

The background is a vibrant, abstract graphic featuring a spectrum of colors (red, orange, yellow, green, blue, purple) arranged in a radial, sunburst-like pattern. The colors transition smoothly from red on the left to blue on the right, with a bright white center. The overall effect is dynamic and energetic.

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Let's go

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The bridge to possible

Network Best Practices for Artificial Intelligence Data Centre

Nemanja Kamenica
Technical Marketing Engineer
BRKDCN-2112

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Agenda

- Why AI is important today and, in the future
- Network For AI Cluster
- Automation and Visibility
- The Blueprint For Today

Cisco Webex App

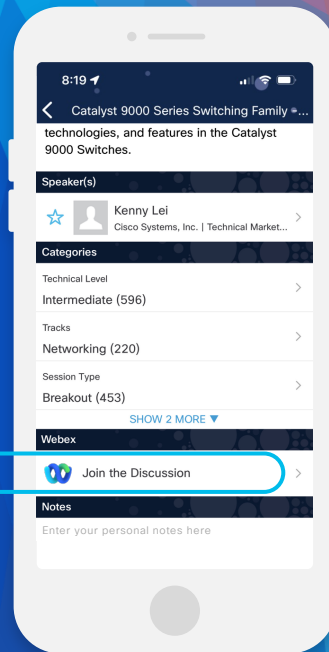
Questions?

Use Cisco Webex App to chat with the speaker after the session

How

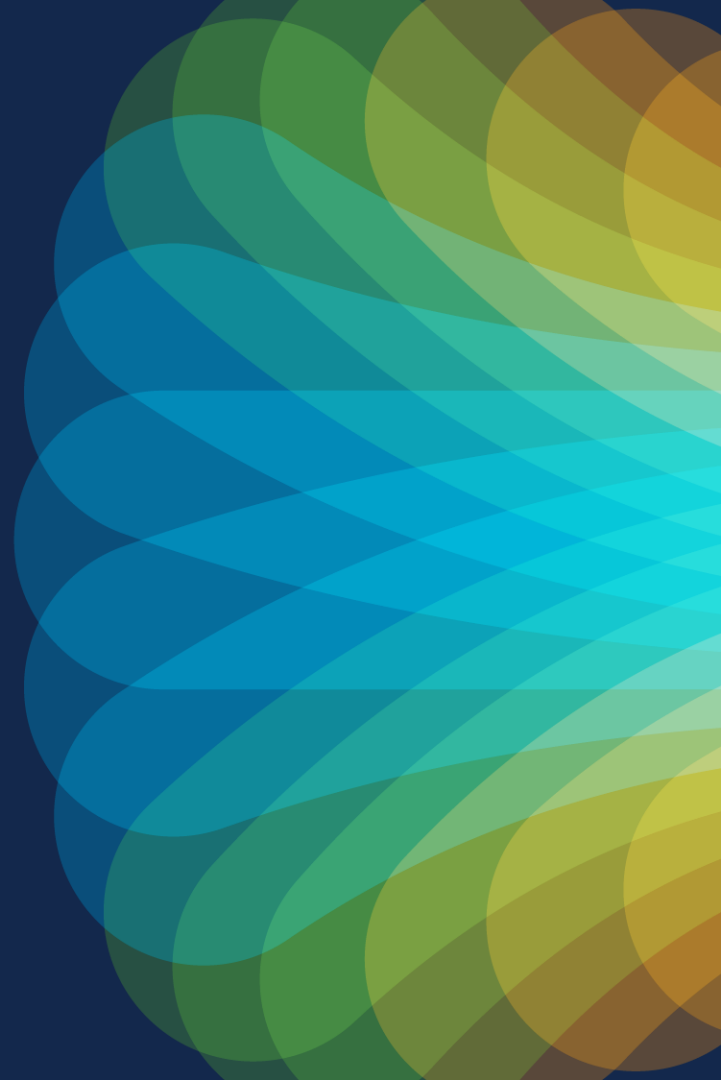
- 1 Find this session in the Cisco Live Mobile App
- 2 Click “Join the Discussion”
- 3 Install the Webex App or go directly to the Webex space
- 4 Enter messages/questions in the Webex space

Webex spaces will be moderated by the speaker until December 22, 2023.



<https://ciscolive.ciscoevents.com/ciscolivebot/#BRKDCN-2112>

Why AI is important today and, in the future



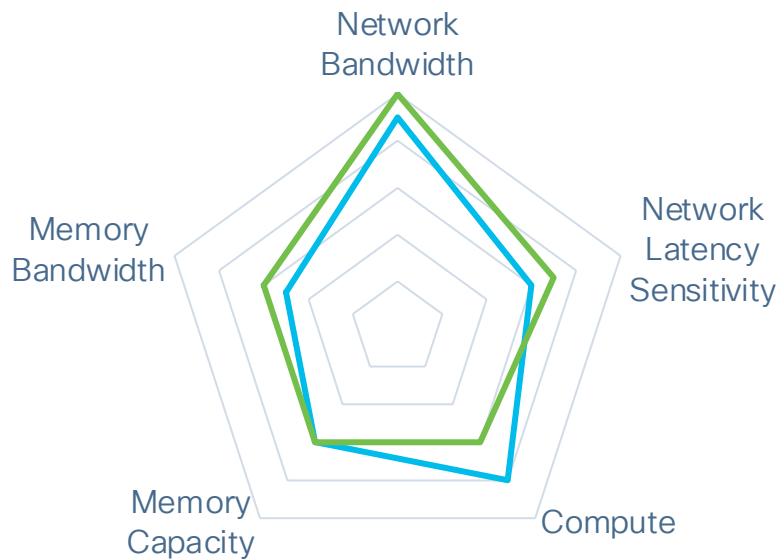
AI/ML Can Help Many Industries

Healthcare	Financial Services	Public Sector	Media and Entertainment	Manufacturing	Retail
Medical Risk Prediction	High Frequency Trading Analysis	Intelligent Public Transport	Speech Recognition	Visual Inspection	Personalized Recommendation
Early diagnostics	Quant Research	Security Log Analytics	Natural Language Processing	Anomaly Detection	Demand Forecasting
Medical Research	Fraud and Risk Analytics	Disaster Recovery Assistance	Content Classification	Asset Management	Visual Search

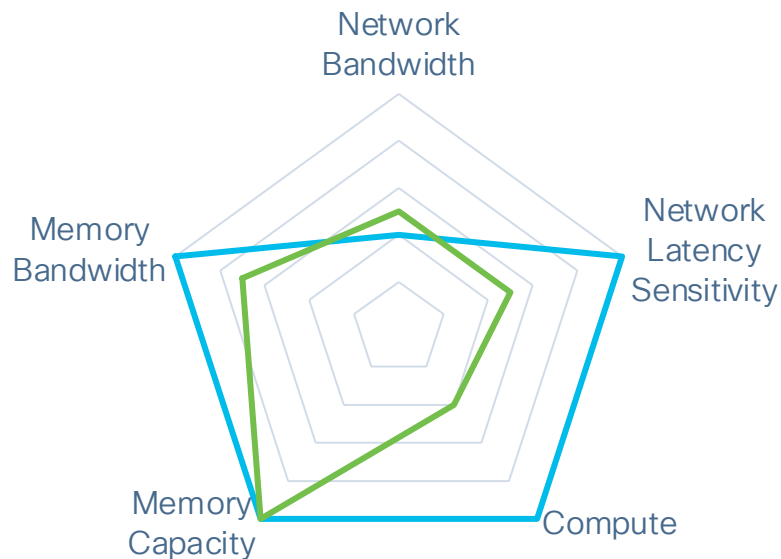
AI cluster types and interaction with network

	Distributed Training	Production Inference
Node to Node Bandwidth	High	Low
Key Metric	Training time of a model	High Availability and Latency
Operational Mode	Model training is offline	Usually online, requires real time response
Infrastructure requirement	Large network with many GPU/CPU hosts	Smaller network with mid size of CPU/GPU hosts

Training vs Inference



— LLM Trainig — Ranking Training

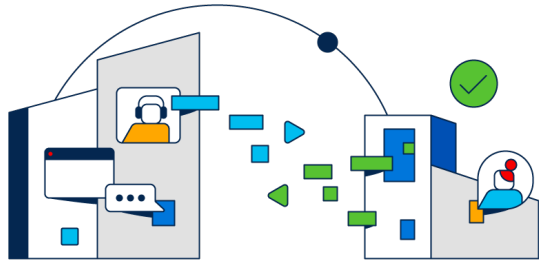


— LLM Inference — Ranking Inference

Where do you run your AI/ML training cluster

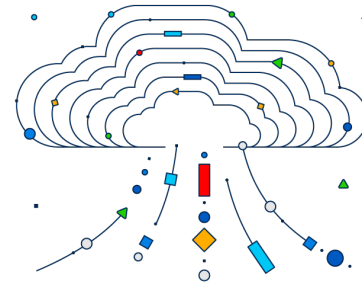
- On Prem

- Always available for enterprise to use
- Flexibility for large enterprise to leverage same cluster for different functions
- Data is stored on prem



- In Public Cloud

- Provides flexibility, pay for what you need
- Cost will grow with more data and training
- Challenge: Cost of egress data from the cloud



Large Scale Distributed Training

- Key Challenge of Training Cluster
 - Model Doubles every 2 months
 - Bigger model, higher accuracy
 - Most common single training runs on 512 GPUs



- Cluster Key Components
 - Compute Nodes
 - Network
 - Distributed File System/Storage
 - Job Scheduling and Orchestration
 - Software Framework for AI model



Large Scale Distributed Training

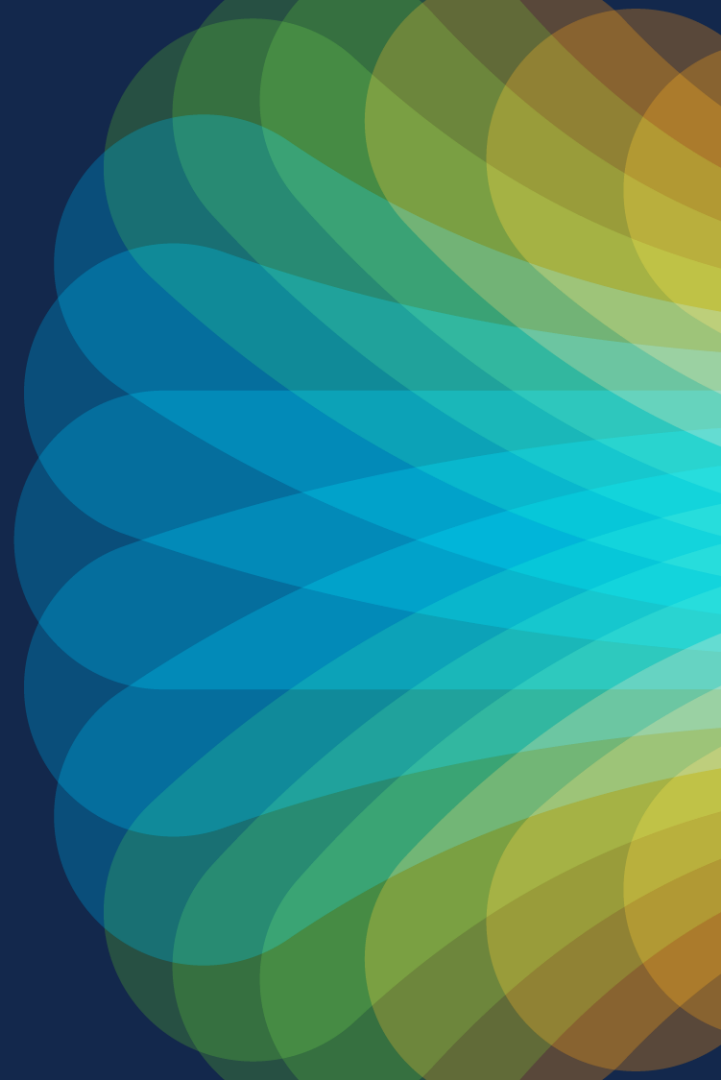
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Network For AI Cluster



AI Training Network



For RoCEv2 transport the network must provide high throughput and low latency by passing CPU/GPU

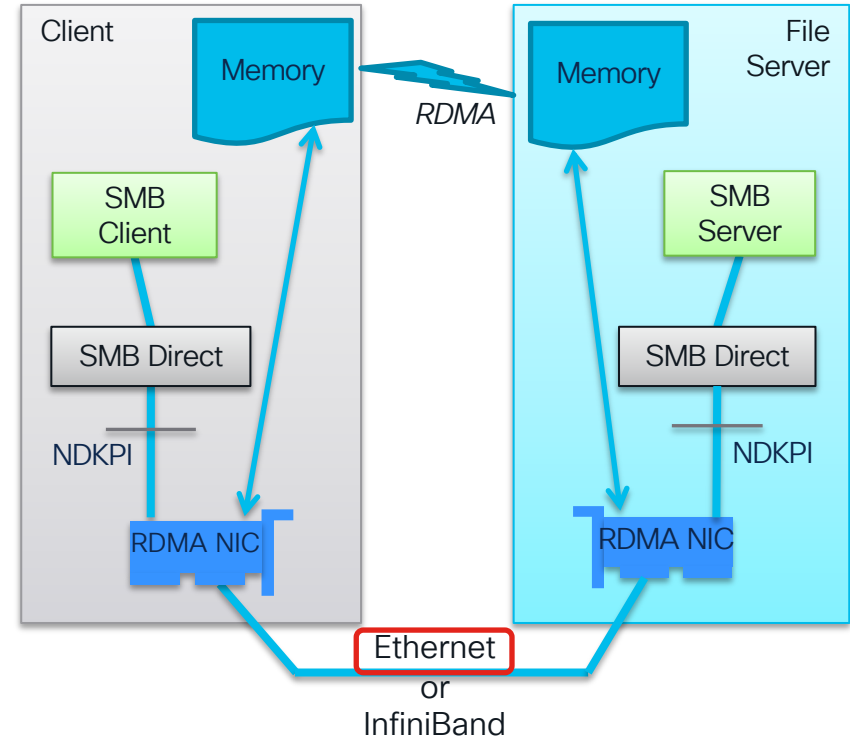


The Cisco Nexus 9000 switches, provide the required low latency, and with up to 25.6Tbps of bandwidth per ASIC, to satisfy AI/ML clusters requirements

Shipping feature set with many customers in production

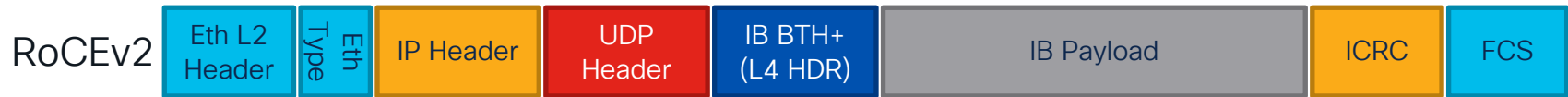
RDMA – Remote Data Memory Access

- Allows application software to communicate directly with the hardware (RDMA NIC)
- Bypasses OS stack
- RDMA delivers, low latency, high throughput, zero copy capabilities
- RDMA Hardware Technologies
 - RoCE: RDMA over Converged Ethernet
 - iWARP: RDMA over TCP/IP
 - Infiniband



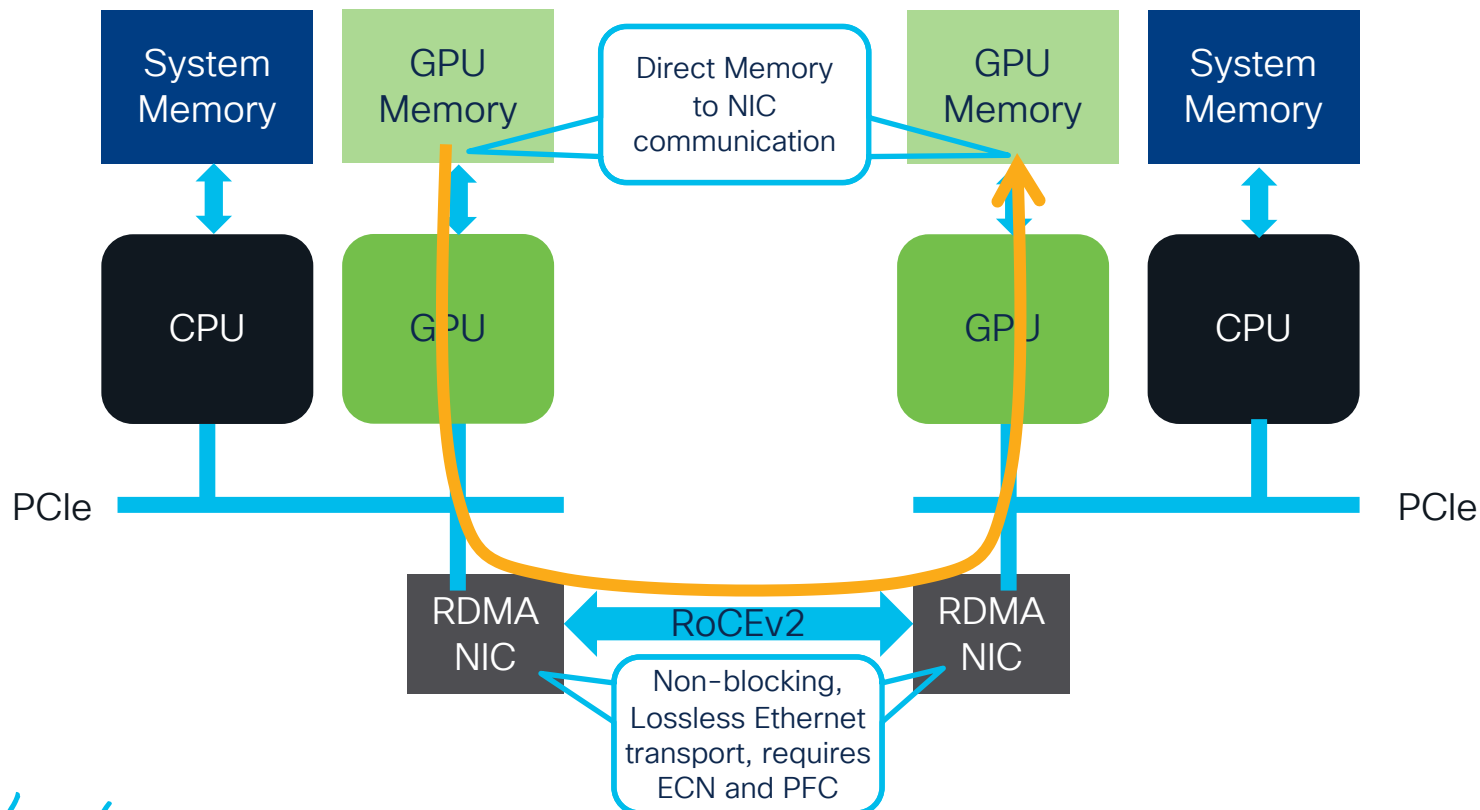
RoCEv2 - Basics

- Extension of RoCE protocol that involves a simple modification of the RoCE packet format
- Carry IP header and UDP header that serves as a stateless encapsulation layer for RDMA transport over IP

