

# Optimizing the Cost and Performance of a Plug-and-Play Fiber Network

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# Topics

- **Data Center Definitions and Requirements**
  - Standards
  - Optical System Performance
  - Typical Topologies and Configurations
  - Polarity
- **Economics**
  - Cost comparison between solutions
  - Cost benefit: where better employed
- **Summary**
- **FOLS**

# Data Center Definitions and Requirements



# What Categorizes a Data Center?

- “Always on” services
  - Limited access time to infrastructure
  - Adds, moves and changes must be performed during specific hours
- Constant changes
  - New equipment, software, applications, customers added or changed constantly

# What Categorizes a Data Center?

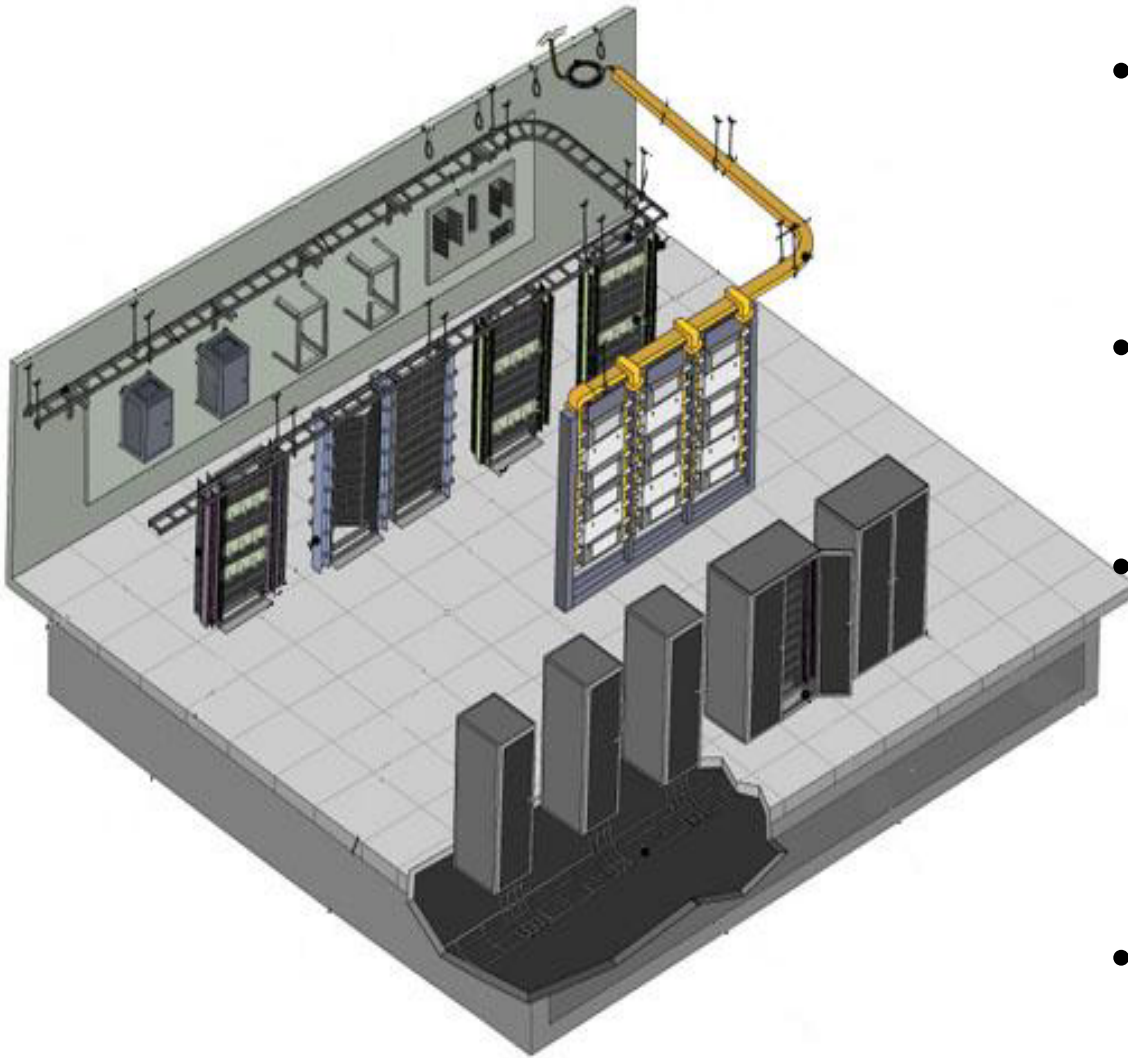
- **Floor space**
  - Sq ft may cost \$1000+, therefore must allocate as much as possible to “production”
- **Reliability**
  - Downtime costs can quickly escalate to \$ millions
- **Resources**
  - IT Operations, Facilities, Networking, Third Party (Consultants)

