

Optical Circuit Switches in AI Networks

OCP Educational Webinar Series

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Community-driven hyperscale innovation for all

Optical Circuit Switches in AI Networks

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Agenda Overview

Market Overview

AI Network Challenges

Optical Circuit Switching Technology

Practical OCS Use Cases

Lumentum Optical Switching

Conclusion

Live Q&A

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New AI Era: Redefining Scaling Laws and Fueling Explosive Compute Demand

2022-2025: Gen AI

2025-2028: Agentic AI

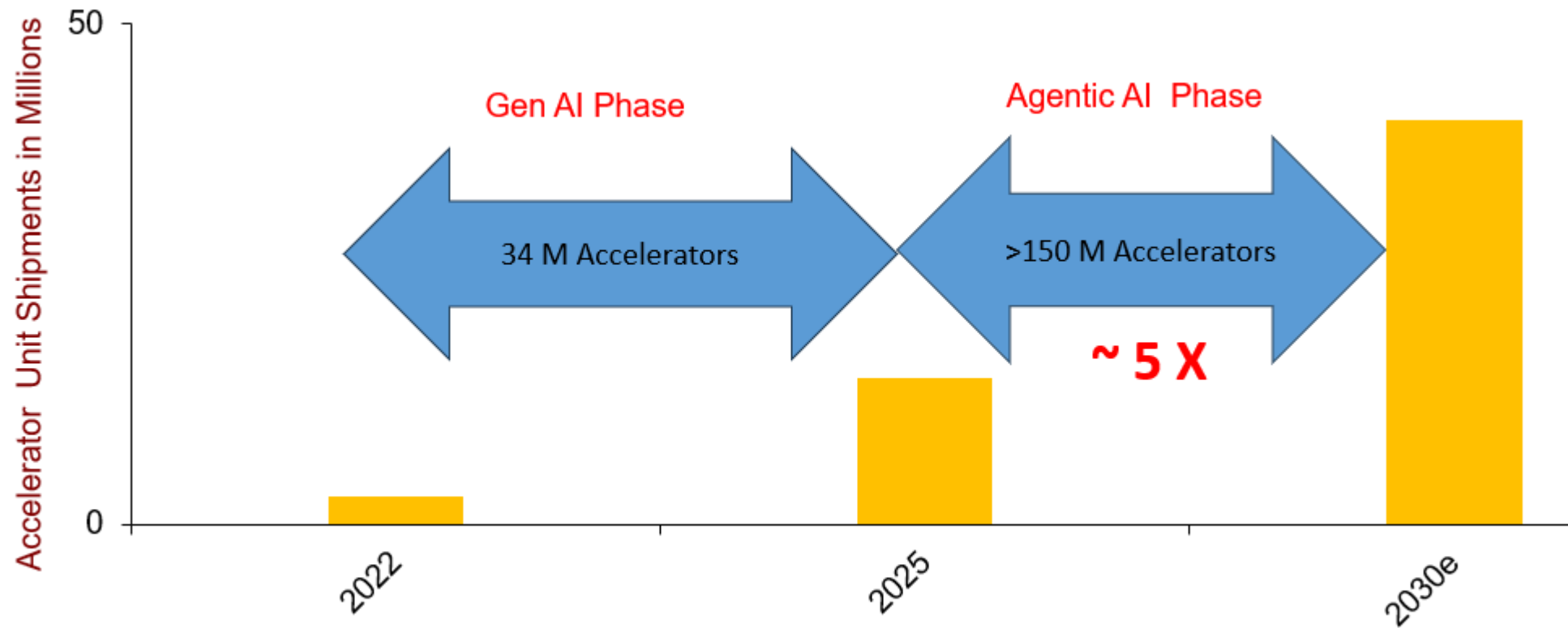
2028+: Physical AI



Number of Tokens Generated = 5X /year

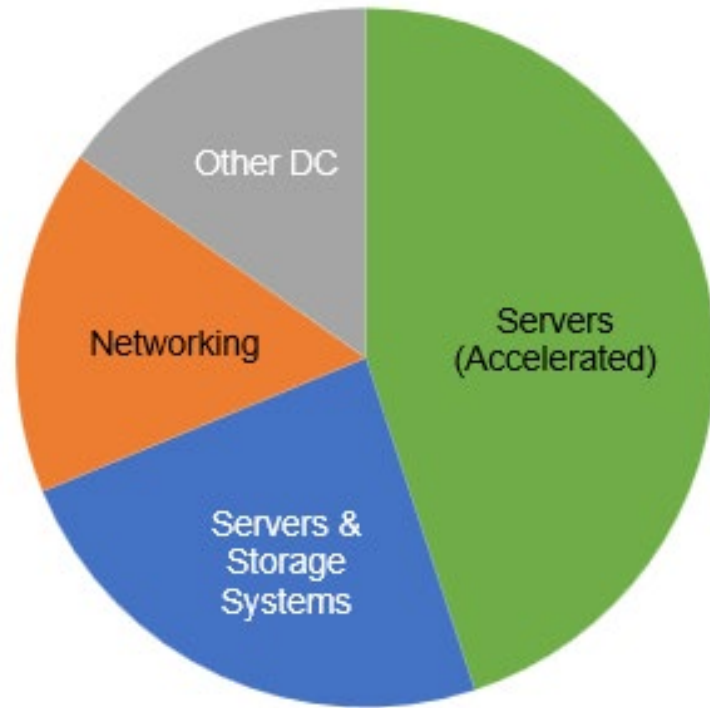
Source: NVIDIA

> 150M Accelerators to be Deployed in the Next 5 Years