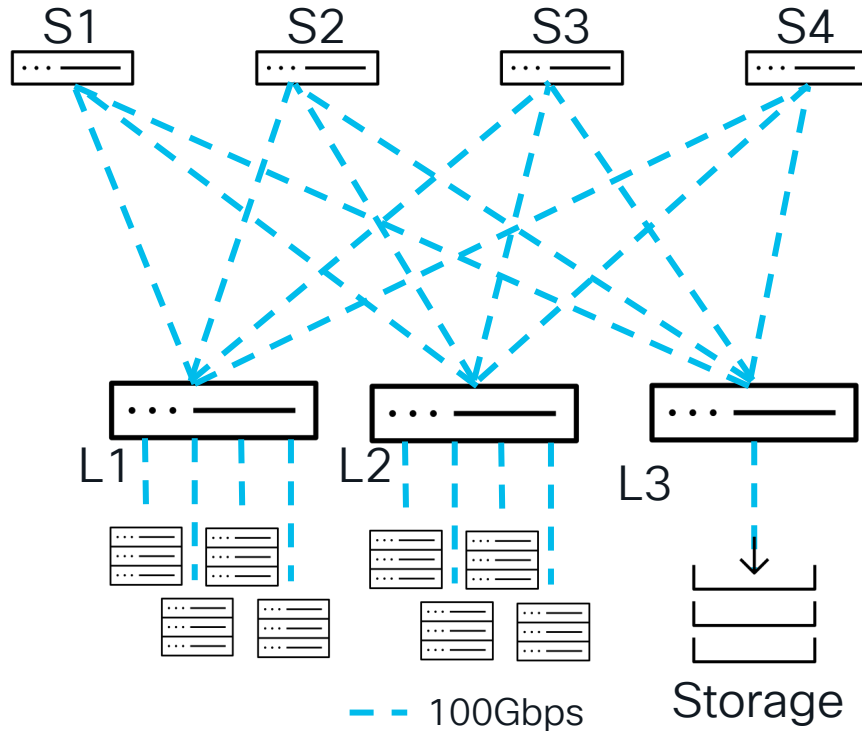


Source: https://en.wikipedia.org/wiki/RDMA_over_Converged_Ethernet

RoCEv2 – Benefits and Requirements



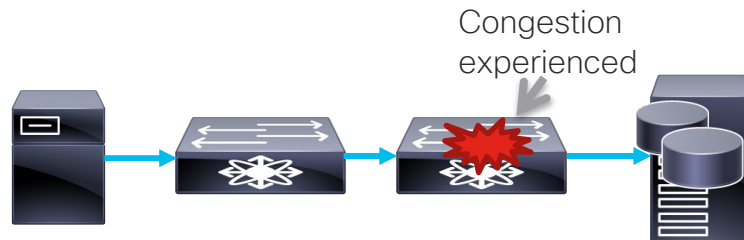
Non-blocking Network



- Non-Blocking Network, allow host to talk to other hosts at full bandwidth
- Leaf: Same bandwidth to the host as to the spine
- Reduces need for congestion management to increase performance

Explicit Congestion Notification (ECN)

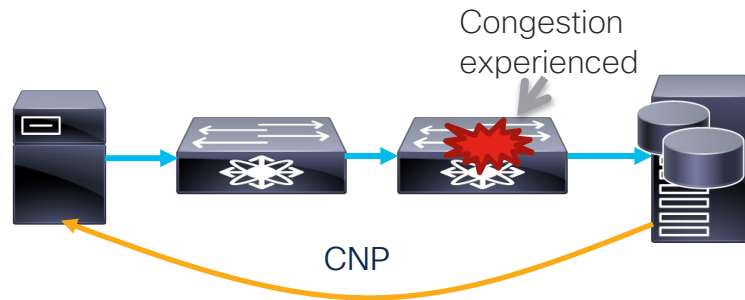
- IP Explicit Congestion Notification (ECN) is used for congestion notification.
- ECN enables end-to-end congestion notification between two endpoints on IP network
- ECN uses 2 LSB of Type of Service field in IP header



ECN	ECN Behavior
00	Non ECN Capable
10	ECN Capable Transport (0)
01	ECN Capable Transport (1)
11	Congestion Encountered

Explicit Congestion Notification (ECN)

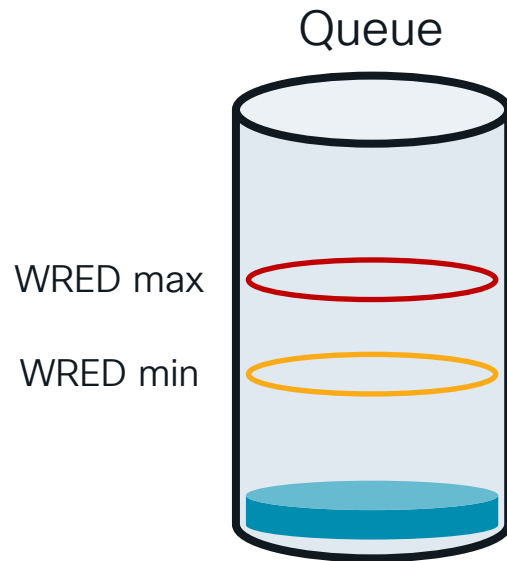
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- ECN enables end-to-end congestion notification between two endpoints on IP network
- ECN uses 2 LSB of Type of Service field in IP header
- In case of congestion, ECN gets transmitting device to reduce transmission rate using Congestion Notification Packet (CNP) without pausing traffic.



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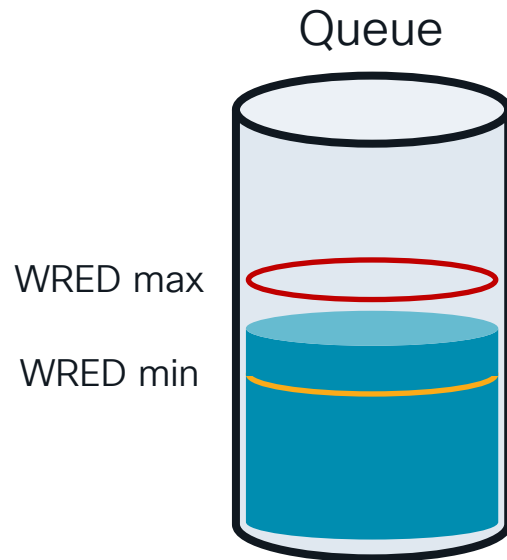
How does WRED ECN work?

- WRED (Weighted Random Early Detection) is used to signalize severity of congestion
- ECN is not marked when buffer usage is below WRED min threshold



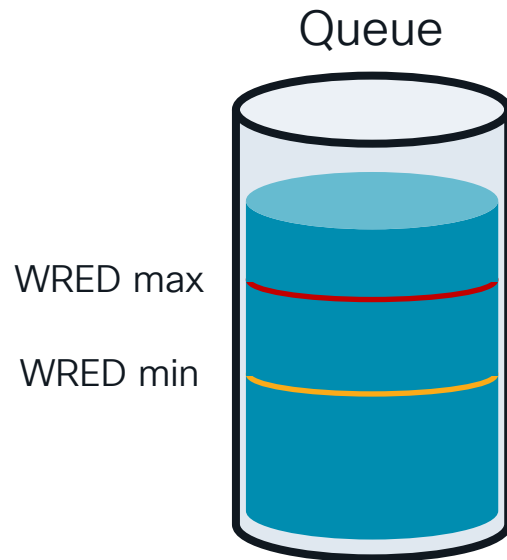
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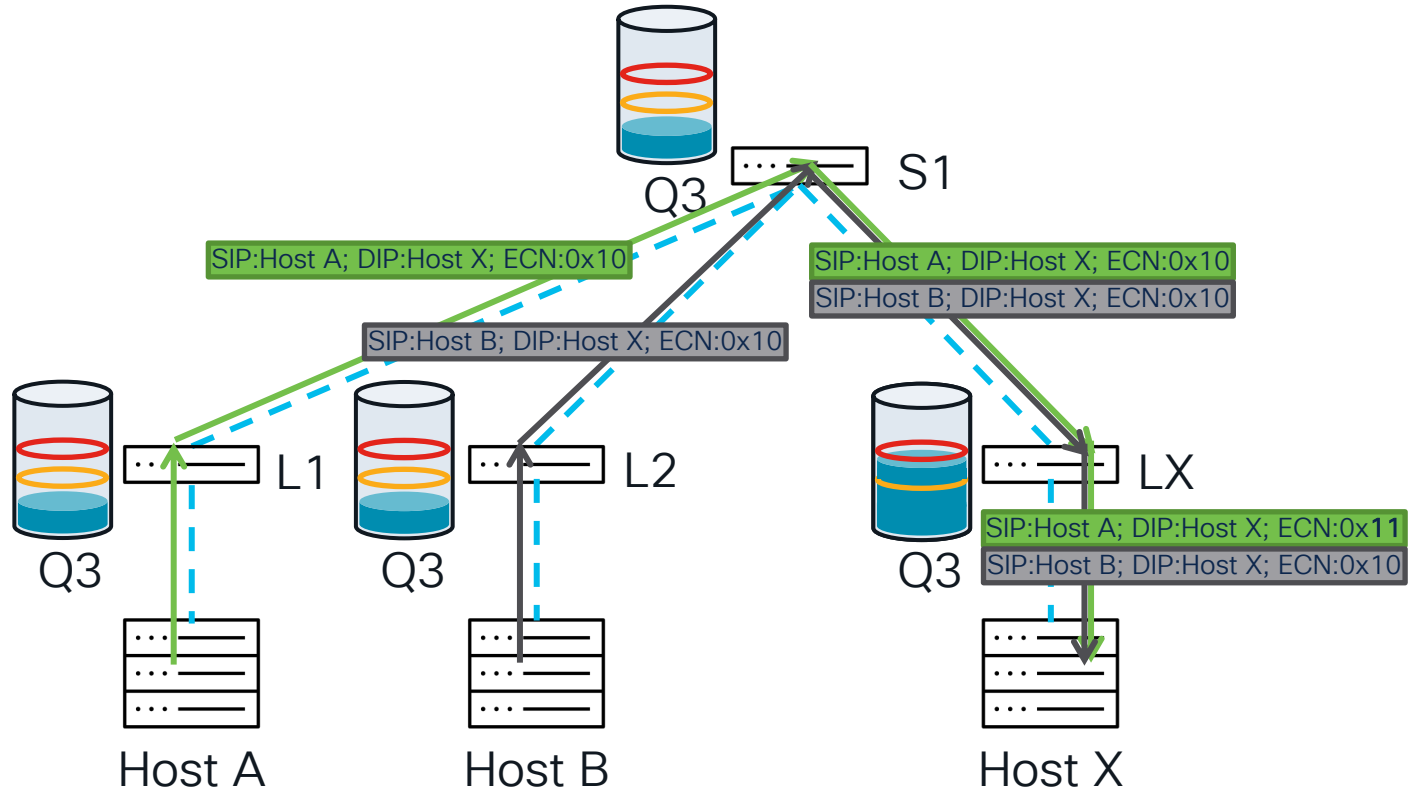


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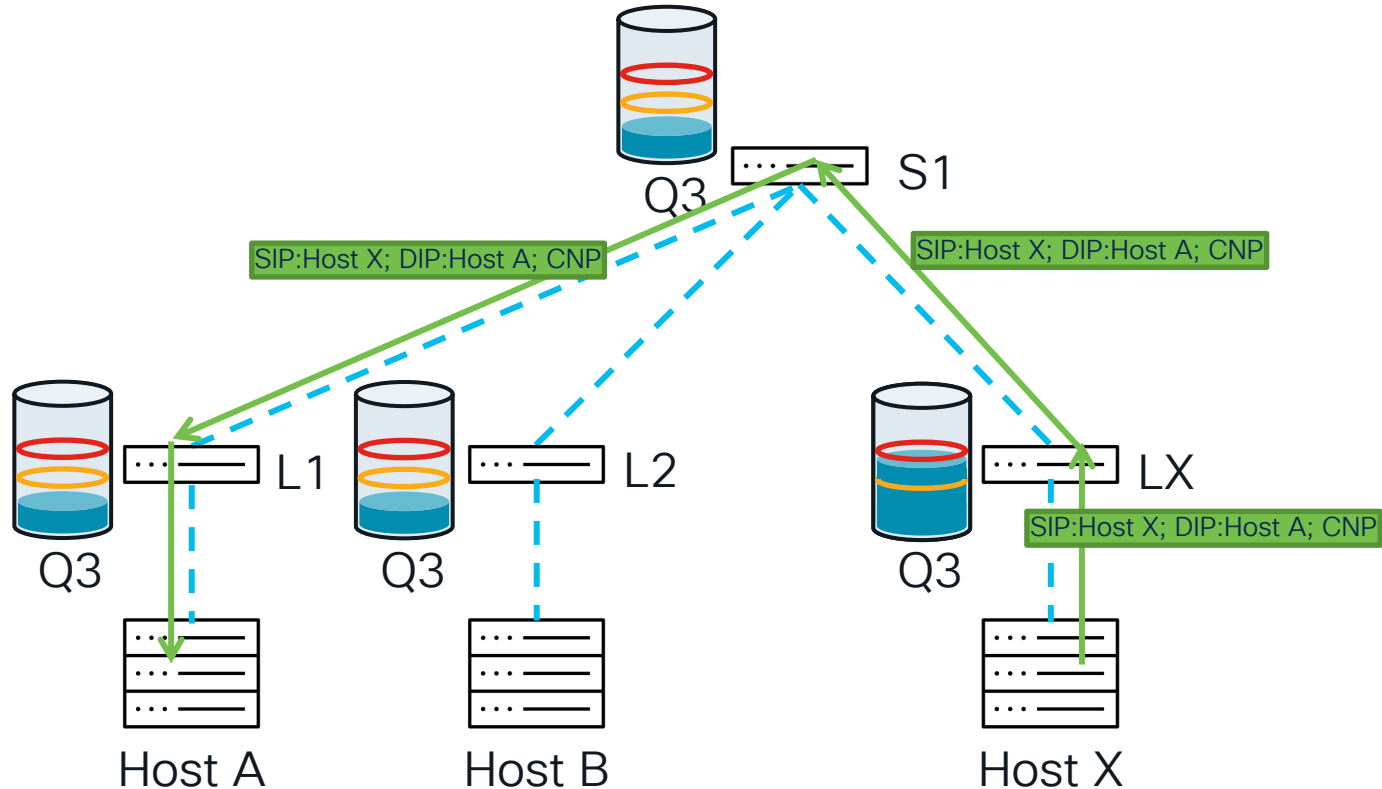
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- When buffer usage is minimal threshold, Congestion Encountered will be marked on N number of randomly selected packets (probability parameter)
- After buffer usage crosses MAX threshold, every ECN capable packet will be marked with Congestion Encountered