# What Categorizes a Data Center?

- Business Continuity
  - Ensure “business goes on”
- Criticality vs. Overall Cost
  - Time to recovery vs. cost of recovery
- Evaluate new technologies “coldly”
  - Does the new “gadget” really do what it says?
- Plan for the Future
  - *“640K ought to be enough for anybody.”*

Bill Gates

# What Categorizes a Data Center?



- **Fiber Intensive**
  - proportionally more fiber than a std. enterprise network
- **High Bandwidth**
  - MM Laser Optimized Fiber
- **Limited access time demands fast installation and maintenance**
  - Plug-n-Play Systems
- **Mission Critical Applications**
  - Reliability

Does This Remind You of Something?



# Design Considerations

## What is Plug-n-Play?

- **Modularity/Flexibility**
  - Pre-terminated trunks, harnesses and modules connect to each other allowing for flexible configuration...and reconfiguration.
- **Density**
  - More efficient use of cable pathways and rack/cabinet space
  - Minimize use of expensive floor space
  - Up to 60% smaller



# What Categorizes a Data Center?

## Why Plug-n-Play?

- **Increased Reliability**
  - Factory terminated cords and cables, remove performance variable of field termination or splicing
- **Speed**
  - No fiber splicing or field termination required
  - Minimum network downtime
  - Fast ongoing maintenance
  - Installation up to 75% faster
  - Installation can be done in a small window of time



# Data Center Standards & Practices



# Standards and Practices

## EIA/TIA-942

PnP Fiber Systems fit well with the emerging “TIA-942 Telecommunications Infrastructure Standard for Data Centers”

- 942 largely focuses on cabling infrastructure
  - Gives limited attention to other infrastructure—power, cooling, etc.
- For the most part, it is TIA 568B and 569A for data centers

# Standards and Practices

- What does TIA-942 cover?
  - Data center sizing and site selection
  - Data center cabling infrastructure administration
  - Architectural and structural considerations
  - Security and fire protection
  - Electrical, grounding and mechanical systems
  - Application distances
  - Access-provider coordination and demarcation

# Standards and Practices

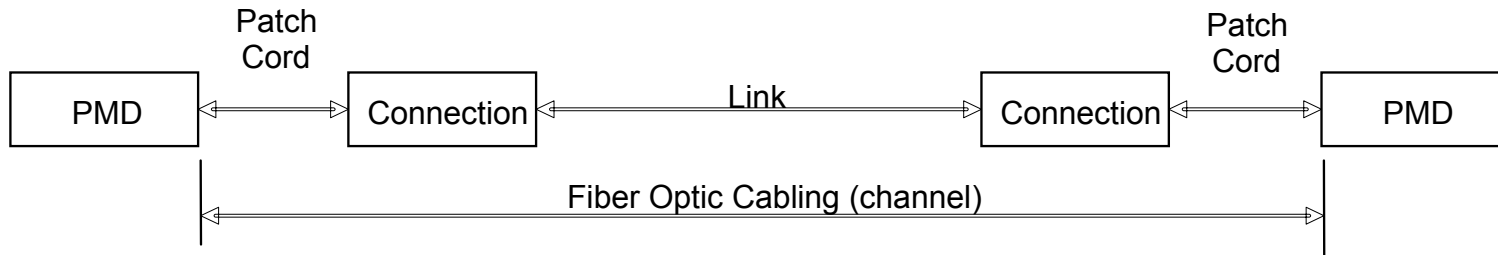
- EIA/TIA 568-B – Commercial Building Telecommunications Cabling Standard
- EIA/TIA 862 – Building Automation Systems Cabling Standard for Commercial Buildings – April 2002
- BICSI (coming)



