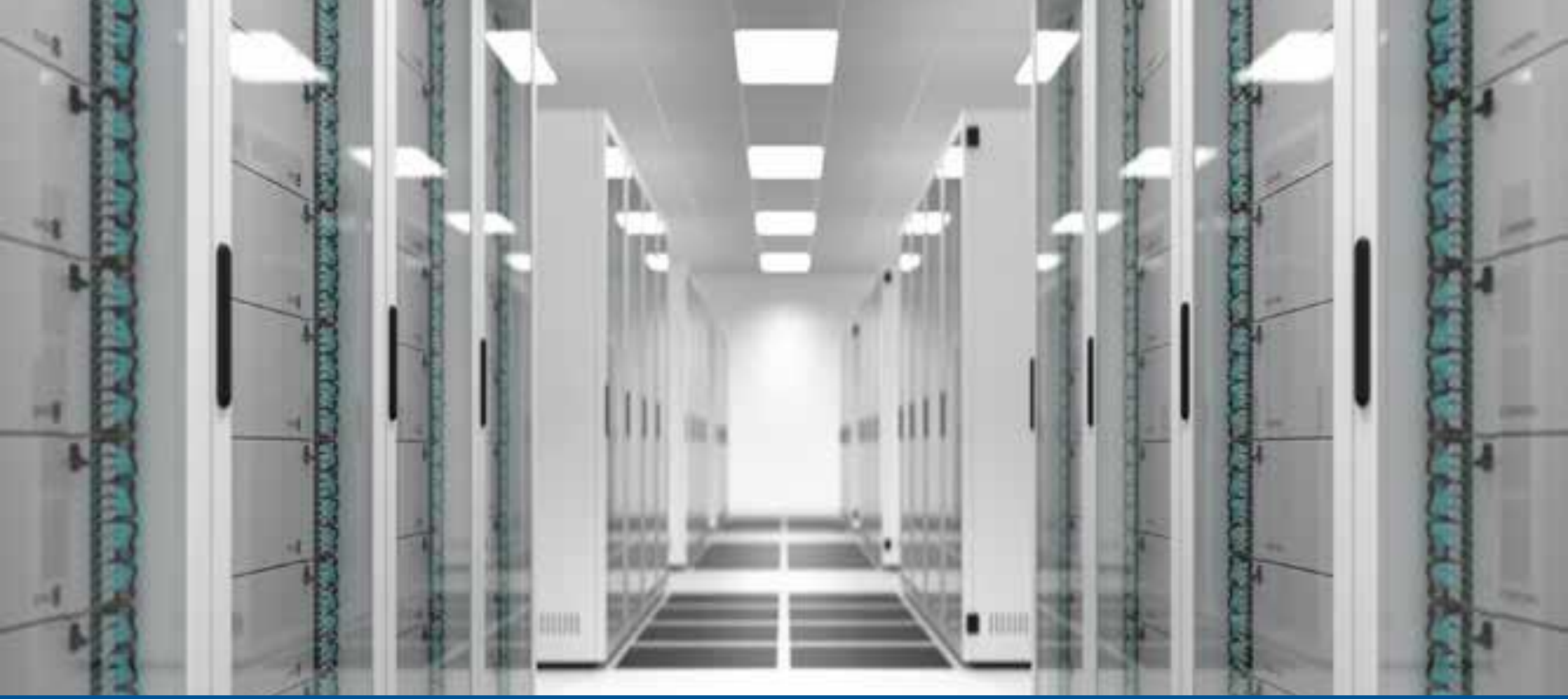

# Optical Communication Trends in Data Centers

Dennis Kom | Director, Sales & Global Strategic Accounts | APAC Enterprise Networks

# Optical Communication Trends in Data Centers

| Area | | Description |
|---|---|---|
| Background |  | • Increasing Bandwidth Demands<br>• WDM versus Parallel Transmission<br>• Ethernet Optical Transceiver Roadmap |
| Cabling Infrastructure |  | • Data Center Cabling Standard & Network Architecture<br>• Pre-Terminated Solutions<br>• Base-2,8,12 and 24 |
| Cabling Optimization |  | • Fiber Utilization<br>• Port Mapping<br>• Port Breakouts<br>• Integrated Port Tapping<br>• High Fiber Count (HFC) Trunks |

# Optical Communication Trends in Data Centers

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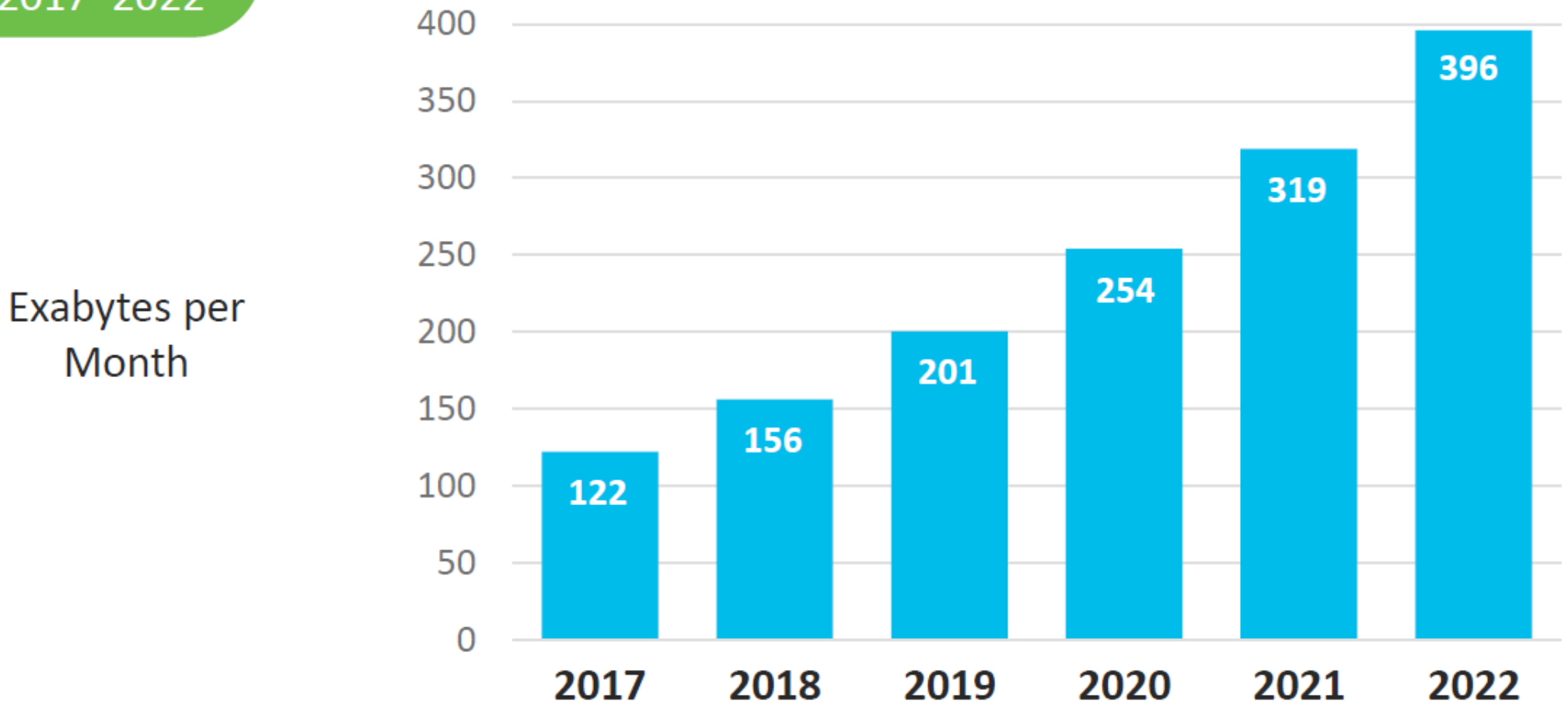
# Increasing Bandwidth Demands