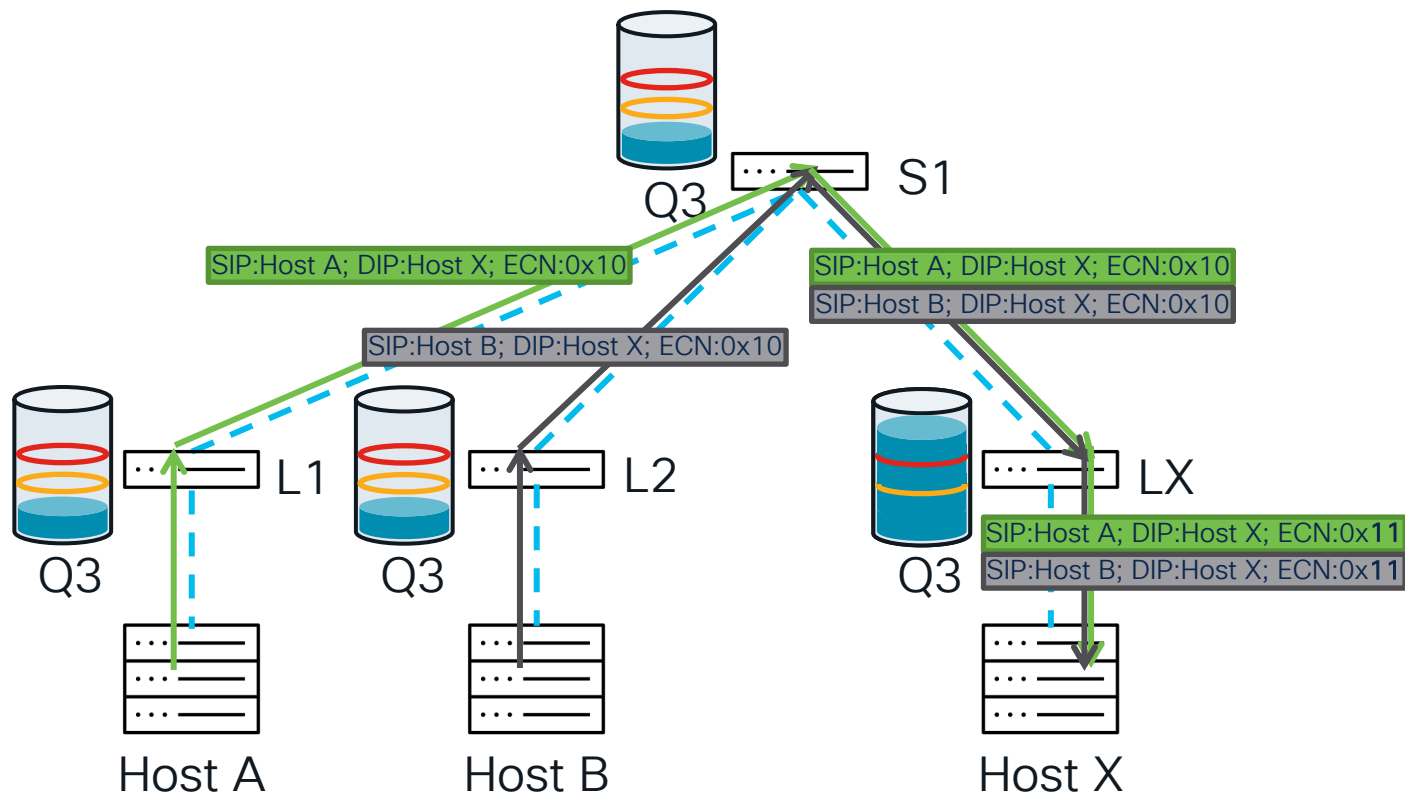
Explicit Congestion Notification – End to End



Explicit Congestion Notification – End to End



Explicit Congestion Notification – End to End

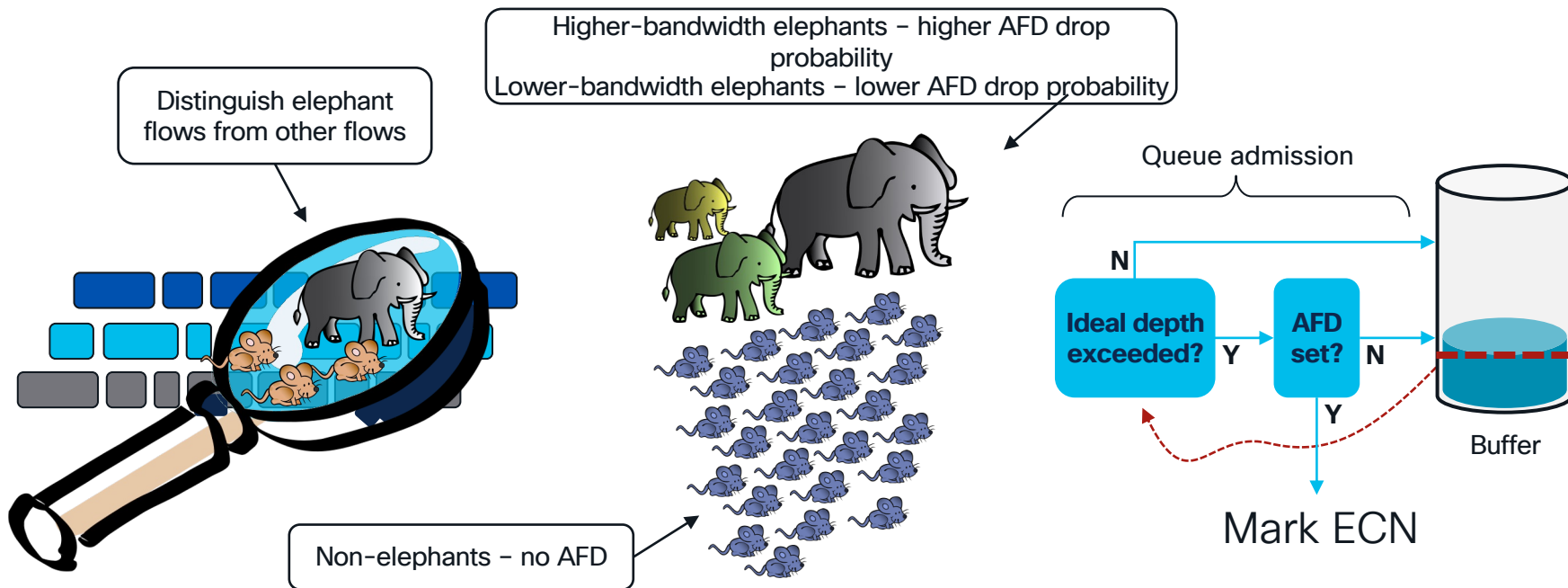


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Approximate Fair Drop (AFD)

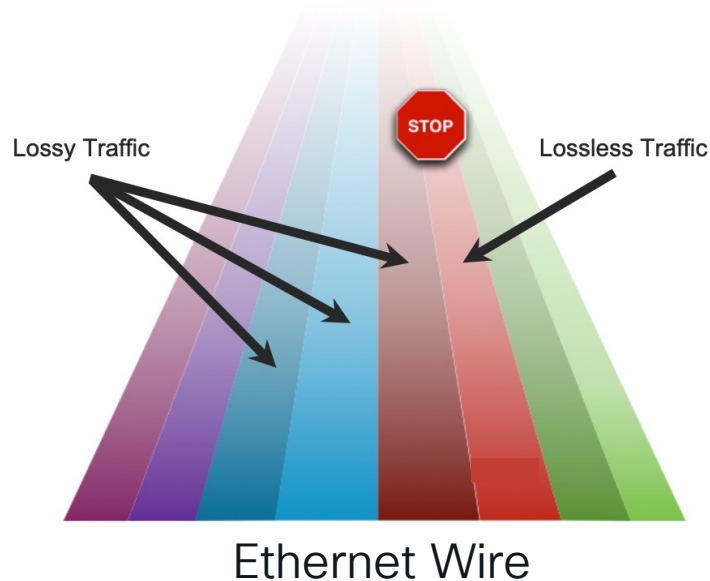
Maintain throughput while minimizing buffer consumption by elephant flows – **keep buffer state as close to the ideal as possible**



Priority Flow Control

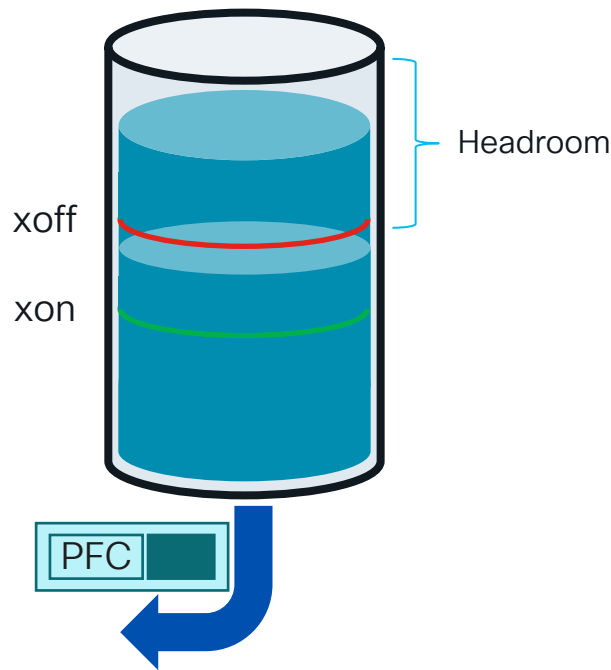
Flow Control Mechanism – 802.1Qbb

- A.k.a "Lossless Ethernet"
- PFC enables Flow Control on a Per-Priority basis
- PFC is also called Per-Priority-Pause
- Therefore, we have the ability to have lossless and lossy priorities at the same time on the same wire
- Allows traffic to operate over a lossless priority independent of other priorities
- Other traffic assigned to other priority will continue to transmit and rely on upper layer protocols for retransmission

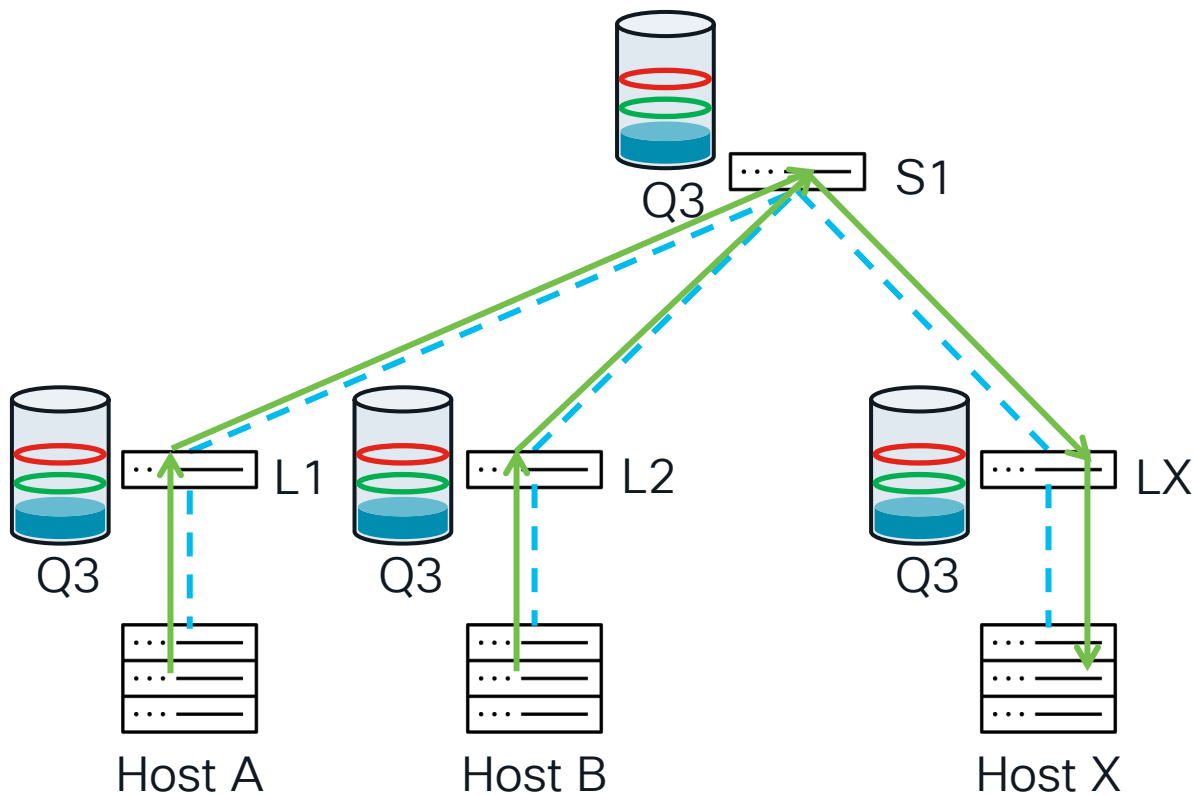


PFC – How pause frames are sent

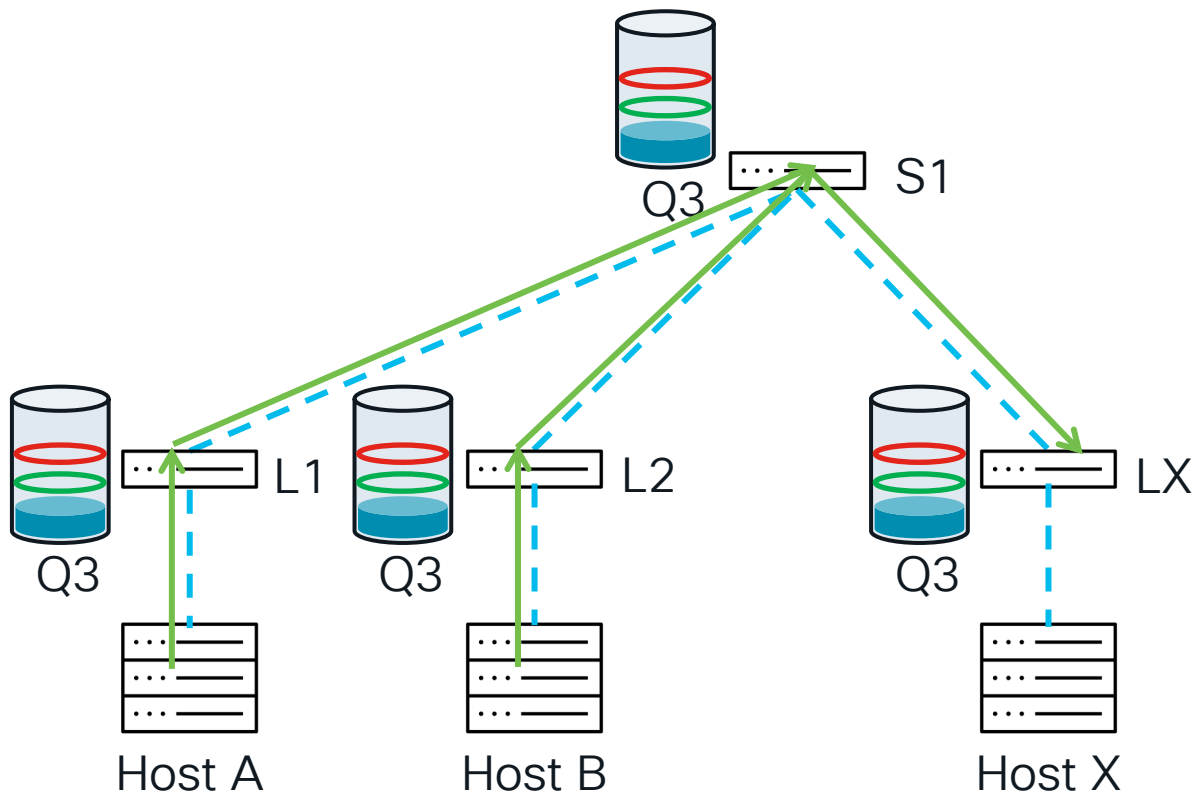
- PFC sets thresholds in no-drop queue
- Headroom is present to accommodate “in flight” packets
- Under congestion, traffic is buffered in non-drop queue
- PFC frames are sent toward sender after queue utilization exceeds *xoff* threshold
- While draining the queue, and utilization is below *xon* threshold system will stop sending PFC frames