# Standards and Practices

- IEEE 802.11ae

- Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications



IEEE Std 802.3ae-2002 Table 52-24 - Fiber optic cabling (channel)									
Description	62.5/125µm MMF		50/125µm MMF			Type B1.1, B1.3 SMF		Unit	
Nominal Wavelength			850 <sup>a</sup>			1310 <sup>b</sup>	1550		nm
Modal bandwidth (min)	160	200	400	500	2000	N/A	N/A	N/A	MHz.km
Operating Distance (max)	26m	33m	66m	82m	300m	10km	30km	40km	
Channel Insertion Loss (max) <sup>c,d,e</sup>	2.6	2.5	2.2	2.3	2.6	6.0	11 <sup>f</sup>		dB
Channel Insertion Loss (min)	0	0	0	0	0	0	5		dB
Dispersion (max)	N/A	N/A	N/A	N/A	N/A	N/A	546	728	ps/nm
DGD_max <sup>g</sup>	N/A	N/A	N/A	N/A	N/A	10	19		ps
Optical return loss	N/A	N/A	N/A	N/A	N/A	N/A	21		dB

Notes: a - channel insertion loss at 850nm includes cable, connectors and splices.

b - channel insertion loss at 1310nm includes cable, connectors and splices

c - these channel insertion loss numbers are based on the nominal wavelength

d - operating distances used to calculate channel insertion loss are those listed in this table

e - maximum attenuation given in table 52-25

f - channel insertion loss at 1550nm includes cable, connectors and splices

g - differential group delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. DGD\_max is the maximum differential group delay that the system must tolerate.

# Standards and Practices

Ethernet	Bandwidth (bps)	Signal Source	Laser Optimized 50 Microns 2000/500 MHz/km	50 Microns typical 500/500 MHz/km	62,5 Microns typical 200/500 MHz/km	Single-mode 8,3 – 10 Microns
10BASE-FL	10 M	850 nm LED	1250	1250	2000	Not supported
100BASE-SX	10/100 M	850 nm LED	300	300	300	Not supported
100BASE-FL	100 M	1300 nm LED	2000	2000	2000	Not supported
1000BASE-SX	1 G	850 nm VCSEL	900 – 1000	550	275	Not supported
1000BASE-LX	1 G	1310 nm FP or VCSEL	600	550	550	5000
10GBASE-SR	10 G	850 nm VCSEL	300	82	33	Not supported
10GBASE-LR	10 G	1310 nm DFB	Not supported	Not supported	Not supported	10000
10GBASE-LX4	10 G (4 x 2.5 G)	Four 1310 nm DFBs	300	300	300	10000