## Global Data Center IP Traffic Growth

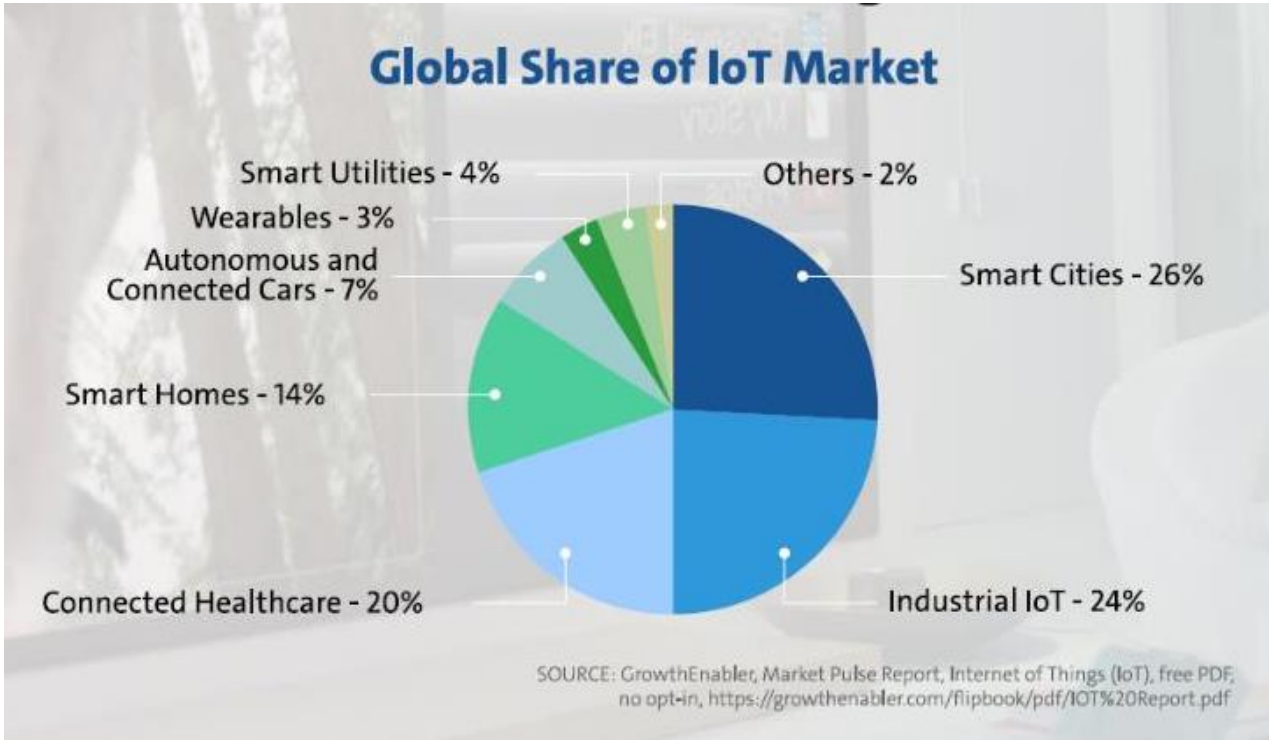
26% CAGR
2017–2022

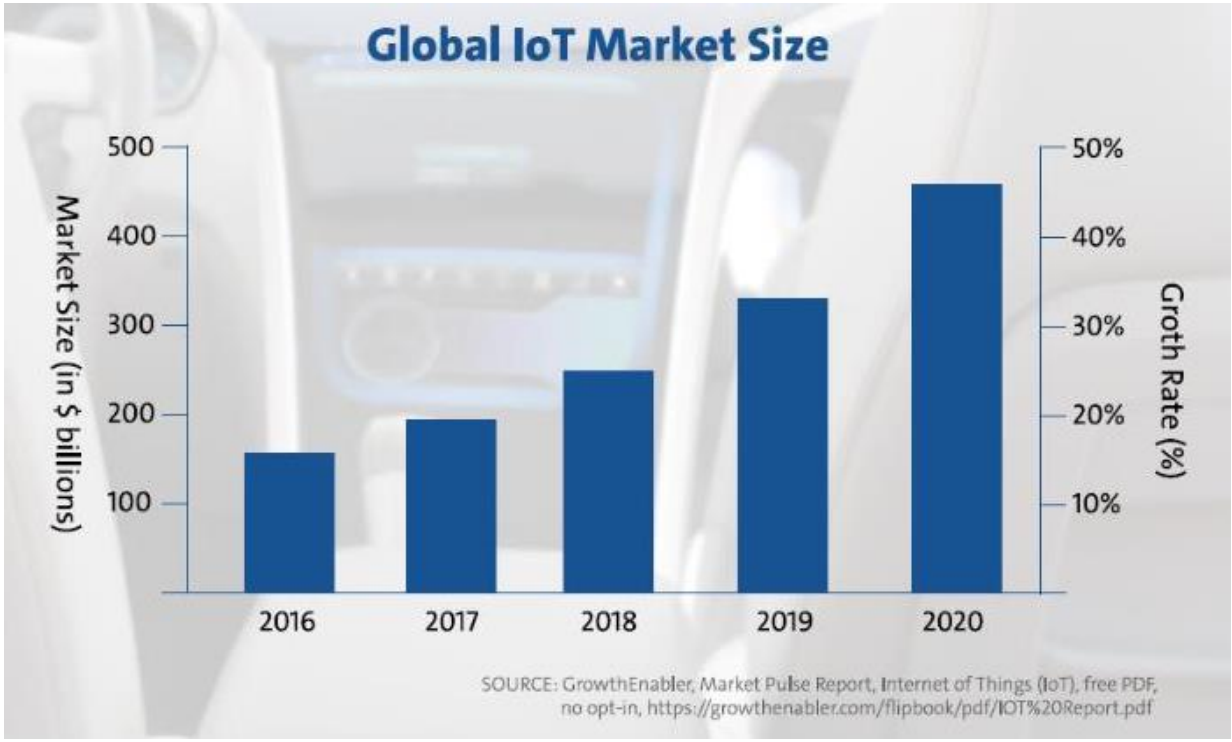



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

# Increasing Bandwidth Demands

## Preparing 5G with Optical Fiber



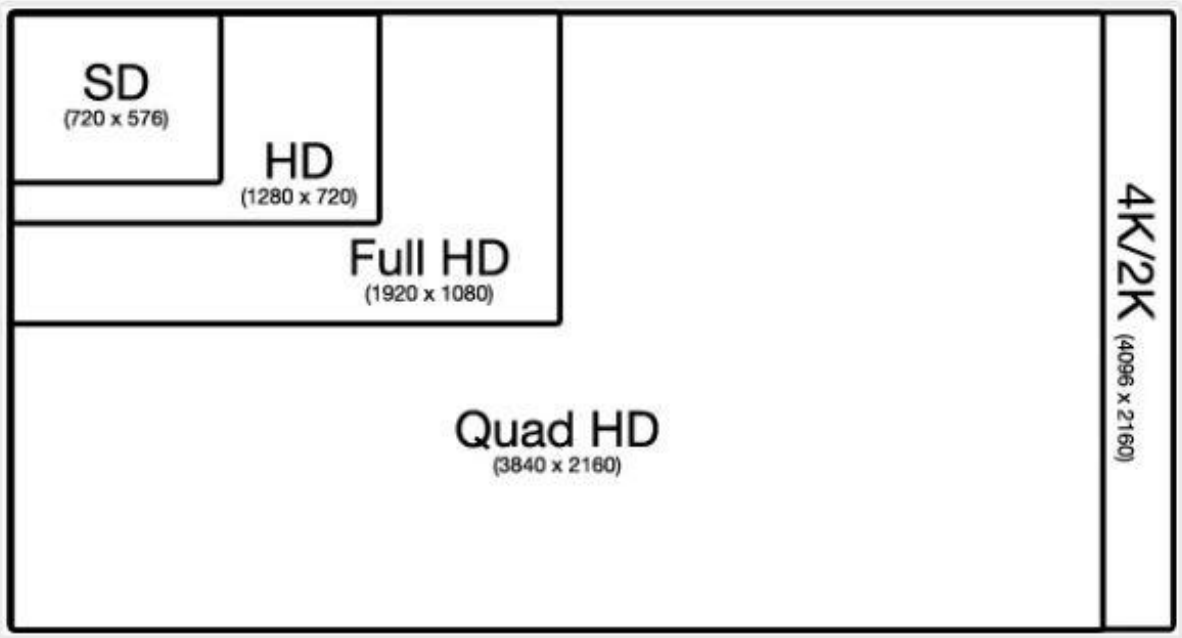

Sources: GrowthEnabler, market Pulse Report, IoT ; HIS Markit – 5G Strategies & Opportunities

# Increasing Bandwidth Demands

## Video is exploding!

How much bandwidth is required for transmission of uncompressed (raw) 4K video?

*4096 (W) x 2160 (H) x 10 (bit/pixel for HDR) x 25 (fps) = 2.2Gps*



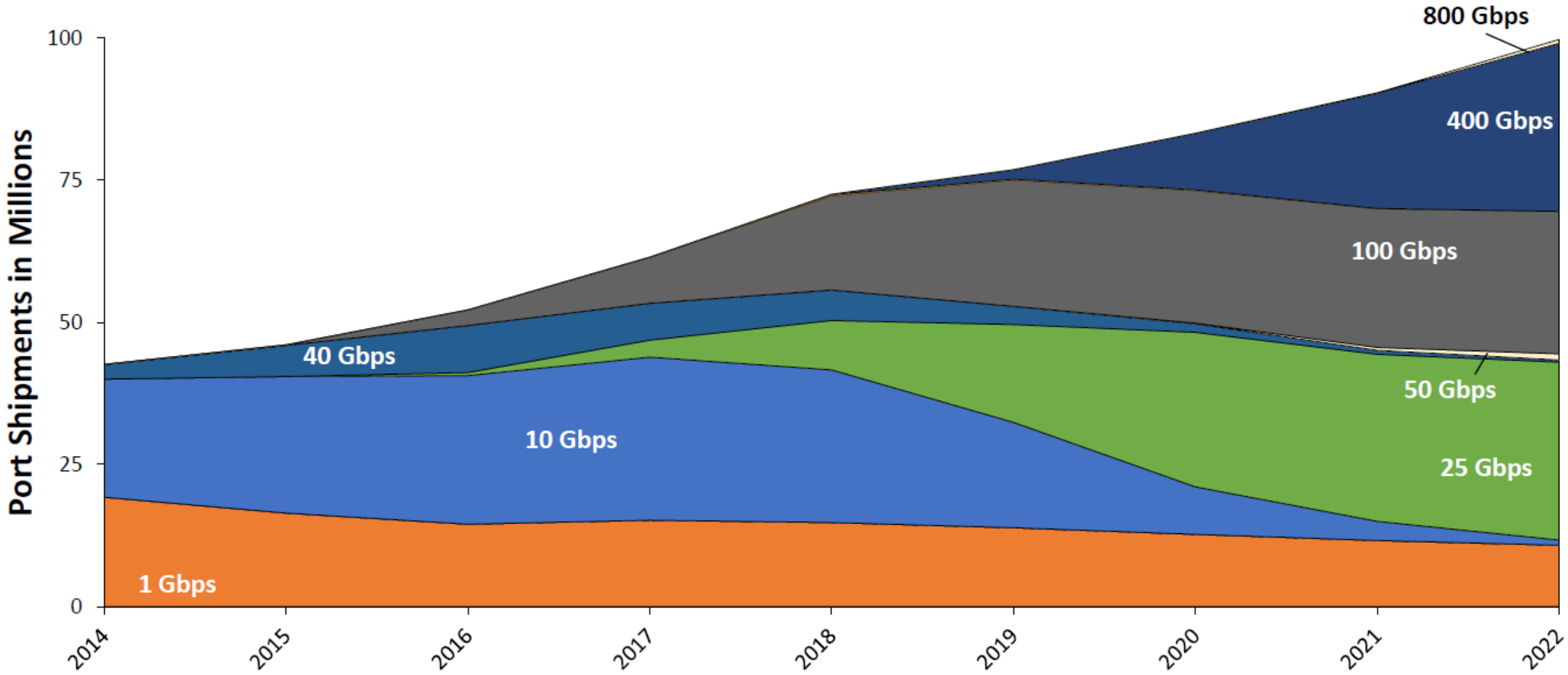

*Four resolutions compared: standard definition, full high definition, Quad HD and 4K/2K.*
*(Credit: Derek Fung/CNET)*

*Source: CNET*


*Source: Intel*

# Increasing Bandwidth Demands

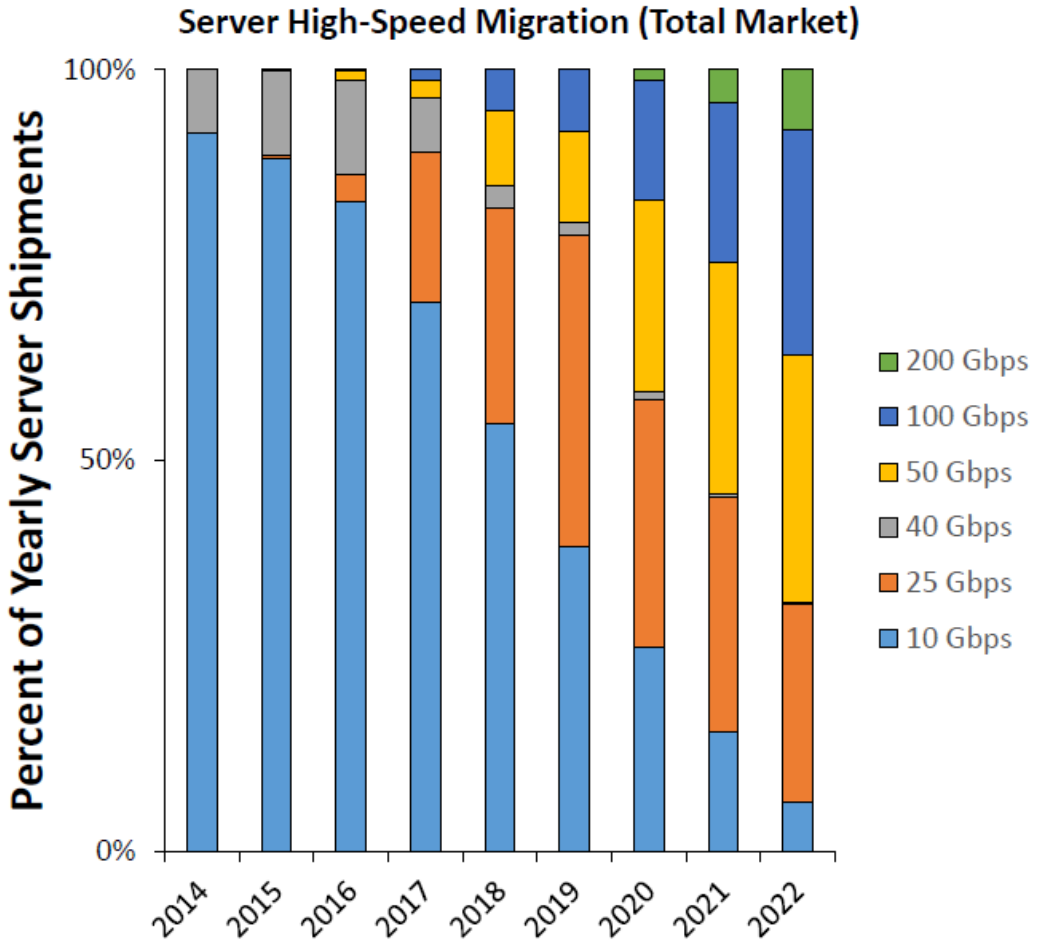
## DC Ethernet Switch: Total Port Shipments