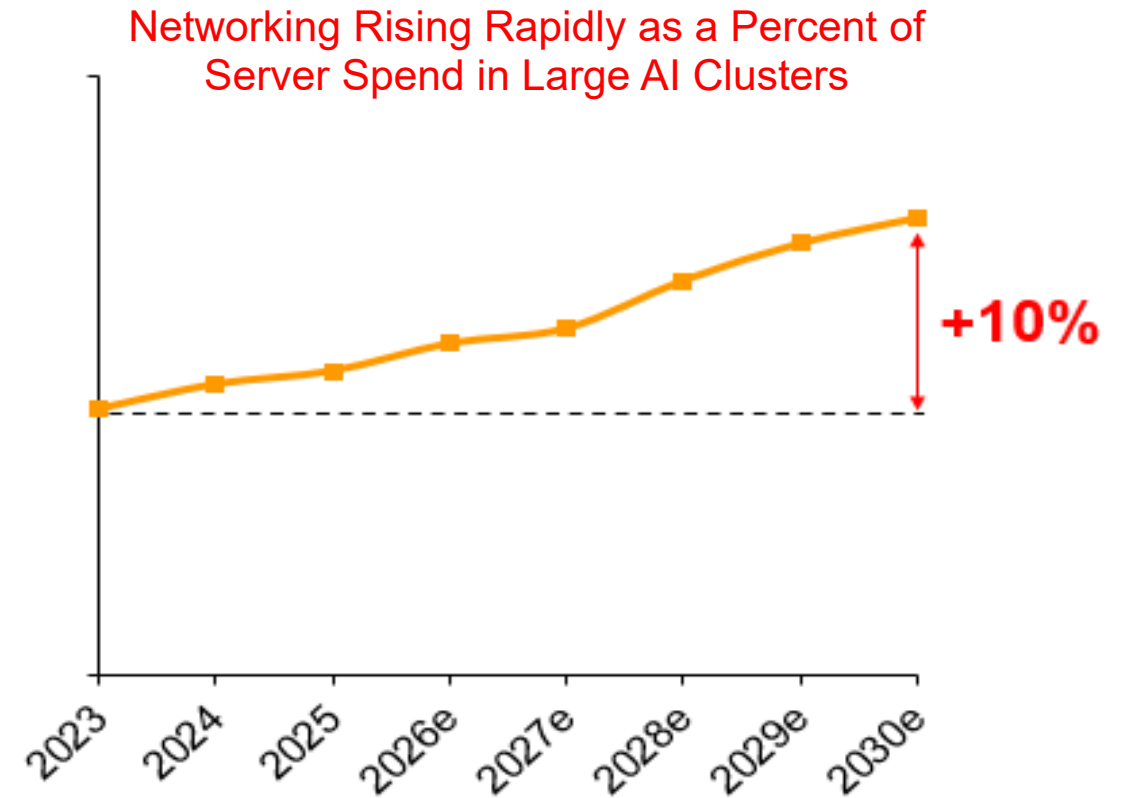


Source: Dell'Oro Data Center IT Semiconductors and Components Report

Data Center Capex Spent to Surpass \$1.7 T by 2030

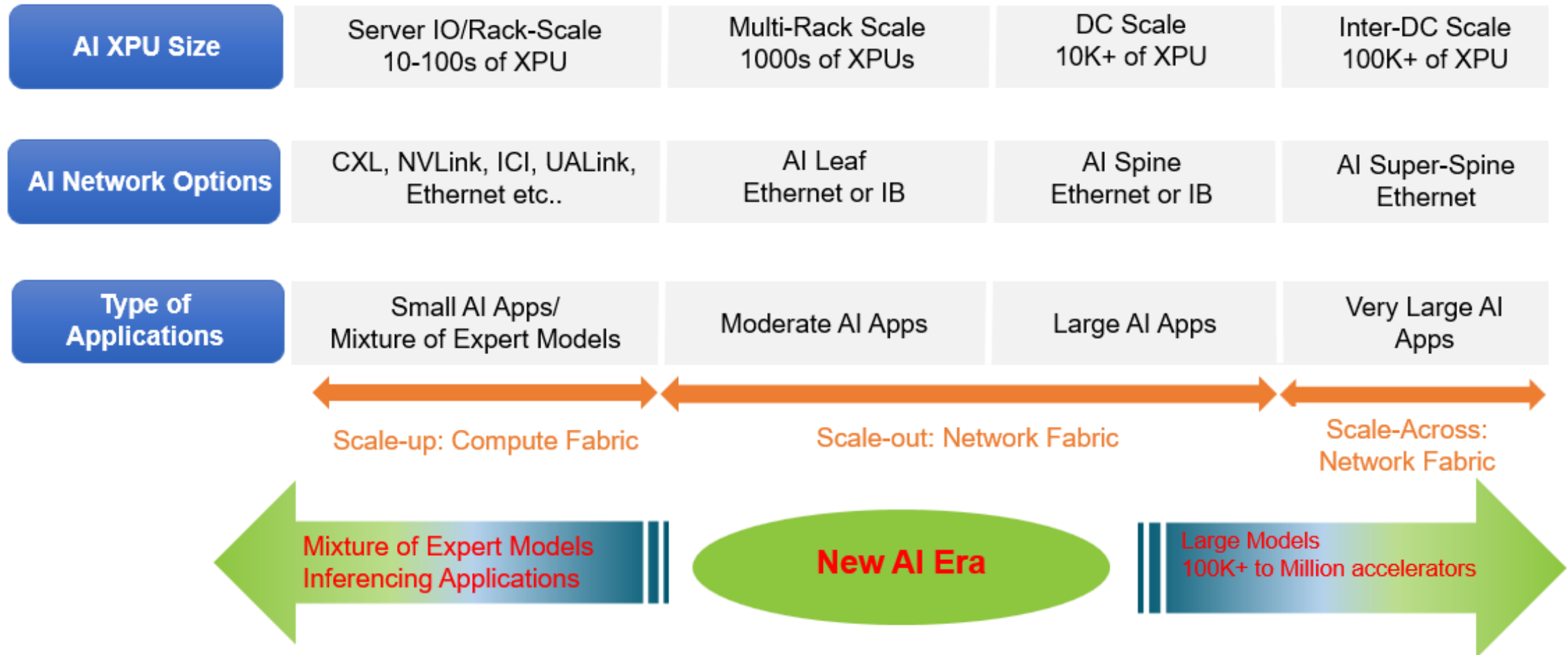


Data Center Capex
\$0.7T (2025) → \$1.7T (2030)



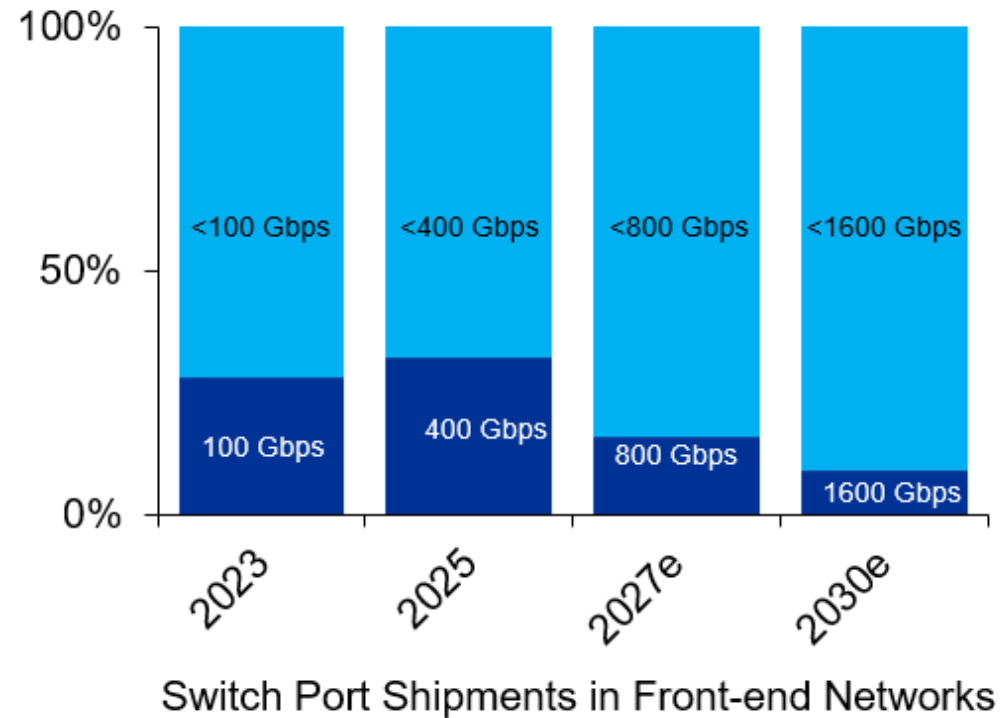
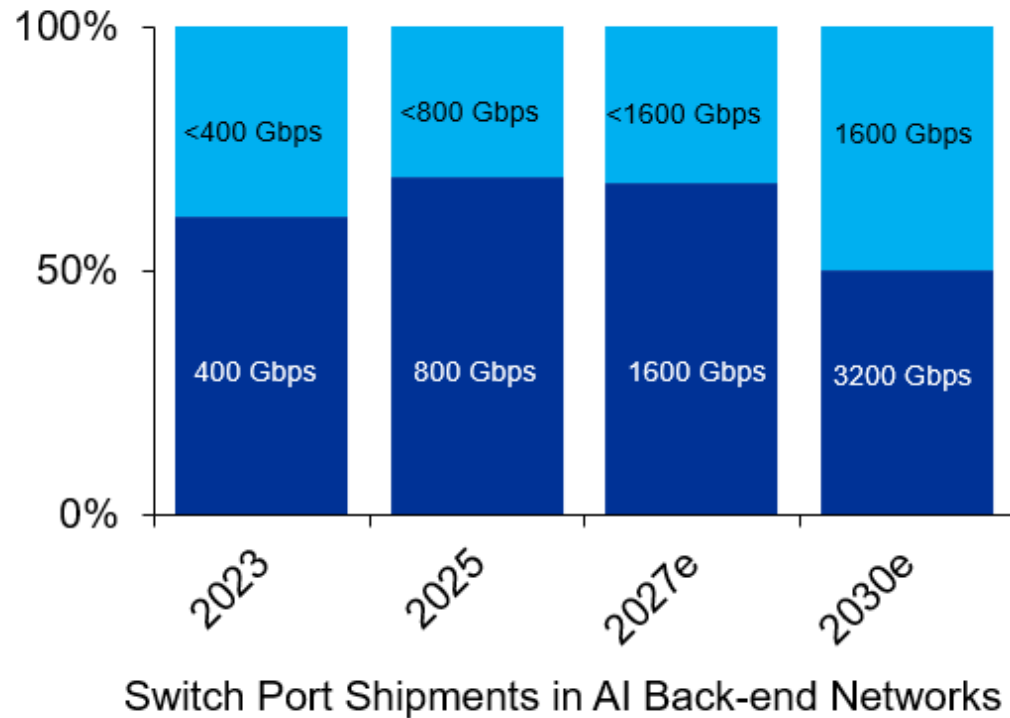
Source: Dell'Oro Data Center IT Capex Report