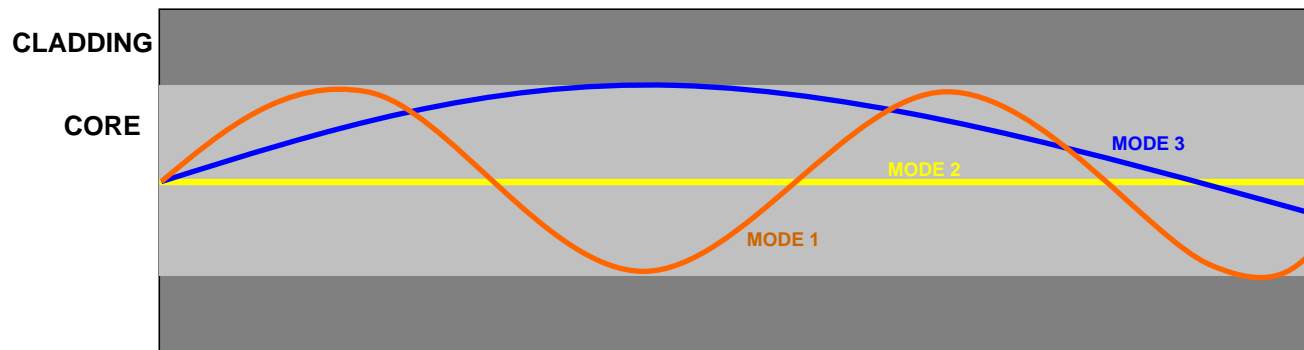
# Optical system Performance

# Optical System Performance

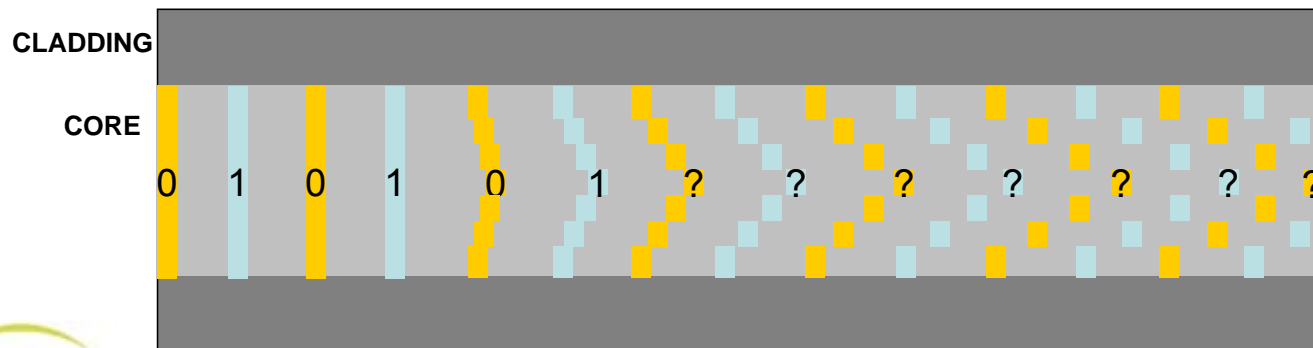
- Fiber

- Standard Multimode Fibers X Laser Optimized

- Differential Mode Delay (DMD)



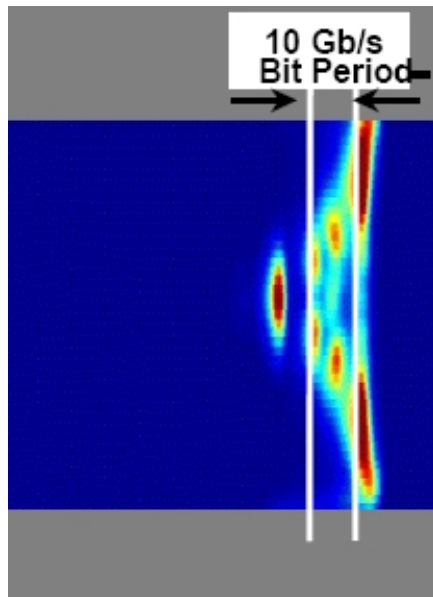
- Intersymbol Interference



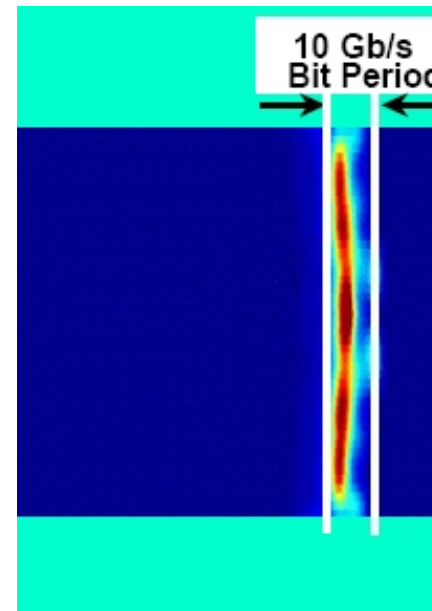
# Optical System Performance

- Fiber
  - Standard Multimode Fibers X Laser Optimized

Conventional Multimode Fiber



Multimode Laser Optimized Fiber



Keeps the bits inside their time slots.

# Optical System Performance

- Connectivity
  - Single-fiber connectors: LC, SC, ST, etc.
    - align one fiber at a time
      - more precision = lower loss
      - more time to connect-disconnect multiple fibers
      - single circuits = do not disturb “neighbor” circuits



# Optical System Performance

- Connectivity
  - Multifiber connectors: MTP, etc.
    - align multiple fibers at a time
      - less time to connect-disconnect multiple fibers
      - less precision = higher loss
      - multiple circuits = bad circuit replacement requires disconnecting working circuits



