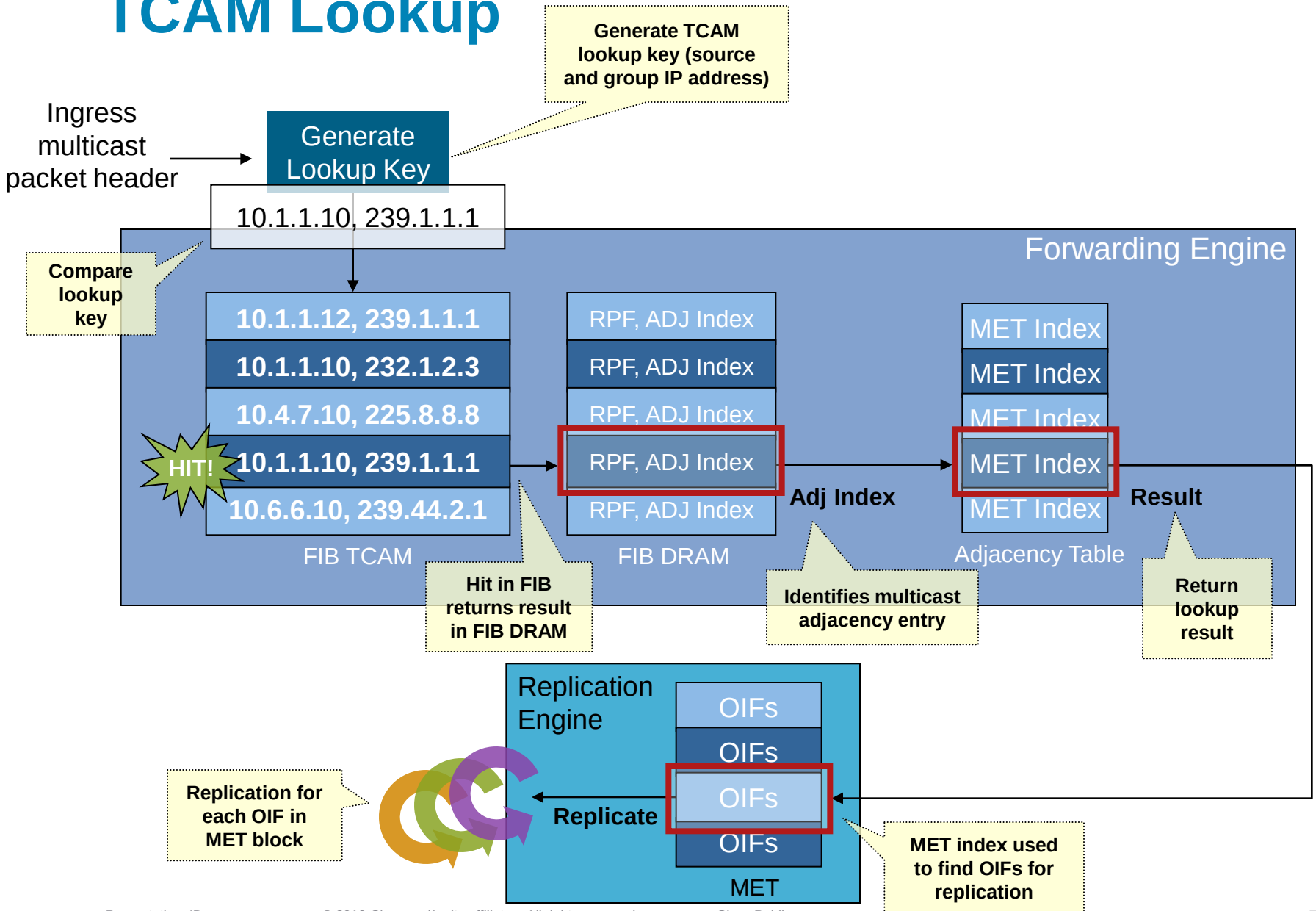
Hardware Programming

IP FIB process on I/O modules programs hardware:

- FIB TCAM
  - Part of Layer 3 Engine ASIC on forwarding engine
  - Consists of (S,G) and (*,G) entries as well as RPF interface
- Adjacency Table (ADJ)
  - Part of Layer 3 Engine ASIC on forwarding engine
  - Contains MET indexes
- Multicast Expansion Table (MET)
  - Part of replication engine ASIC on I/O modules
  - Contains output interface lists (OILs), i.e., lists of interfaces requiring replication



Multicast FIB TCAM Lookup



Displaying Multicast Routing and Forwarding Information

- **`show routing [ipv4|ipv6] multicast [vrf <vrf>] [<source-ip>] [<group-ip>] [summary]`**

  Displays software multicast routing (MRIB) information

  Can also use traditional **`show ip mroute`** command

- **`show forwarding [ipv4|ipv6] multicast route [source <ip>] [group <ip>] [vrf <vrf>] module <mod>`**

  Displays hardware multicast forwarding (FIB) information on
  per-module basis

Displaying Multicast Routing and Forwarding Information (Cont)

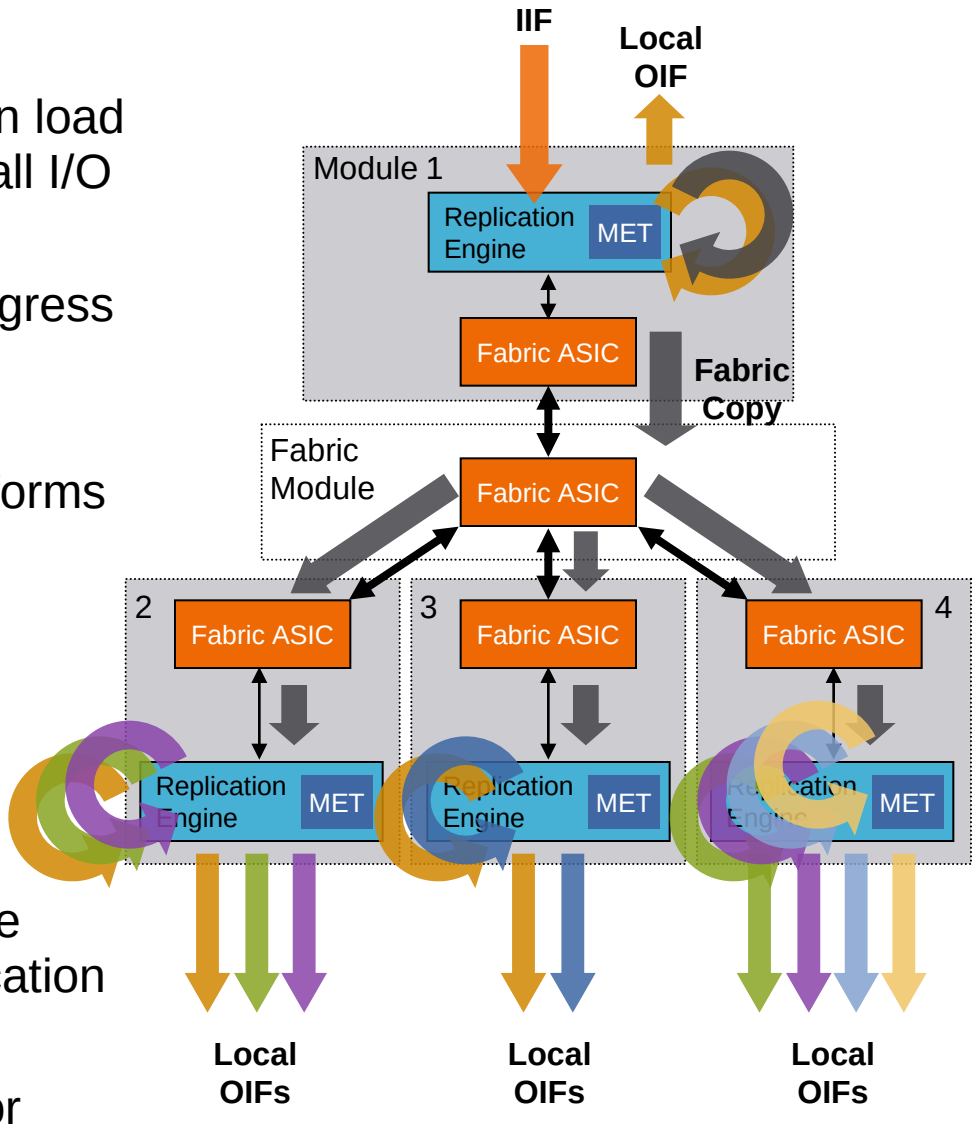
```
n7010# sh routing multicast 10.1.1.2 239.1.1.1
IP Multicast Routing Table for VRF "default"

(10.1.1.2/32, 239.1.1.1/32), uptime: 00:40:31, ip mrib pim
  Incoming interface: Ethernet9/1, RPF nbr: 10.1.1.2, internal
  Outgoing interface list: (count: 2)
    Ethernet9/17, uptime: 00:05:57, mrib
    Ethernet9/2, uptime: 00:06:12, mrib
n7010# sh routing multicast 239.1.1.1 summary
IP Multicast Routing Table for VRF "default"

Total number of routes: 202
Total number of (*,G) routes: 1
Total number of (S,G) routes: 200
Total number of (*,G-prefix) routes: 1
Group count: 1, average sources per group: 200.0

Group: 239.1.1.1/32, Source count: 200
Source            packets       bytes           aps   pps       bit-rate  oifs
(*,G)             767           84370           110   0         0 bps     2
10.1.1.2          9917158       1269395810      127   4227      4 mbps    2
10.1.1.3          9917143       1269393890      127   4227      4 mbps    2
10.1.1.4          9917127       1269391824      127   4227      4 mbps    2
<…>
```