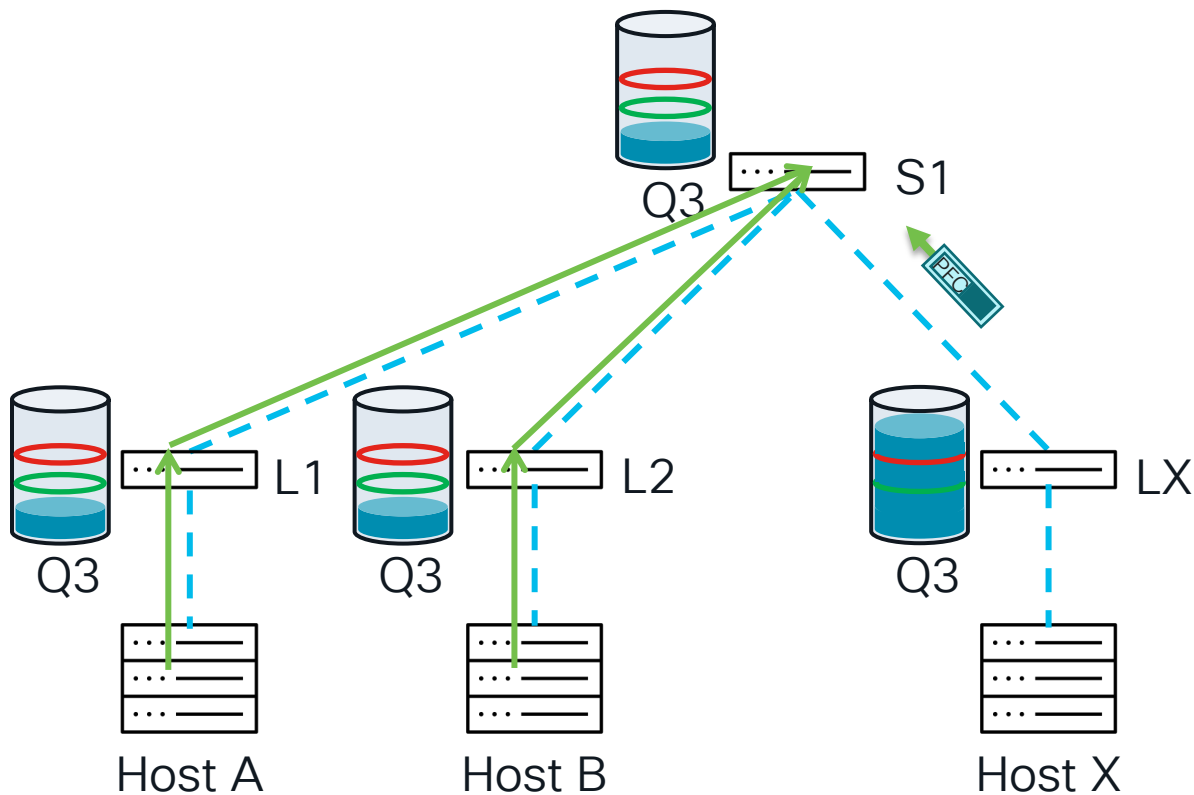
PFC Hop by hop



PFC Hop by hop



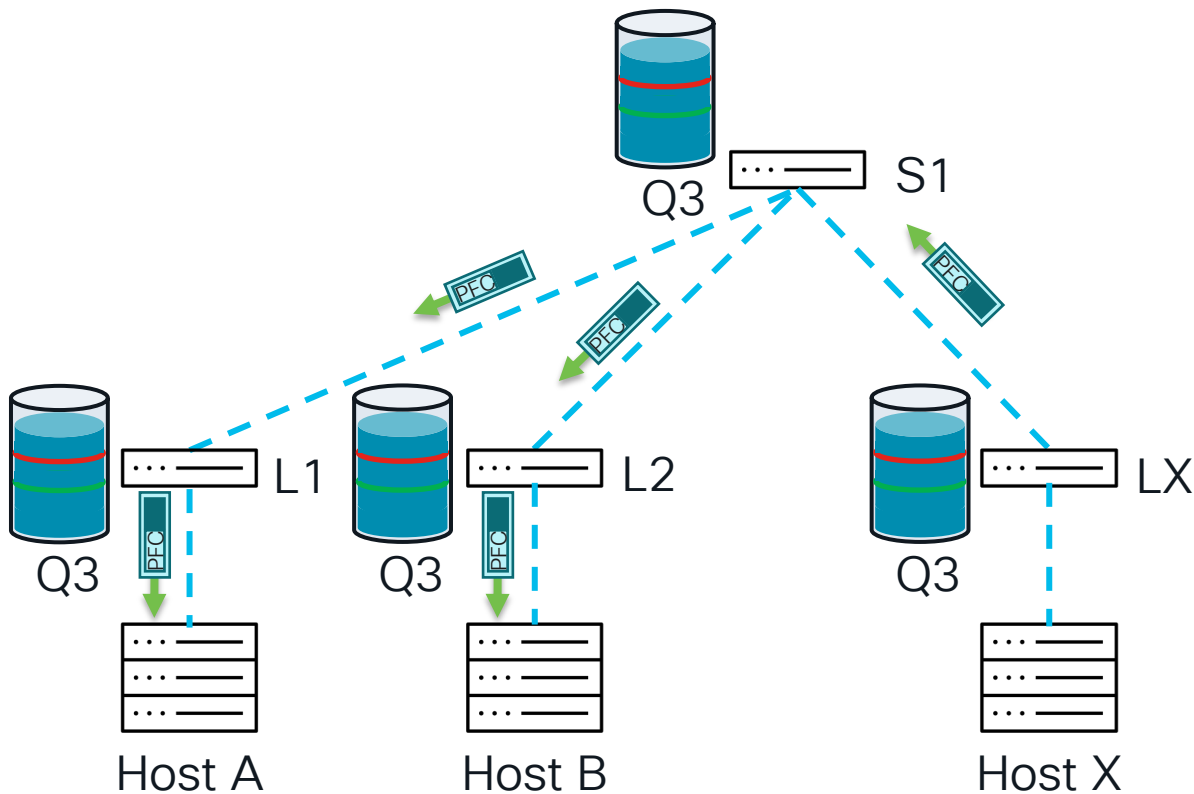
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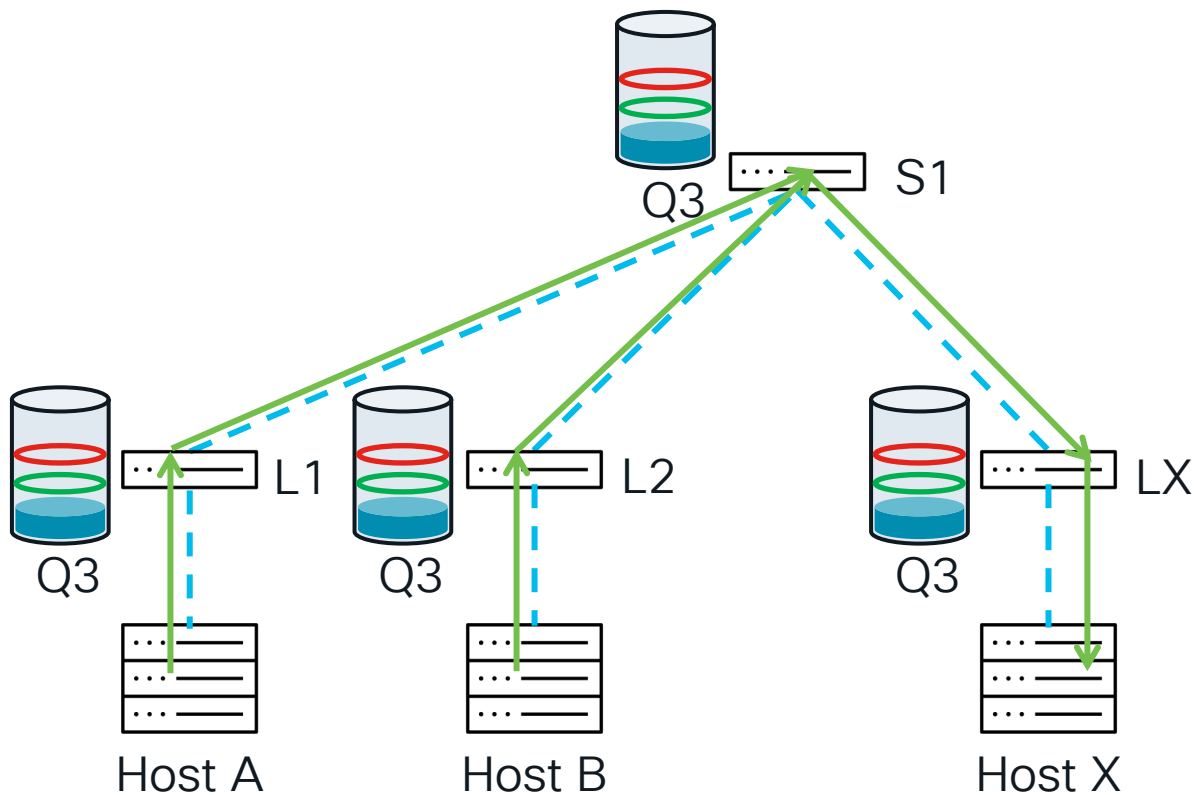
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PFC Hop by hop



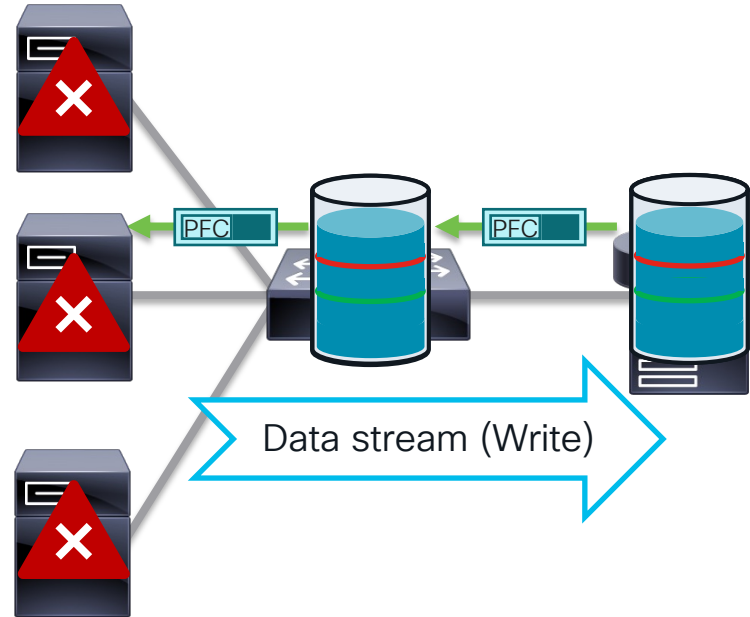
PFC Hop by hop





NIC PFC Storm

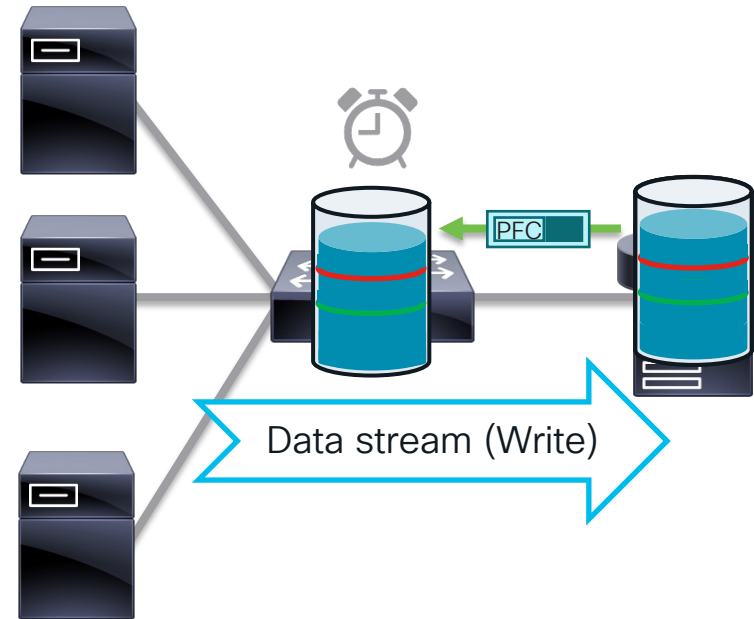
- In occasion of NIC malfunction, PFC storm can be triggered to send continues PFC frames in the network
- Network will propagate those frame to all senders
- PFC storm will stop traffic coming from sender
- PFC watchdog can drain the queue





PFC Watchdog

- PFC watchdog sets a timeout, if a packet exceeds time out, all packets from a queue will be cleared
- The watchdog prevents PFC frames propagating to sender and blocking it
- PFC Watchdog is supported on Cisco Nexus 9000 switches



RoCEv2: PFC and ECN together

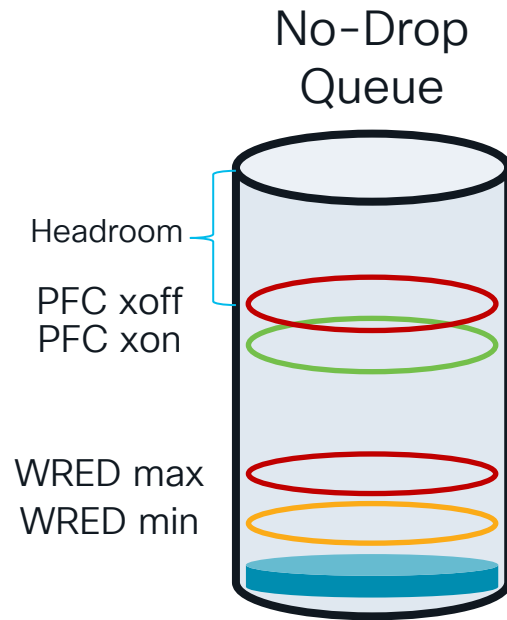
- PFC is Layer 2 congestion avoidance protocol
- ECN is Layer 3 congestion avoidance protocol
- PFC and ECN can work together, Ethernet and IP headers carry both information
- It can be used as prevention for PFC storm



RoCEv2: PFC and ECN together

How does it work?

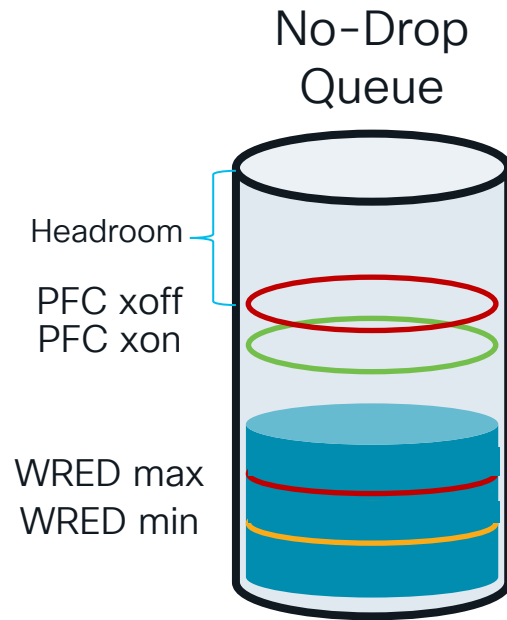
- WRED threshold are set low in no-drop queue
 - Signalize early for congestion, give enough time for end points to react
- PFC threshold are set higher than ECN
 - In case oversubscription buffers can be filled quickly without giving time to ECN to react
 - PFC will react and mitigate congestion