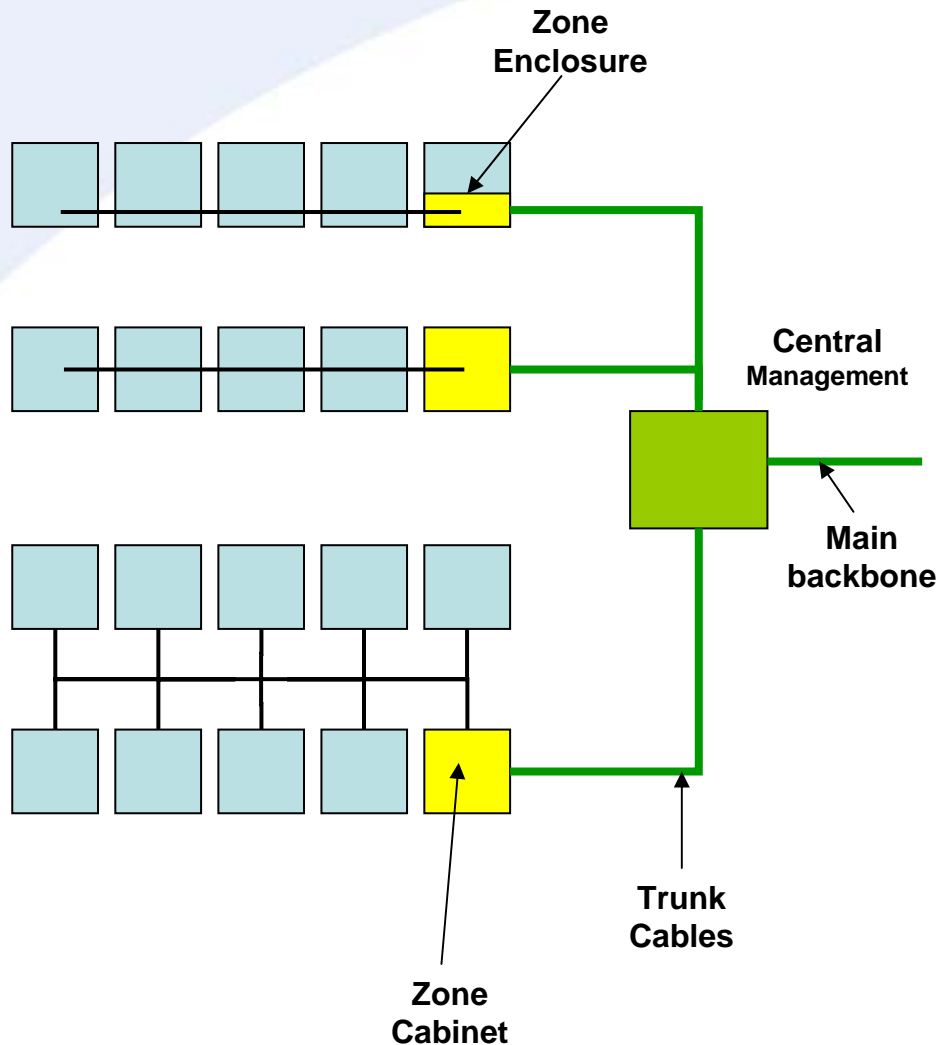
# Optical System Performance

- Typical optical performance

	<b>TIA</b>	<b>Market Average</b>
<b>Connectors (mated pair)</b>	<b>0.75dB</b>	<b>0.30dB (0.5dB MTPs)</b>
<b>Std MM Fiber</b>	<b>3.5dB/km (850nm)</b>	<b>2.9dB/km (850nmn)</b>
	<b>1.5dB/km (1300nm)</b>	<b>0.7dB/km (1300nm)</b>
<b>OM3 Fiber (laser optimized)</b>	<b>same</b>	<b>2.4dB/km (850nm)</b>

