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Tim Takala – RCDD

Vice President
Field Application Engineer APAC

Mobility is Driving…
Changing Network Architectures
& Transceiver Evolutions

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5 TOP TRENDS SHAPING NETWORKS

1. Mobility
2. Connected Devices
3. Cloud
4. The Edge
5. Disruptive Models

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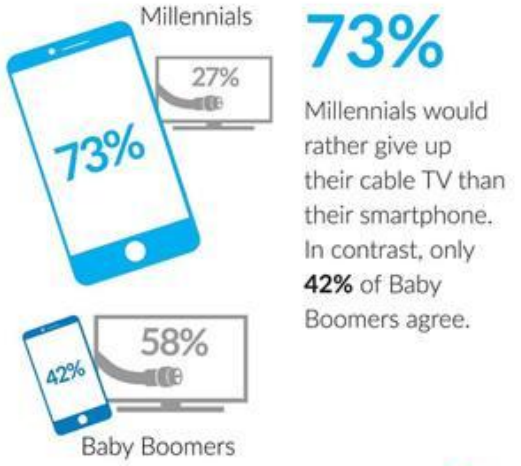
An increasingly mobile workforce

Workplaces will change dramatically in the next five years!

- Mobility (licensed/unlicensed) becoming more relevant to the Enterprise
- Wireless driving need for WAP backhaul speeds in excess of 5 Gb/s
- Connectivity requirements change to support new architecture



73%

Millennials would rather give up their cable TV than their smartphone. In contrast, only **42%** of Baby Boomers agree.

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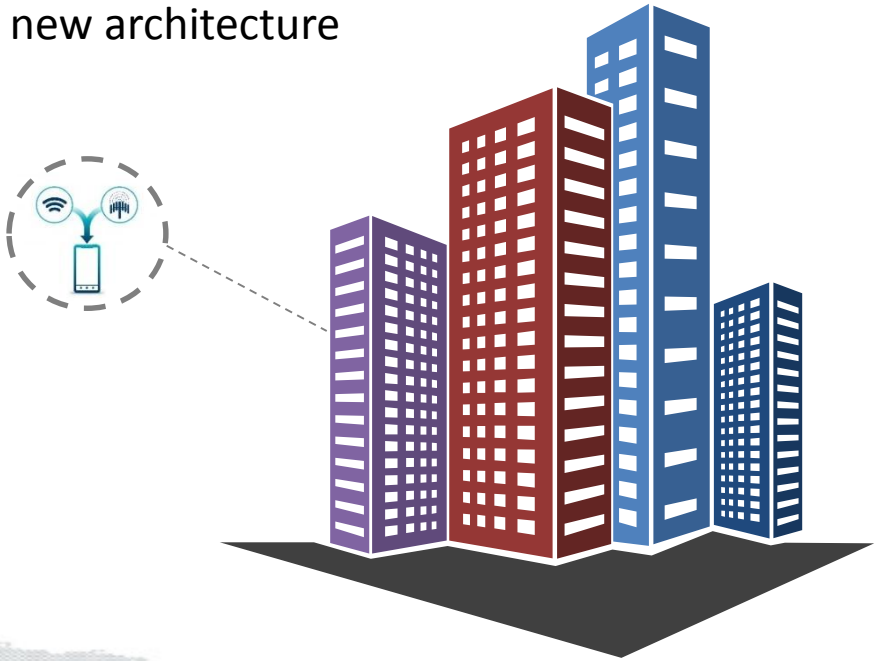

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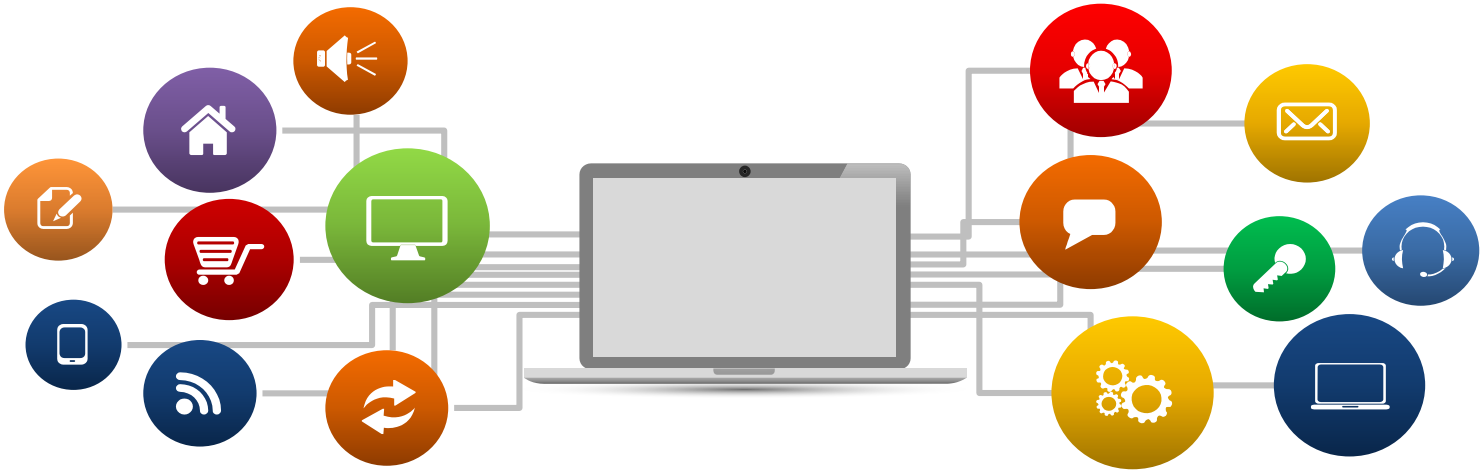
IoT driving growth of connected devices

IoT driving 12-17% annual growth in fixed line devices through 2020

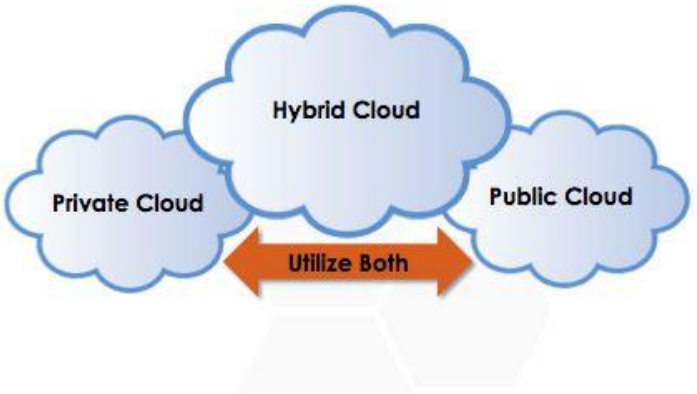
- Network extends into non-traditional IT environments
- Growing overlap between facility and IT systems
- Devices need more than Connectivity – **<u>They need POWER</u>**



Cloud Deployments

Enterprises assets moving to the cloud and multi tenant data centers (MTDC)

- Emerging Cloud segment growing at 16+%
- Enterprise options for sourcing DCs: Private, Public, Hybrid Cloud, MTDC
- Cloud is fastest growing Data Center Segment