RoCEv2: PFC and ECN together

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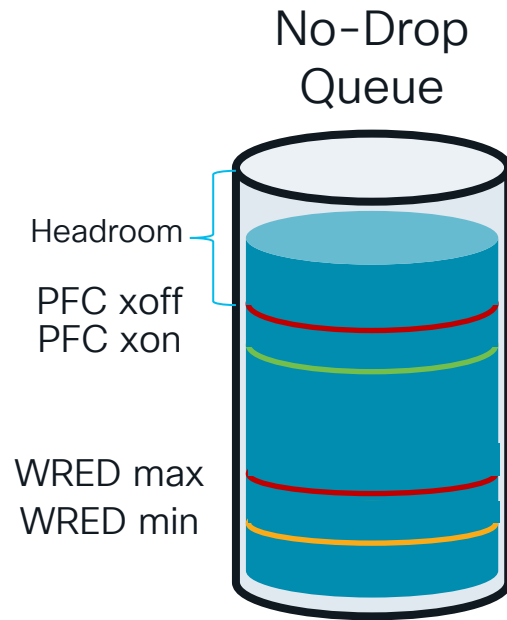
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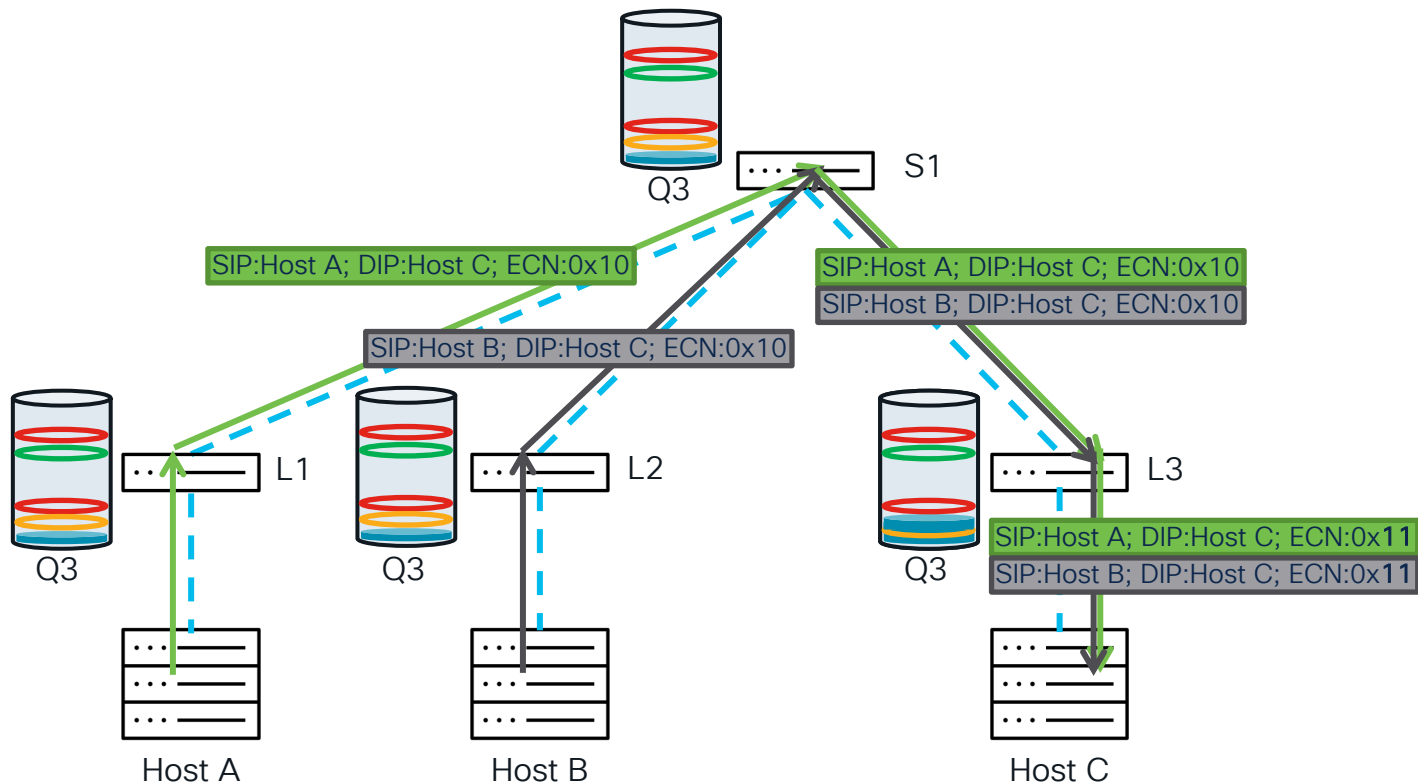
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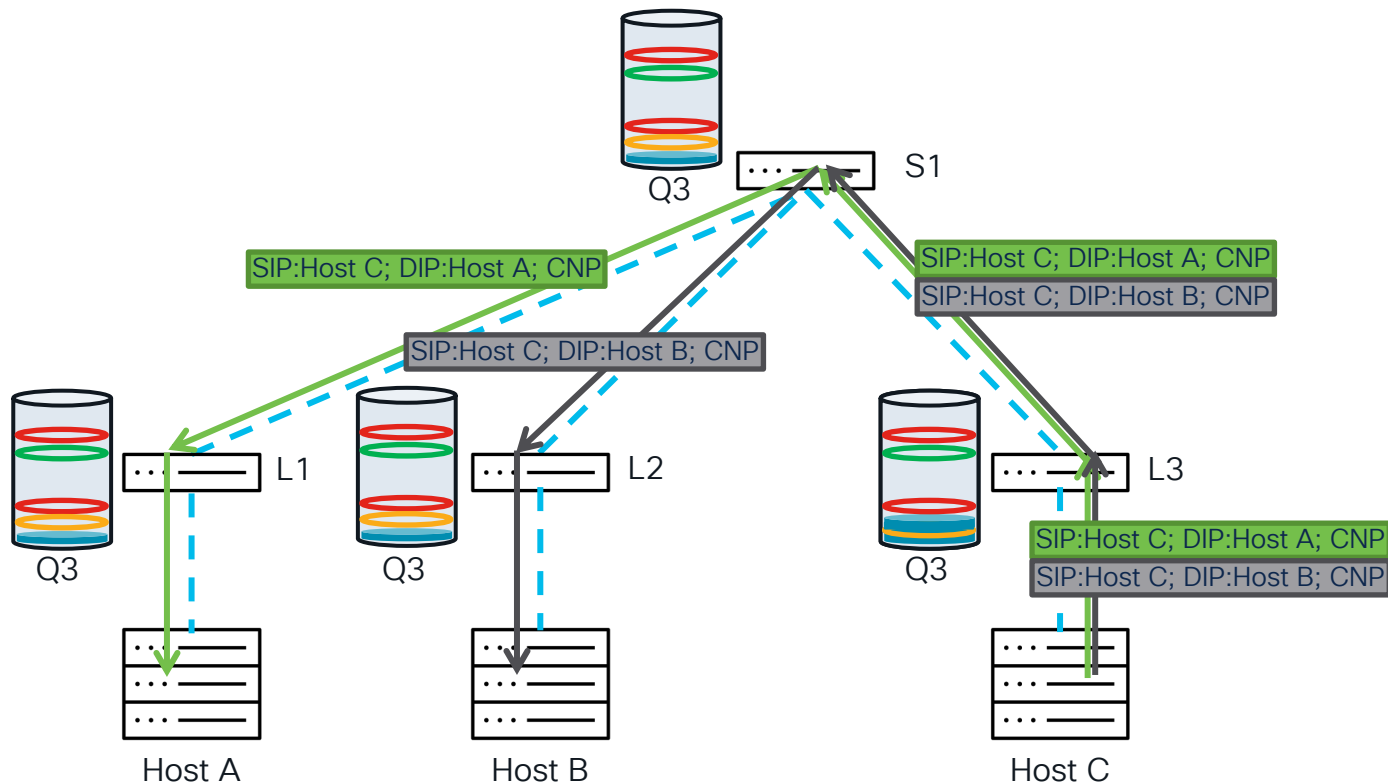
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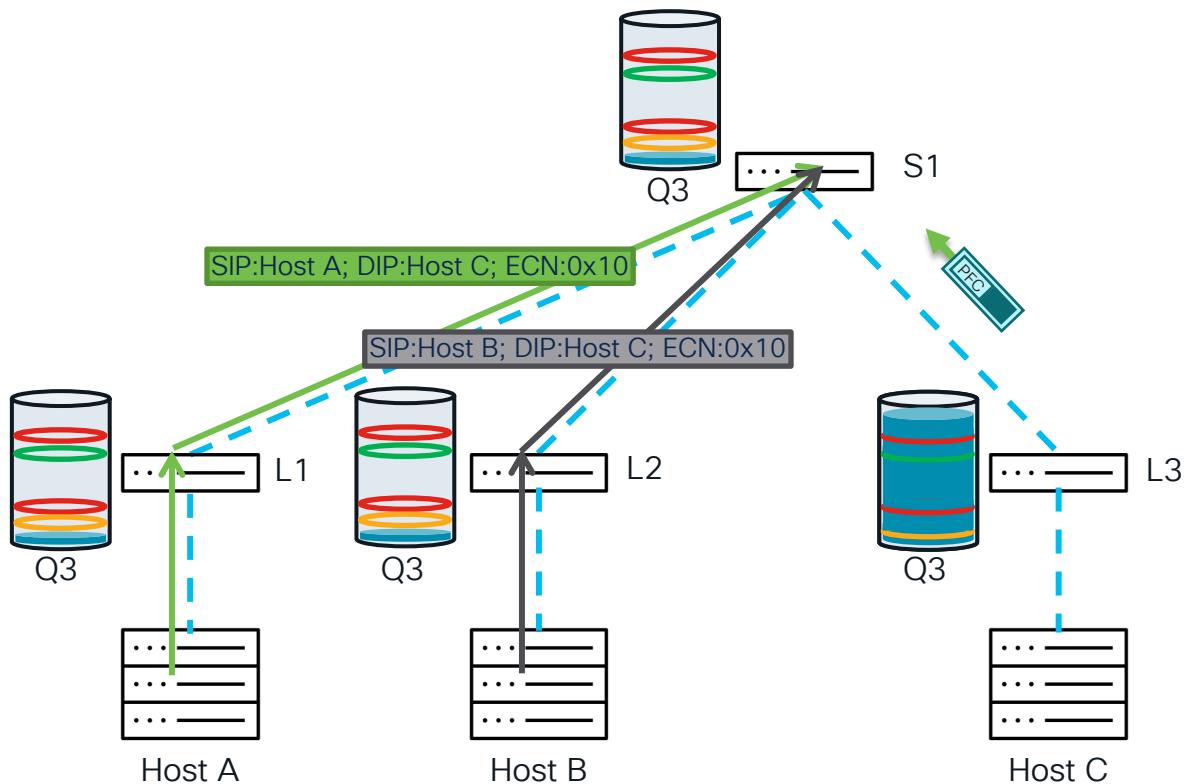
ECN and PFC make DCQCN



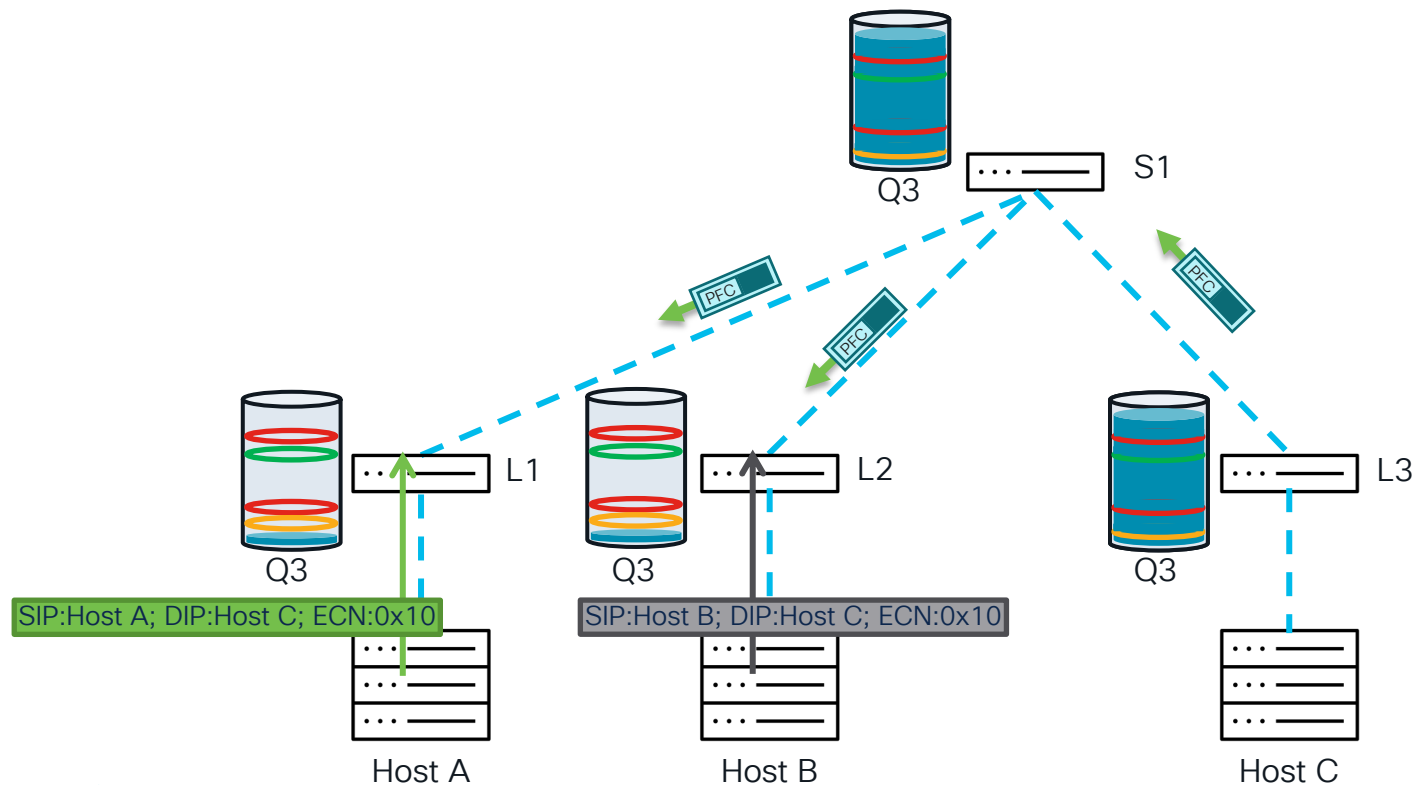
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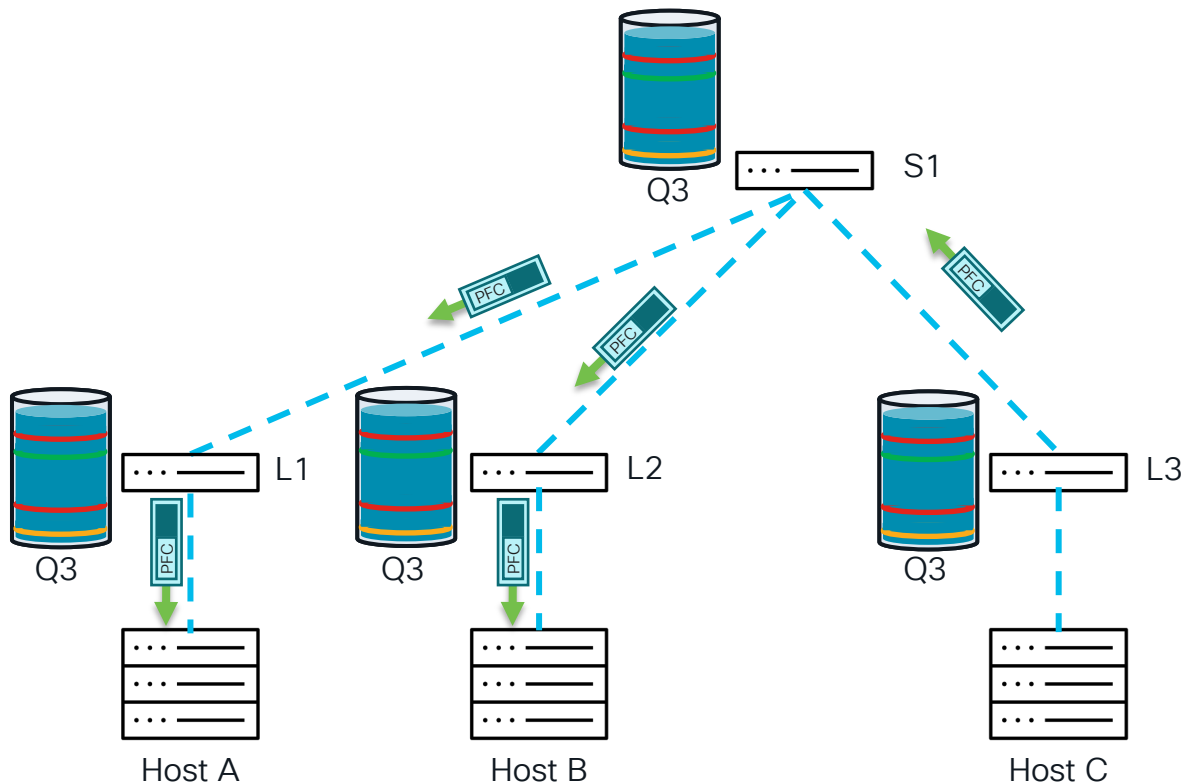
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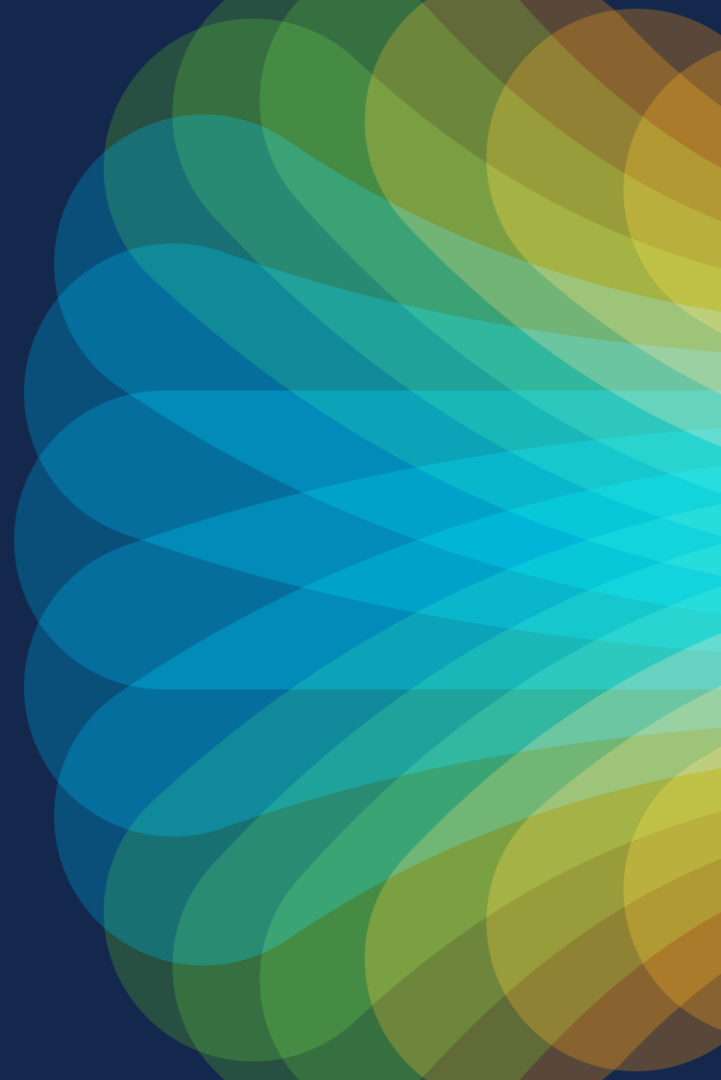
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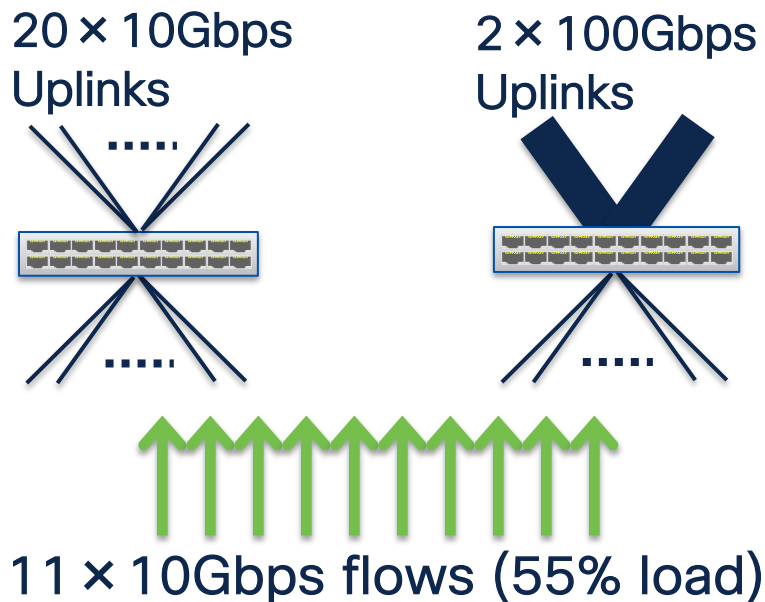


Traffic Load-balancing



Hashing – Where traffic goes?