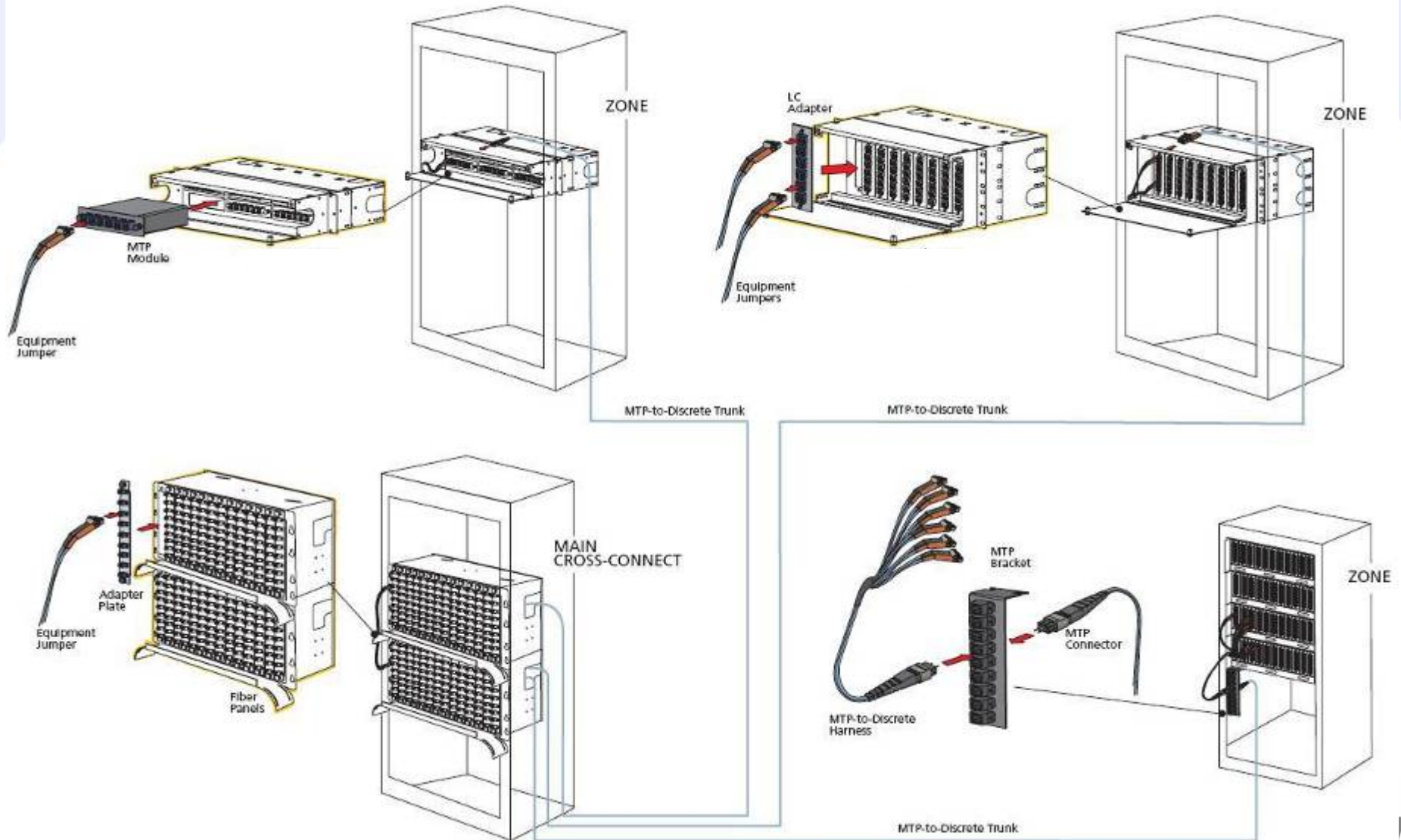
# Typical Topologies & Configurations

# Topologies



- Facilitates cabling and connectivity management
- Allows for organized growth
- Investment protection – fiber backbones allow for virtually unlimited bandwidth
- Zone enclosures may also accommodate cable slack and/or active equipment such as wireless points, switches, media converters, etc.