Different Networks within the AI Back-end Networks



Bandwidth Requirements in AI Networks

- AI clusters are network-bound
- AI networks need to operate at nearly 100%
- Refresh cycle: 18 to 24 months



Networking Challenges in Operating Large Scale AI Clusters

- **Network spending rising with the size of AI clusters:** The network is the computer
- **Network speed requirements:** doubling every two years
- **Fast refresh cycles:** ~2 years
- **Implication:** The electrical layer must be replaced at every speed generation, creating an unprecedented upgrade cadence

The Potential Role of OCS in Addressing AI Clusters Networking Challenges

Benefits		Savings	
Lower Latency	No OEO conversion is done to read packets	Opex	Increases efficiency and productivity
Speed Agnostic	It switches the photons regardless of the underlying electrical signal rate	Capex	Same OCS can be used over multiple electrical speed generations (400 Gbps,800 Gbps, 1.6 Tbps, 3.2 Tbps,...)
Increased Reliability	Fewer optical modules and switches in the network	Capex/Opex	Fewer parts to replace/more network uptime
Lower Power	It has fewer electronics inside the system, and the ports are passive optical connectors	Opex	Less demand on the electrical grid
Reconfigurable	Topology of an OCS grouping can be changed	Opex	With an NxN switch, an optical signal can be re-routed remotely without a person on-site to move a fiber from one port to another

OCS Adoption Progress Update

- **OCS is a mature, proven solution**, known over time as OOO switch, all-optical switch, optical switch, and OXC
- **Extensively deployed in WAN and carrier networks for over a decade** by tier-one operators with stringent performance and reliability requirements
- **Adoption expanding beyond Google's original deployment**
- **Use cases include spine, super spine, scale-up**
- **On the path for a multi-billion-dollar opportunity by 2030**

Agenda: AI Network Challenges

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AI Network Challenges

In an AI cluster network performance drives system performance

AI Networks Need



Massive Interconnect

- Challenge: Electrical switch radix is a limitation



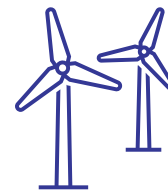
High Reliability / Availability

- Challenge: Huge number of elements drive more potential points of failure



Extreme Bandwidth

- Challenge: Switch ASIC BW is a constraint



Sustainable Power Scaling

- Challenge: Switch ASICs and optics DSPs are power hungry

Agenda: Optical Circuit Switching Technology

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Optical Circuit Switching

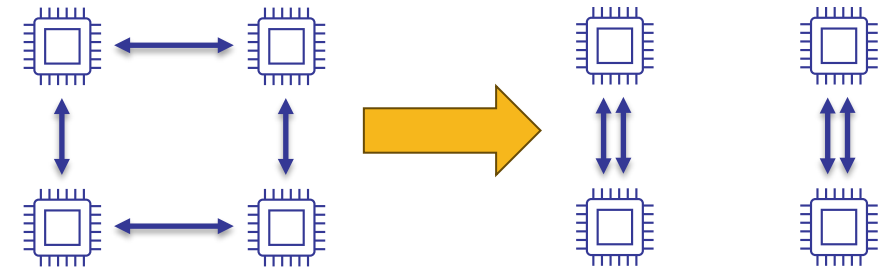
OCS allows dynamic reconfiguration of optical network links