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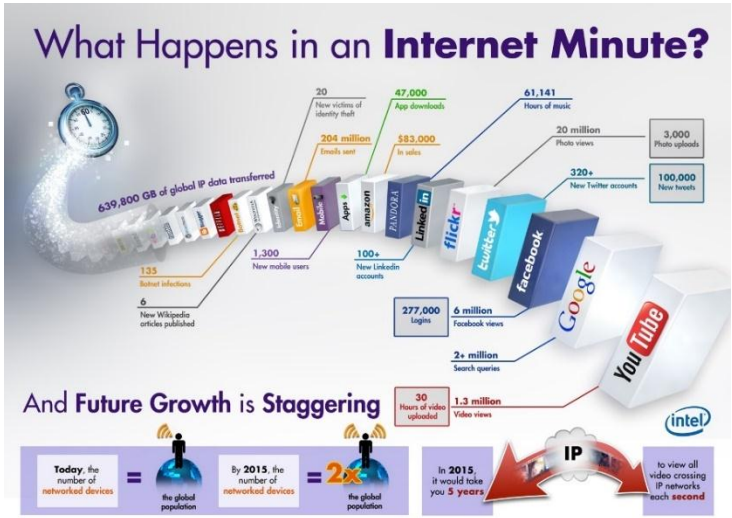
Closer to the Edge

Businesses and Consumers require lower latency

- By 2025 60% of cloud servers will be deployed in Edge
- Proliferation of dense, small-scale facilities
- Driven by Smart Cities and New Applications



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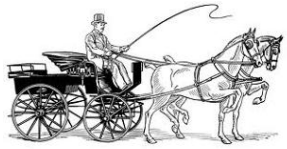
Disruptive technologies and business models

Disruptive technologies will transform infrastructure and user experience

- Open source platforms disrupting established models
- Software defined “X”
- Disruptive business Models Change “Everything”



Uber
world’s largest taxi company, **owns no vehicles**

Facebook
world’s most popular media owner, **creates no content**

Alibaba
most valuable retailer, **has no inventory**

Airbnb
world’s largest accommodation provider, **owns no real estate**

Source: Tom Goodwin

FITCH

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3 KEY QUESTIONS FOR THE FUTURE

1. What is changing?
2. Where is the impact?
3. How can I plan ahead?

Enterprise moving to Hybrid Cloud

Cloud Infrastructure is-

- Architected for failures and manageability
- Minimizes manual intervention
- Designed to survive rack failures
- Allows for rolling upgrades
- Singlemode and/or Multimode

Use common Hardware

- Pooled resources / automated self provisioning

Software Defined Storage/Networking

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WEB Scale Best Practices for Enterprises?

In Common?

- Uniform x86
- Local HDD and Flash
- Software driven
- Scale-out design

What is absent?

- Storage Networks
- SAN/NAS controllers
- Separate Storage management

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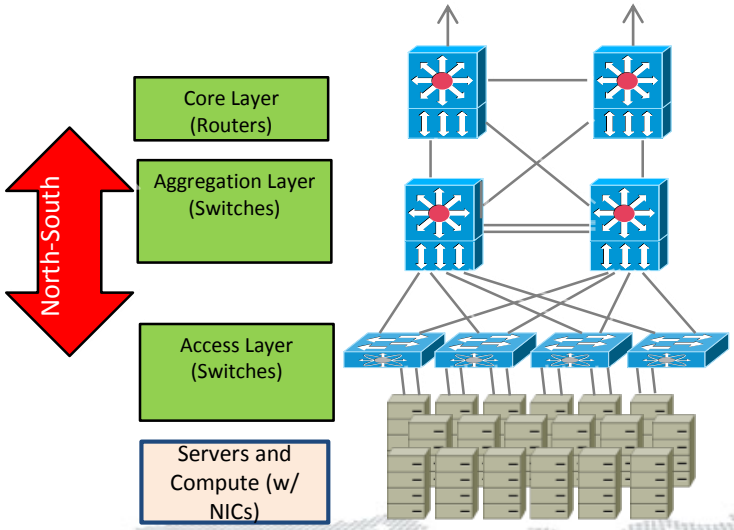
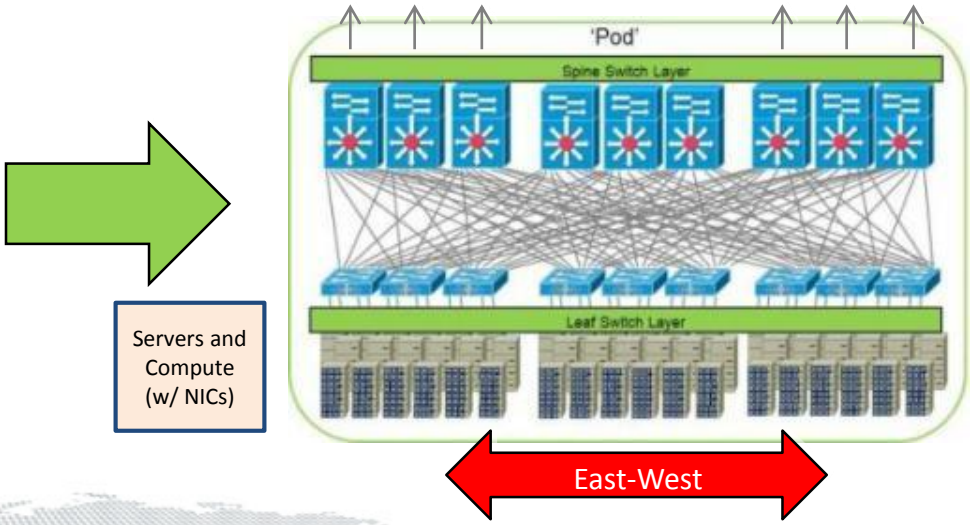
Hyperscale Architectures adapted for Enterprise Data Centers

- Historically Enterprise has been a 3-tier topology – aggregation and blocking architecture
- Cloud data center networks are 2-tier topology
  - Optimized for East-West traffic
  - Workloads spread across 10s, 100s, sometimes 1000s of VMs and hosts
  - Higher degree (10-20X) of east-west traffic across network (server to server)