Displaying Multicast Routing and Forwarding Information (Cont.)

```
n7010# sh forwarding ipv4 multicast route group 239.1.1.1 source 10.1.1.2 module 9

 (10.1.1.2/32, 239.1.1.1/32), RPF Interface: Ethernet9/1, flags:
    Received Packets: 10677845 Bytes: 1366764160
    Number of Outgoing Interfaces: 2
    Outgoing Interface List Index: 15
      Ethernet9/2 Outgoing Packets:432490865 Bytes:55358830720
      Ethernet9/17 Outgoing Packets:419538767 Bytes:53700962176
n7010#
```

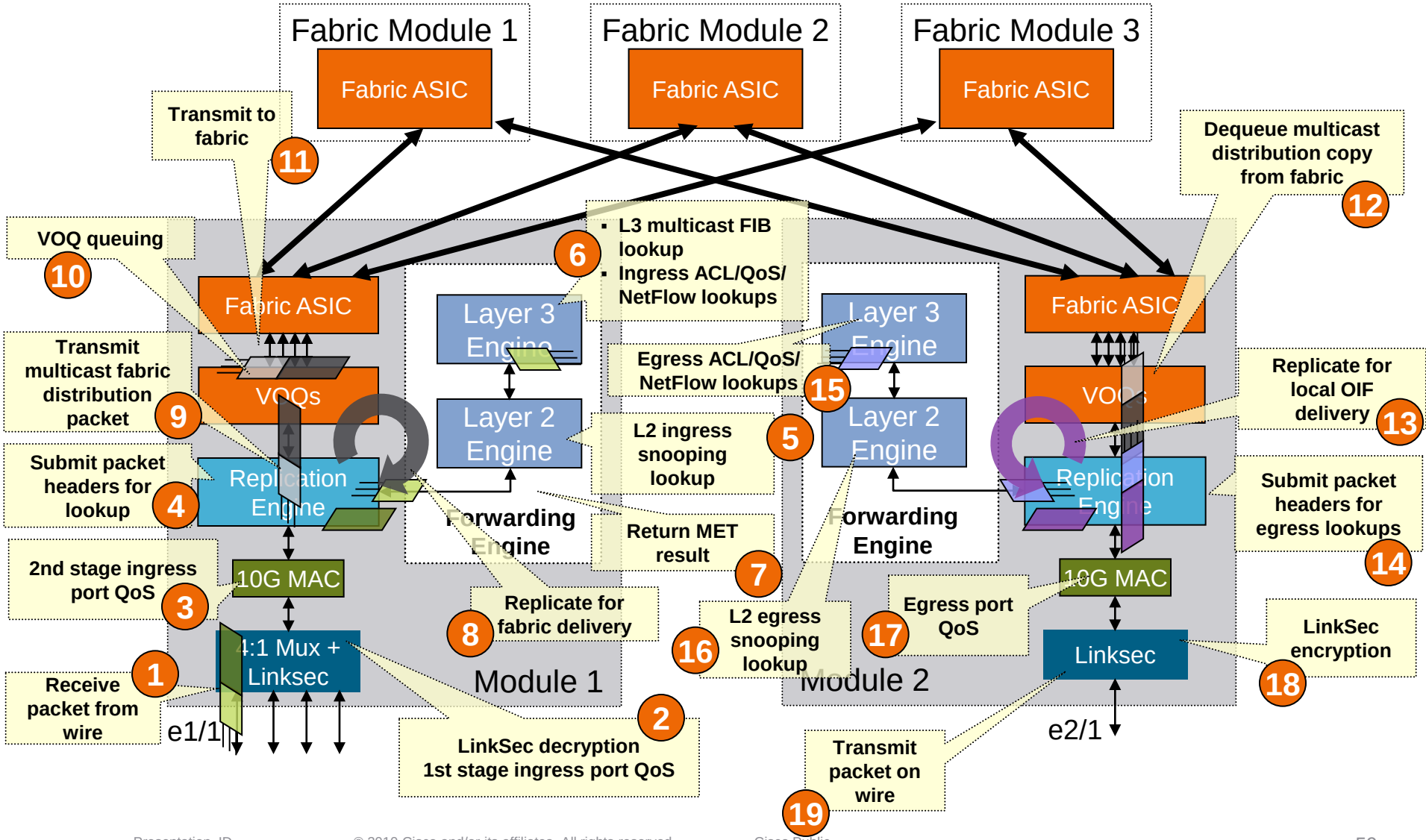
Egress Replication

- Distributes multicast replication load among replication engines of all I/O modules with OIFs
- Input packets get lookup on ingress forwarding engine
- For OIFs on ingress module, ingress replication engine performs the replication
- For OIFs on other modules, ingress replication engine replicates a single copy of packet over fabric to those egress modules
- Each egress forwarding engine performs lookup to drive replication
- Replication engine on egress module performs replication for local OIFs



HDR = Packet Headers DATA = Packet Data

L3 Multicast Packet Flow



Unicast vs. Multicast on Fabric

Fabric consists of two parallel “fabric planes”:

- Unicast traffic
  - Centrally arbitrated
  - Round-robin load balanced over available fabric channels
- Multicast traffic
  - Locally arbitrated
  - Load balanced over available fabric channels using hash