Can happen at chip, box or fabric scale

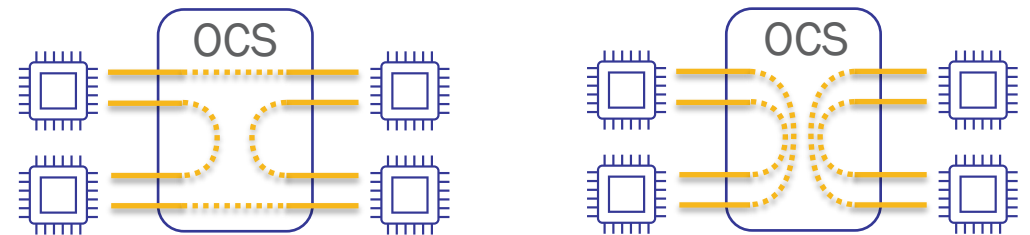
Typical Characteristics (box scale)

- Passive optical device
- No traffic processing is performed
- 1-3dB+ insertion loss
- Usually two-sided; all-to-all also possible
- Often supports bi-directional use
- Usually single fiber, multi-fiber possible

Logical Topology



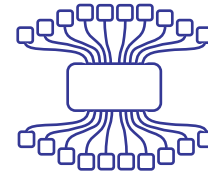
Physical Connections



OCS Benefits

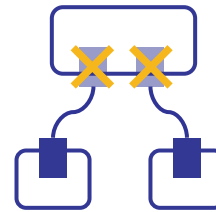
No O-E-O conversions at switch

- ✓ Reduced power consumption
- ✓ Link BW limited only by fiber capacity
- ✓ Highly deterministic, low latency
- ✓ Data rate and protocol agnostic



Natively high radix

- ✓ Enables flatter networks with fewer planes



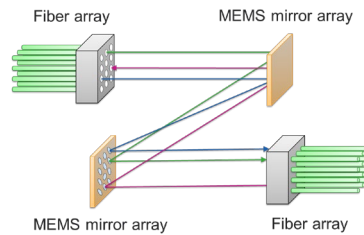
50% fewer optical modules in links

- ✓ Reduced capital cost
- ✓ Improved network reliability

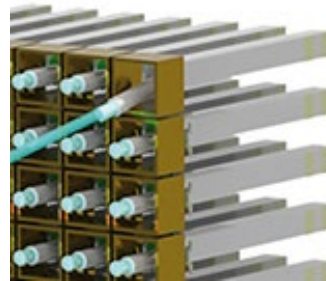
- OCS can bring significant benefits but needs to address the right applications
- Deterministic traffic patterns of AI workloads are a great fit for OCS

OCS Technologies

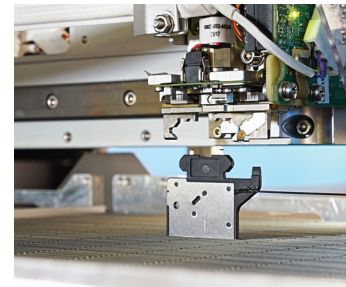
MEMS



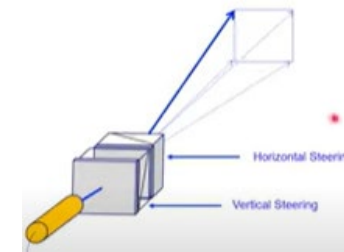
Piezo-electric



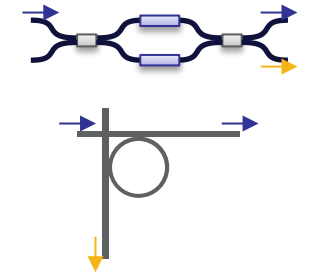
Robotic



Liquid Crystal



Waveguide
(SiP)

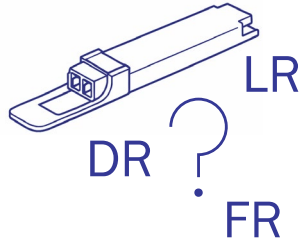


Insertion Loss	Low-Med	Low	Low	Low-Med	Med-High
Radix	High	High	Very High	Medium	Low-Med
Speed	Medium	Medium	Slow	Medium	Fast
Maturity in OCS*	>10 yrs	>10 yrs	>10 yrs	<2 yrs	<1 yr
Vendor Support	Many	One	Few	One	Many

* Maturity defined as years that a technology has been used in commercially available OCS devices

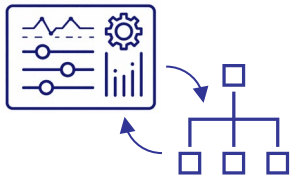
Image references: Lumentum [MEMS], Huber+Suhner Polatis [piezo-electric], Eaton [robotic], Coherent [liquid crystal]