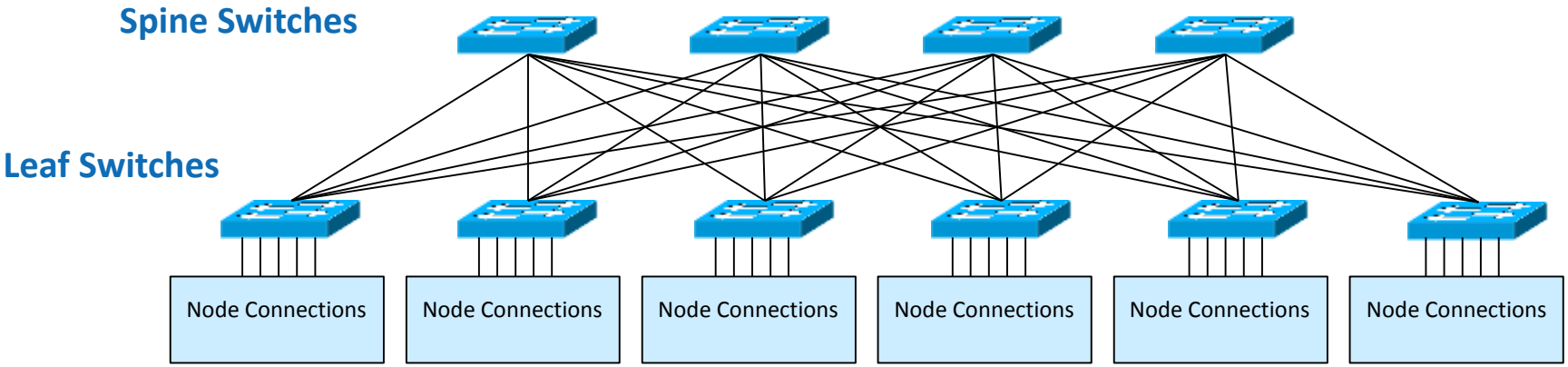
Traditional '3-tier' Tree Network

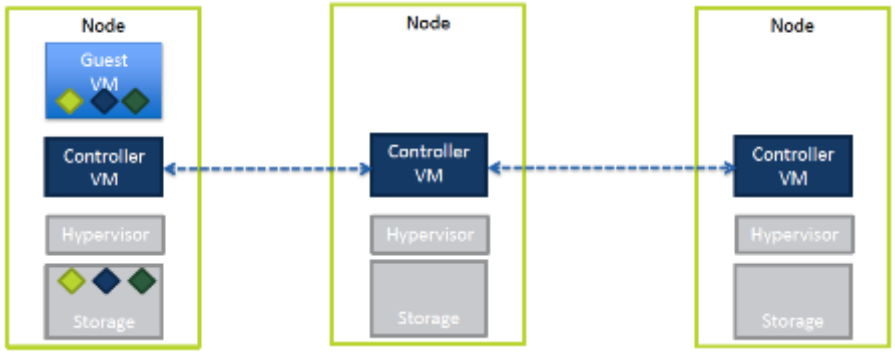


New '2-tier' Leaf-Spine Network



Enterprise Scale Fabric Networks





Software ties Compute, storage and control networks together