Agenda

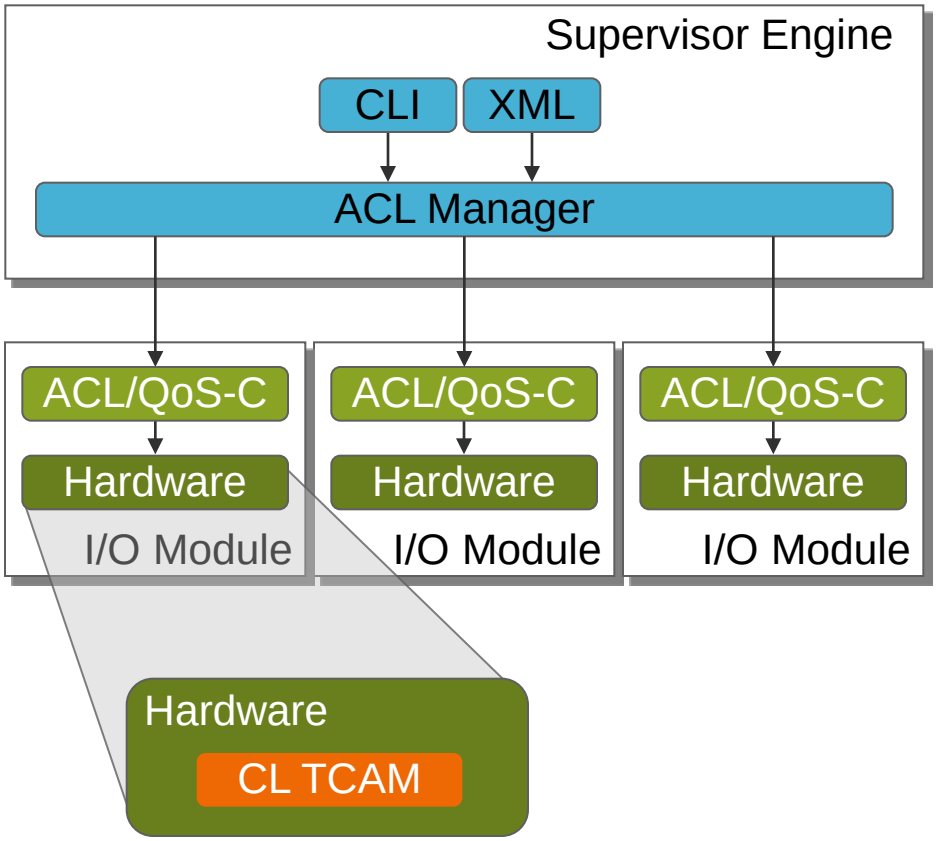
- Chassis Architecture
- Supervisor Engine Architecture
- I/O Module Architecture
- Forwarding Engine Architecture
- Fabric Architecture
- Layer 2 Forwarding
- IP Forwarding
- IP Multicast Forwarding
- ACLs
- QoS
- NetFlow

Security ACLs

- Enforce security policies based on Layer 2, Layer 3, and Layer 4 information
- Classification TCAM (CL TCAM) provides ACL lookups in forwarding engine
  - 64K hardware entries
- Router ACL (RACL)–Enforced for all traffic crossing a Layer 3 interface in a specified direction
  - IPv4, ARP RACLs supported
- VLAN ACLs (VACLs)–Enforced for all traffic in the VLAN
  - IPv4, MAC VACLs supported
- Port ACLs (PACLs)–Enforced for all traffic input on a Layer 2 interface
  - IPv4, MAC PACLs supported

ACL Architecture

- ACL manager receives policy via configuration
- ACL manager distributes policies to ACL/QoS Clients on I/O modules
- Clients perform ACL merge and program ACEs in Classification (CL) TCAM in forwarding engines



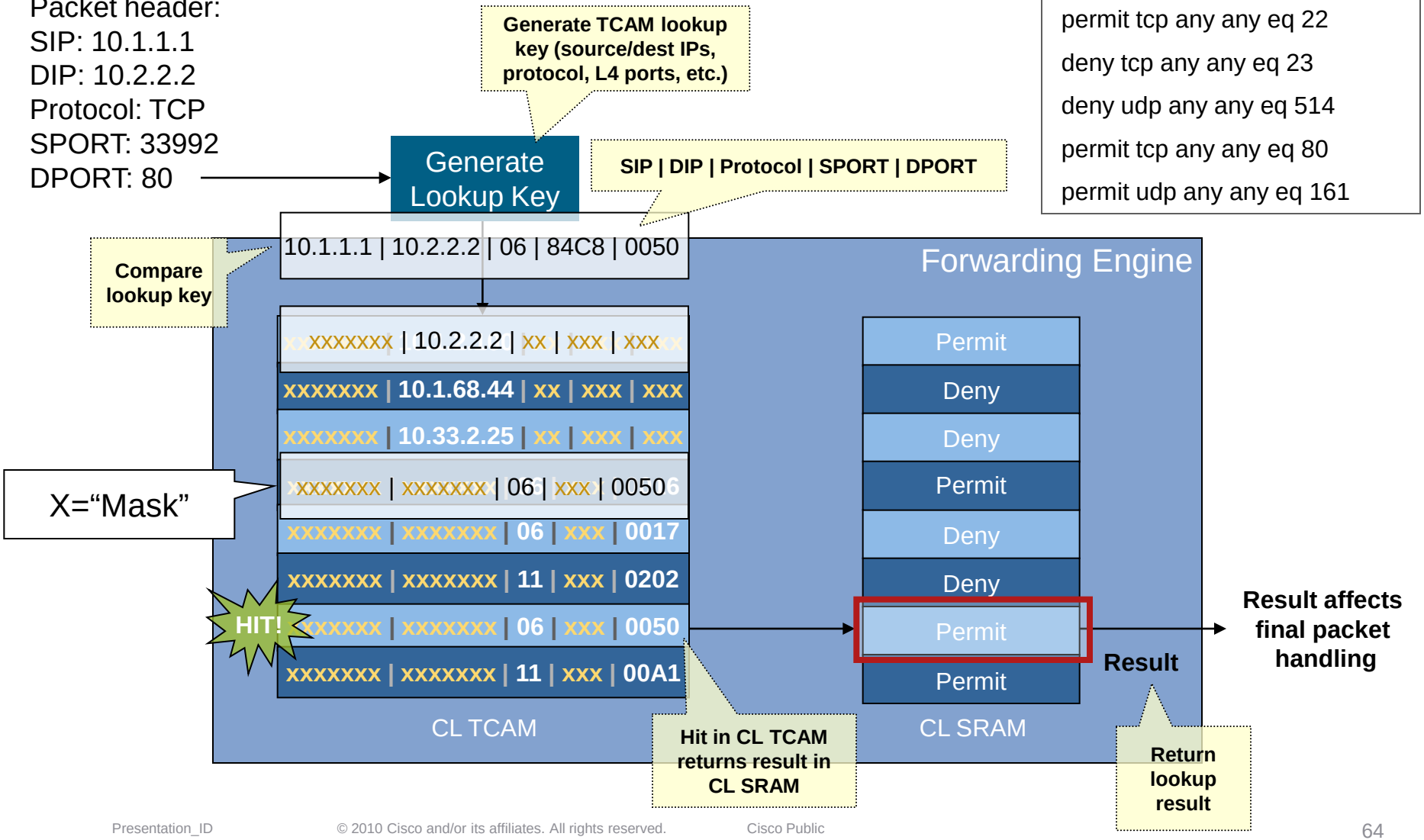

```
n7010# sh processes cpu | egrep aclmgr|PID
PID    Runtime(ms)  Invoked   uSecs  1Sec    Process
 3589         1662  516430000      0      0  aclmgr

module-9# sh processes cpu | egrep aclqos
 1532         9885    671437     14    0.0  aclqos
module-9#
```