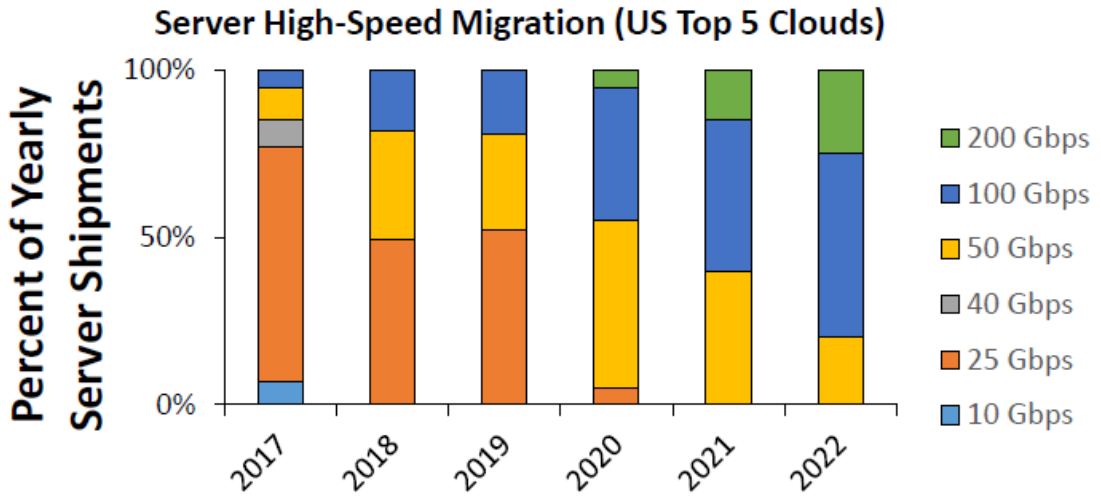


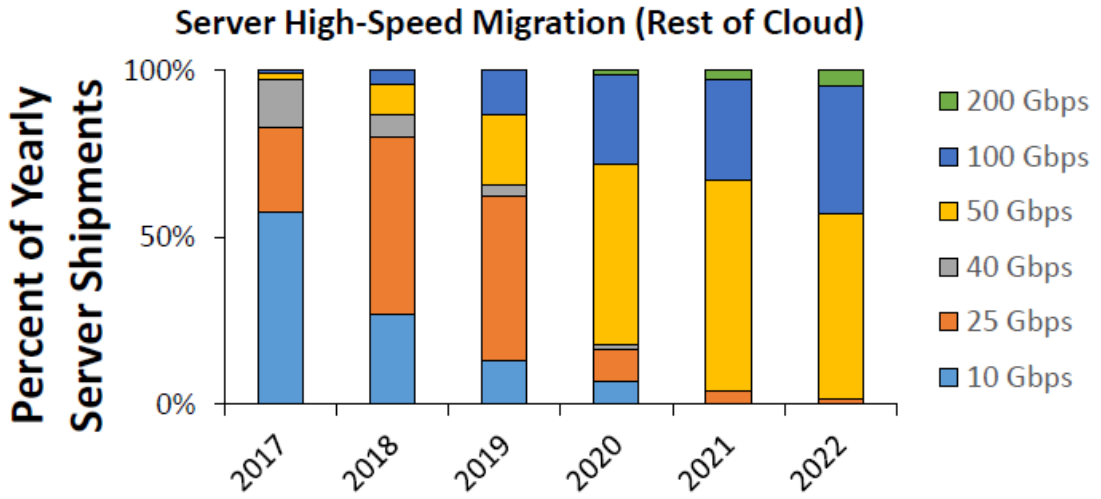

*Source: 650 Group, 2018*

# Increasing Bandwidth Demands

## Server and Smart NICs: Connectivity Metrics



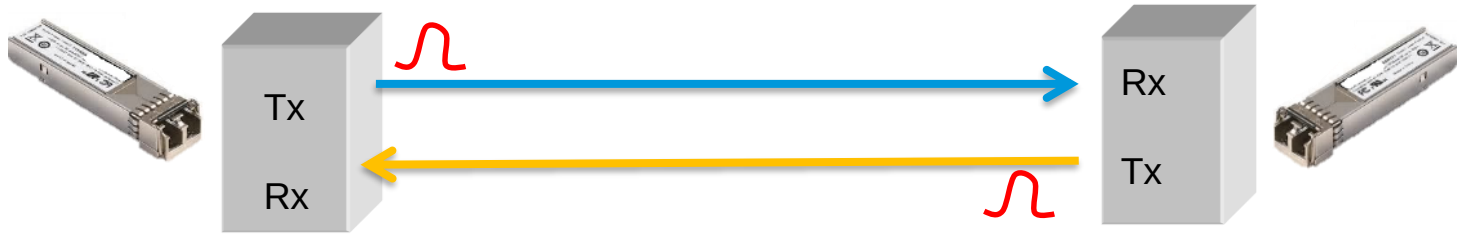




*Source: 650 Group, 2018*

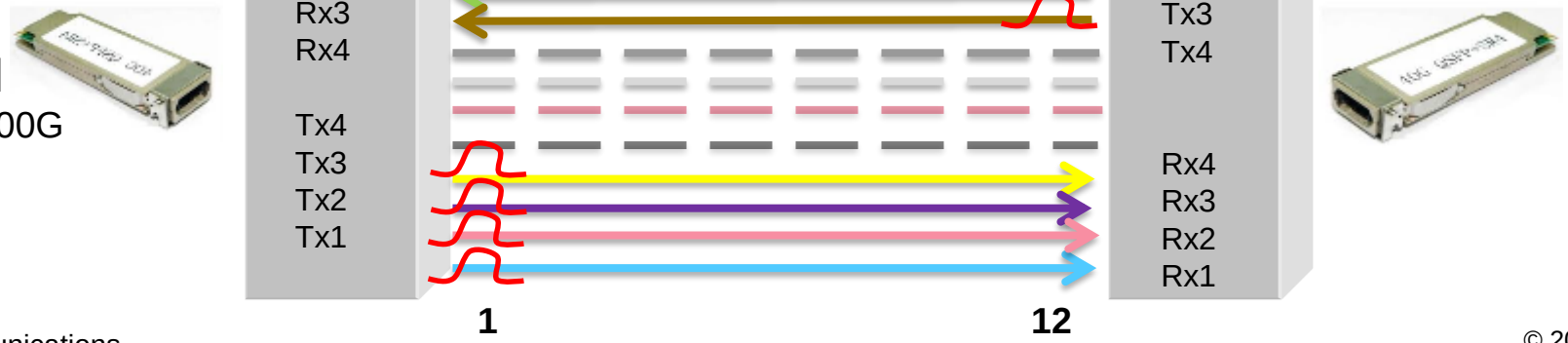
# WDM versus Parallel Transmission

**Duplex Serial 10G**

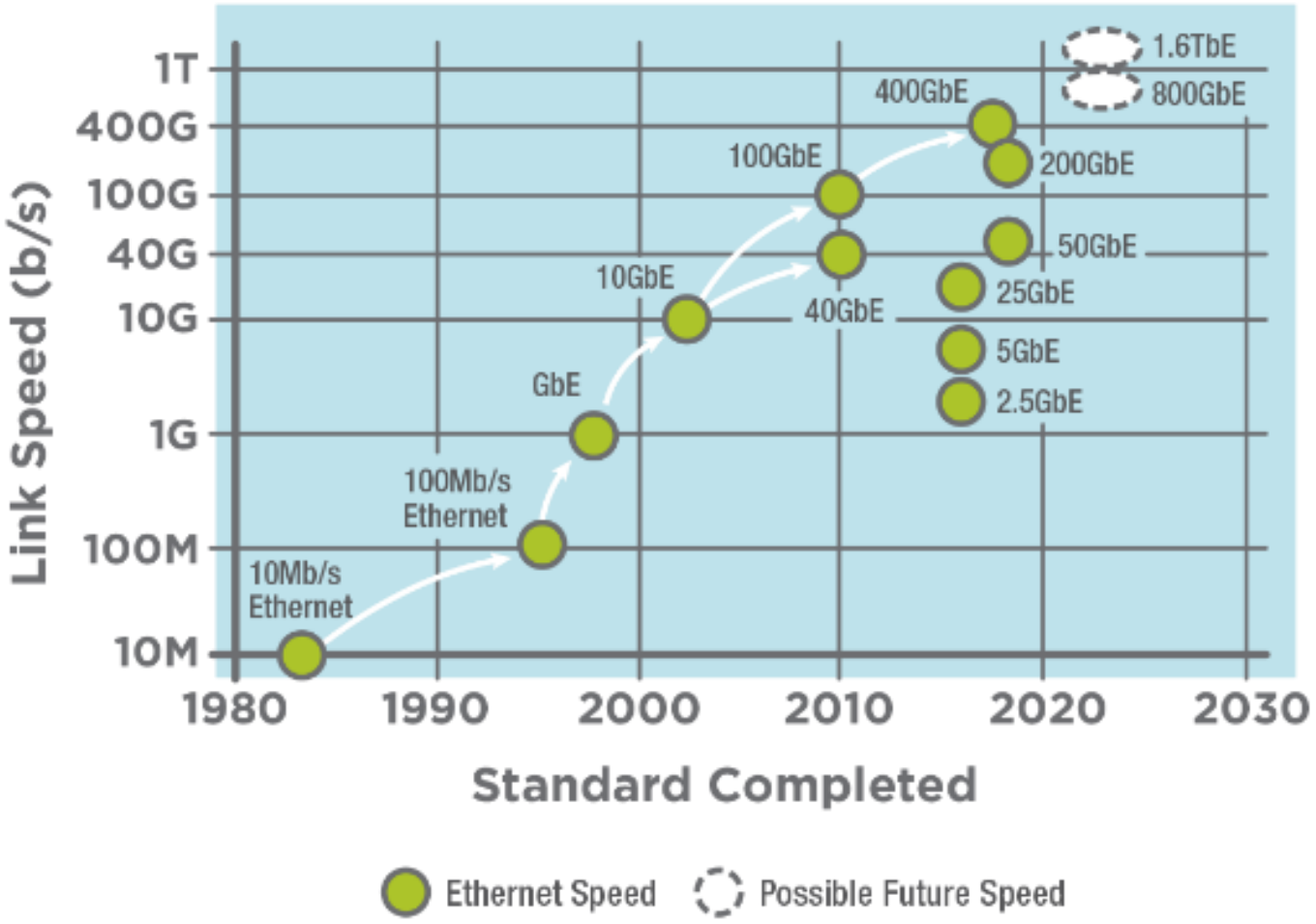


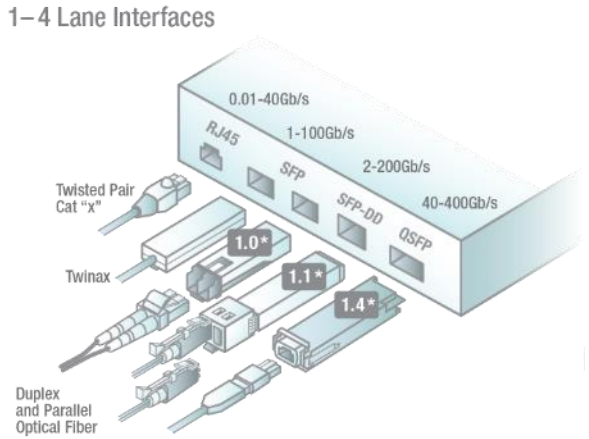

**WDM**
Wavelength Division Multiplexing
40G, 100G

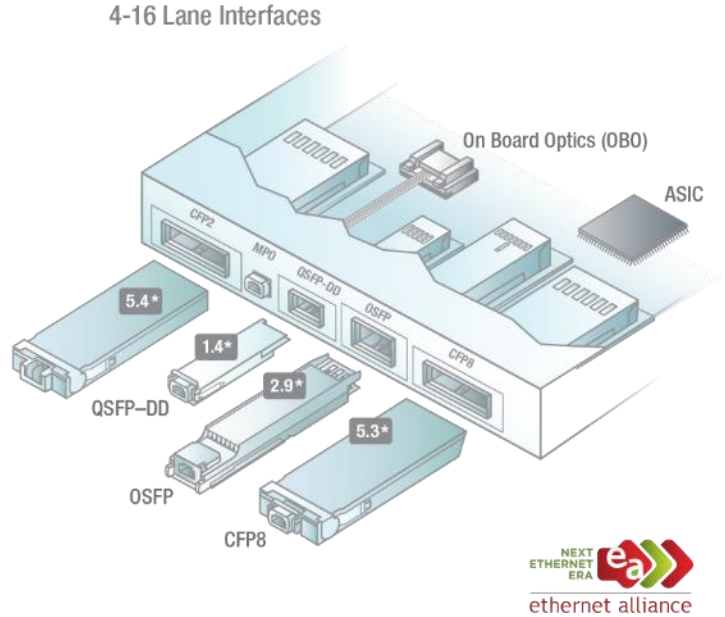

**Parallel**
40G, 100G, 400G



# Ethernet Speed Roadmap



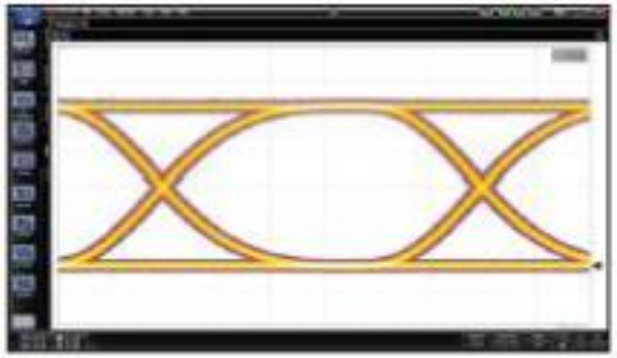
# Ethernet Speed Roadmap

## 200G / 400G update

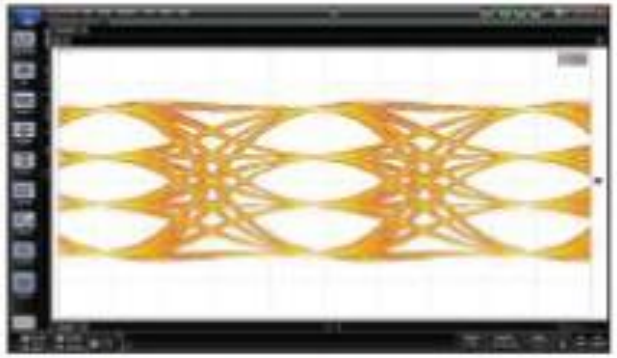
- Non-Return to Zero (NRZ), a 2-level modulation scheme has limitation to drive data rate beyond 25Gps.
- Adoption of Pulse Amplitude Modulation (PAM4) for multi level signaling, to drive data rate at 50/100Gps over a single fiber. PAM4 is expected to be the de facto standard for 100G connectivity. Read more: http://100glambda.com

| PMD Name | Number of Fibers | Reach | Medium | Date Standard Ratified |
|---|---|---|---|---|
| 200GBASE-DR4 | 8 | 500 m | OS1/OS2 | 2017 |
| 200GBASE-FR8 | 2 | 2 km | OSI/OS2 | 2017 |
| 200GBASE-LR8 | 2 | 10 km | OS1/OS2 | 2017 |
| 400GBASE-SR16 | 32 | 70/100/100 m | OM3/OM4/OM5 | 2017 |
| 400GBASE-DR4 | 8 | 500 m | OS1/OS2 | 2017 |
| 400GBASE-FR8 | 2 | 2 km | OS1/OS2 | 2017 |
| 400GBASE-LR8 | 2 | 10 km | OS1/OS2 | 2017 |

NRZ (PAM-2)



PAM-4



Source: KEYSIGHT Technologies

# Ethernet Speed Roadmap

## 400G update

First generation standards guidance

- 32F parallel optics
- 400GBASE-SR16
- Tx 16x25G and Rx 16x25G (NRZ)
- CFP8 Transceiver
- 32F MPO connector, double array
- Minimal traction expected

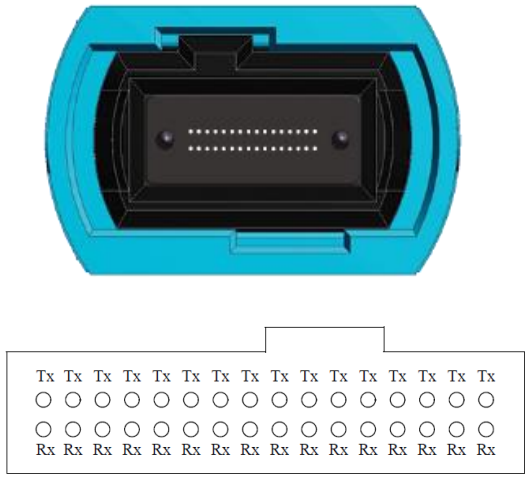
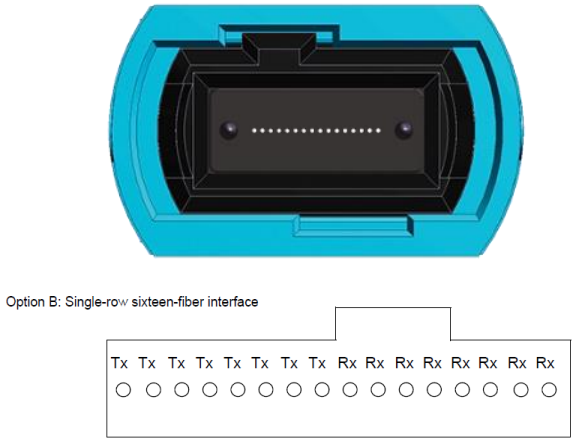



**Figure 123–4—400GBASE-SR16 optical lane assignments**

2nd generation 400 Gb/s MMF PHYs Task Force - 400GBASE-SR8.