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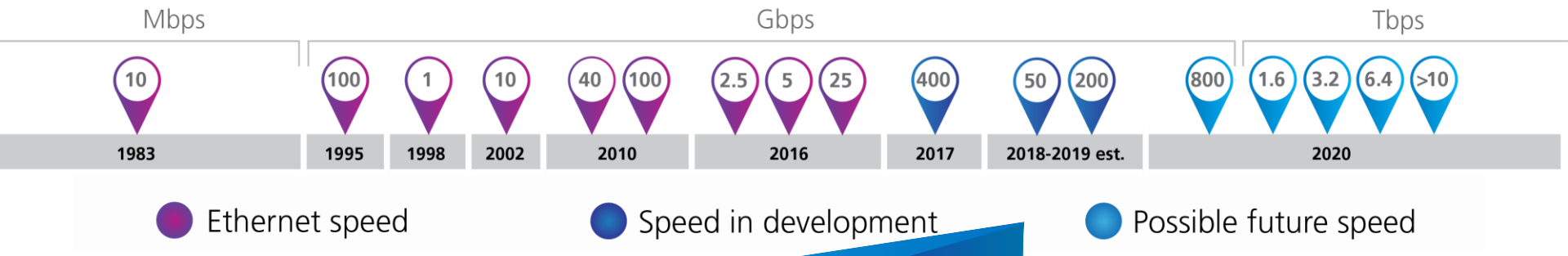
ETHERNET SPEED ROADMAP



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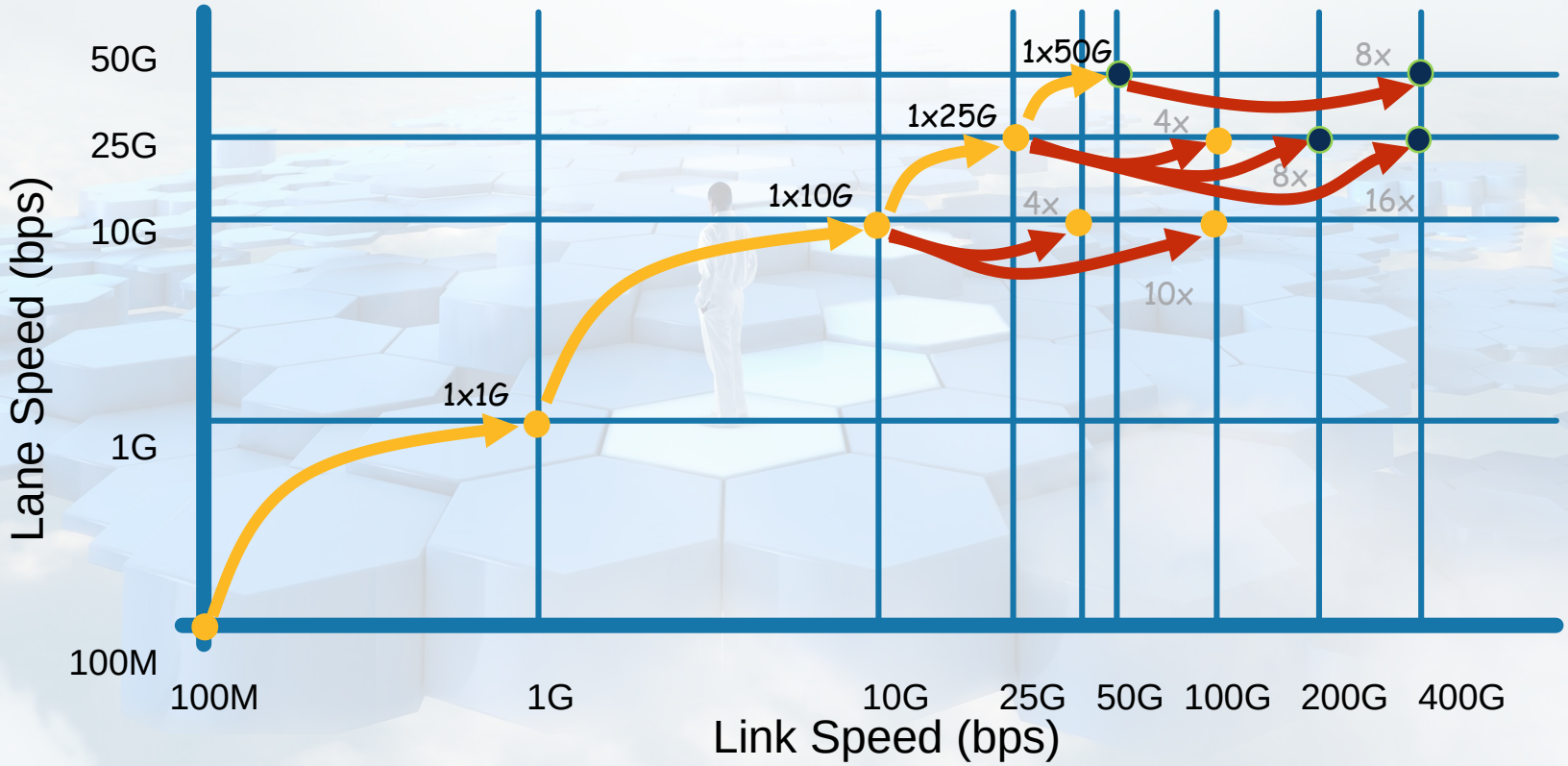
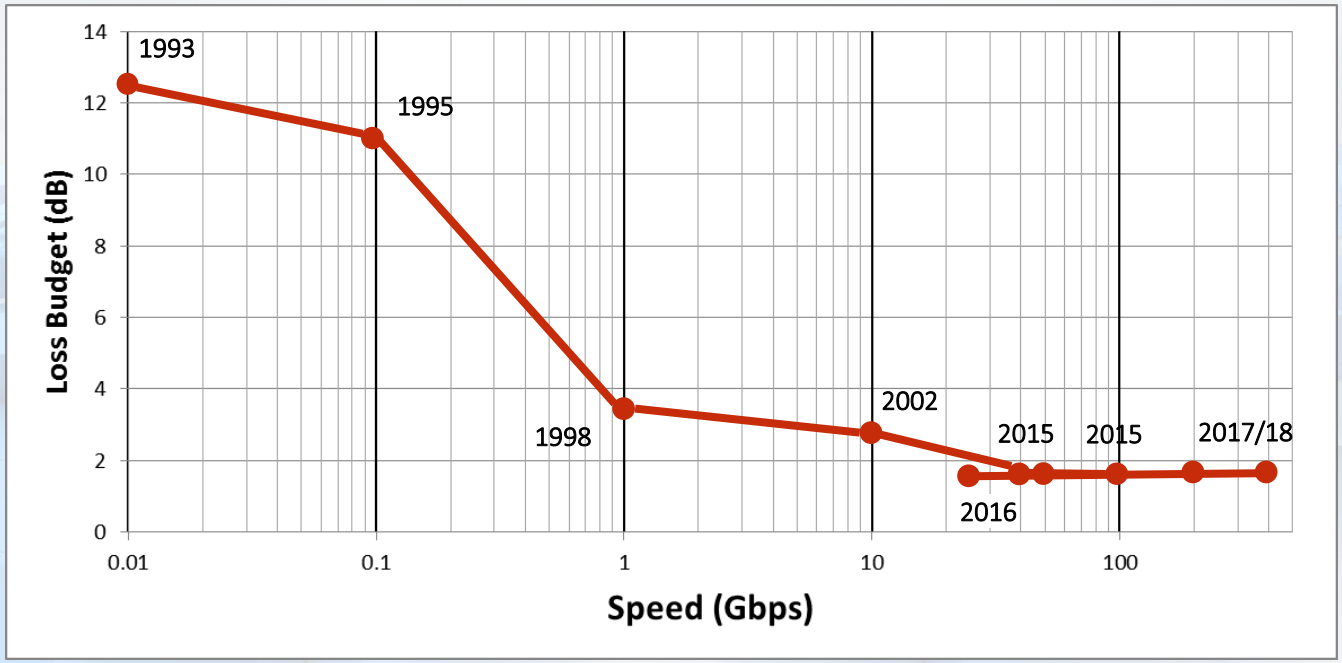
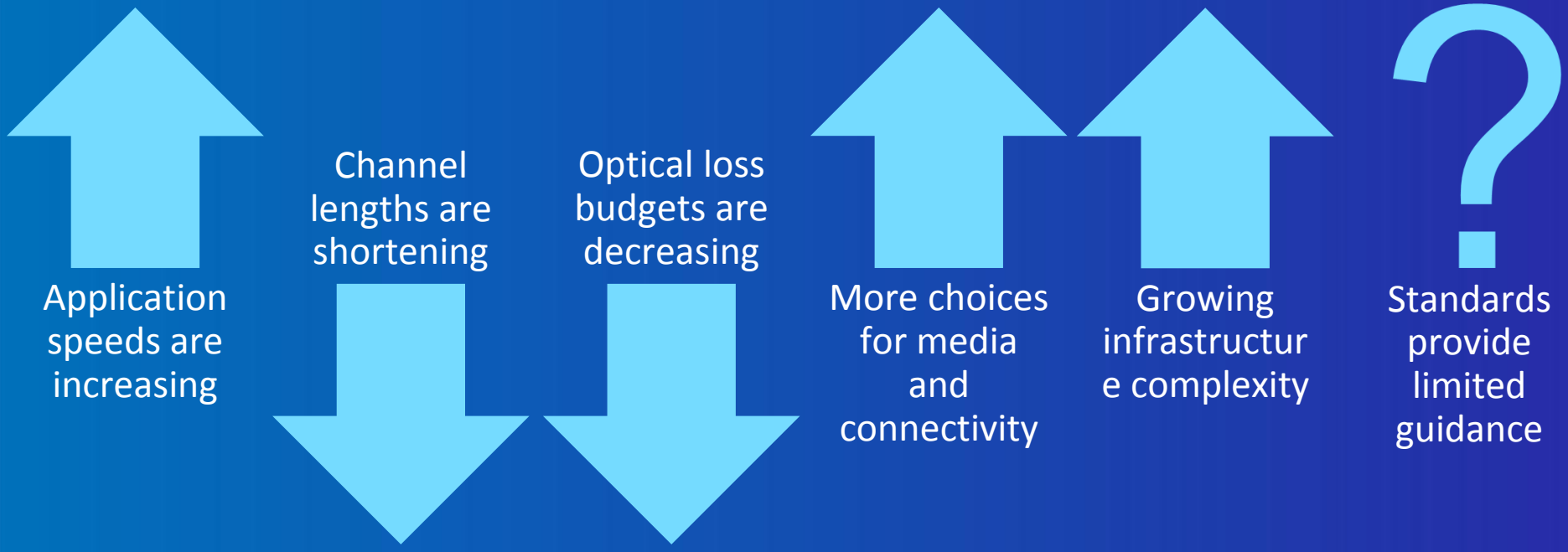
ETHERNET SPEED ROADMAP