ACL CL TCAM Lookup

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

Packet header:
SIP: 10.1.1.1
DIP: 10.2.2.2
Protocol: TCP
SPORT: 33992
DPORT: 80



Displaying Classification Resources

- **show hardware access-list resource utilization module <mod>**

```
n7010# sh hardware access-list resource utilization module 9

Hardware Modules          Used    Free    Percent
                                          Utilization
-----------------------------------------------------
Tcam 0, Bank 0            1       16383   0.000
Tcam 0, Bank 1            4121    12263   25.000
Tcam 1, Bank 0            4013    12371   24.000
Tcam 1, Bank 1            4078    12306   24.000

LOU                       2       102     1.000
Both LOU Operands         0
Single LOU Operands       2

TCP Flags                 0       16      0.000
Protocol CAM              4       3       57.000
Mac Etype/Proto CAM       0       14      0.000

Non L4op labels, Tcam 0   3       6140    0.000
Non L4op labels, Tcam 1   3       6140    0.000

L4 op labels, Tcam 0      0       2047    0.000
L4 op labels, Tcam 1      1       2046    0.000
n7010#
```

Agenda

- Chassis Architecture
- Supervisor Engine Architecture
- I/O Module Architecture
- Forwarding Engine Architecture
- Fabric Architecture
- Layer 2 Forwarding
- IP Forwarding
- IP Multicast Forwarding
- ACLs
- QoS
- NetFlow

Quality of Service

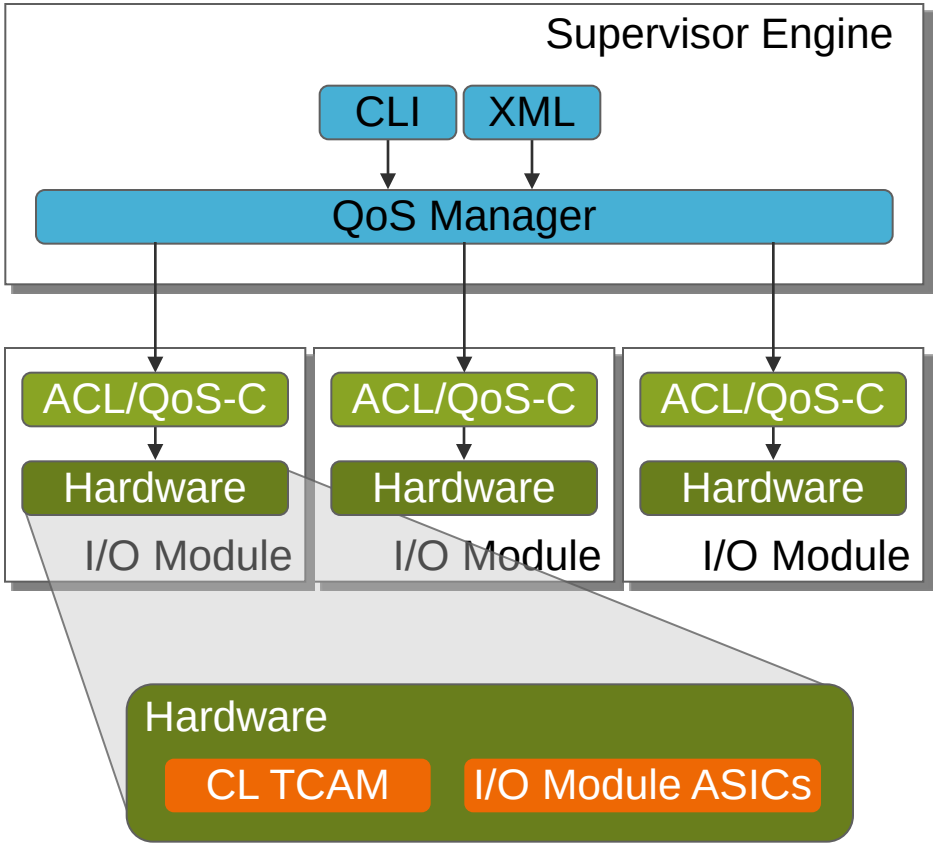
- Comprehensive LAN QoS feature set
- Ingress and egress queuing and scheduling
  - Applied in I/O module port ASICs
- Ingress and egress mutation, classification, marking, policing
  - Applied in I/O module forwarding engines
- All configuration through Modular QoS CLI (MQC)
  - All QoS features applied using class-maps/policy-maps/service-policies

QoS Architecture

- QoS manager receives policy via configuration
- QoS manager distributes policies to ACL/QoS Clients on I/O modules
- Clients perform ACL merge and program hardware:

  ACEs in Classification (CL) TCAM in forwarding engines

  Queuing policies in I/O module port ASICs

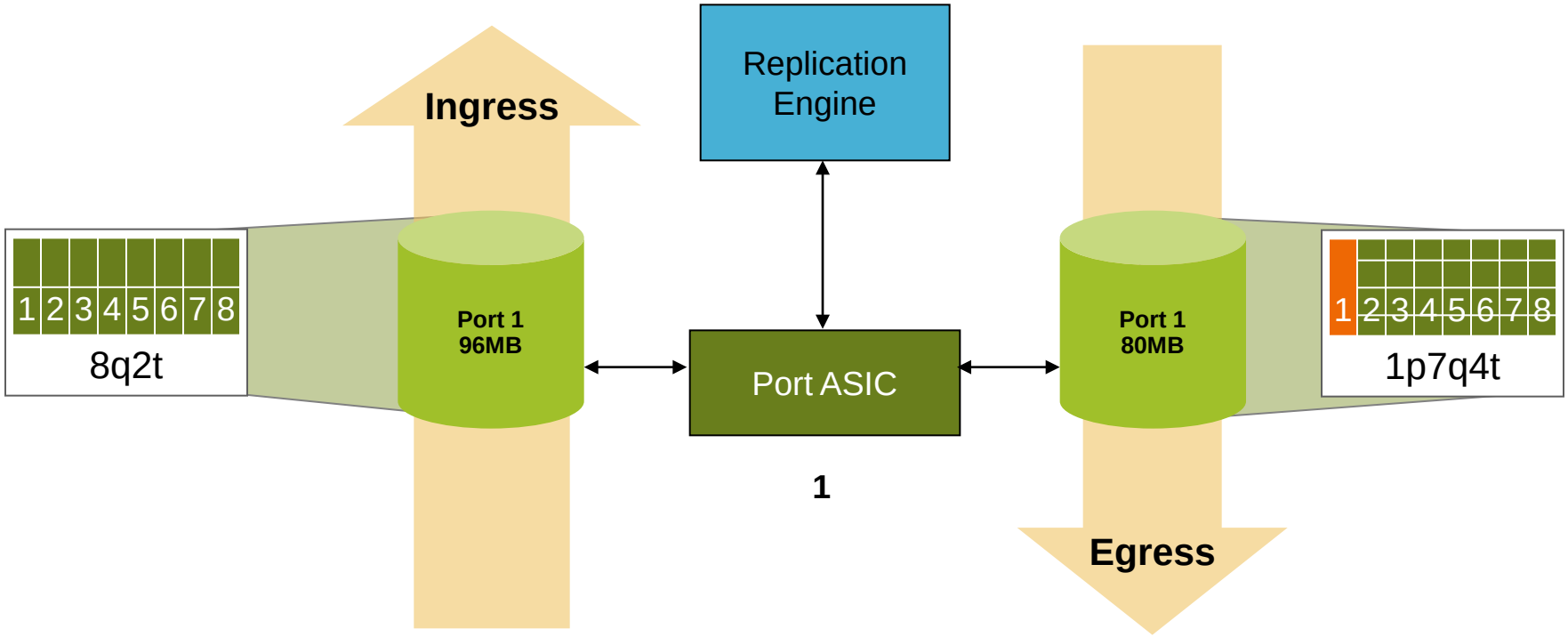



```
n7010# sh processes cpu | egrep qos|PID
PID    Runtime(ms)  Invoked   uSecs  1Sec   Process
 3849         1074  66946870      0      0  ipqosmgr

module-9# sh processes cpu | egrep aclqos
 1532         9885    671437     14    0.0  aclqos
module-9#
```