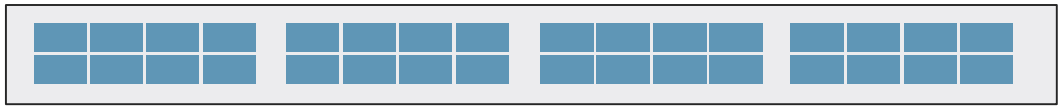
- eight pairs of MMF with reach of at least 100 m
- 16F Parallel Optics
- OM3 70m, OM4 100m and OM5 100m
- QSFP-DD / OSFP Transceiver
- 16F MPO Flat polish connector
- QSFP-DD / OSFP Transceivers
- TOR breakout cable for server interconnects



# Ethernet Speed Roadmap

## 400G Pluggable Modules

- QSFP-DD and OSFP
- 32/36 ports per 1U line card
- 100/200G breakout capability
- Module power 10-12 w
- MPO, LC, CS or MDC connector
- MM and SM capable
- 2019-2020 availability



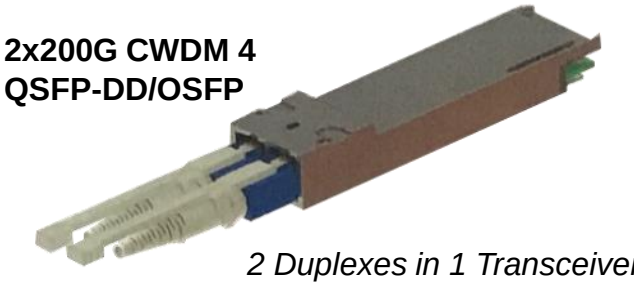
**32 OSFP or 32 QSFP-DD Ports**
**12.8 Tb / 1U**

**OSFP**

**QSFP-DD**

**CS Connector**

**2x200G CWDM 4**
**QSFP-DD/OSFP**



*2 Duplexes in 1 Transceiver*

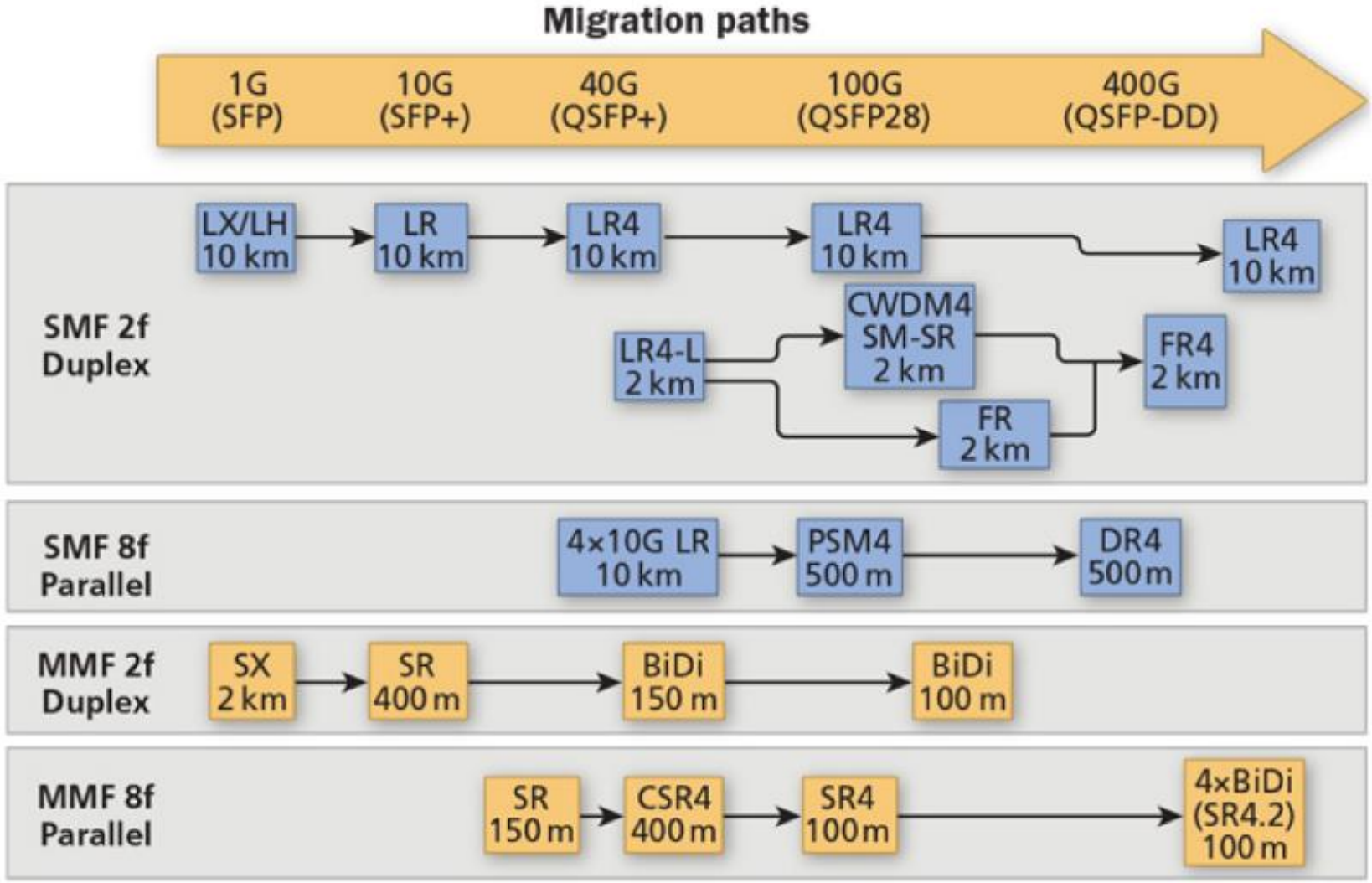
# Ethernet Optical Transceiver Roadmap

Analyzing the benefits and tradeoffs of deploying structured cabling in a data center begins with the network equipment and its continuously evolving offerings from major transceiver, switch, server, and storage manufacturers.

| Solution | Reach | 40G | 100G | 200G | 400G |
|---|---|---|---|---|---|
| **Duplex OM3/4/5** | Short | BiDi (100m/200m)<br>SWDM (240m/350m/440m) | BiDi (70m/100m)<br>SWDM (75m/100m/150m) | To be defined | To be defined |
| **Parallel OM3/4/5** | Short and Mid | SR4 (100m/150m/150m)<br>eSR4 4x10G (300m/400m) | Gen1: SR10 10x10G (100m/150m/150m)<br>Gen2: SR4 4x25G (70m/100m/100m)<br>Gen3: SR2 2x50G (70m/100m/100m) | Gen1: SR8 8x25G<br>Gen2: SR4 4x50G (70m/100m/100m) | BiDi 4.2 (70m/100m/150m)<br>Gen1: SR16 16x25G (70m/100m/100m)<br>Gen2: SR8 8x50G<br>Gen3: SR4.2 4x50Gx2λ |
| **Duplex SM** | Long | LRL4 (2km)<br>LR4 WDM (10km) | CLR4 (2km)<br>CWDM4 (2km)<br>LR4 WDM (10km) | FR4 WDM (2km)<br>LR4 WDM (10km)<br>ER4 WDM (40km) | FR8 WDM (2km)<br>LR8 WDM (10km)<br>ER8 WDM (40km) |
| **Parallel SM** | Mid | PLR4 (10km) | DR 2x50G (500m)<br>PSM4 (500m) | DR4 4x50G (500m) | DR4 4x 100G (500m) |

**Black text = MSA or Proprietary**
**Green text = Approved IEEE 802.3 standards**
**Red text = In Progress IEEE 802.3 standards**

# All Roads Lead to 2F or 8F



# Optical Communication Trends in Data Centers

| Area | | Description |
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# Data Center Standards

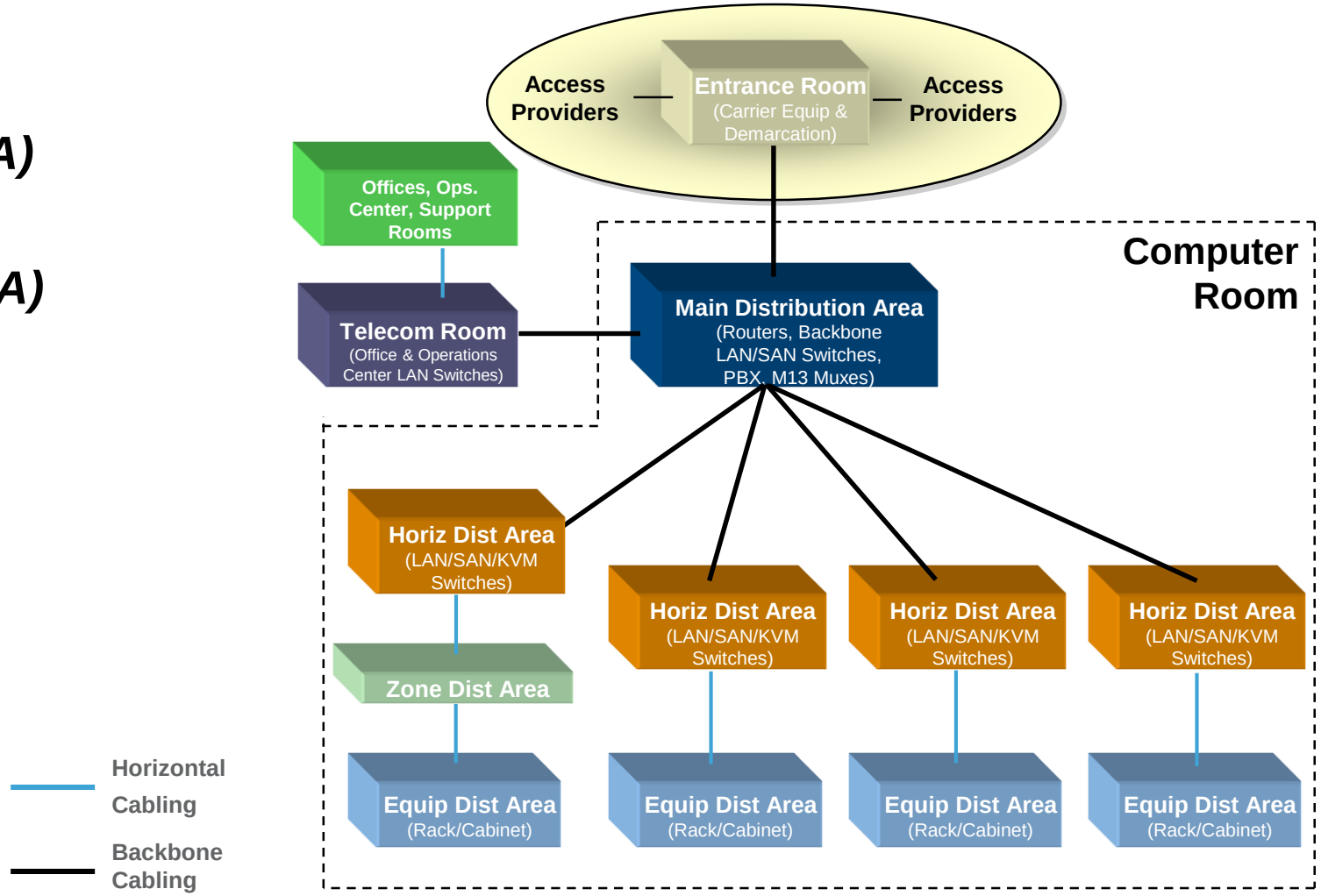
## TIA-942 Data Center Standard

- TIA-942 Telecommunications Infrastructure Standard for Data Centers
  - Provides information on the factors to be considered when planning and preparing the installation of a data center or computer room
    - Architectural design (door, floor, lightning, etc.)
    - Electrical and HVAC
    - Grounding and bonding
    - Structured wiring
  - Structured wiring guidance
    - Recognized media
    - Star topology
    - Cable types
    - Distances
    - Racks and spaces
    - Pathway and spaces
    - Redundancy