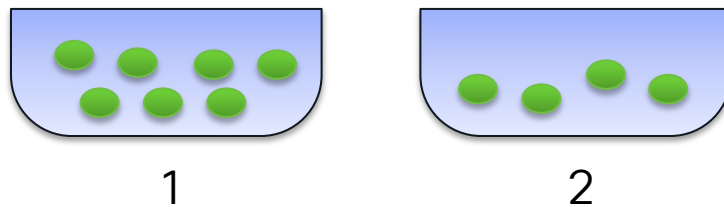
- Avoid oversubscribing link, allow multiple paths to ECMP



Prob of 100% throughput = 3.27%



Prob of 100% throughput = 99.95%



Default ECMP algorithm

- By default, ECMP looks at source and destination IP and Layer 4 ports
- Hosts in AI fabric may belong to uniform subnets
- Layer 4 ports, destination port is 4791 for RoCEv2
- Entropy comes from Layer 4 Source Port

```
N9K-switch# show ip load-sharing
IPv4/IPv6 ECMP load sharing:
Universal-id (Random Seed): 2467474893
Load-share mode : address source-destination port source-destination
Rotate: 32
```

User Defined Filed (UDF) ECMP algorithm

- UDF ECMP looks at source and destination IP and User Defined Filed in a packet
- User can choose what filed to look at to enhance entropy
- Every RoCE conversation is identified by Destinate Queue Pair, in IB header
- Destination Queue Pair is 3 byte filed

```
N9K-switch# show ip load-sharing
IPv4/IPv6 ECMP load sharing:
Universal-id (Random Seed): 908907021
Load-share mode : address source-destination udf offset 33 length 24
Rotate: 32
```

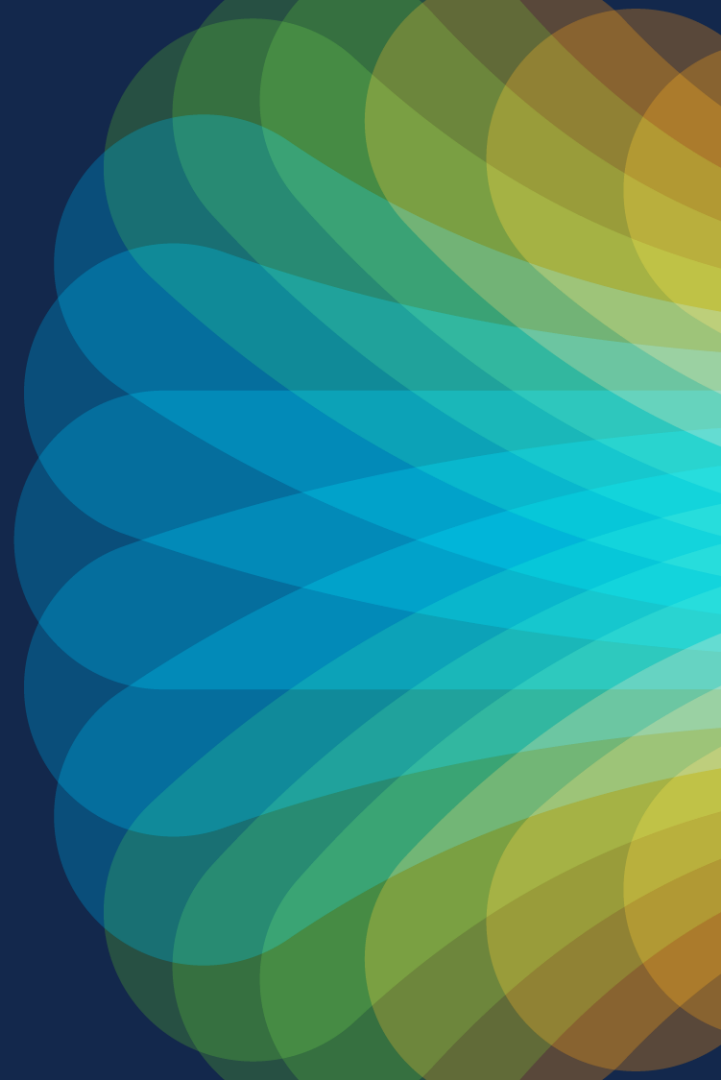
User Defined Filed (UDF) – Destination Q Pair

- UDF offset of Nexus 9000 switches starts from IP header
- Destination Q Pair is 33 bytes from beginning of IP filed (IP (20B) + UDP (8B) + IB (5B)) or 6th byte in InfiniBand header

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	172.16.103.11	172.16.101.11	RRoCE	1086	RC RDMA Read Response Middle QP=0x000a19
2	0.000020260	172.16.103.11	172.16.101.11	RRoCE	1086	RC RDMA Read Response Middle QP=0x000a19
5	0.116549167	172.16.103.11	172.16.104.11	RRoCE	78	RC RDMA Read Request QP=0x000a00
6	0.116561041	172.16.103.11	172.16.104.11	RRoCE	78	RC RDMA Read Request QP=0x000a00
7	0.122176963	172.16.103.11	172.16.112.11	RRoCE	1086	RC RDMA Read Response Middle QP=0x000903
8	0.122185013	172.16.103.11	172.16.112.11	RRoCE	1086	RC RDMA Read Response Middle QP=0x000903
9	0.236039751	172.16.103.11	172.16.101.11	RRoCE	78	RC RDMA Read Request QP=0x000a19
10	0.236050373	172.16.103.11	172.16.101.11	RRoCE	78	RC RDMA Read Request QP=0x000a19

> Frame 7: 1086 bytes on wire (8688 bits), 1086 bytes captured (8688 bits) on interface Ethernet II, Src: MellanoxTech_c4:7c:ab (b8:ce:f6:c4:7c:ab), Dst: Cisco_23:d3:95:802.1Q Virtual LAN, PRI: 0, DEI: 0, ID: 103	0030	ff ff 00 00 09 03 00 14 72 81 f5 e
> Internet Protocol Version 4, Src: 172.16.103.11, Dst: 172.16.112.11	0040	64 3d 50 c3 60 3d db 77 94 3d 05 e
> User Datagram Protocol, Src Port: 49152, Dst Port: 4791	0050	1b 3d fd f2 da 3c c7 a1 87 3d 78 t
> InfiniBand	0060	a2 3c 4f 94 47 3d 00 24 f4 3a bc 5
Base Transport Header	0070	8c 3d 89 88 16 3d 9d c4 a0 3c b5 c
Opcode: Reliable Connection (RC) – RDMA READ response Middle (14)	0080	57 3d a3 14 9d 3d 39 76 85 3d a5 c
Op... = Solicited Event: False	0090	a2 3d 43 f0 96 3d a9 a5 96 3d f2 e
..1.. = MigReq: True	00a0	0c 3b 45 49 11 3d 61 df 82 3d 6b 7
..00 = Pad Count: 0	00b0	1a 3d b5 8e 38 3d 25 33 ed 3c bd t
... 0000 = Header Version: 0	00c0	57 3d 6d 44 55 3d 80 12 da 3a 90 3
Partition Key: 65535	00d0	ad 3c 5d 92 34 3d 2b 2a 22 3c fd 3
Reserved: 00	00e0	31 3d 60 ca 70 3d 1f 68 6d 3d 6d 3
Destination Queue Pair: 0x000903	00f0	10 3d 65 e8 aa 3c e4 4f 75 3d 4b e
Op... = Acknowledge Request: False	0100	81 3d 5c 15 a5 3d b8 1e 82 3d 22 3
..000 0000 = Reserved (7 bits): 0	0110	0f 3d 88 9e 1a 3d 65 97 7f 3c 29 c
Packet Sequence Number: 1340033	0120	8d 3d a7 8c 41 3d 58 48 ff 3c 07 5
Invariant CRC: 0xb5bae4d	0130	17 3d 5b 72 64 3c d5 b7 d7 3a 71 5
> Data (1024 bytes)	0140	a1 3d d9 f9 45 3d eb 6a 1c 3c 03 3
	0150	06 3d 73 c4 60 3d 1b 8d a3 3d 50 4
	0160	7a 3c a0 6e e6 3b a0 16 6d 3c b9 e
	0170	28 3d ec b9 5e 3d eb f6 28 3c a3 e
	0180	13 3d 4b 93 86 3d 85 28 c4 3c 6b e
	0190	53 3a 53 c9 f4 3c 6c fa 51 3d 64 e
	01a0	3d 3d 44 69 3d f2 8e 90 3d 0b 1
	01b0	5f 3d 91 cb 97 3d 43 51 ba 3c e5 c

Automation and Visibility



Nexus Dashboard Fabric Controller

Create Fabric?—×

N9K Cloud Scale Platform Queuing Policy	
Select an Option	Queuing Policy for all 92xx, -EX, -FX, -FX2, -FX3, -GX series switches in the fabric
N9K R-Series Platform Queuing Policy	
Select an Option	Queuing Policy for all R-Series switches in the fabric
Other N9K Platform Queuing Policy	
Select an Option	Queuing Policy for all other switches in the fabric
Enable AI / ML QoS and Queuing Policies	
☒	Configures QoS and Queuing Policies specific to N9K Cloud Scale switch fabric for AI / ML network loads
AI / ML QoS & Queuing Policy*	
AI_Fabric_QOS_100G	Queuing Policy based on predominant fabric link speed: 400G / 100G / 25G
AI_Fabric_QOS_400G	
AI_Fabric_QOS_100G	Enable MACsec in the fabric
AI_Fabric_QOS_25G	
	Cisco Type 7 Encrypted Octet String

Nexus Dashboard Fabric Controller

Edit interface(s) ? — ×

Additional CLI for the interface

Enable Interface* ☒ Uncheck to disable the interface

Enable Netflow ☐ Netflow is supported only if it is enabled on fabric

Netflow Monitor Provide the Layer 3 Monitor Name

Netflow Sampler Netflow sampler name, applicable to N7K only

Enable priority flow control ☒ Enable priority flow control

Enable QoS Configuration ☒ Enable to configure a QoS Policy for this interface. If AI/ML Queuing is enabled on the fabric, will use the QOS_CLASSIFICATION policy. Enter a custom policy below to override

Custom QoS Policy Custom QoS Policy must be defined previously

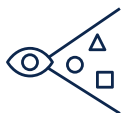
Custom Queuing Policy Queuing Policy must be defined previously

Visibility – Flow Table

- Collects full flow information plus metadata
 - 5-tuple flow info
 - Interface/queue info
 - Flow start/stop time
 - Packet disposition (drop indicators)
 - Burst measurement
- Direct hardware export
- Leveraged by Nexus Dashboard Insights



Cisco Nexus Dashboard Insights



With the granular visibility provided by Cisco Nexus Dashboard Insights the network administrator can observe drops

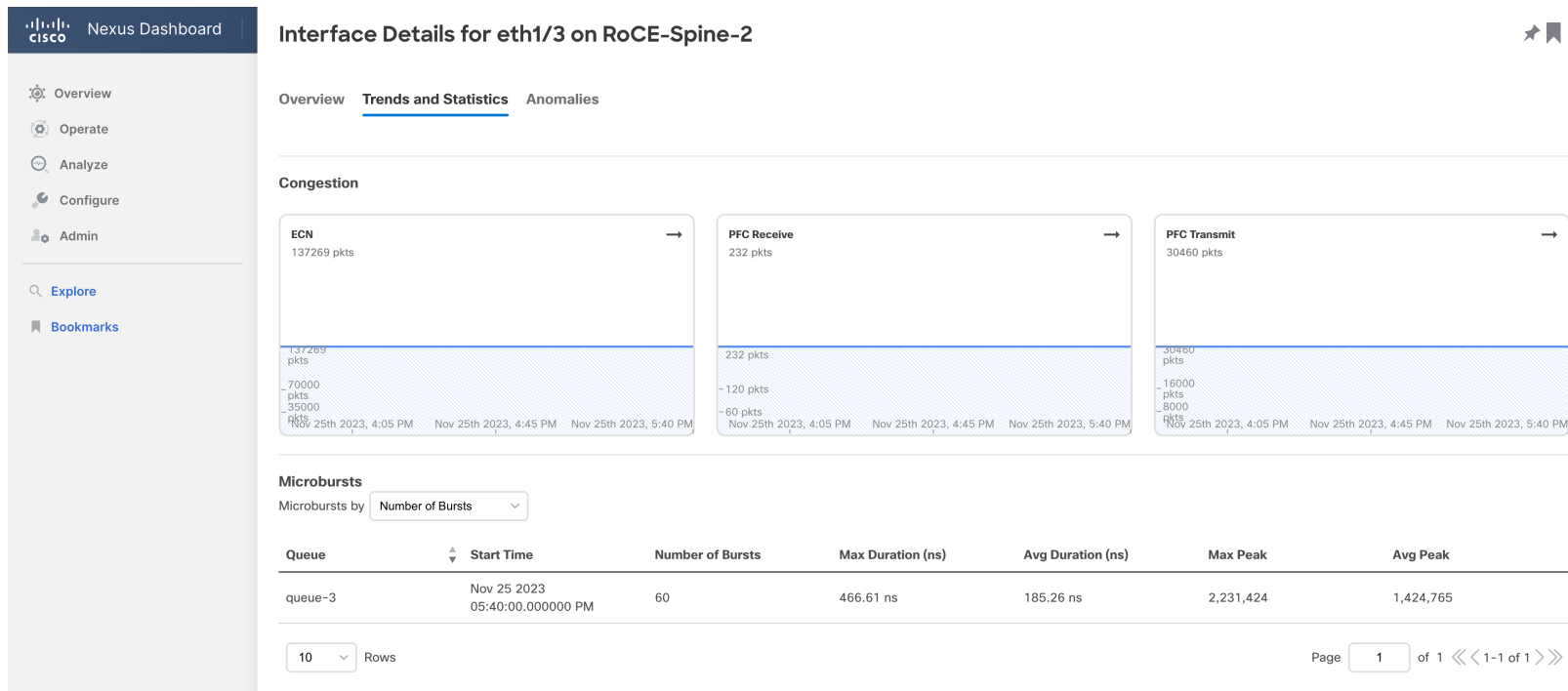


Tune thresholds until congestion hot spots clear and packet drops stop in normal traffic conditions

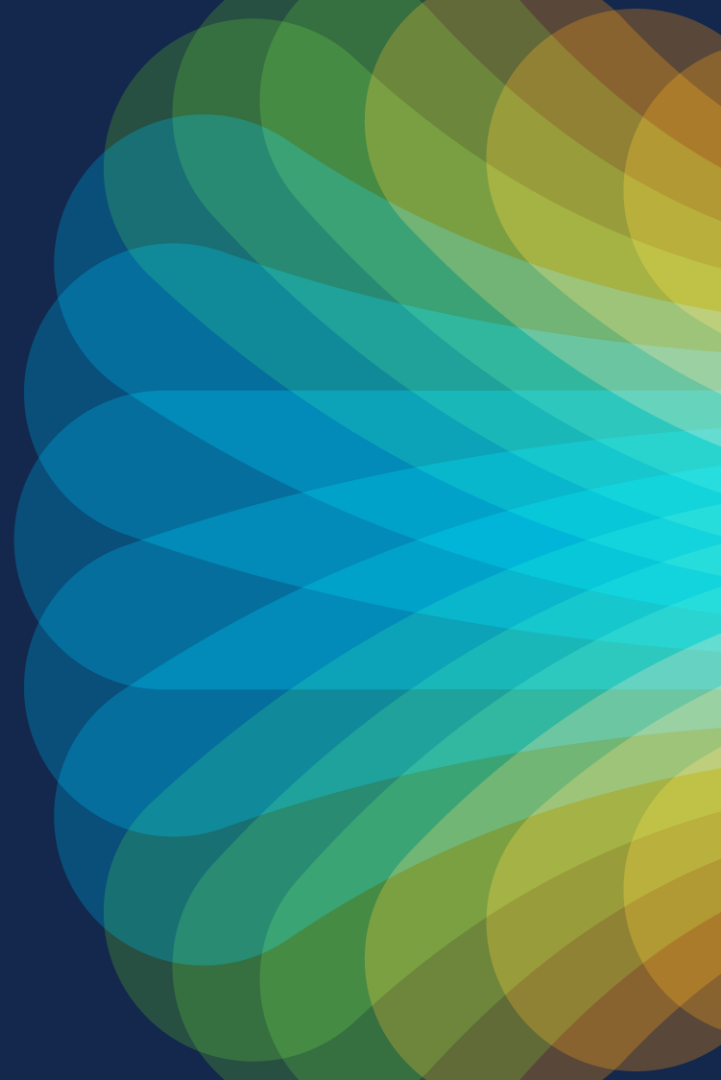


This is the first and most important step to ensure that the AI/ML network will cope with regular traffic congestion occurrences effectively

Nexus Dashboard Insights – Congestion Visibility

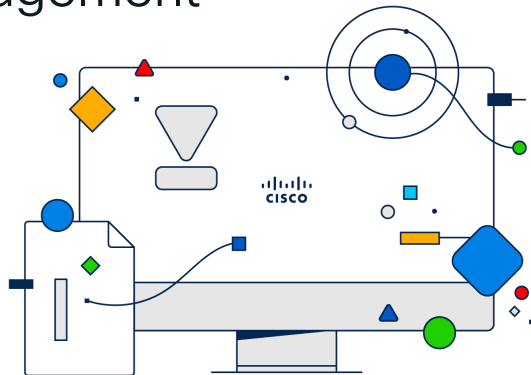


Blueprint of Today



Choosing the right infrastructure

- Build a Clos Fabric / Spine-Leaf
- Fixed Switches
 - Lower Latency, single AISC
 - Power Efficient
- Right Congestion management
- Routed Fabric
 - Use BGP for control plane
- Scalable design
 - Two tier design
 - Three tier design