Port QoS – 8-Port 10G Module

- Buffers
  - 96MB ingress per port
  - 80MB egress per port
- Queue Structure
  - 8q2t ingress
  - 1p7q4t egress

8-Port 10G Module Buffering



Port QoS – 32-Port 10G Module

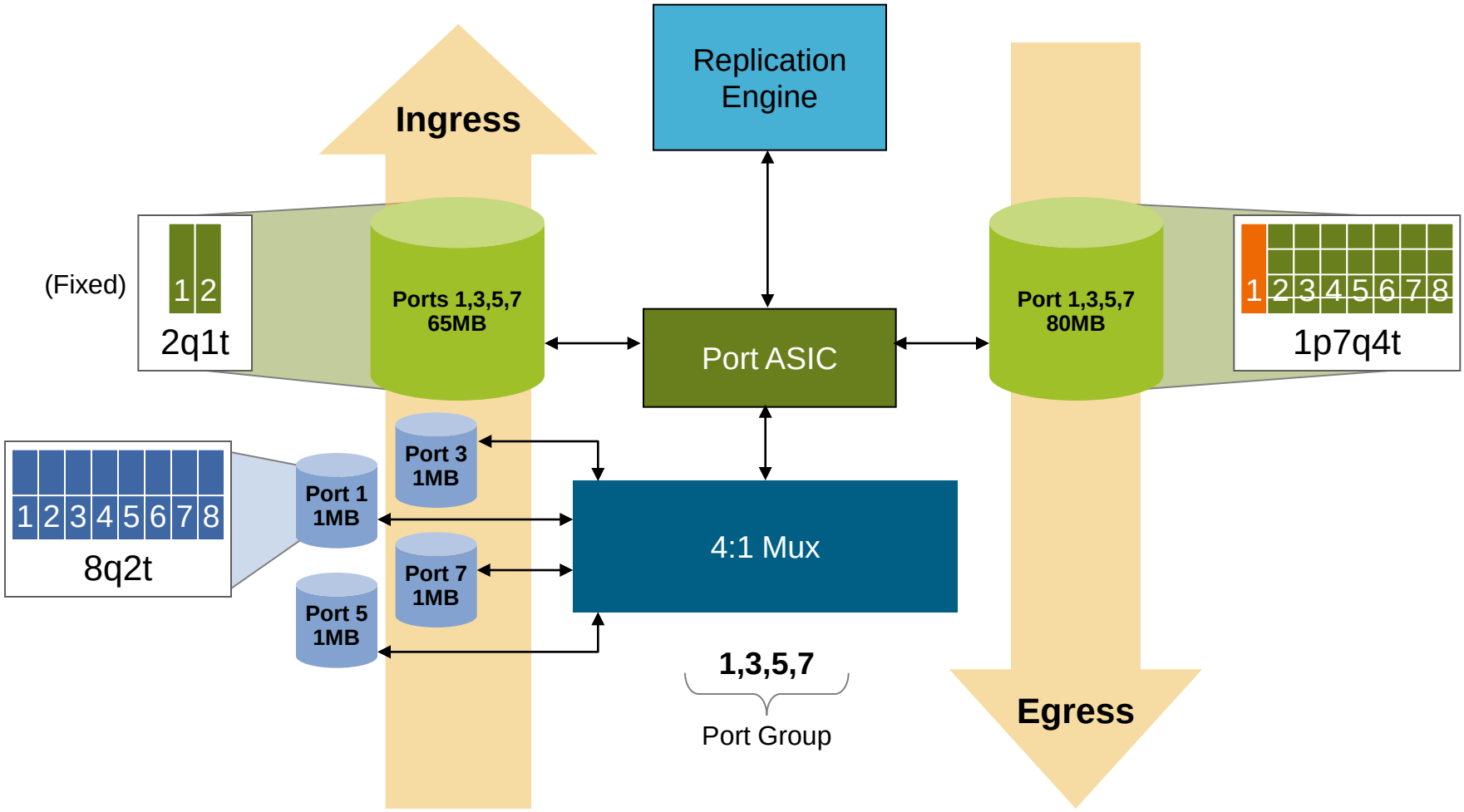
Buffers

- Ingress (two-stage ingress buffering)
  - Dedicated mode: 1MB per port + 65MB per port
  - Shared mode: 1MB per port + 65MB per port group
- Egress
  - Dedicated mode: 80MB per port
  - Shared mode: 80MB per port-group