OCS Adoption Considerations



Optics selection

- Link budget for OCS insertion loss and other optical impairments
- Single mode, single fiber optics preferred for OCS



New control plane requirements

- Physical layer topology management
- OCS is transparent to connected devices



Today's solutions are proprietary

- Community is working toward open standards and interfaces



OCP Optical Circuit
Switching Sub-Project



OCS Working
Group



Audience Poll Question

Which statement most closely matches your organization's position regarding Adoption of OCS switches

- a) We are using only electrical switches and don't envision to use OCS in the next 2-3 years
- b) We are using only electrical switches but we may deploy OCS in the 2-3 years
- c) We have already started to deploy OCS switches

Agenda: Practical OCS Use Cases

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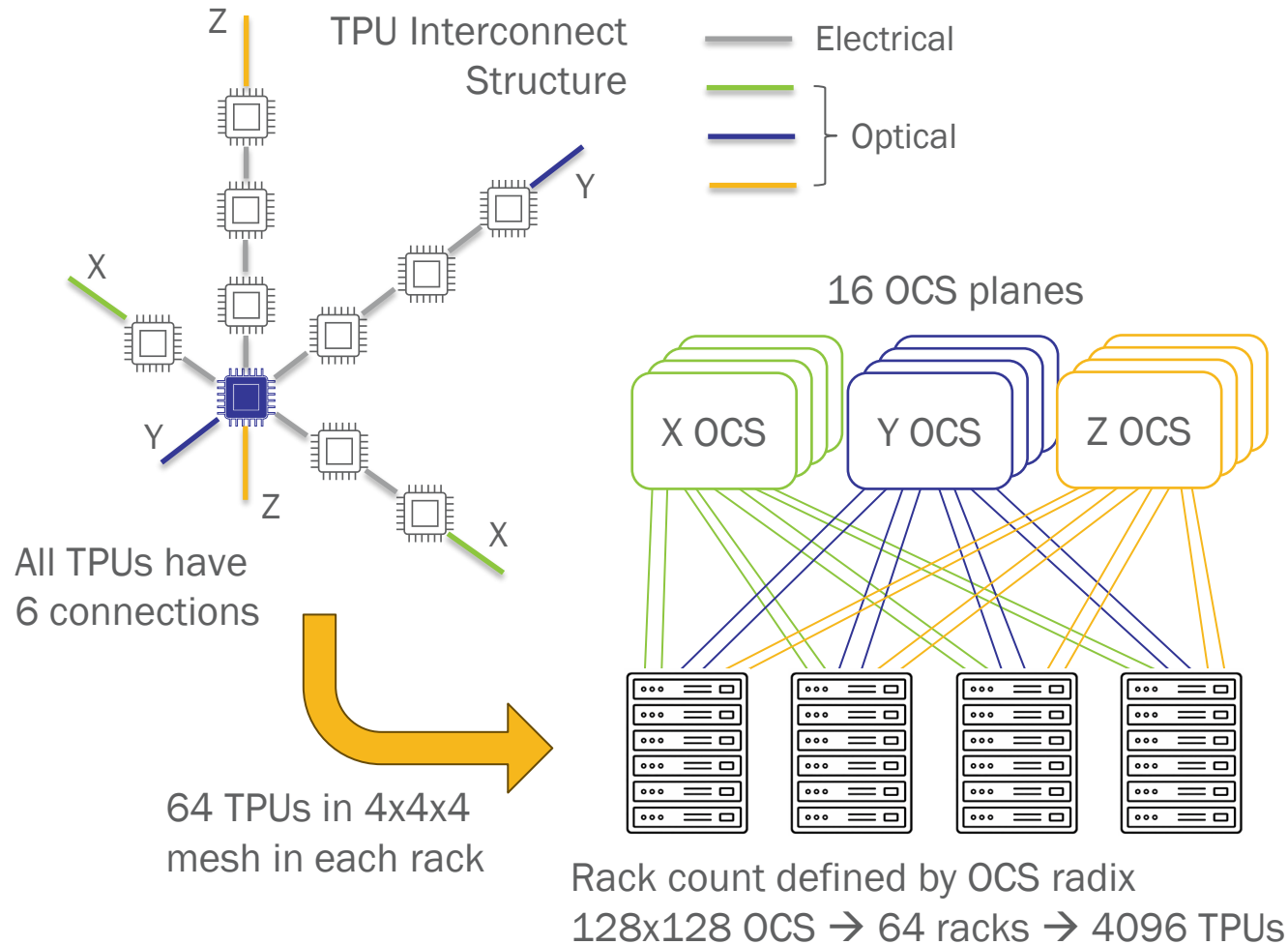
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Use Case 1: Google TPU Scale Up