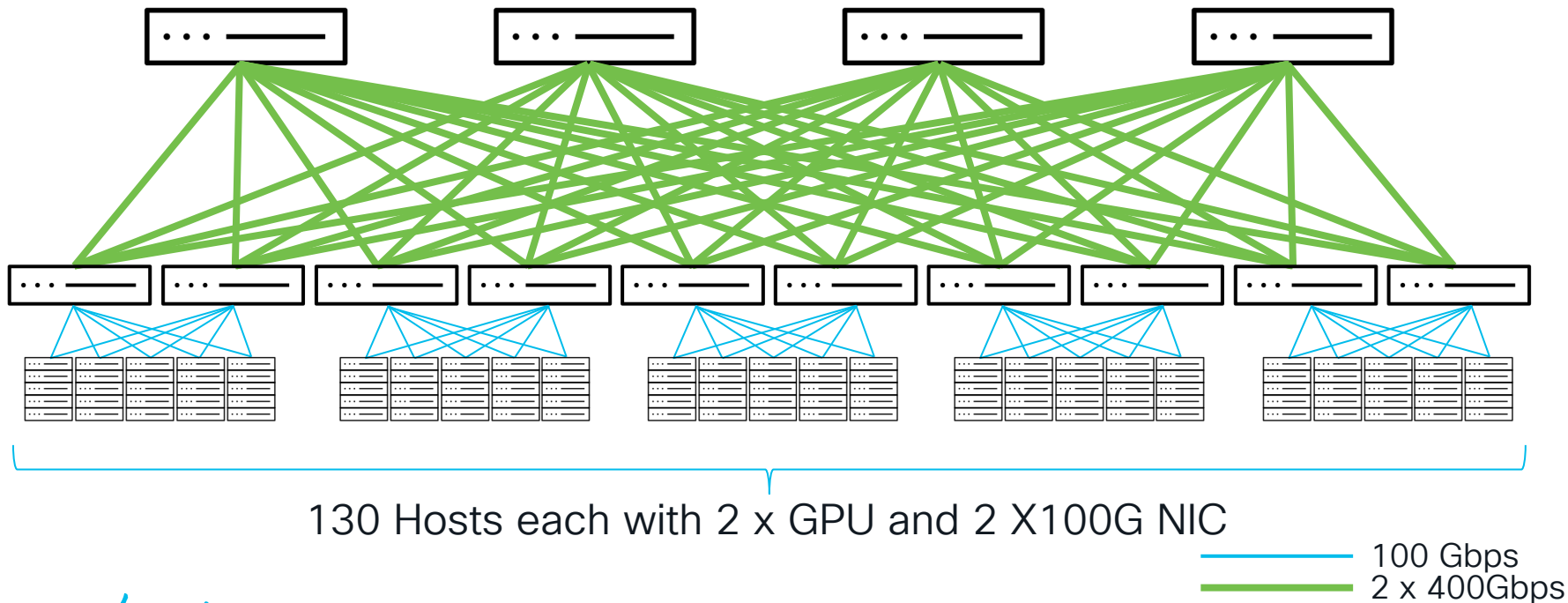
Customer Request #1

- Build Cluster of 260 GPUs, for small training model use case
 - Cluster is built with stand alone server (e.g. Cisco UCS-C240-M7)
- Build non-blocking network, for GPU communication
- Predictable and low latency for efficient training
- Host connectivity at dual 100Gbps
- Fabric at 400Gbps for efficient load-balancing

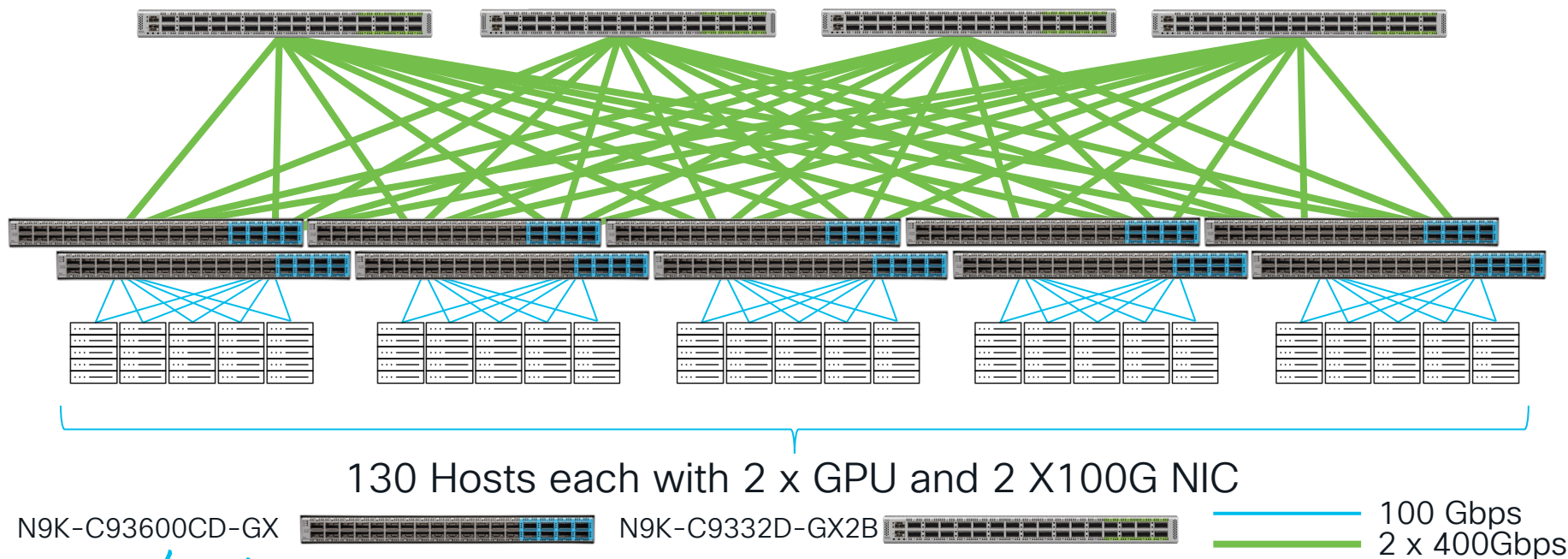
Customer Request #1 – Proposal

- Standalone server can have up to 2 GPUs
 - As required is 260 GPUs, 130 Stand alone servers are needed
 - Each standalone server is equipped with dual 100G port NIC
- 260 x 100G ports required for host connectivity in leaf layer
 - 26 x 100G host interfaces per leaf switch, for 10 leaf switches
 - For seeped up have 8 x 400G uplinks per switch for Spine connectivity
- Total of 4 spines 20 x 400G ports used per Spine
- Leave room for future expansion

Customer Request #1 - Design



Customer Request #1 - Design



Customer Request #1 - Design

- Fabric is running BGP in the fabric
- Non-blocking network design
- Congestion management through PFC and ECN for optimal performance
- Efficient traffic load-balancing in the fabric
- Automated with NDFC

Customer Request #2

- Build Powerful Cluster of 320 GPUs, for large training model use case
 - Cluster is built with powerful accelerators (e.g. NVIDIA DGX H100)
- Build non-blocking back-end network, for GPU communication
 - Predictable and low latency for efficient training
 - Host connectivity at 8 ports of 4 x 100Gbps (Logical 400Gbps)
 - Fabric at 400Gbps for efficient load-balancing
- Build front-end network, for server-to-server interaction, and storage connectivity
 - 2 x 100Gbps ports for connectivity, non-blocking and future expansion

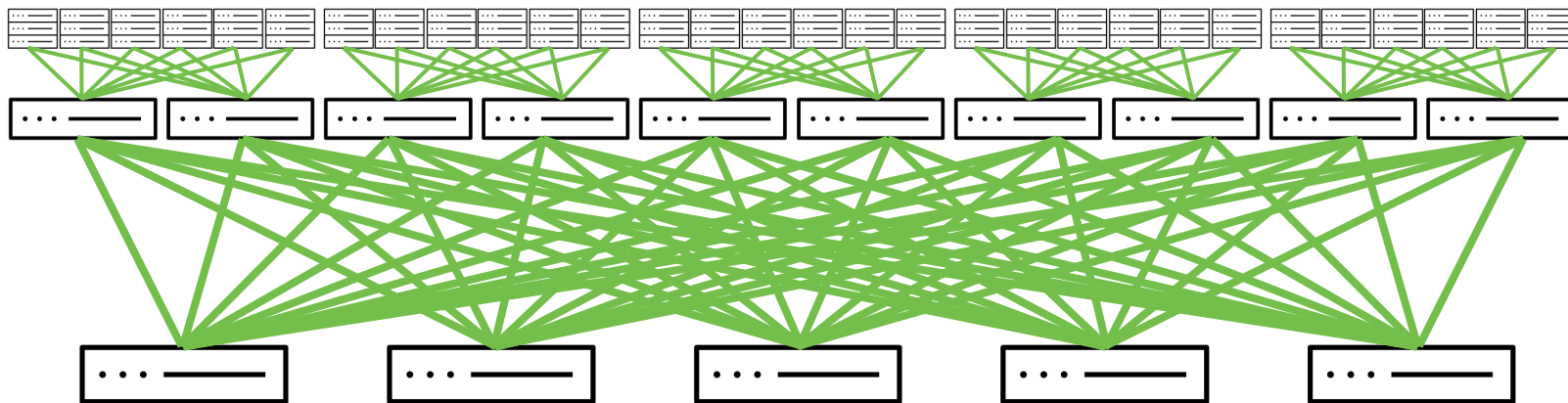
Customer Request #2 – Proposal for Back-End

- Powerful AI training accelerator, has 8 GPUs per server
 - As required is 320 GPUs, 40 host are sufficient
 - Each host is equipped with 4 NICs each with dual QSFP-DD ports
- 320 x 400G ports required for host connectivity in leaf layer
 - 32 x 400G host interfaces per leaf switch, for 10 leaf switches
 - Non-blocking network 32 x 400G uplinks per leaf for Spine connectivity
- Total of 5 spines 64 x 400G ports used per Spine