ETHERNET SPEED ROADMAP



Migration to Higher Speeds comes with… CHALLENGES



What should your physical infrastructure do…?

Support current and future applications

Optimize channel distances

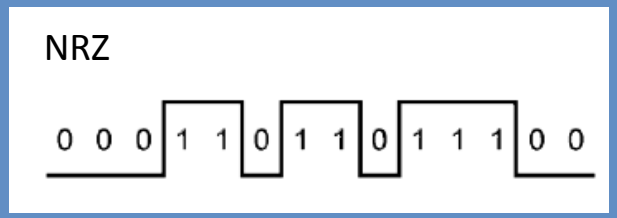
Allow for additional connections

Simplify optical media selection

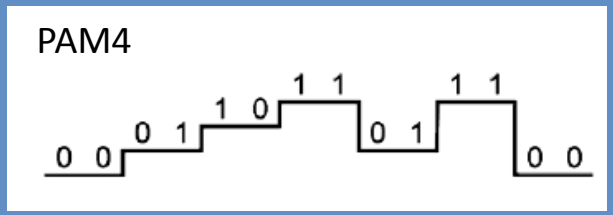
Provide for automated management

Enable flexible topologies

Achieving faster speeds on optical fiber



Faster Baud Rates



More bits per Baud

More fibers

More wavelengths

These techniques are now being applied for both multimode and singlemode fiber

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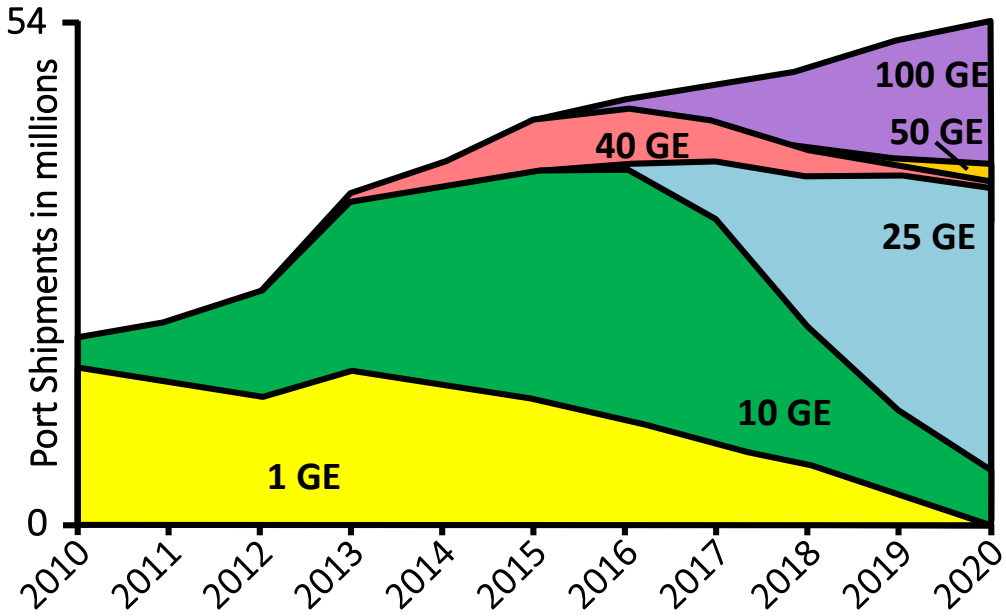
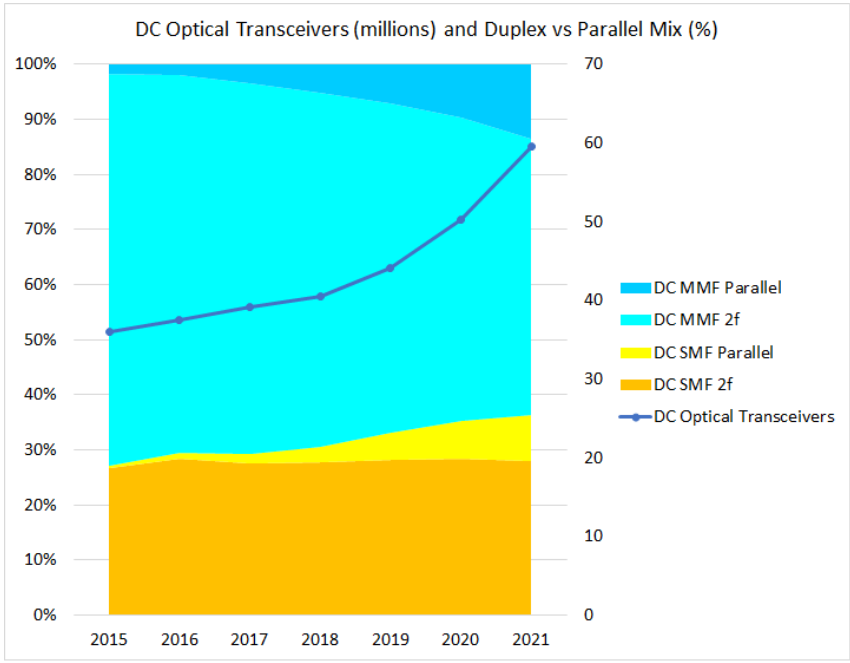
Optical Fiber in Enterprise Data Centers



Dell'Oro, Sept 2016



OVUM OC Q4 2016, for internal use only

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Data Center Optics Speed roadmap

# lanes			
16		400GBASE-SR16	
10	100GBASE-SR10		
8			
4	40GBASE-SR4	100GBASE-SR4	
2			
1	10GBASE-SR	25GBASE-SR	
Lane rate >	10 Gb/s	25 Gb/s	
Encoding >	NRZ		PAM-4

Data Center Fiber Support roadmap

# lanes				
16		400GBASE-SR16		
10	100GBASE-SR10			
8				
4	40GBASE-SR4	MMF	200GBASE-SR4	MMF/SMF
2			100GBASE-SR2	
1	40GBASE-SWDM4	100G-SWDM4	50GBASE-SR	
Lane rate >	10 Gb/s	25 Gb/s	50 Gb/s	
Encoding >	NRZ		PAM-4	

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Data Center Multimode Speed roadmap

# lanes			
16		400GBASE-SR16	
10	100GBASE-SR10		
8			
4	40GBASE-SR4	400G-SWDM4?	800G-SWDM4?
2			400G-SWDM4?
1	40GBASE-SWDM4	100G-SWDM4	200G-SWDM4?
Lane rate >	10 Gb/s	25 Gb/s	50 Gb/s
Encoding >	NRZ		PAM-4

SWDM4 supported by MMF

Data Center MMF/SMF Speed roadmap

Likely supported by both SMF and MMF

# lanes				
16		400GBASE-SR16		
10	100GBASE-SR10			1 Tb/s?
8				800 Gb/s?
4	40GBASE-SR4	400G-SWDM4?	800G-SWDM4?	400 Gb/s?
2			400G-SWDM4?	200 Gb/s?
1	40GBASE-SWDM4	100G-SWDM4	200G-SWDM4?	100 Gb/s?
Lane rate >	10 Gb/s	25 Gb/s	50 Gb/s	100 Gb/s
Encoding >	NRZ		PAM-4	

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IEEE considering WDM options for 200G and 400G

Technical options for next-gen MMF PMDs

Technology (per fiber)	1 fiber pair	2 fiber pairs	4 fiber pairs	8 fiber pairs	16 fiber pairs
25G-λ NRZ	25G-SR		100G-SR4		400G-SR16
50G-λ PAM4	50G-SR	100G-SR2	200G-SR4	400G-SR8	
2x50G-λ PAM4	100G-SR1.2	200G-SR2.2	400G-SR4.2		
4x25G-λ NRZ	100G-SR1.4	200G-SR2.4	400G-SR4.4		
4x50G-λ PAM4	200G-SR1.4	400G-SR2.4	800G-SR4.4		

Technology options for 200 & 400 Gb/s links over fewer MMF fiber pairs

Existing IEEE standard

In progress in 802.3bs, cd

Multi-Wavelength Nomenclature

SRm.n m = # fiber pairs

n = # wavelengths

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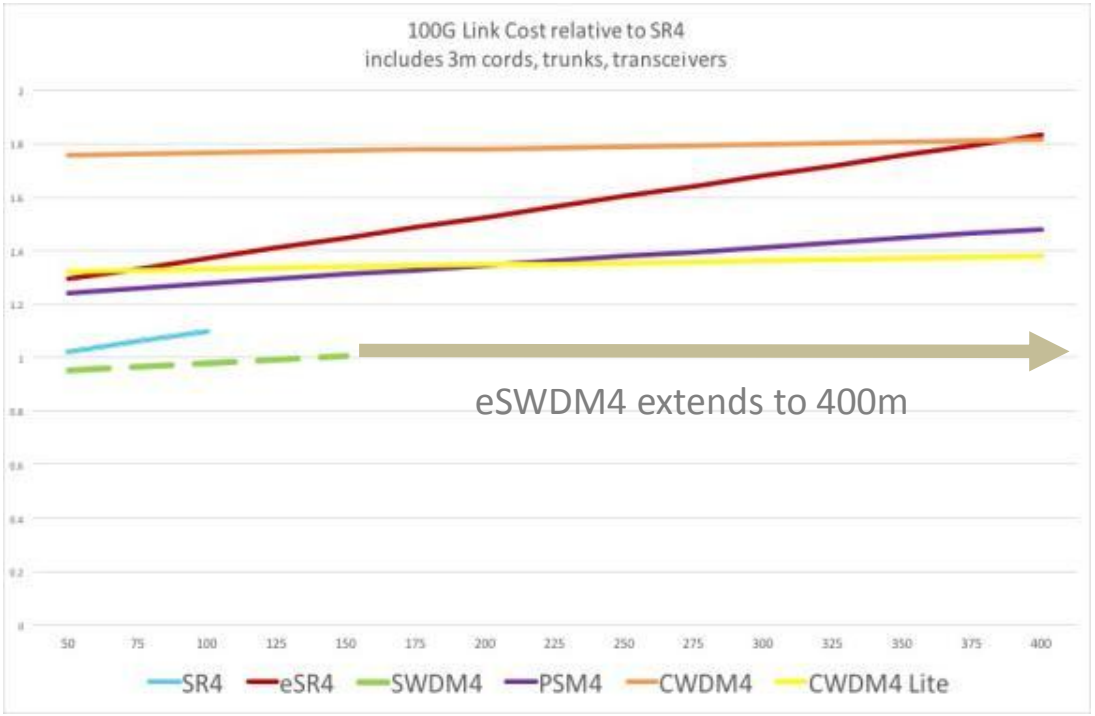
Relative link costs for Data Center Applications

- Link cost includes Transceivers and cabling (Trunks, Modules, Cords)
- Shows the relative capital cost for the applied solution
- Cost advantage for some applications is only better for short links
- With the introduction of eSWDM4 @400m on OM5 the reach for cost-effective Data Center solutions for SM and MM will be very similar



- **SWDM4 and eSWDM4 lower total cost options for 100G moving forward**
- **Cost difference is little or none with 40G**

Which MPO for Migration to Higher Speeds?