OCS Network Role

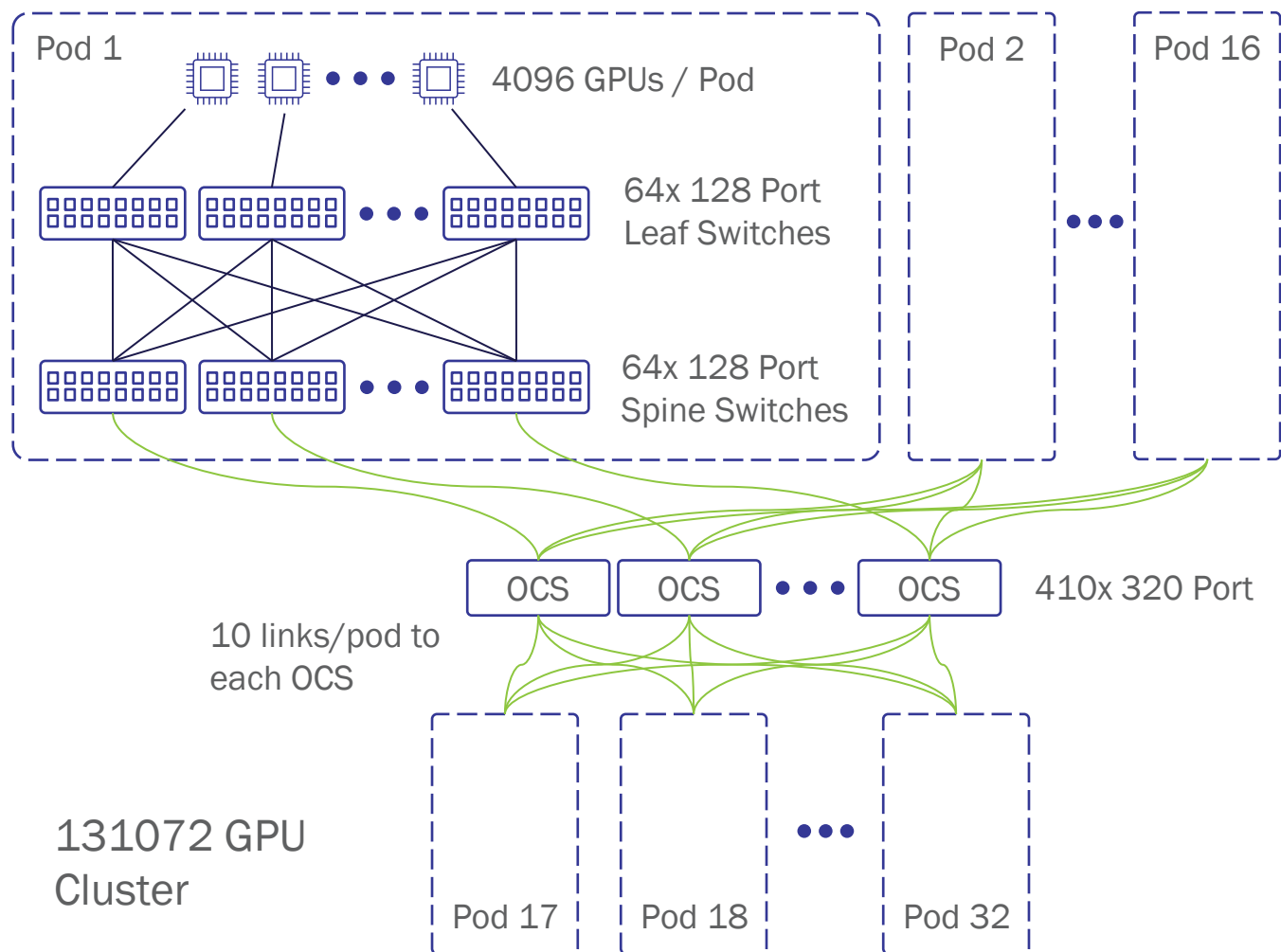
- TPU “cubes” are 64 TPUs in a rack with electrical ICI links in a 4x4x4 structure
- OCS extends ICI optically between racks to form slice with 3D torus network

Solution Benefits

- Very large scale up world size with simple, flat, flexible network
- Cost and power savings vs. EPS fabric
- Performance gains from optimizing topology to workloads
- Improved cluster scheduling and availability relative to fixed network
- Easy incremental deployment

References: *Lightwave Fabrics*, Google, ACM SIGCOMM '23 and *TPUv4*, Google, ISCA 2023