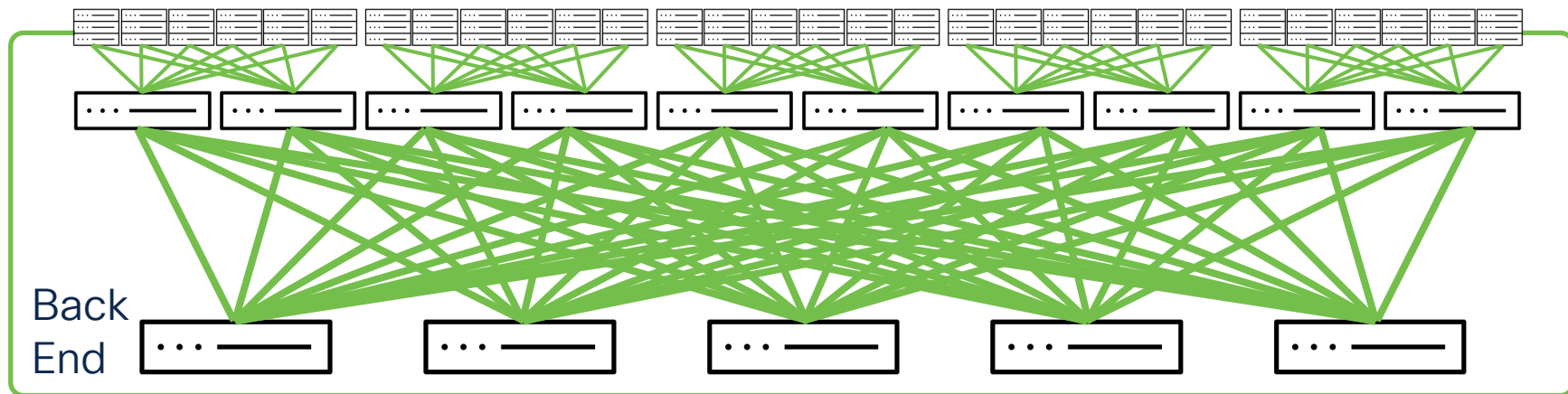
Front-End and Back-End Cluster Network



Back-End Cluster Network



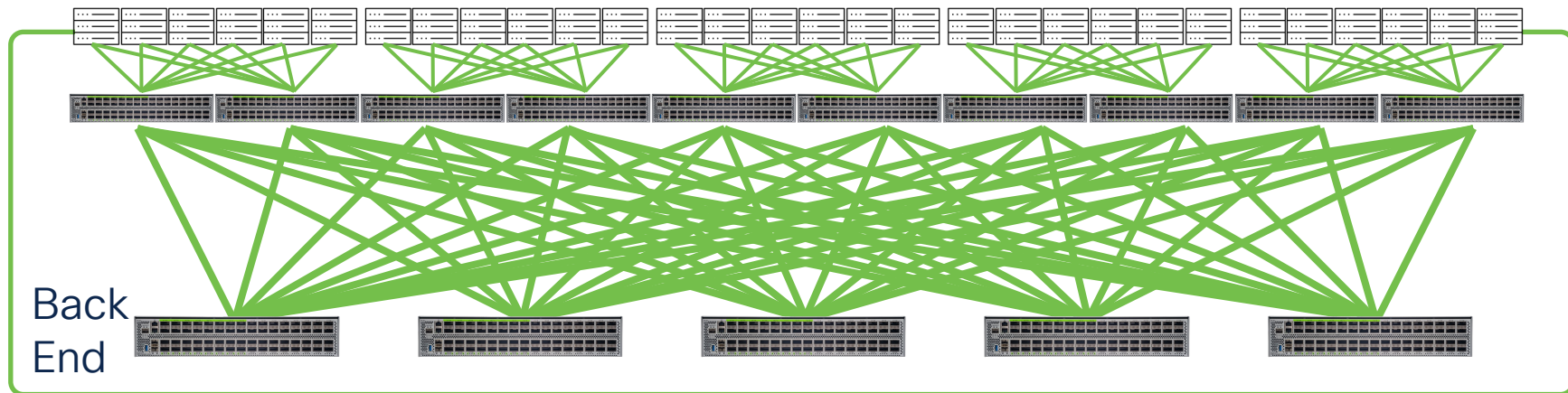
Back-End Cluster Network



Back-End Cluster Network



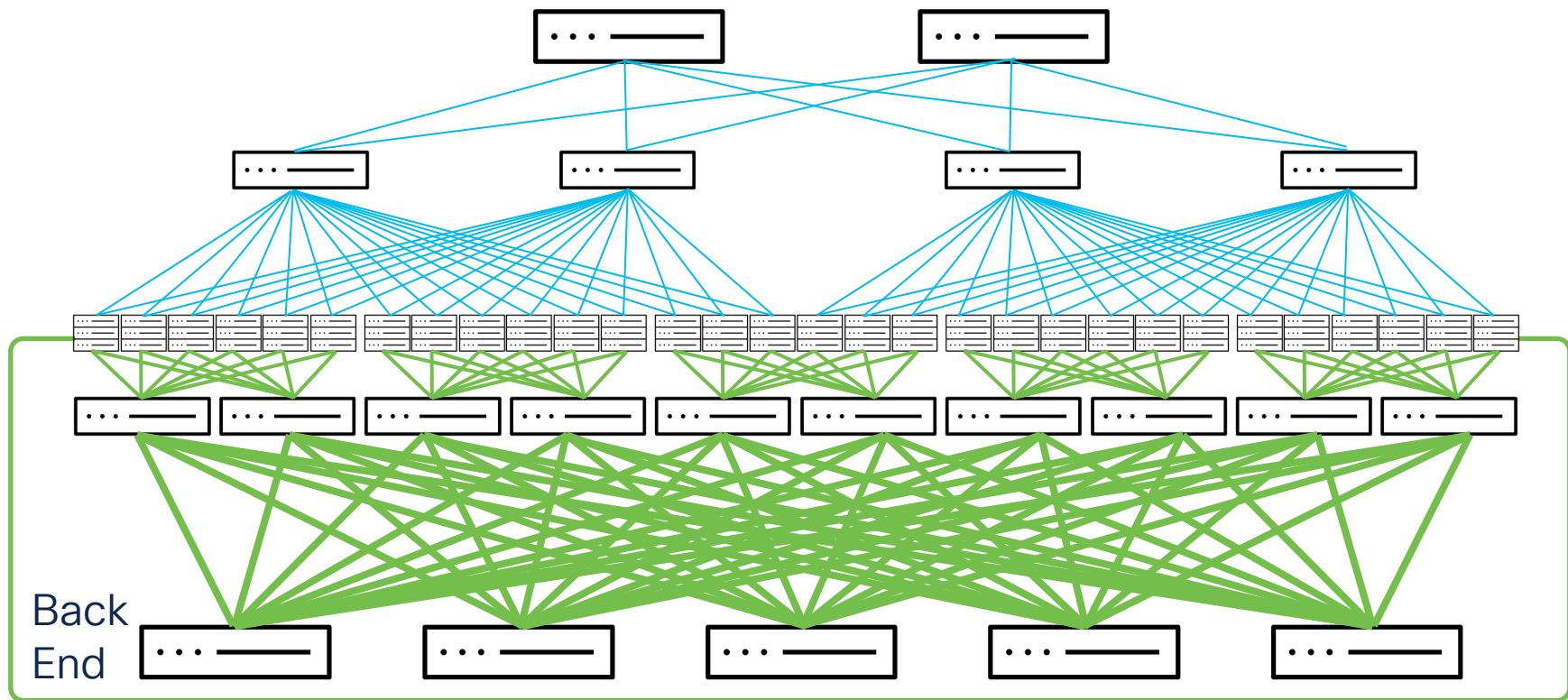
N9K-C9364D-GX2A



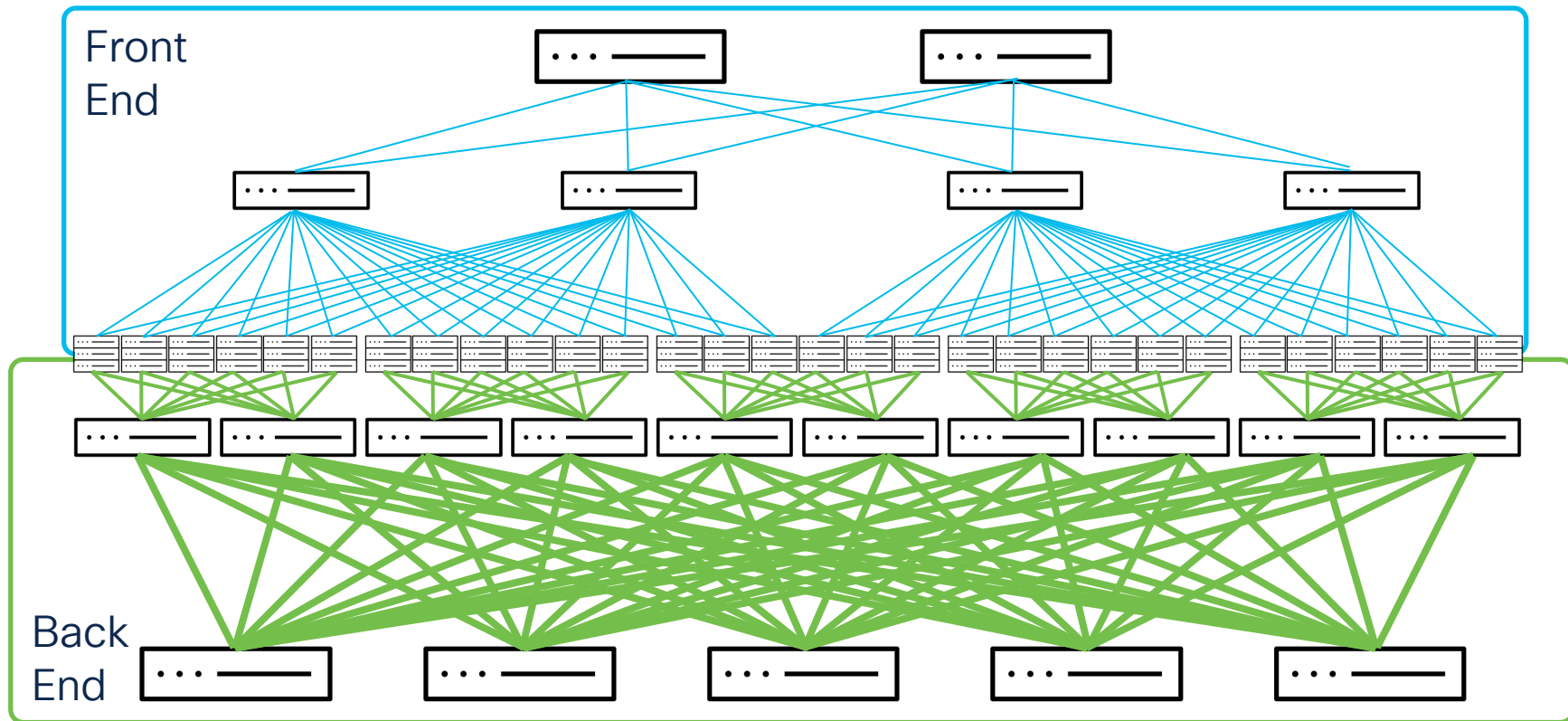
Customer Request #2 – Proposal for Front-End

- Front End network for host communication, and storage
 - Each server has 2 x 100G ports
- 80 x 100G ports required for host connectivity in leaf layer
 - 20 x 100G host interfaces per leaf switch, for 4 leaf switches
 - Non-blocking network 20 x 100G uplinks per leaf for Spine connectivity
- Total of 2 spines 64 x 100G ports used per Spine
- Storage NFS network in Front End
 - 3 Storage array connected to leaf
 - RoCEv2 for storage networks

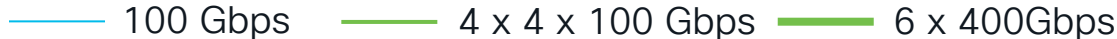
Front-End and Back-End Cluster Network



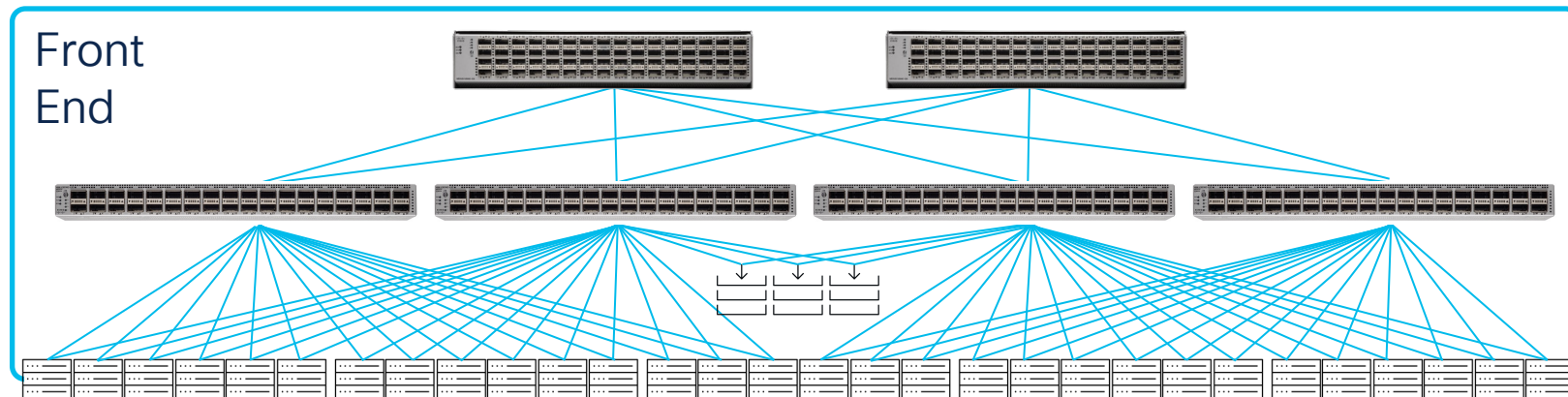
Front-End and Back-End Cluster Network



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Front-End Cluster Network

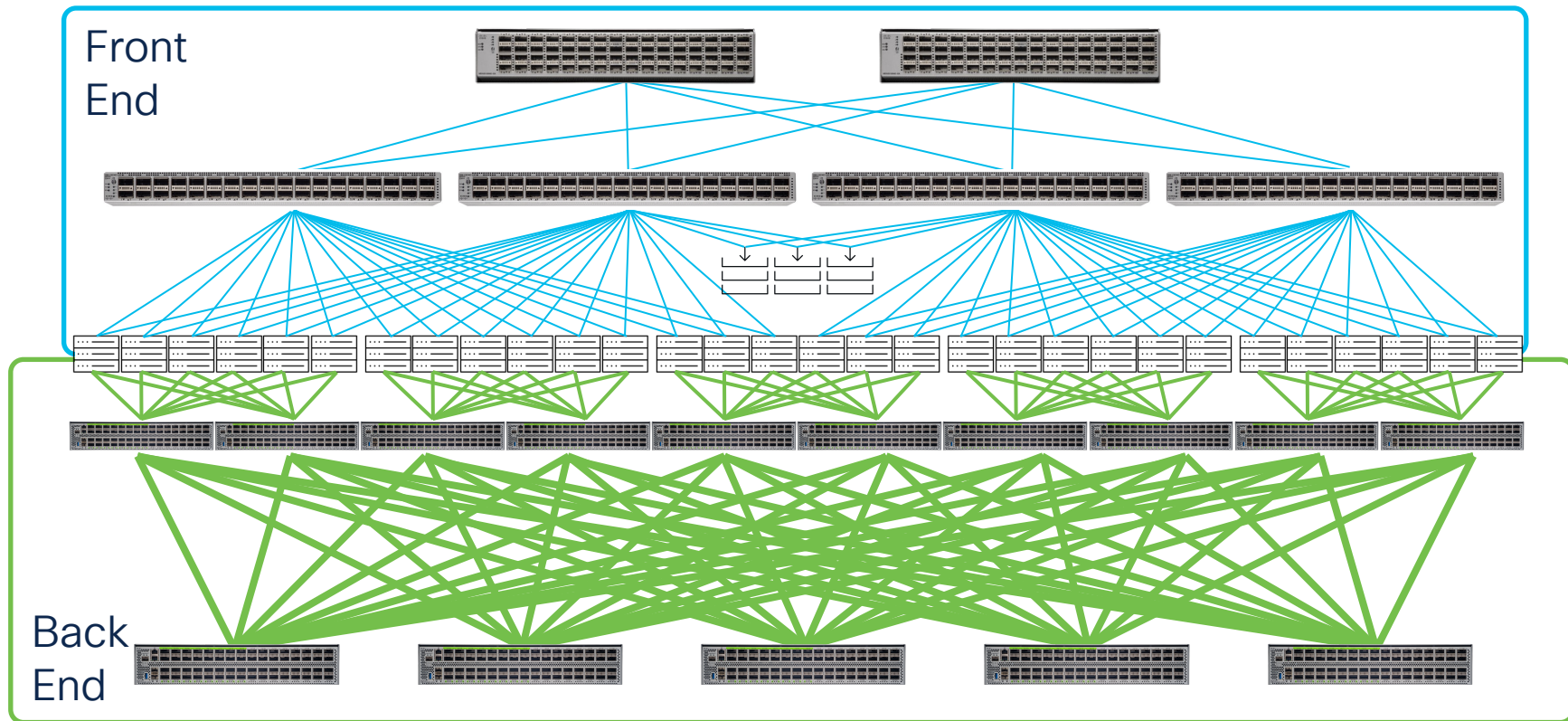


N9K-C9364C-GX



N9K-C9336C-FX2

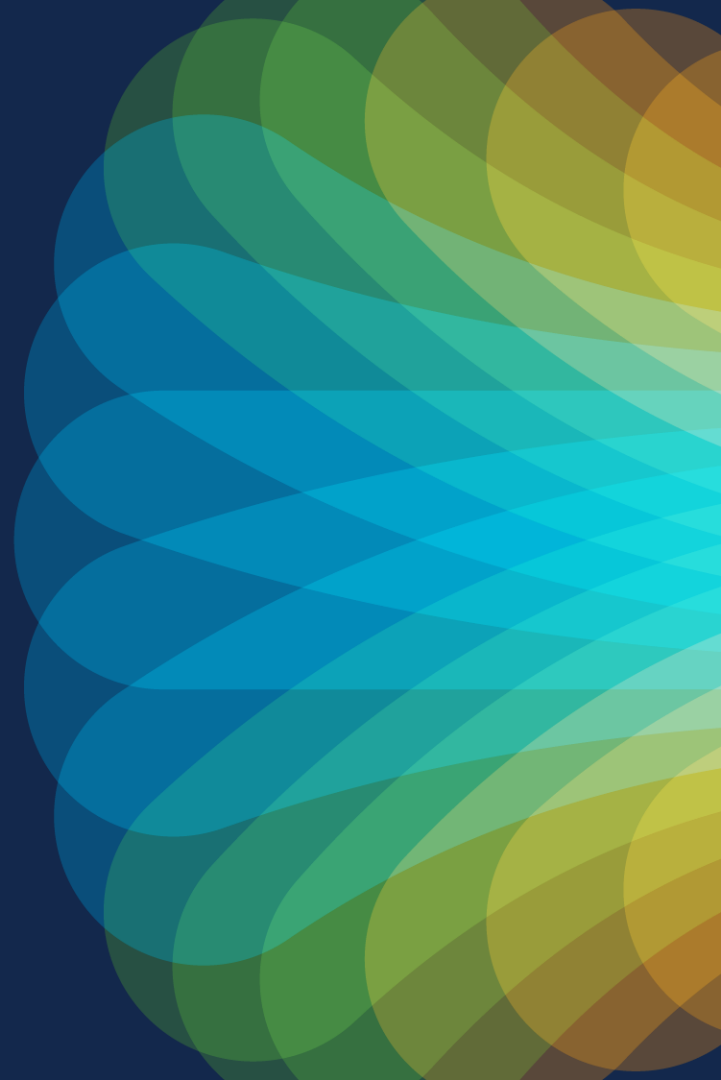
Front-End and Back-End Cluster Network



Customer Request #2 - Design

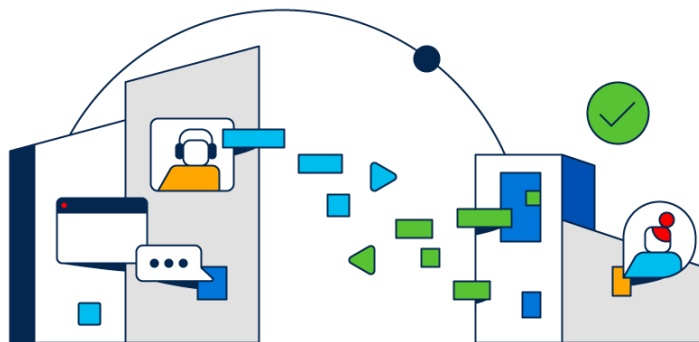
- Back-End Fabric is running BGP
 - Non-Blocking design
 - Congestion Management through ECN and PFC for optimal performance
 - Efficient traffic load-balancing in the fabric with UDF ECMP
 - Automated with Nexus Dashboard Fabric Controller
 - Visibility with Nexus Dashboard Insights
- Front-End Fabric
 - Congestion management for NFS traffic, with ECN and PFC
 - Automated with Nexus Dashboard Fabric Controller
 - Visibility with Nexus Dashboard Insights

Conclusion



Takeaways

- Network that you can build for this use case
- Use familiar data center fabric technologies
- Automate network for easier bring up and operation
- Visibility in network congestion, and bottleneck to troubleshoot and optimize



Recommended Sessions

- BRKAPP-2698 – Building a High-Performance AI Data Center using Nexus, UCS, and NVIDIA GPUs
 - Friday, Dec 8th | 9:00 AM – 10:30 AM AEDT
- BRKDCN-3939 – Cisco Nexus 9000 Architecture
 - Friday, Dec 8th | 1:30 PM – 3:00 PM AEDT

The Blueprint For Today



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Cisco Data Center Networking Blueprint for AI/ML Applications

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Introduction

Table of Contents

Introduction

RoCEv2 as Transport for AI Clu...

AI Clusters Require Lossless N... +

How to Manage Congestion Eff... +

How Visibility into Network Be... +

Network Design to Accommod... +

Conclusion

Related Materials

Introduction

RoCEv2 as Transport for AI Clusters

AI Clusters Require Lossless Networks

Explicit Congestion Notification (ECN)

Priority Flow Control (PFC)

How to Manage Congestion Efficiently in AI/ML Cluster Networks

How ECN Works

How PFC Works

Using ECN and PFC Together to Build Lossless Ethernet Networks

Using Approximate Fair Drop (AFD)



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main ▾ 1 branch 0 tags

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Code ▾

 allenrobel	Ignore .graffle files	6101d38 47 minutes ago	🕒 10 commits
	doc	Update with current 'show running-config ipqos'	1 hour ago
	inventory	Initial commit	5 days ago
	.gitignore	Ignore .graffle files	47 minutes ago
	AIML_Fabric.yml	Template name will probably change, so let's not hardcode it	2 hours ago
	AI_Cluster_QOS_template.template	Adding new QOS template	2 hours ago
	README.md	Add topology diagram	5 days ago
	ansible.cfg	Initial commit	5 days ago

☰ README.md

NDFC-AIML-Fabric

About

About

Ansible playbook to create an NDFC fabric which supports AI/ML workloads

 Readme

 0 stars

 2 watching

 0 forks

Report repository

Releases

No releases published

Packages

No packages published



The Blueprint For Today



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Preferred Networks, Inc. Eliminates Overlapping Investment and Network Bottlenecks

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Challenge



Table of Contents

Preferred Networks, Inc.

Challenge

Solution

Results and the future

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Preferred Networks, Inc. chose Cisco due to high reliability, quick response to the latest protocol, and hardware-based streaming telemetry and used Integrated Interconnect Network for deep-learning computing infrastructure into Ethernet and eliminated overlapping investment and network bottlenecks.

Executive Summary

Customer Name: Preferred Networks, Inc.

Industry: Artificial Intelligence

Location: Chiyoda-ku, Tokyo

Number of Employees: Approximately 300





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The bridge to possible

Thank you

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- Fixed switches instead of modular chassis for spines
- 100G Server Connectivity vs 400G
- Nexus 93600CD-GX leaf switches and Nexus 9332D-GX2B spines
- WRED vs AFD
- BGP for control plane