# Data Center Standards

## TIA-942 Data Center Standard

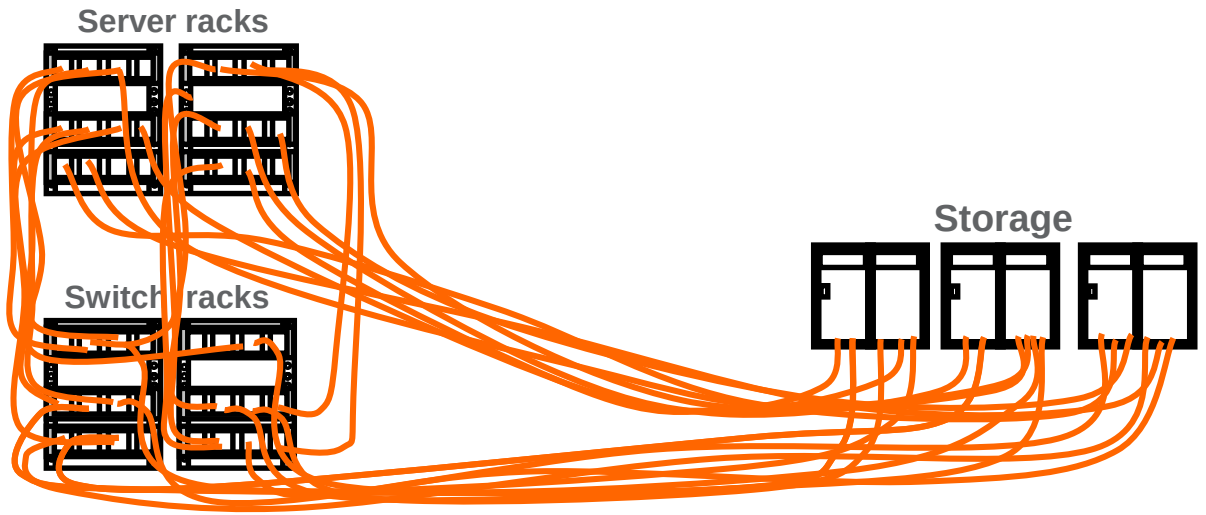
- Entrance Room
- Main Distribution Area ***(MDA)***
- Horizontal Distribution Area ***(HDA)***
- Zone Distribution Area ***(ZDA)***
- Equipment Distribution Area ***(EDA)***



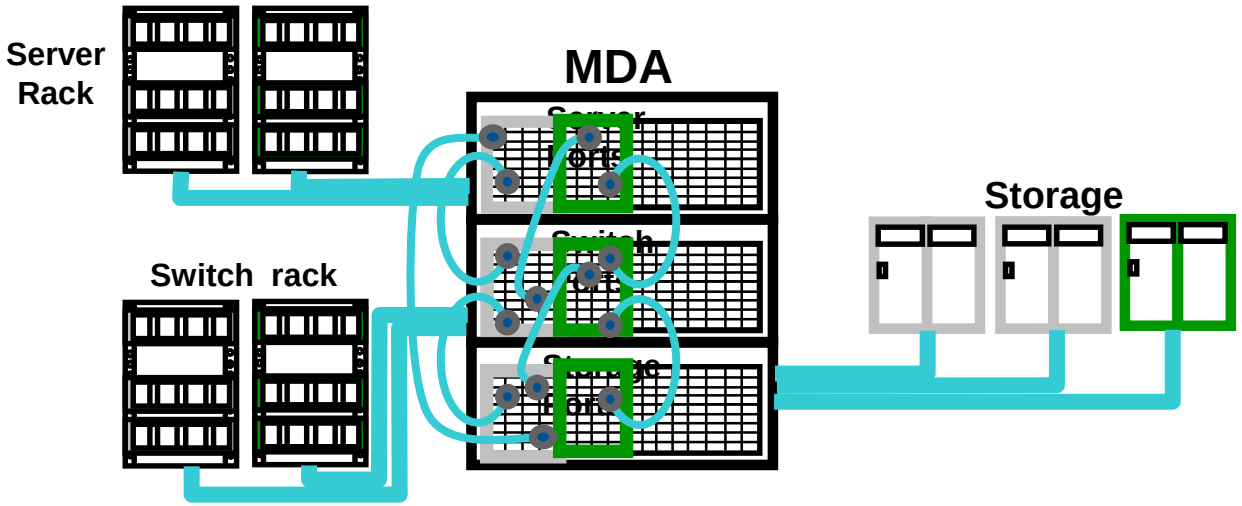
# Data Center Standards

## TIA-942 Data Center Standard

- Unstructured Cabling:
  - Point to point installation
  - Direct connections to all equipment via jumpers

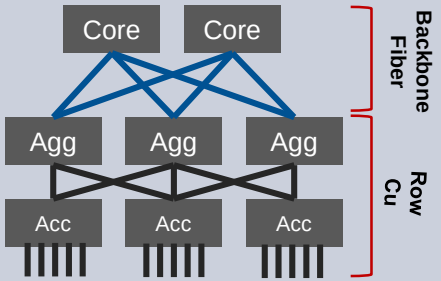
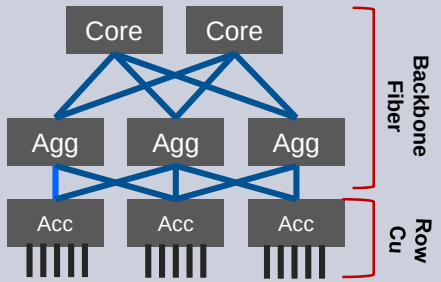
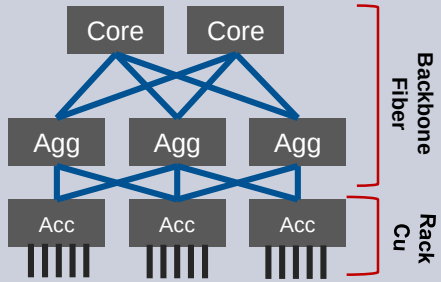
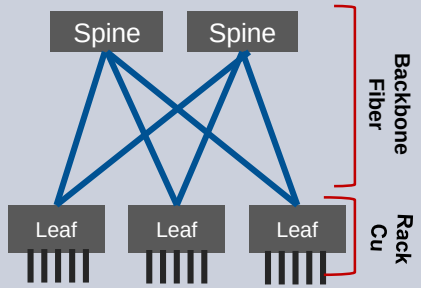
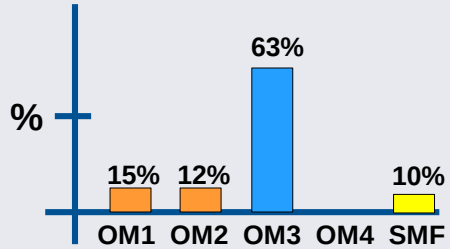
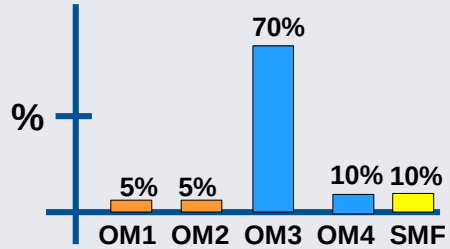
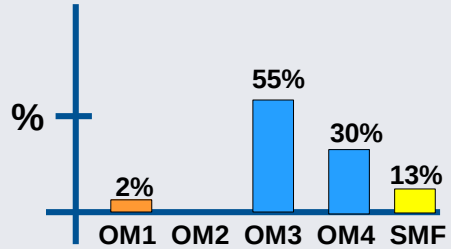
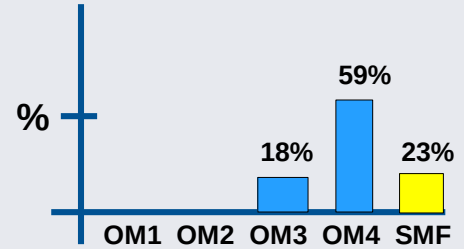



- Structured Cabling:
  - Star Topology
  - High fiber count trunks & central patching locations



# Data Center Network Architecture

## Migration from Copper to Fiber

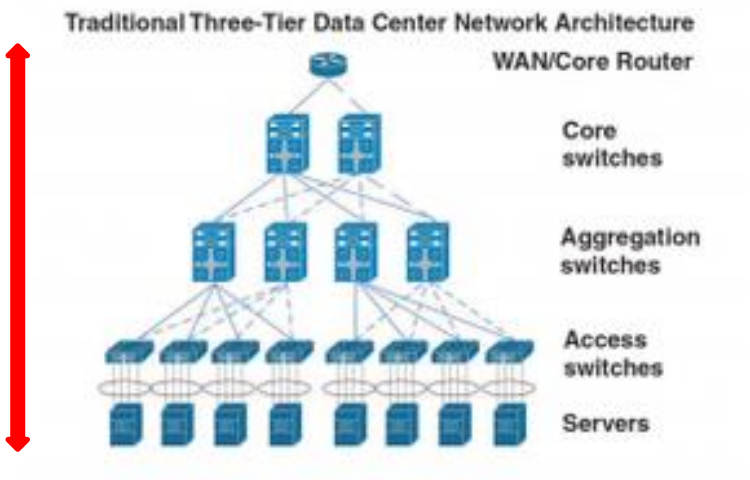
| | 3-Level Architecture | 3-Level Architecture End of Row (EoR), Middle of Row (MoR) | 3-Level Architecture Top of Rack (ToR) | 2-Level Architecture Spine and Leaf |
|---|---|---|---|---|
| **Architecture** |  |  |  |  |
| Time | 2004-2007 | 2007-2010 | 2010-2013 | 2013-2017* |
| % Fiber | 20% | 40% | 60% | 80% |
| % CU | 80% | 60% | 40% | 20% |
| SW SAN **Speed** | 10Mbps-100Mbps<br>2Gbps-4Gbps | 100Mbps-1000Mbps<br>4Gbps-8Gbps | 1000Mbps-10Gbps<br>8Gbps-16Gbps | **10Gbps-100Gbps**<br>**16Gbps-32Gbps** |
| **Fiber Mix** |  |  |  |  |

Source: Infonetics, Corning

# Data Center Network Architecture

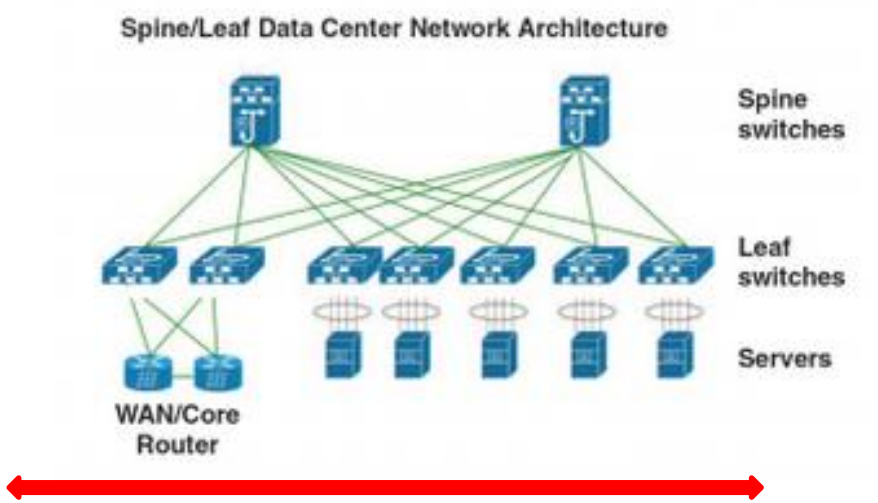
## Flattening Network Design

### Traditional 3-Tier




- Design for redundancy - spanning Tree Protocol **(STP)** cannot support parallel forwarding path.
- Adopt 80/20 rule where 80% of IP traffic is kept local, while 20% of IP traffic goes across the WAN
- Poor utilization of links and difficult to scale

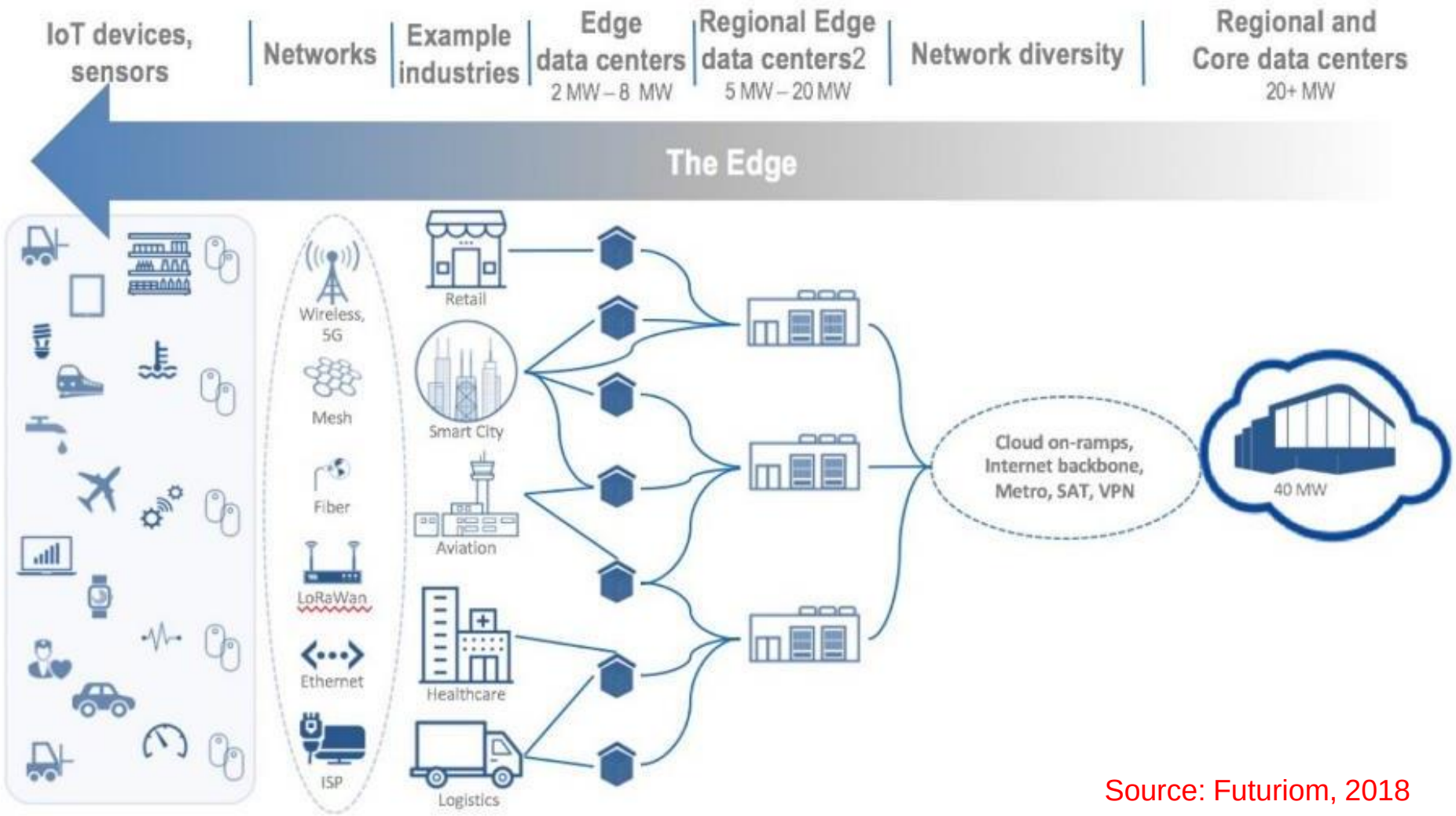
### Spine-Leaf




- Design for resiliency and scalability with Two Tier Hierarchy Architecture using **ECMP**
  - Non-blocking Spine-Leaf
  - Over-subscription Leaf to Server
- “east-west” layer 2 switch to server traffic flow
  - Low network latency
  - Ease VM movement
- Transparent Interconnection of Lots of Links (TRILL) management increases overall network bandwidth and availability
- Proliferation of DCI