MPO-24	MPO-12	MPO-8
		
Future ready Lowest cost duplex support for multimode applications Highest panel density	**Large installed base** Existing multimode and singlemode preterm deployments Familiar interface and trunks	**Supports QSFPs** For multimode and singlemode transceivers and breakouts Lowest panel density

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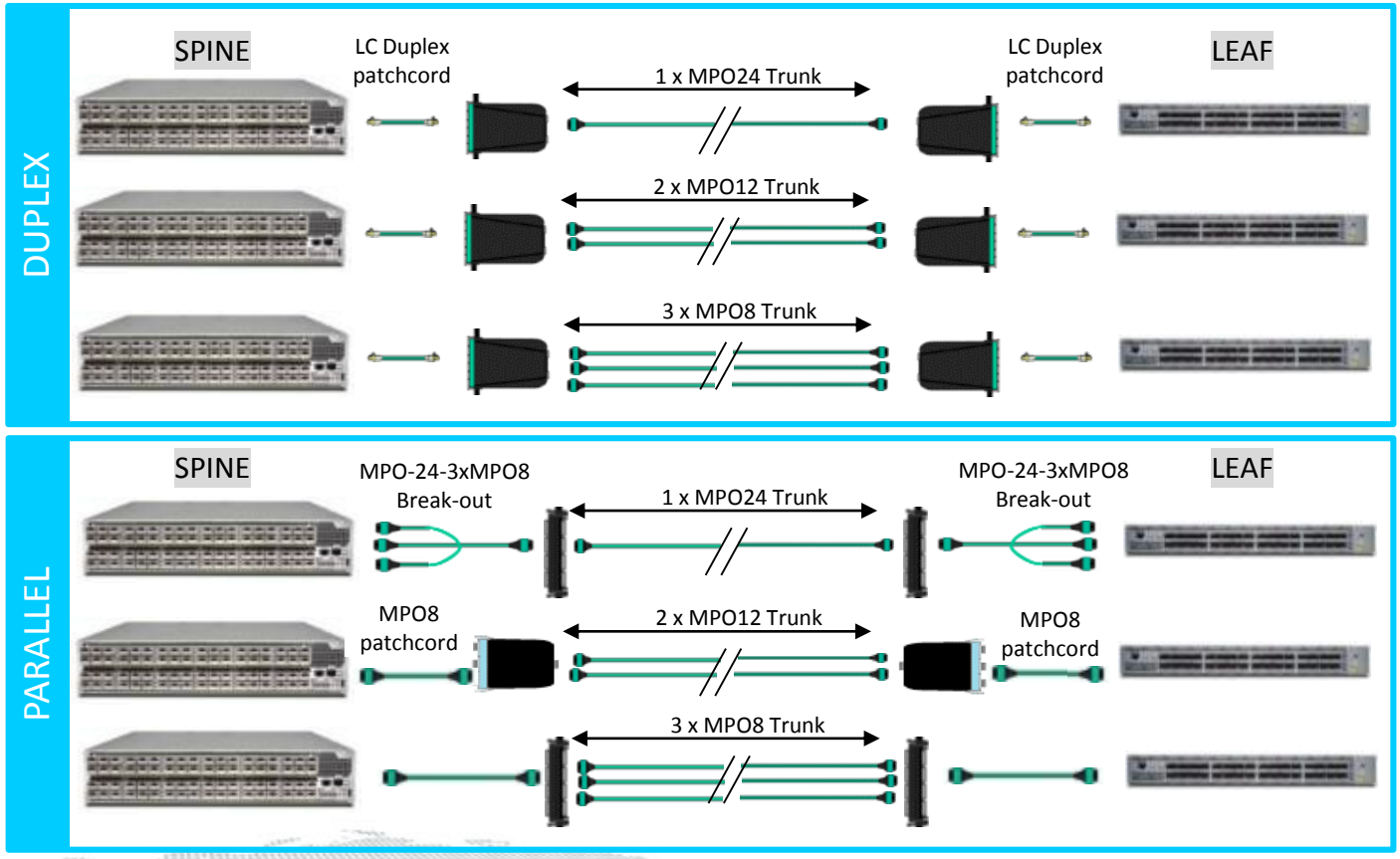
MPO24 vs MPO12 vs MPO8 for MMF trunks

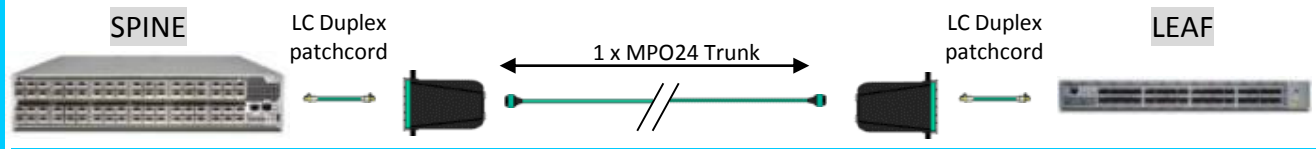
Leaf-Spine Applications on multimode fiber	
Application	**#Fibers**
10GBASE-SR	**2**
40G-SR4	**8**
40G-BiDi	2
40G-SWDM4	2
100G-SR4	**8**
100G-SR2	***4***
100G-SWDM4	2
100G-BiDi (?)	2
200G-SR4	***8***
200G-SR1.2 (?)	2
400G-SR4.2/4.4 (?)	8
400G-SR2.4 (?)	4
400G-SR1.4 (?)	2



Advantages of MPO24 for MMF trunks

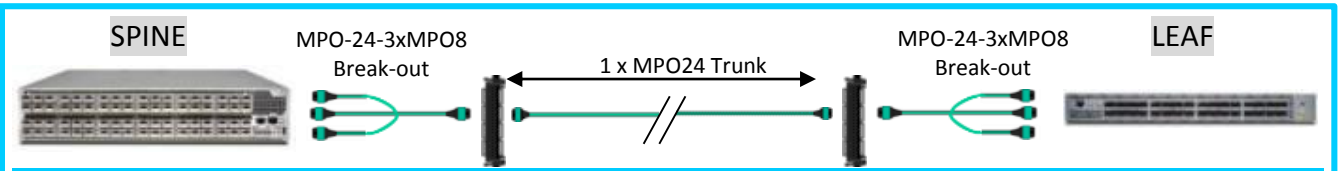
Leaf-Spine Applications on multimode fiber	
Application	**#Fibers**
10GBASE-SR	**2**
40G-SR4	**8**
40G-BiDi	2
40G-SWDM4	2
100G-SR4	**8**
100G-SR2	***4***
100G-SWDM4	2
100G-BiDi (?)	2
200G-SR4	***8***
200G-SR1.2 (?)	2
400G-SR4.2/4.4 (?)	8
400G-SR2.4 (?)	4
400G-SR1.4 (?)	2