Use Case 2: Scale Out Super-spine



OCS Network Role

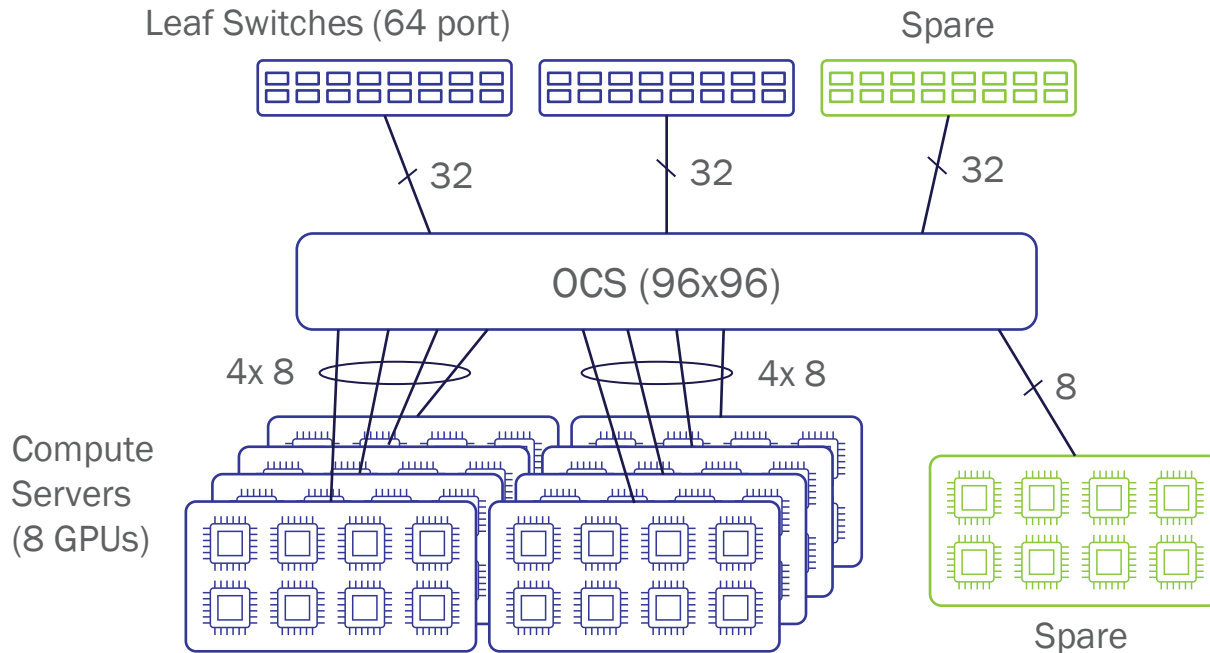
- Top layer interconnect in a very large scale AI cluster
- Creates reconfigurable dragonfly+ topology

Solution Benefits

- Massive scale with minimal packet switch layers
- Lower cost and power than adding an additional layer of packet switches
- Easy interconnect beyond building scale
- Flexible partitioning of the cluster from sub building to multi-campus

Use Case 3: AI Cluster Resiliency

↑ Additional Network Layers ↑



OCS Network Role

- OCS interconnects GPUs and packet switches or packet switch layers
- OCS does not replace an electrical switching layer in this use case

Solution Benefits

- Fast, automated recovery from cluster HW failures
- Maintains full performance after any link, compute or packet switch failure
- Allows N+1 sparing

Audience Poll Question

If you are interested in exploring OCS, which use case are you considering:

- a) Scale out spine
- b) Scale up
- c) Cluster resiliency
- d) Scale across/DCI
- e) Others

(For ON24: Question can be multi-select)

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Lumentum Optical Circuit Switching



Optical Switching: Building on telecom success

- Performance enabled by 20+ years of MEMS and free space optics design and deployment
- Manufacturing expertise and scale as the world leader in wavelength switching
- Reliability understanding informed by 130,000 WSS with 1 trillion mirror operating hours

Lumentum R300 OCS



300x300 Radix

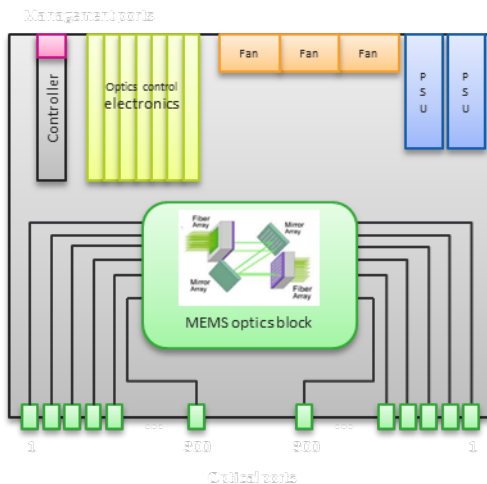
- Supports 300 duplex or 600 bidi links in two-side configuration

Key benefits

- Ultra wide band: O + C Bands
- Low IL: typically <1.5 dB in O band
- Use any data rate/modulation format today (or tomorrow)
- Field proven, ultra stable MEMS technology

Architected for the data center

- High availability with modular electronics, power and cooling
- SONiC-based OS with gNMI connection management



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Take Aways

- New Agentic AI Era is putting tremendous pressure on the network: The Network is the Computer
- Numerous challenges rising with operating large scale AI clusters: cost, power, latency, frequent upgrades, reliability, etc...
- OCS brings a solution to these challenges: lower cost, lower power, lower latency, speed agnostic, increased reliability
- Use cases and customers expanding beyond Google's original deployments
- OCS on the path to achieve multi-billion-dollar opportunity by 2030

Agenda: Live Q&A

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Live Q&A, with:

James Kelly

VP Market Intelligence and
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Sameh Boujelbene

VP, Ethernet Switch—Data Center and AI Networks for AI
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