# Data Center Network Architecture

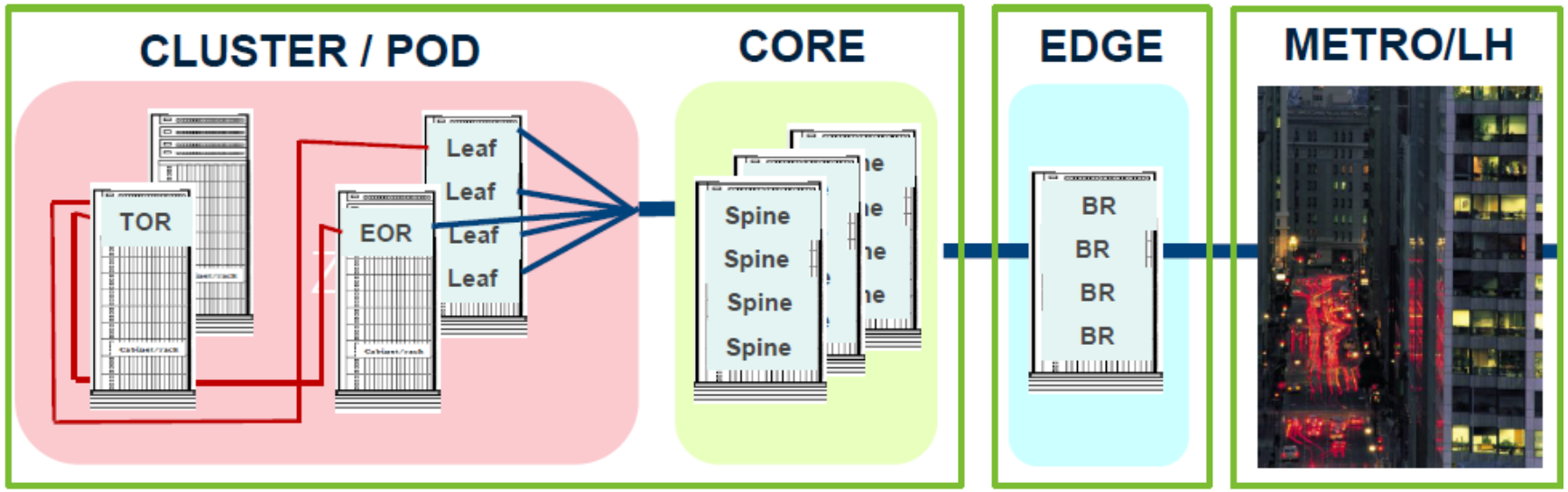
## Emergence of EDGE Computing




Source: Futuriom, 2018

# Data Center Network Architecture

## Fiber Across all Network Segments




| TOR / EOR | To Core | Campus | Metro/LH |
|---|---|---|---|
| Cables<br>Cu / AOC | Transceivers<br>MMF, SMF | Transceivers<br>SMF | Transceivers<br>SMF |
| 3m, 5m / 30m | 100m, 300-500m | 2 – 10km | > 10km, up to 1000s of km |


Bend Matters

Loss Matters

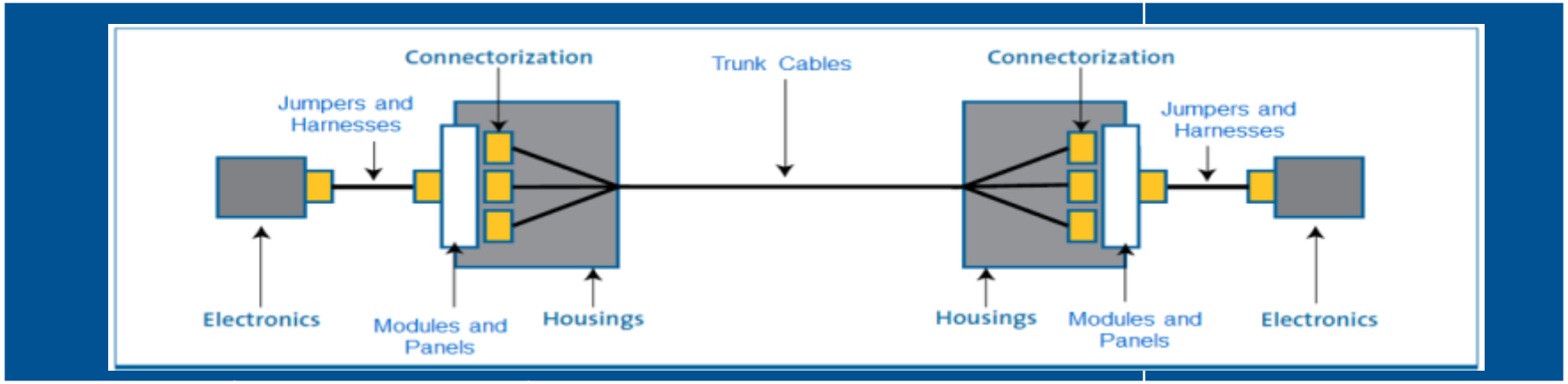
# Pre-Terminated Solutions

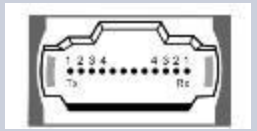
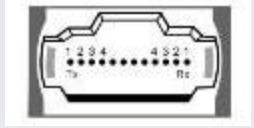
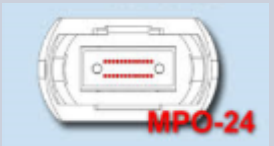
## EDGE8™ Solutions – Base 8 Wiring Configuration

| Product Family | Description | Product |
|---|---|---|
| EDGE8™ Trunks | • 8-fiber MTP Trunks (pinned MTPs)<br>• 8, 16, 24, 32, 48, 72, 96F (Plenum & LSZH), 144F (Plenum)<br>• OM3, OM4, SM | *Ex: 24F EDGE8™ Trunk*  |
| EDGE8™ Housings | • EDGE8™ HD Housings with the usability & density of EDGE using 6-slot trays<br>• 6-slot trays also available individually for field retrofit applications<br>• 1U, 2U, 4U | *4U Housing*   |
| EDGE8™ Modules & Panels | • 8-fiber MTP-LC Module & Pigtail Module<br>• 1, 2, 4-port MTP Adapter Panels<br>• OM3/OM4, SM | *8F Module*  *8F Pigtail Module*  *4-port MTP Panel*  |
| EDGE8™ Harness | • 8-fiber MTP-LC Harness<br>• Staggered & Uniform length LC UniBoot Legs<br>• OM3, OM4, SM | *8F Harness*  |
| EDGE8™ Jumpers | • 2-fiber UniBoot LC Jumper<br>• 8-fiber MTP Jumper<br>• OM3, OM4, SM | *LC UniBoo Jumper*  *8F M Jump*  |

# Defining the Cabling System

## Base Type is Determined by Trunk Cable & Connector Types



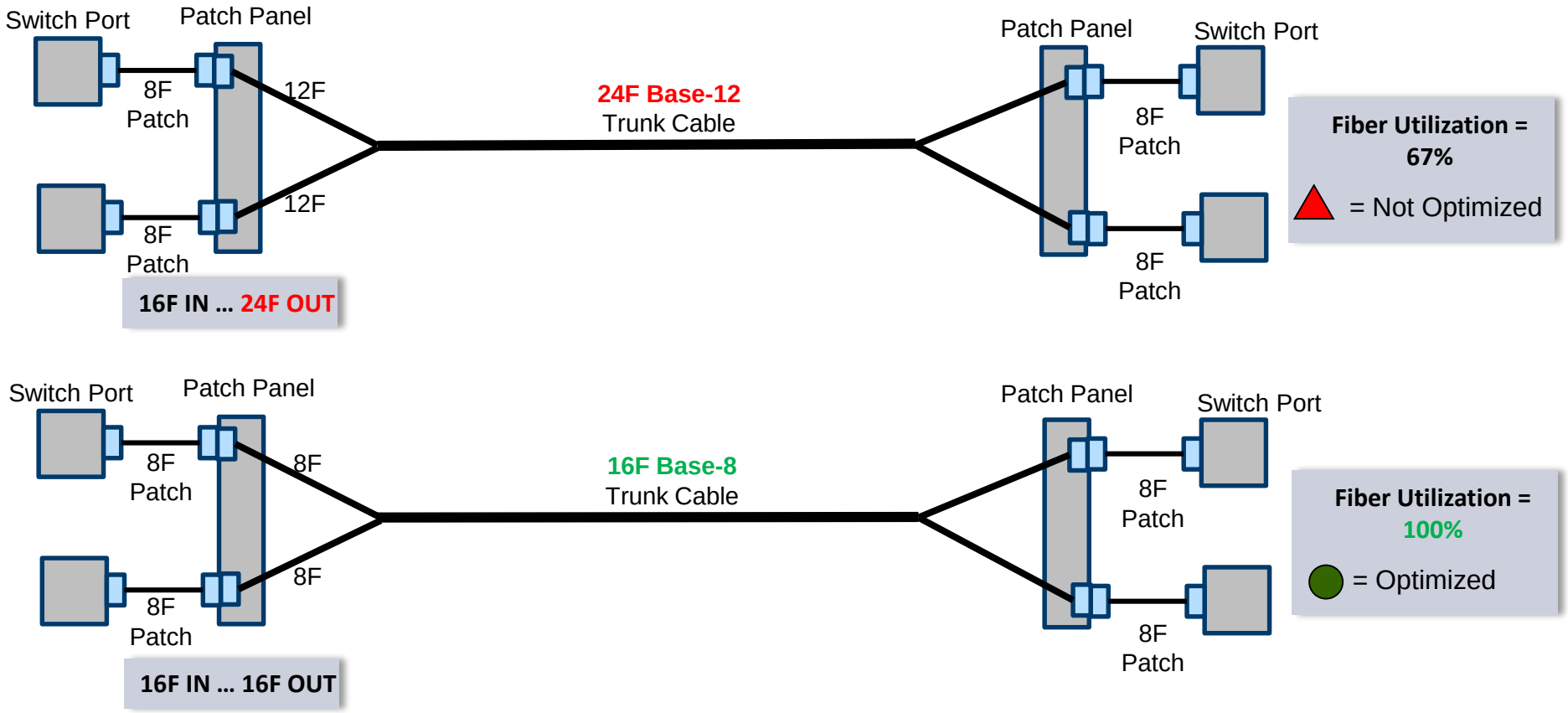

| System | Trunk Cable | Connector | Breakout to Base-2 |
|---|---|---|---|
| **Base-2** | Multiples of 6 or 12 | LC Duplex  | N/A |
| **Base-8** | Multiples of 8 | 8F MPO   | Module  |
| **Base-12** | Multiples of 12 | 12F MPO   | Module  |
| **Base-24** | Multiples of 24 | 24F MPO    | Module  |

# Optical Communication Trends in Data Centers

| Area | | Description |
|---|---|---|
| Background | | • Increasing Bandwidth Demands<br>• WDM versus Parallel Transmission<br>• Ethernet Optical Transceiver Roadmap |
| Cabling Infrastructure | | • Data Center Cabling Standard & Network Architecture<br>• Pre-Terminated Solutions<br>• Base-2,8,12 and 24 |
| Cabling Optimization |  | • Fiber Utilization<br>• Port Mapping<br>• Port Breakouts<br>• Integrated Port Tapping<br>• High Fiber Count (HFC) Trunks |