DUPLEX



Fastest Installation
Best pathway efficiency
Lowest cost

PARALLEL



Fastest Installation
Best pathway efficiency
Highest panel density
Lowest cost

Which way – Let's explore

- SM or MM, WB – all are good choices for Enterprise DCs
  - We support all options equally well – any direction is good for us and our customers
  - We can offer some useful data that customers might use to make their choice
- HD and UD offer intelligence – a key differentiator
- EHD offers higher MPO density and higher 1U density
  - Great for MPO-MPO trunking
- Most enterprise use MMF – we cover 8,12,24f MPO
- SMF offering is LL and ULL in 8f and 12f MPO
  - Demand is for 8f and 12f SMF topologies
  - Higher data rates driving demand for lower loss making LL solutions unusable
  - SMF ULL makes benefits of preterm solutions viable
- Optics: duplex, parallel or both – extensive options

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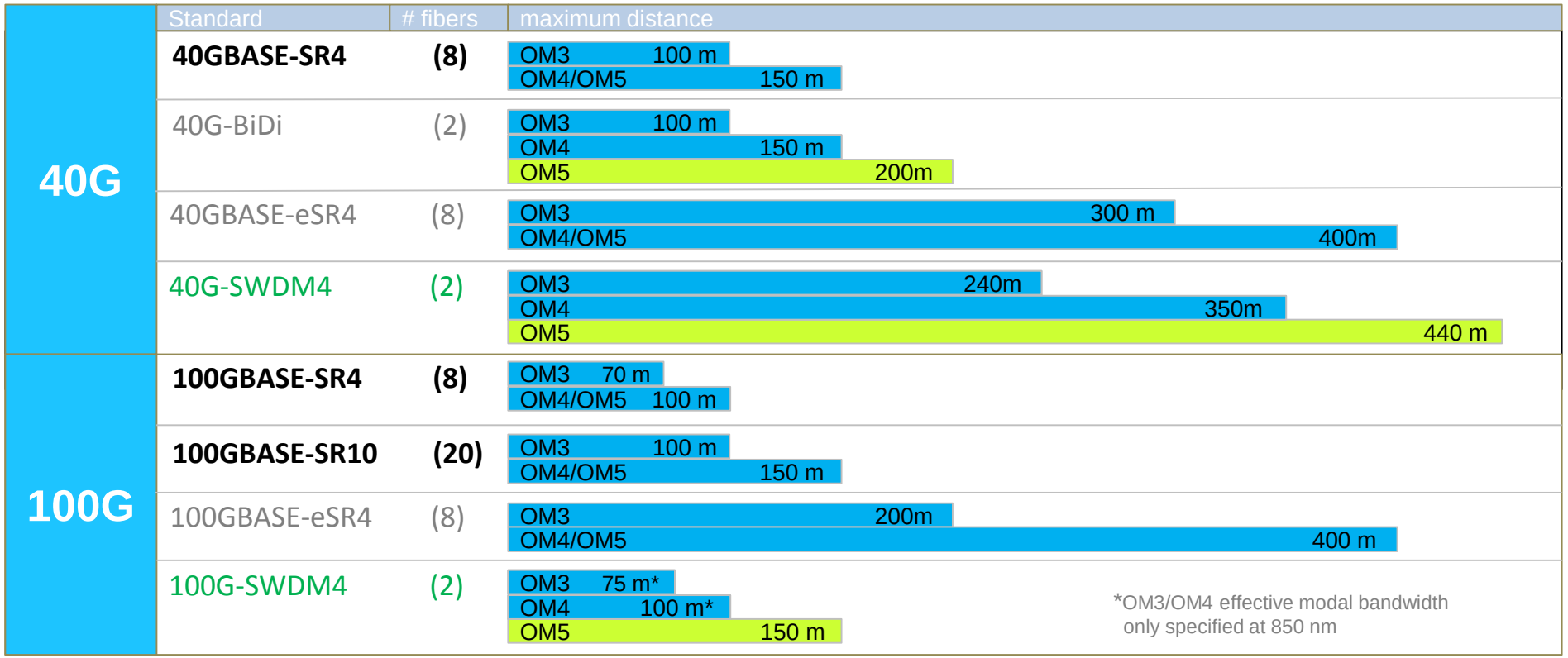
40G/100G Applications and Multimode Fiber

Maximum reach based on Standards, MSAs and/or vendor specifications



"In addition to supporting the same 850nm and 1300nm applications as OM4, *OM5 provides advantage in the support of future applications using WDM in the wavelength range 850nm to 953nm*" *(FDIS ISO/IEC 11801-1)*

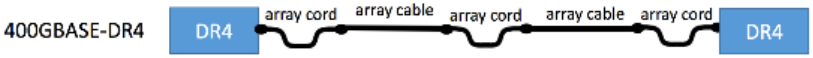
Going the Extra Distance

	Standard	# fibers	maximum distance
40G	**40GBASE-SR4**	**(8)**	OM3 100 m OM4/OM5 215 m
	40G-BiDi	(2)	OM3 100 m OM4 150 m OM5 210m
	40GBASE-eSR4	(8)	OM3 300 m OM4/OM5 500 m
	40G-SWDM4	(2)	OM3 240m OM4 350m OM5 460 m
100G	**100GBASE-SR4**	**(8)**	OM3 70 m OM4/OM5 130 m
	100GBASE-SR10	**(20)**	OM3 100 m OM4/OM5 150 m
	100GBASE-eSR4	(8)	OM3 200m OM4/OM5 300 m
	100G-SWDM4	(2)	OM3 75 m OM4 100 m OM5 150 m

Refer to the SYSTIMAX Performance Specifications Volume 6 for a detailed list channel specifications **including guaranteed supportable distances as a function of number of connections in the channel**

DC Short Reach SM optics = Reduced Power Budgets!

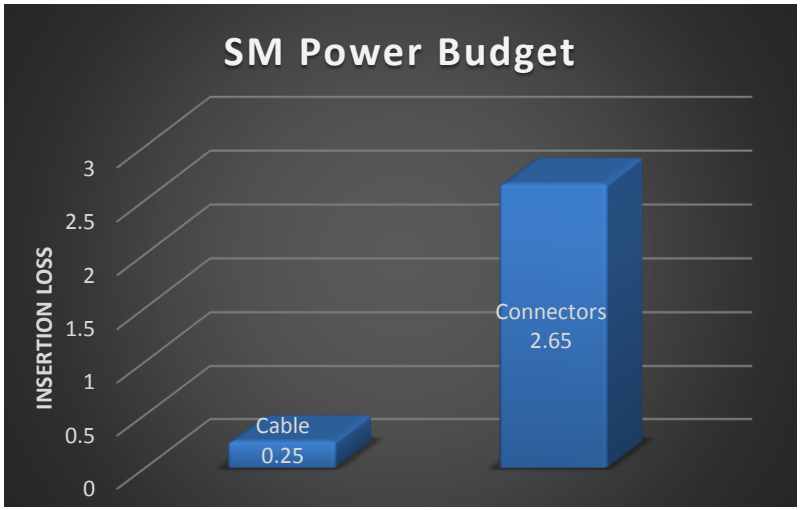
400GBASE-DR4 Reference



500m Double link with 4 MPO connectors

Connector Losses = 2.65 dB,
Fiber loss = 0.25dB,

-> Link Loss = 2.9 dB (rounded to 3 dB)



- IEEE Connector loss = .66db
- Each connector aprox. = 1.3km fiber
- Additional penalties for high reflections (pending)
- PSM4, CWDM lite similar
- ULL SM connectors a definite advantage in supporting PSM4, CWDM4 Lite and other low cost MSAs (similar power budgets)