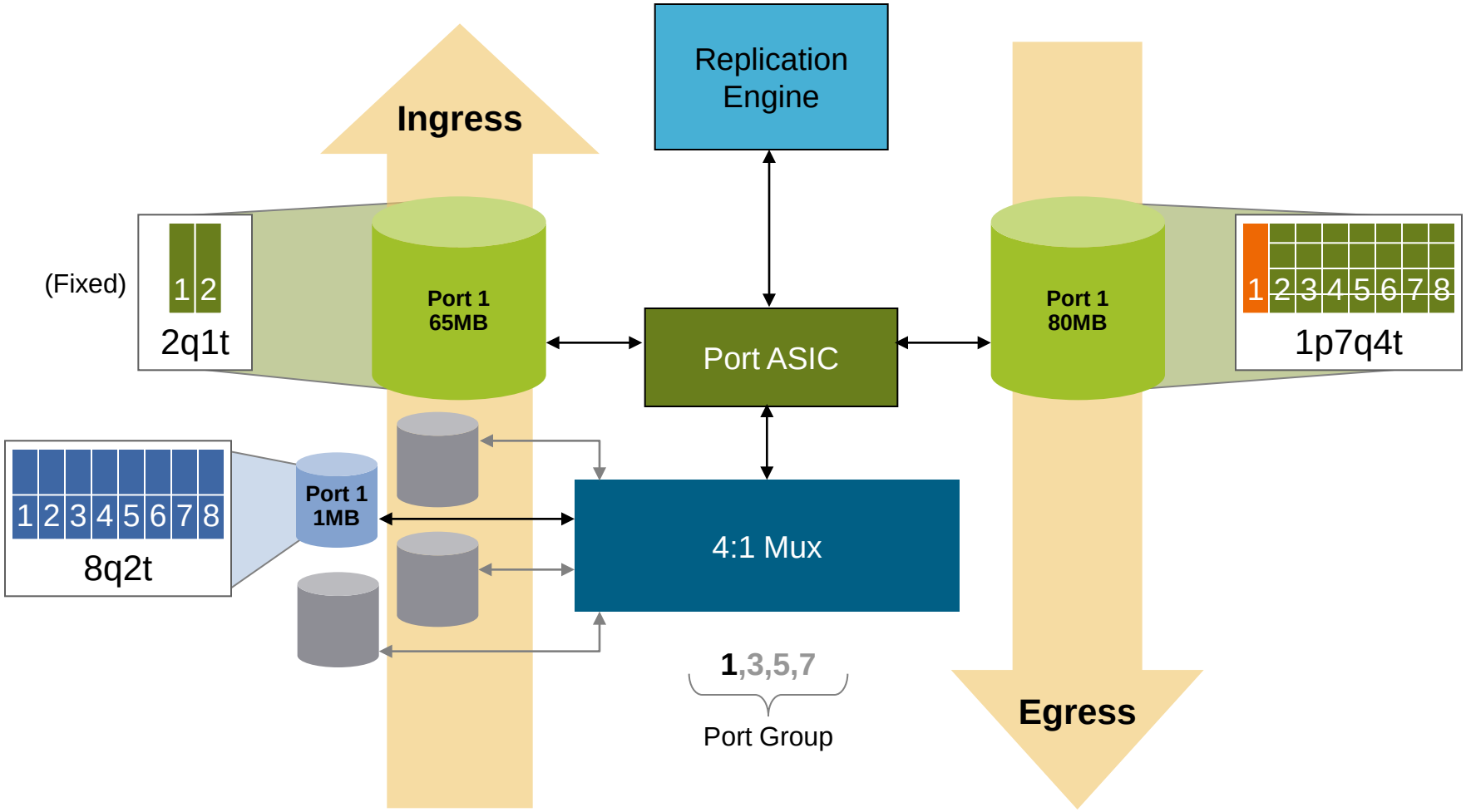
Queue Structure

- 8q2t + 2q1t ingress
- 1p7q4t egress

32-Port 10G Module Buffering – Shared Mode



32-Port 10G Module Buffering – Dedicated Mode



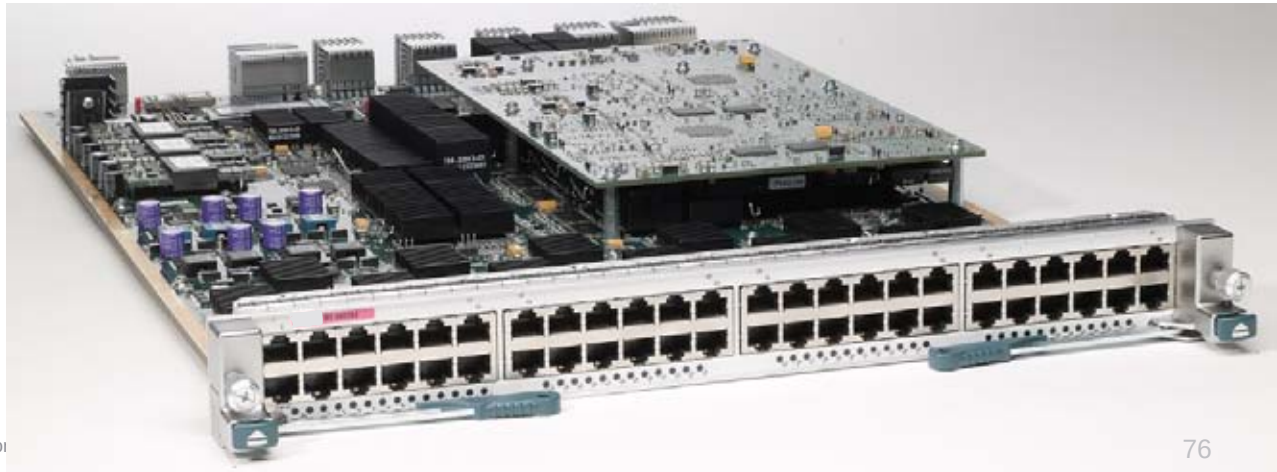
Port QoS – 48-Port 1G Modules

Buffers

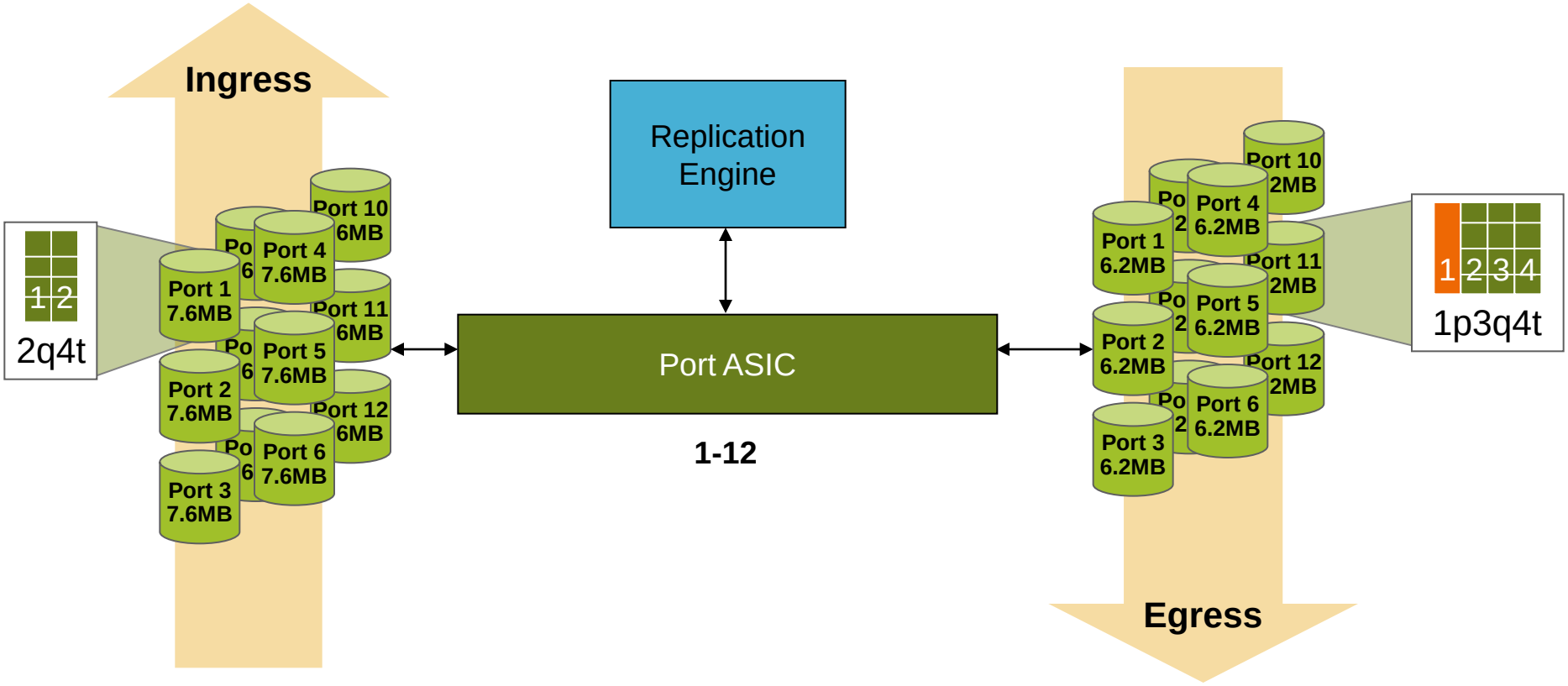
- 7.56MB ingress per port
- 6.15MB egress per port

Queue Structure

- 2q4t ingress
- 1p3q4t egress



48-Port 1G Modules Buffering



Marking and Policing

- Classification uses CL TCAM in forwarding engine to match traffic
- After classification, traffic can be marked or policed
- Marking policies statically set QoS values for each class
- Policing performs markdown and/or policing (drop)
- Policers use classic token-bucket scheme