# Fiber Utilization

## Base-12 vs. Base-8

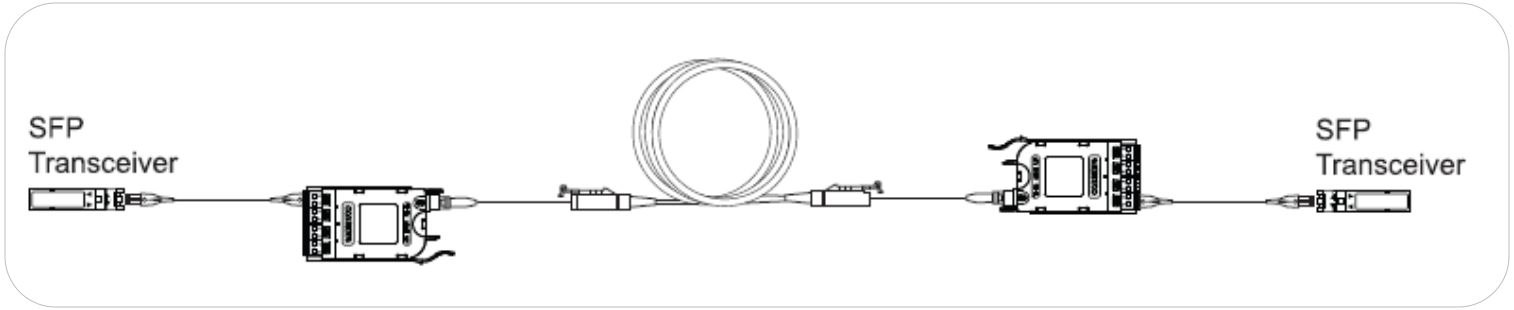



- Base-8 systems enable 100% fiber utilization for 8-fiber transceivers (SR4, PLR4, PSM4)

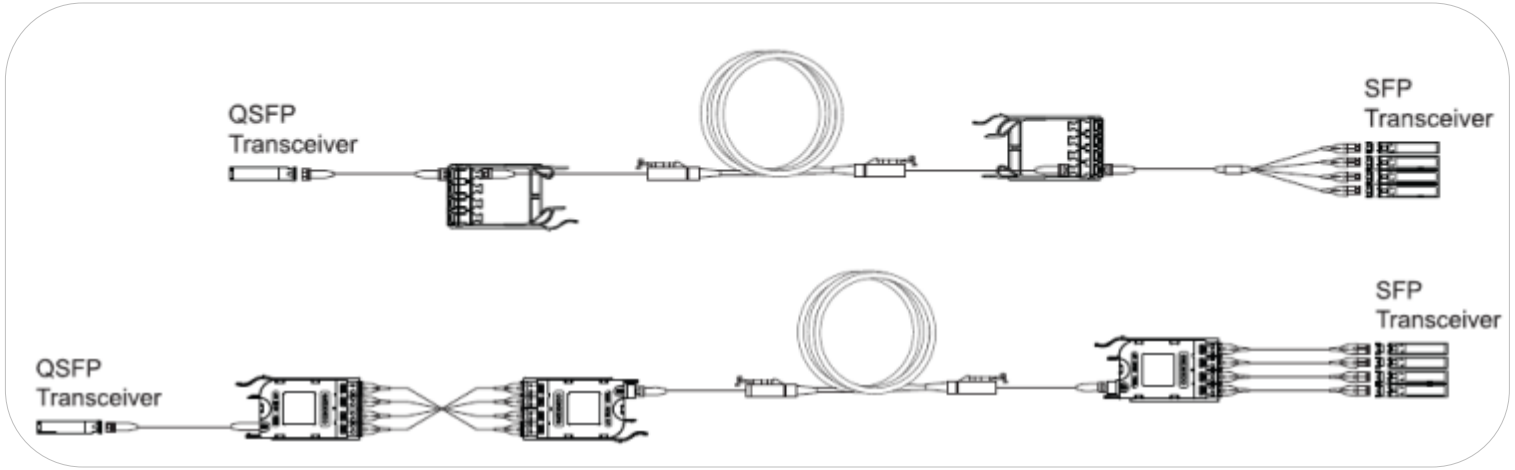
# Fiber Utilization

## Achieving 100% Utilization from 10G to 400G

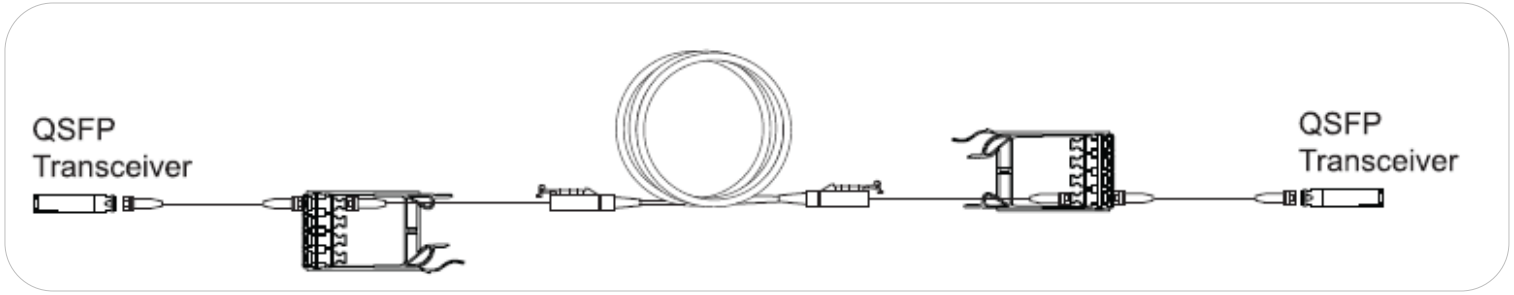
**10G**
**(Duplex)**




**40G-4x10G**
**100G-4x25G**
**200G-4x50G**
**400G-4x100G**
**(Parallel Breakout)**




**40/100G/ 200G/ 400G**
**(Parallel)**

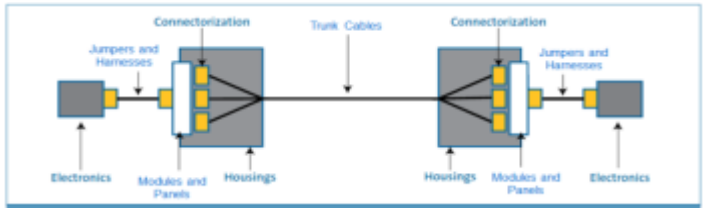



100% Fibre Utilisation

0.5 dB Channel Loss

# Base Type Comparison Across Transceiver Options

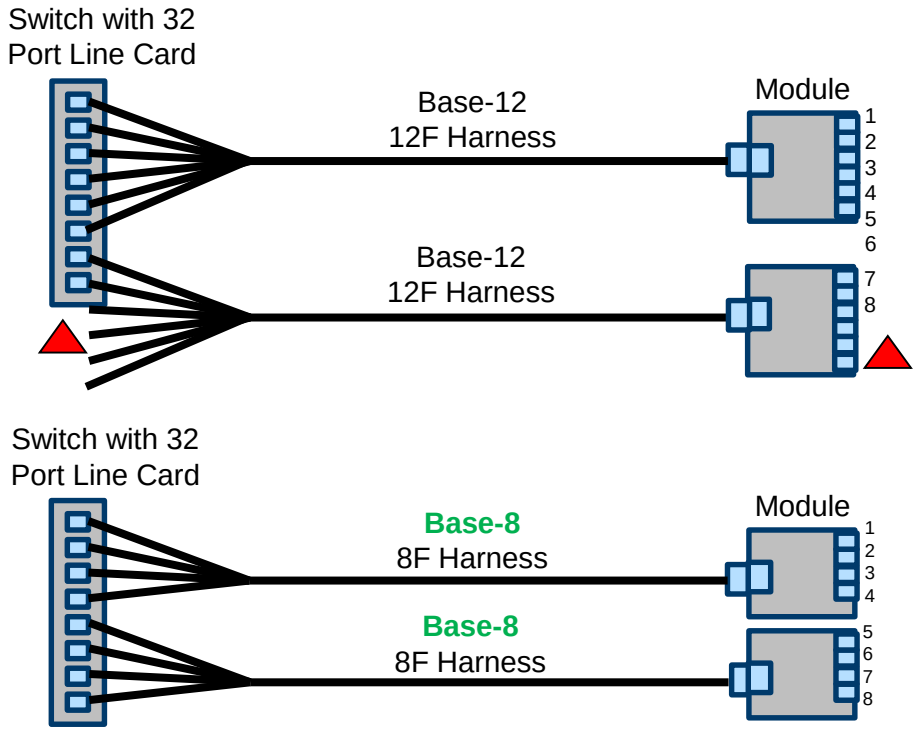
| Ethernet | Fibers | Available | Base-2 | Base-8 | Base-12 | Base-24 |
|---|---|---|---|---|---|---|
| 1-10G | 2 | Yes | ● | ● | ● | ● |
| 40G | 8 | Yes | ▲ | ● | ▲ | ▲ |
| | 2 | Yes | ● | ● | ● | ● |
| 100G | 20 | Yes | ▲ | ▲ | ▲ | ▲ |
| | 8 | Yes | ▲ | ● | ▲ | ▲ |
| | 2 | Yes | ● | ● | ● | ● |
| 200G | 16 | Yes | ▲ | ● | ▲ | ▲ |
| | 8 | Yes | ▲ | ● | ▲ | ▲ |
| | 2 | Yes | ● | ● | ● | ● |
| 400G | 32 | Future | ▲ | ● | ▲ | ▲ |
| | 16 | Yes | ▲ | ● | ▲ | ▲ |
| | 8 | Yes | ▲ | ● | ▲ | ▲ |
| | 2 | Yes | ● | ● | ● | ● |




● = 100% Fiber Utilization and good port organization

▲ = Not Optimized

# Port Mapping




Does not breakout cleanly when line cards have port counts which are not divisible by six (for example 32-port) hence you are left with unused connectors

▲ = Not Optimized

When line cards have port counts which are divisible by four, all connectors are utilized

● = Optimized

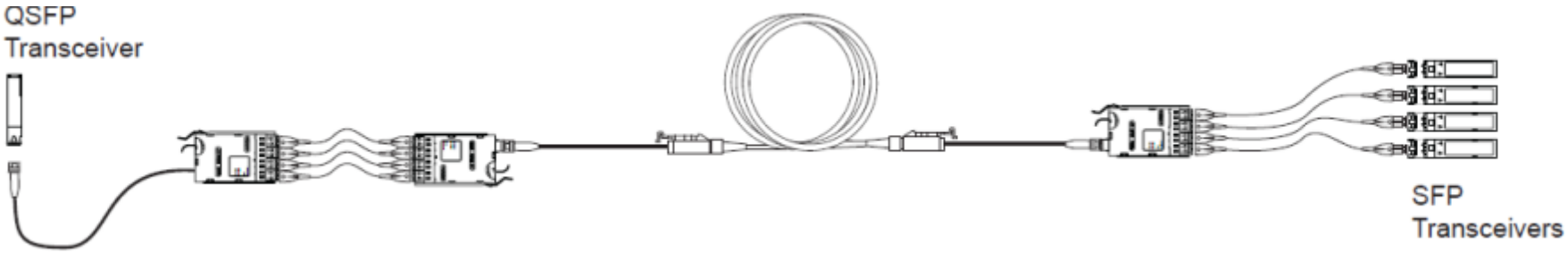
- Base-8 systems allow for 8, 16, 32 and 64-port line cards to be cabled cleanly without having unused connectors

# Parallel Optics Port Break-out Applications

## Active vs. Passive

24 port 40GE QSFP Line Card
Core Network

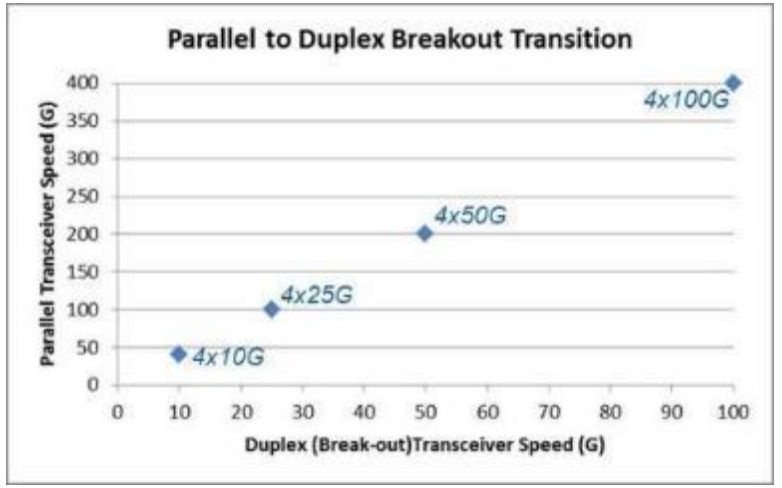
2X48 port 10GE SFP+ Line Card
TOR / MOR / EDGE Switch