Our Standards Development Mission

Anticipate Market Requirements

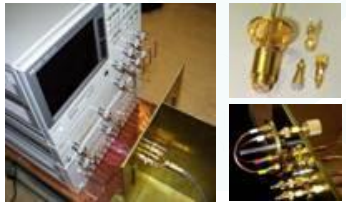
IEEE 802 IEEE

InfiniBand Trade Association

The ATM Forum Technical Committee

FCIA Fibre Channel Industry Association

Develop & Refine Blueprint



Drive Global Consensus

TIA Advancing Global Communications

ISO IEC

CENELEC

A CONTINUOUS PROCESS

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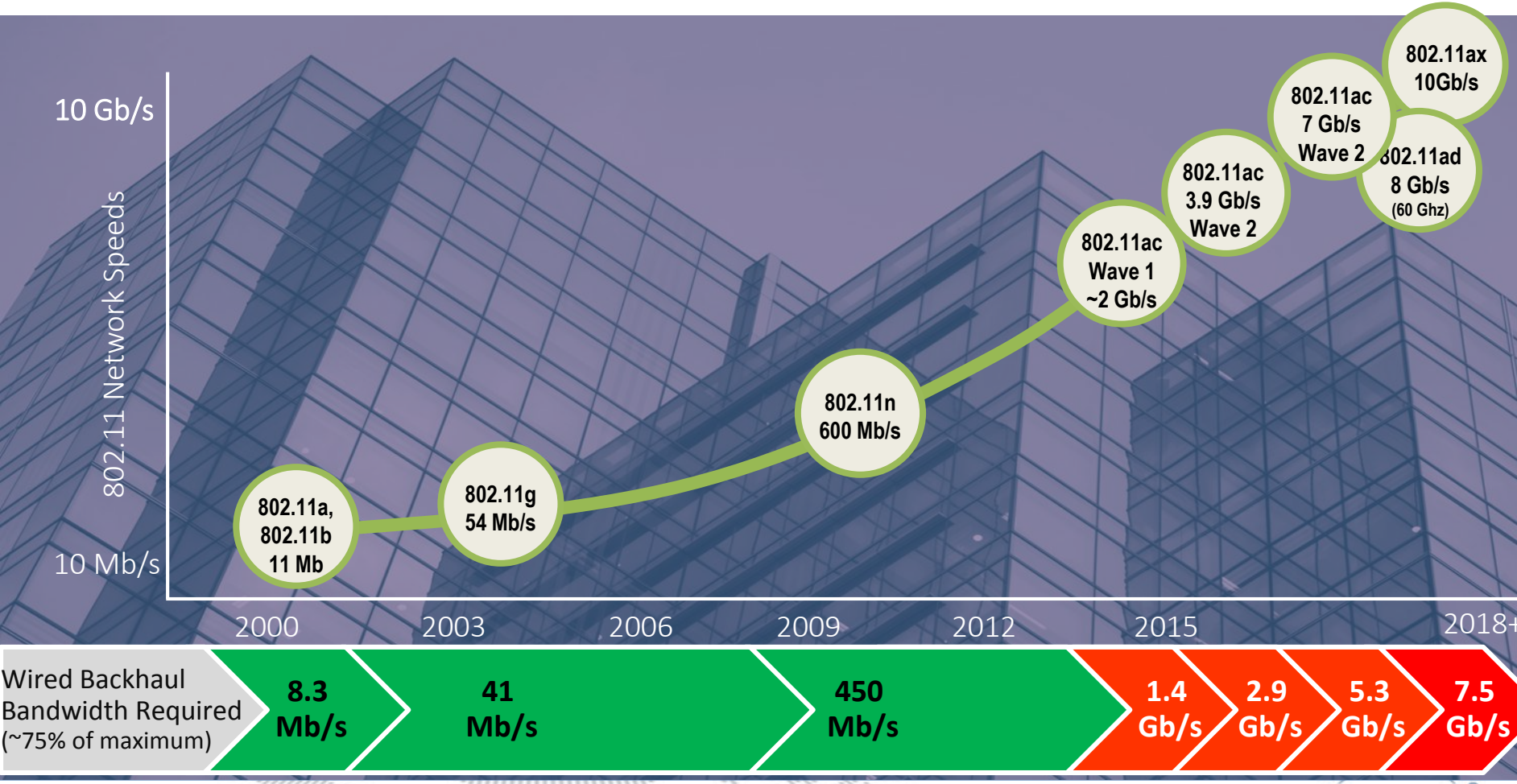
IEEE 802.3 wireless LAN standards



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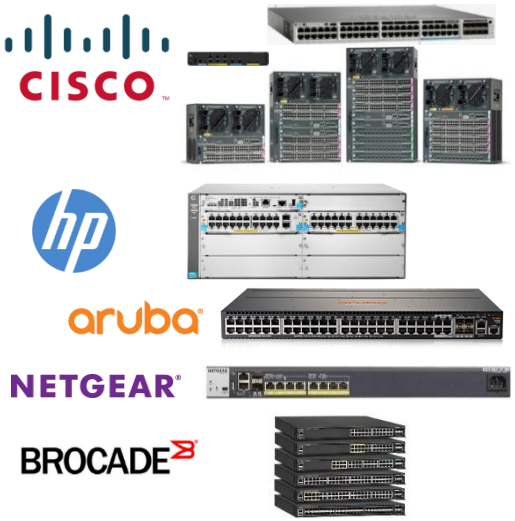
A Fast-growing Multigigabit Ecosystem

- IEEE 802.3bz approved September 2016 - for 2.5GBASE-T and 5GBASE-T
- Multigigabit applications are quickly expanding beyond wireless backhaul

Ethernet Switches



Wireless Access Points

DAS/IBW

Small Cell

Desktop Workstations

Other

Approximately 4 million 2.5/5-Gbit/sec switch ports will be shipped by the end of 2017 - Dell'Oro Group

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Standards guidelines for multigigabit on copper

- **Cat 5e and Cat 6 not fully specified for 2.5/5GBASE-T**
- **Guidelines for existing Cat 5e and Cat 6 installations**
  - ISO/IEC TR 11801-9905 and TIA TSB-5021
  - **ALSNR risk assessment guidelines and mitigation steps**
  - Category 6A recommended for new installations
- **ISO/IEC 11801 3rd Edition**
  - Upgrades minimum office cabling to Class E (Cat 6)
  - **Recommends Class E_A (Cat 6A) for applications above 1 Gb/s**

ISO/IEC TR 11801-9904 Risk Assessment Tables

Class D (Cat 5e)

Bundled Distance	Speed	Victim Length		
		1 m to 20 m	20 m to 75 m	75 m to 100 m
Up to 20 m	2.5G	Low	Low	Low
	5G	Low	Low	Medium
20 m to 75 m	2.5G	N/A	Low	Medium
	5G	N/A	Medium	High
75 m to 100 m	2.5G	N/A	N/A	Medium
	5G	N/A	N/A	High

Class E (Cat 6)

Bundled Distance	Speed	Victim Length		
		1 m to 20 m	20 m to 75 m	75 m to 100 m
Up to 20 m	2.5G	Negligible	Low	Low
	5G	Negligible	Low	Low
20 m to 75 m	2.5G	N/A	Low	Low
	5G	N/A	Medium	Medium
75 m to 100 m	2.5G	N/A	N/A	Medium
	5G	N/A	N/A	High

Class E_A (Cat 6A)

Bundled Distance	Speed	Victim Length		
		1 m to 20 m	20 m to 75 m	75 m to 100 m
Up to 20 m	2.5G	None	None	None
	5G	None	None	None
20 m to 75 m	2.5G	N/A	None	None
	5G	N/A	None	None
75 m to 100 m	2.5G	N/A	N/A	None
	5G	N/A	N/A	None

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We are moving toward a converged world.

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Thank you!

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