  Uses Layer 2 frame size when determining rate

- Note: policing performed on per-forwarding engine basis

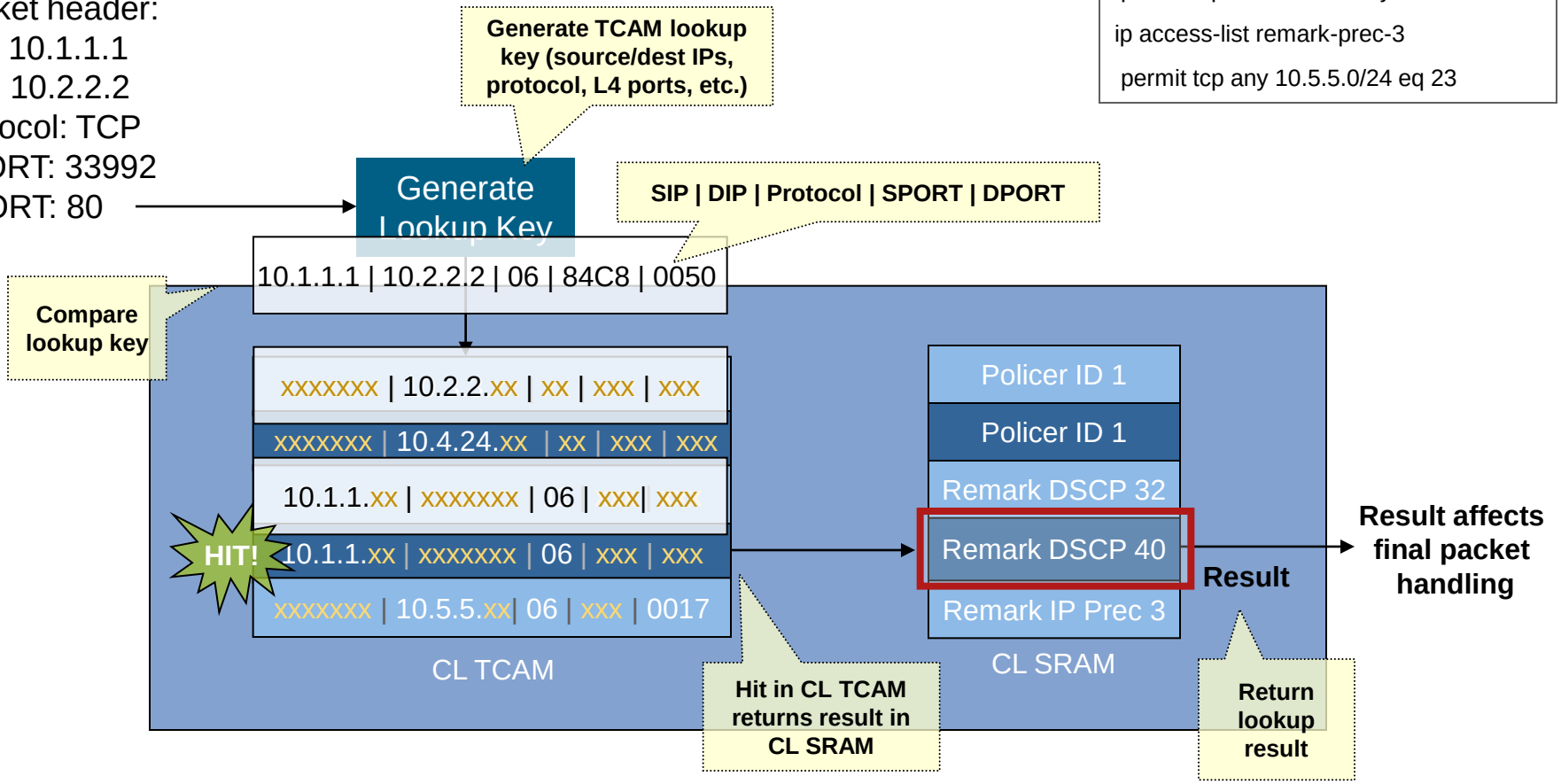
  Shared interfaces (such as SVI/EtherChannel) and egress policies could be policed at <policing rate> * <number of forwarding engines>

QoS CL TCAM Lookup

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
```

Packet header:
SIP: 10.1.1.1
DIP: 10.2.2.2
Protocol: TCP
SPORT: 33992
DPORT: 80



Monitoring QoS Service Policies

show policy-map interface [[<interface>] [type qos|queuing]]|brief]

```
n7010# show policy-map interface e9/1
Global statistics status :   enabled
Ethernet9/1

  Service-policy (qos) input:   mark
    policy statistics status:   enabled

    Class-map (qos):   udp-mcast (match-all)
      432117468 packets
      Match: access-group multicast
      set dscp cs4

    Class-map (qos):   udp (match-all)
      76035663 packets
      Match: access-group other-udp
      police cir 2 mbps bc 1000 bytes pir 4 mbps be 1000 bytes
        conformed 587624064 bytes, 3999632 bps action: transmit
        exceeded 293811456 bytes, 1999812 bps action: set dscp dscp table cir-markdown-map
        violated 22511172352 bytes, 153221133 bps action: drop
n7010#
```

Agenda

- Chassis Architecture
- Supervisor Engine Architecture
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- Forwarding Engine Architecture
- Fabric Architecture
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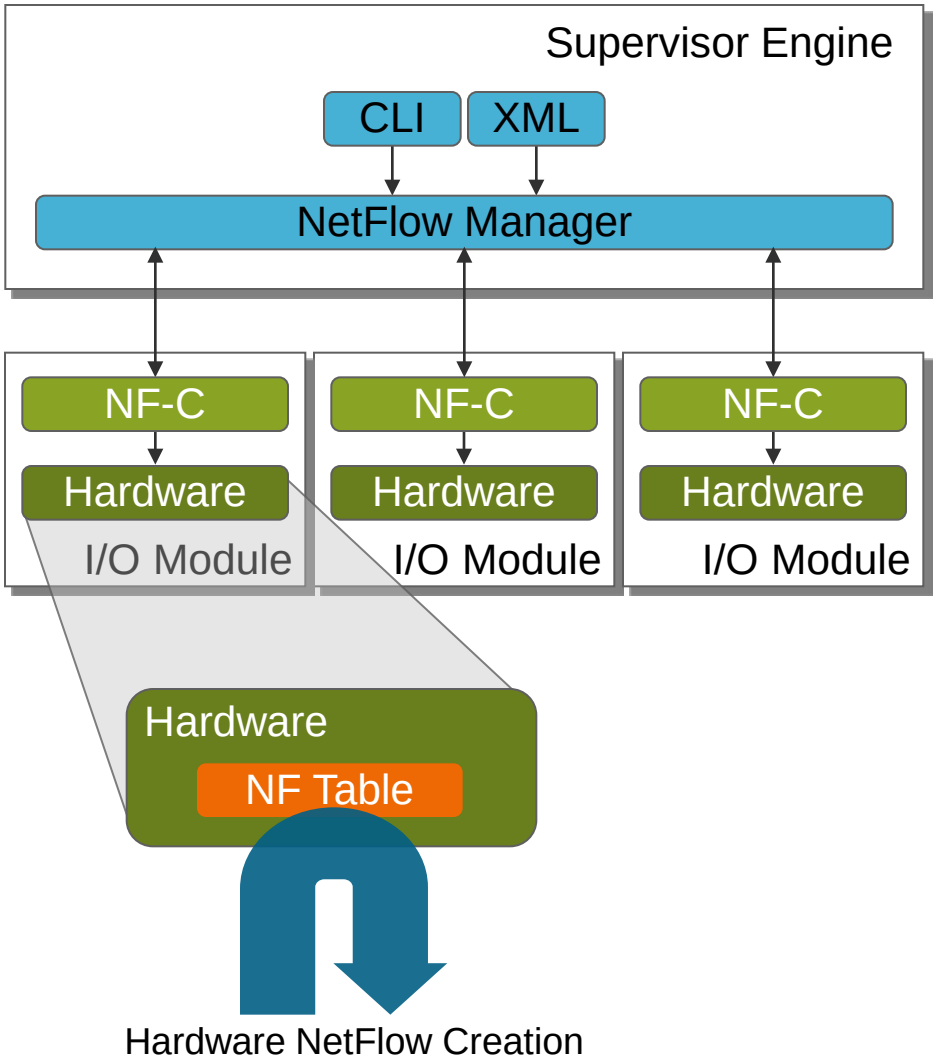
NetFlow

- NetFlow table is 512K entries (490K effective), shared between ingress/egress NetFlow
- Hardware NetFlow entry creation
  - CPU not involved in NetFlow entry creation/update
- All modules have independent NetFlow table
- Full and sampled NetFlow supported by hardware

NetFlow Architecture

- NetFlow manager receives configuration via CLI/XML
- NetFlow manager distributes configuration to NetFlow-Clients on I/O modules
- NetFlow-Clients apply policy to hardware