# Parallel Optics Port Break-out Applications

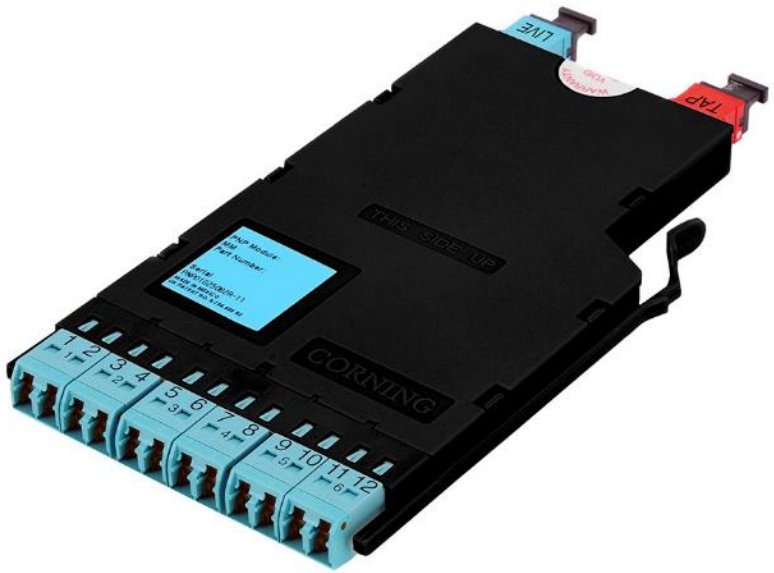
## The Economies of Port Breakout

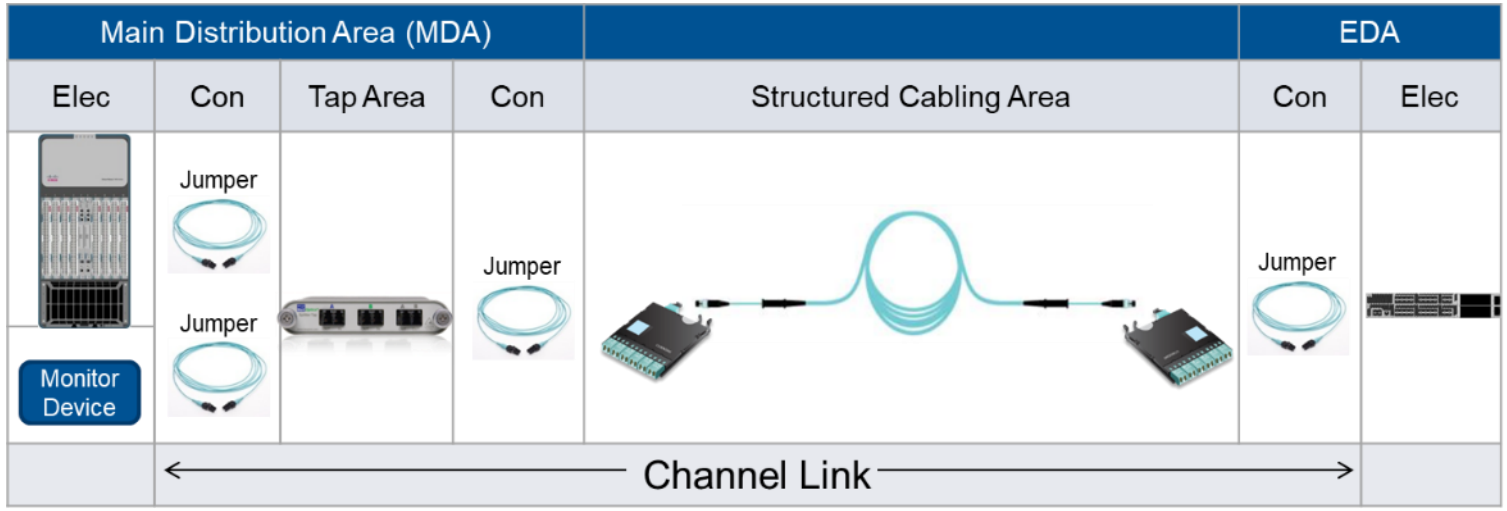
- Over half of 40GbE QSFP ports shipped are being used to break-out to 4x10G
- Why operate a 40GbE port in a “break-out” configuration?
  - 2-3x the 10G density per blade
  - 50% less power per port
  - 30% cost savings per port
  - Switch migration path (do not repurchase 40G optics or cards)
- Works for Parallel Optic Only

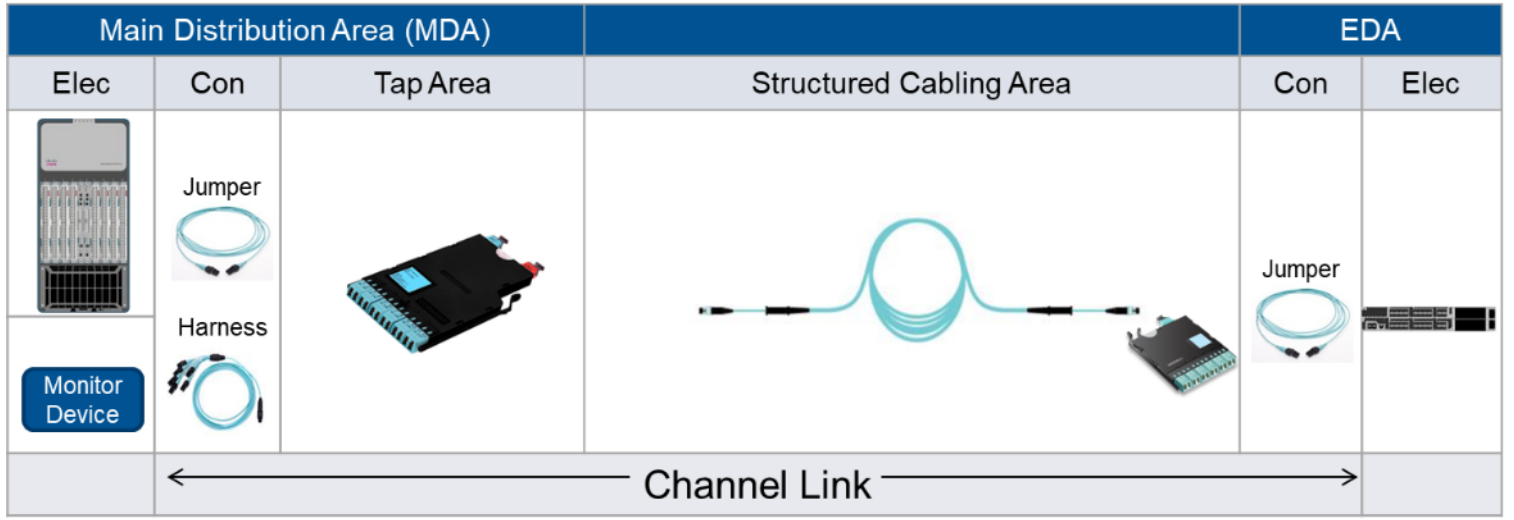



| Qty | Qty | Total List |
|---|---|---|
| 48 Port 10GbE (SFP+) Line card | 1 | $44,000 |
| 10GBASE-SR SFP Module | 48 | $47,760 |
| **Cost/10G port (total of 48)** | | **$1912/port** |
| 24 Port 40GbE (QSFP) Line card | 1 | $55,000 |
| QSFP 4x10GBASE-SR Transceiver, MPO, 300M | 24 | $71,880 |
| **Cost/10G port (total of 96)** | | **$1322/port** |

# Integrated Port Tapping

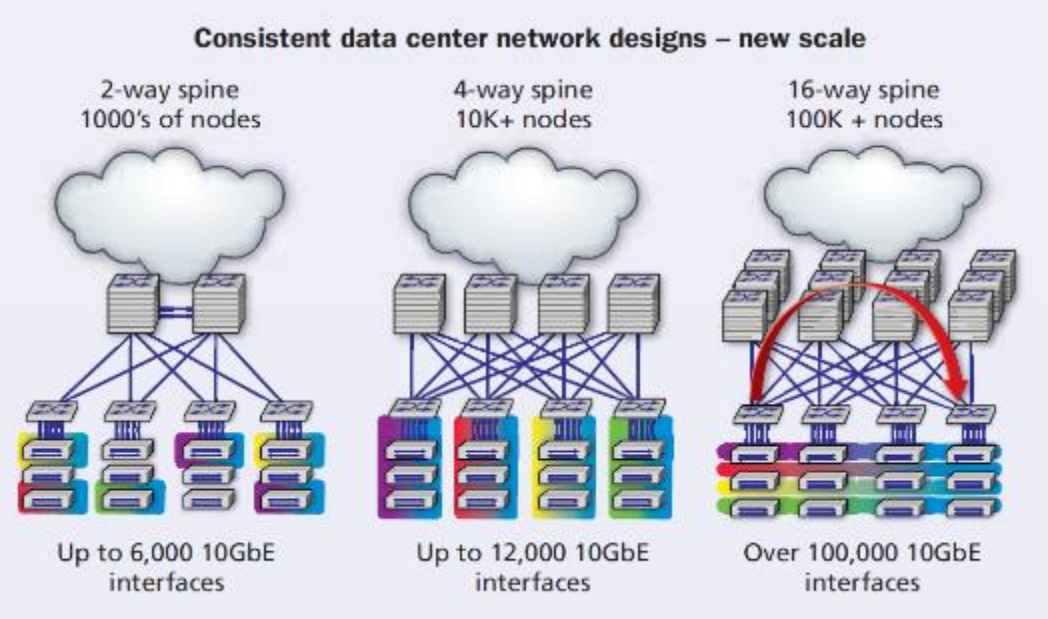


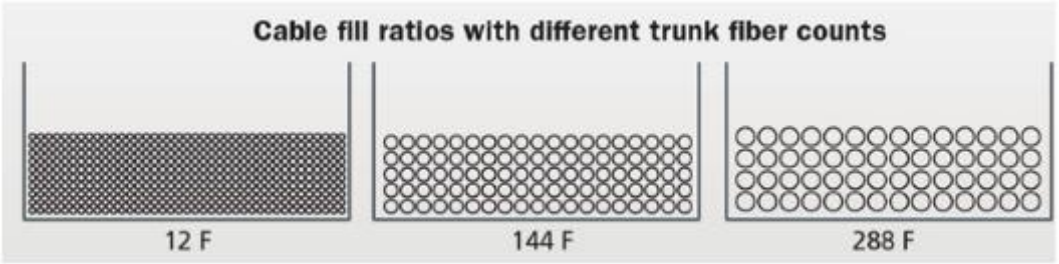



# High Fiber Count (HFC) Trunks

## Improve Density. Reduce Deployment Time. Save Cost



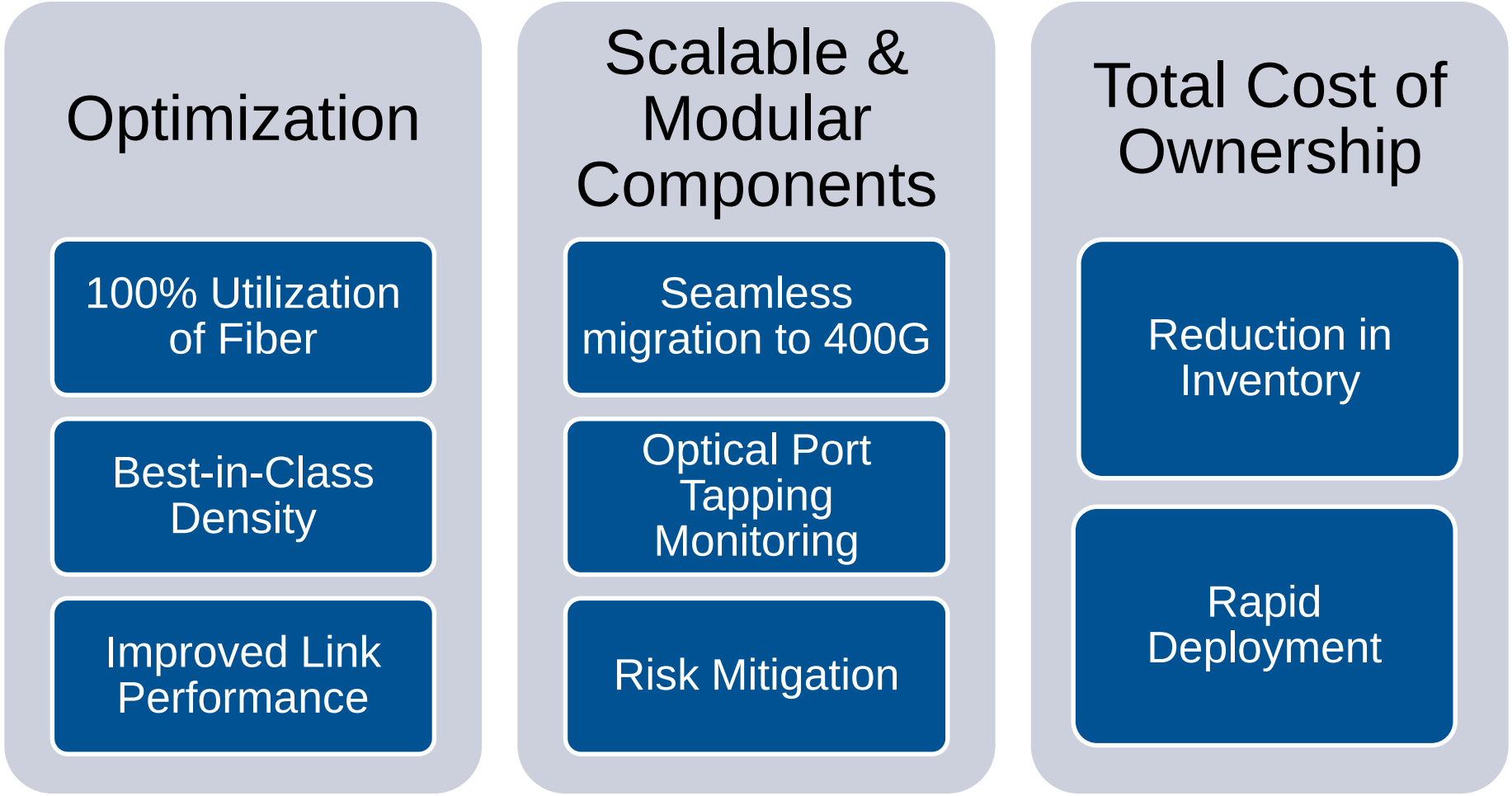

| | Ribbon | Single Fiber |
|---|---|---|
| Fiber Count | 1728F | 1728F |
| Number of splices | 144 | 1728 |
| Time per splice | 8 minutes ($40 per splice) | 4 minutes ($25 per splice) |
| Total Splicing Time(hrs) | 19 hours | 115 hours |




4400 total fibers using 370 x 12-fiber MTP-to-MTP Edge trunks
13,680 total fibers using 95 x 144-fiber MTP-to-MTP Edge trunks
16,128 total fibers using 56 x 288-fiber MTP-to-MTP Edge trunks

# Take Away

## Helping Customers to Maximize their Network Infra Assets



CORNING