```
n7010# sh processes cpu | egrep nfm|PID
PID    Runtime(ms)  Invoked   uSecs  1Sec    Process
24016         1463  735183570      0      0  nfm

module-9# sh processes cpu | egrep nfp
 1538        68842    424290    162    0.0  nfp
module-9#
```

Full vs. Sampled NetFlow

- NetFlow configured per-direction and per-interface
  - Ingress and/or egress on per-interface basis
- Each interface can collect full or sampled flow data
- Full NetFlow: Accounts for every packet of every flow on interface, up to capacity of NetFlow table
- Sampled NetFlow: Accounts for M in N packets on interface, up to capacity of NetFlow table

Viewing NetFlow Records

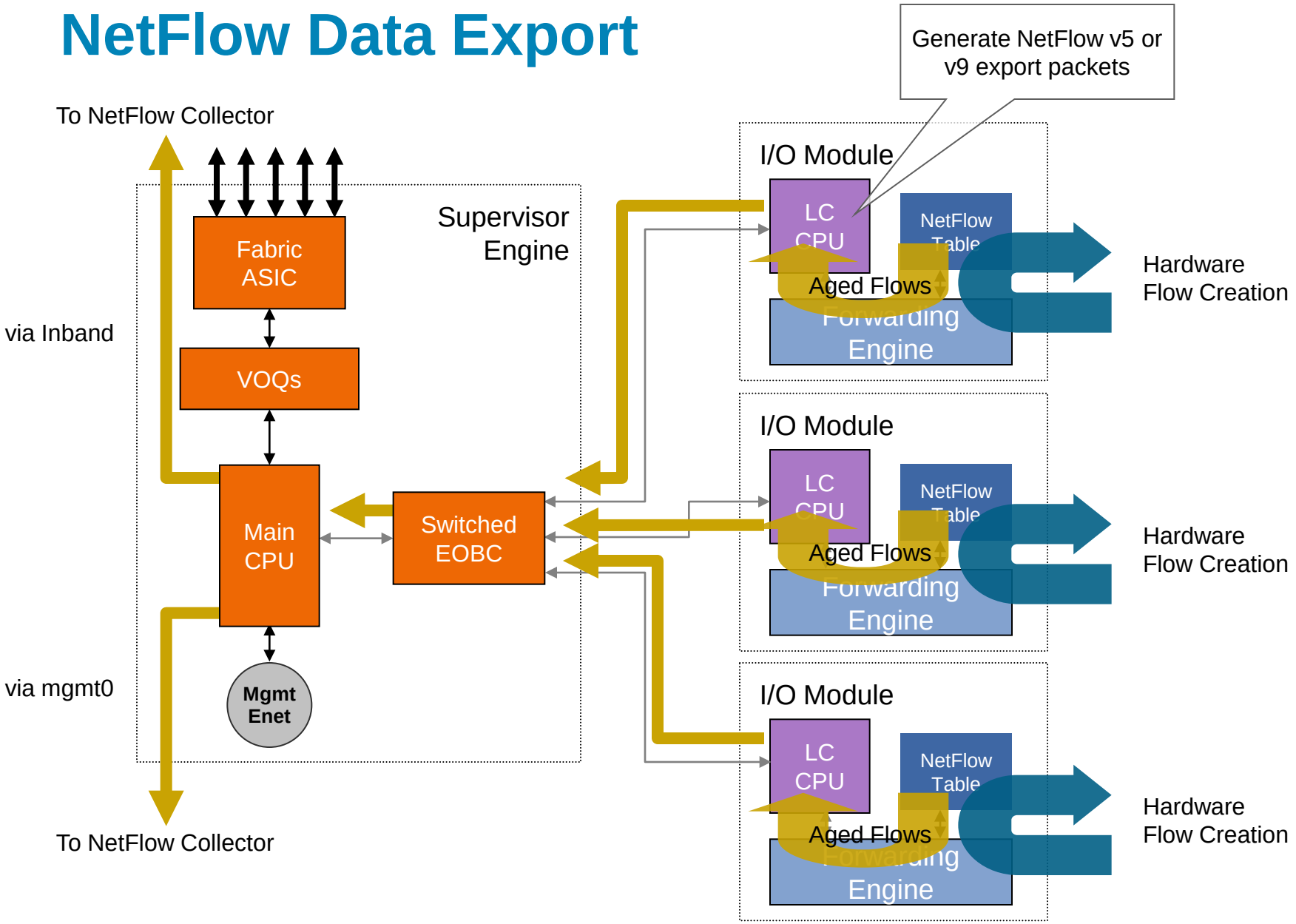
show hardware flow ip [detail] module <mod>

```
n7010# sh hardware flow ip interface e9/1 module 9
D - Direction; IF - Intf/VLAN; L4 Info - Protocol:Source Port:Destination Port
TCP Flags: Ack, Flush, Push, Reset, Syn, Urgent

D IF    SrcAddr         DstAddr         L4 Info         PktCnt     TCP Flags
-+-----+---------------+---------------+---------------+----------+-----------
I 9/1   010.001.001.002 010.001.002.002 006:01024:01024 0001403880 A . . . S .
I 9/1   010.001.001.003 010.001.002.003 006:01024:01024 0001403880 A . . . S .
I 9/1   010.001.001.004 010.001.002.004 006:01024:01024 0001403880 . . . . S .
<…>
n7010# sh hardware flow ip interface e9/1 detail module 9
D - Direction; IF - Intf/VLAN; L4 Info - Protocol:Source Port:Destination Port
TCP Flags: Ack, Flush, Push, Reset, Syn, Urgent; FR - FRagment; FA - FastAging
SID - Sampler/Policer ID; AP - Adjacency/RIT Pointer
CRT - Creation Time; LUT - Last Used Time; NtAddr - NT Table Address

D IF    SrcAddr         DstAddr         L4 Info         PktCnt     TCP Flags
-+-----+---------------+---------------+---------------+----------+-----------
ByteCnt       TOS FR FA SID   AP       CRT   LUT   NtAddr
-------------+---+--+--+-----+--------+-----+-----+--------
I 9/1   010.001.001.002 010.001.002.002 006:01024:01024 0001706722 A . . . S .
0000218460416 000 N  Y  0x000 0x000000 02168 02571 0x000331
```

NetFlow Data Export



Conclusion

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

Q and A


[communication]
[leadership]
[invention]
[inspiration]
[knowledge]
[collaboration]

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