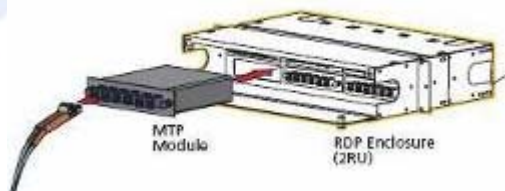
# Applications - Data Centers



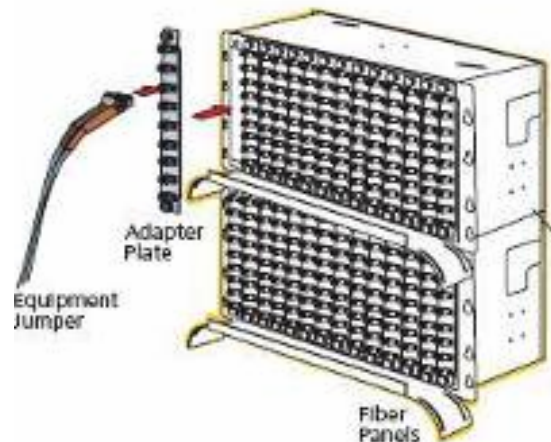
# Data Centers Typical Configurations

10Gb (10GBASE-SR) PnP – Sample Configuration 1

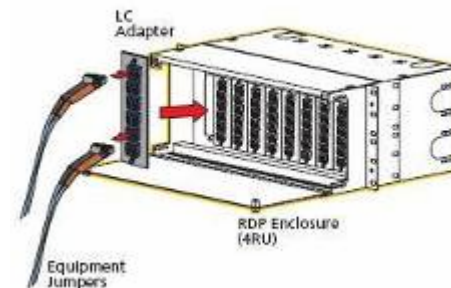
POD 1



Central X-Connect



POD 2



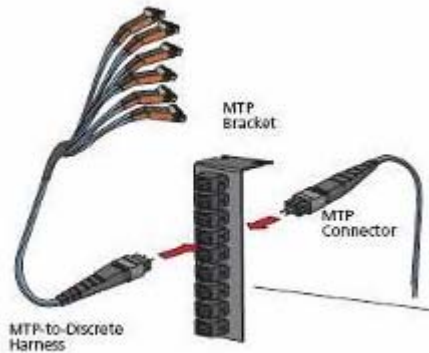
	POD 1 (db)		Central Cross Connect (db)		POD 2 (db)	Total (db)	Remaining Budget	Length Allowed (m)
<b>TIA</b>	<b>0.75</b>	<b>0.75</b>	<b>0.75</b>	<b>0.75</b>	<b>0.75</b>	<b>3.75</b>	<b>-1.15</b>	<b>-383</b>
<b>Premium</b>	<b>0.30</b>	<b>0.40</b>	<b>0.30</b>	<b>0.30</b>	<b>0.30</b>	<b>1.60</b>	<b>1.00</b>	<b>333</b> 3.0db/km MM LO Fiber



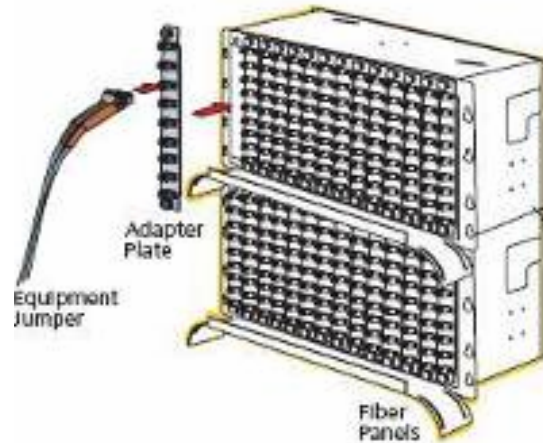
# Data Centers Typical Configurations

10Gb PnP (10GBASE-SR) – Sample Configuration 2

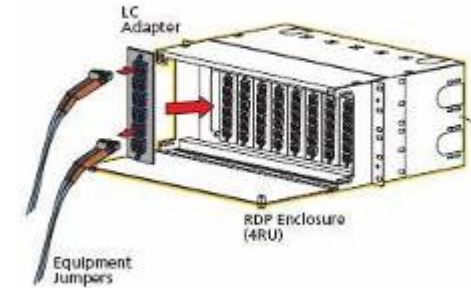
POD 1



Central X-Connect



POD 2

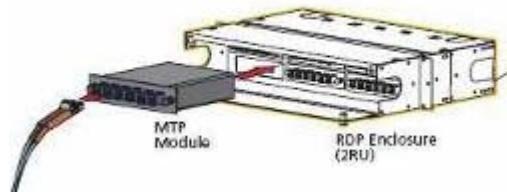


	POD 1 (db)	Central Cross Connect (db)		POD 2 (db)	Total (db)	Remaining Budget	Length Allowed (m)
TIA	0.75	0.75	0.75	0.75	3.00	-0.40	-133
Premium	0.40	0.30	0.30	0.30	1.30	1.30	433 3.0db/km MM LO Fiber

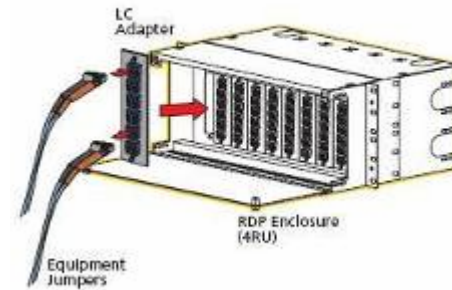
# Data Centers Typical Configurations

10Gb PnP (10GBASE-SR) – Sample Configuration 3

POD 1



POD 2

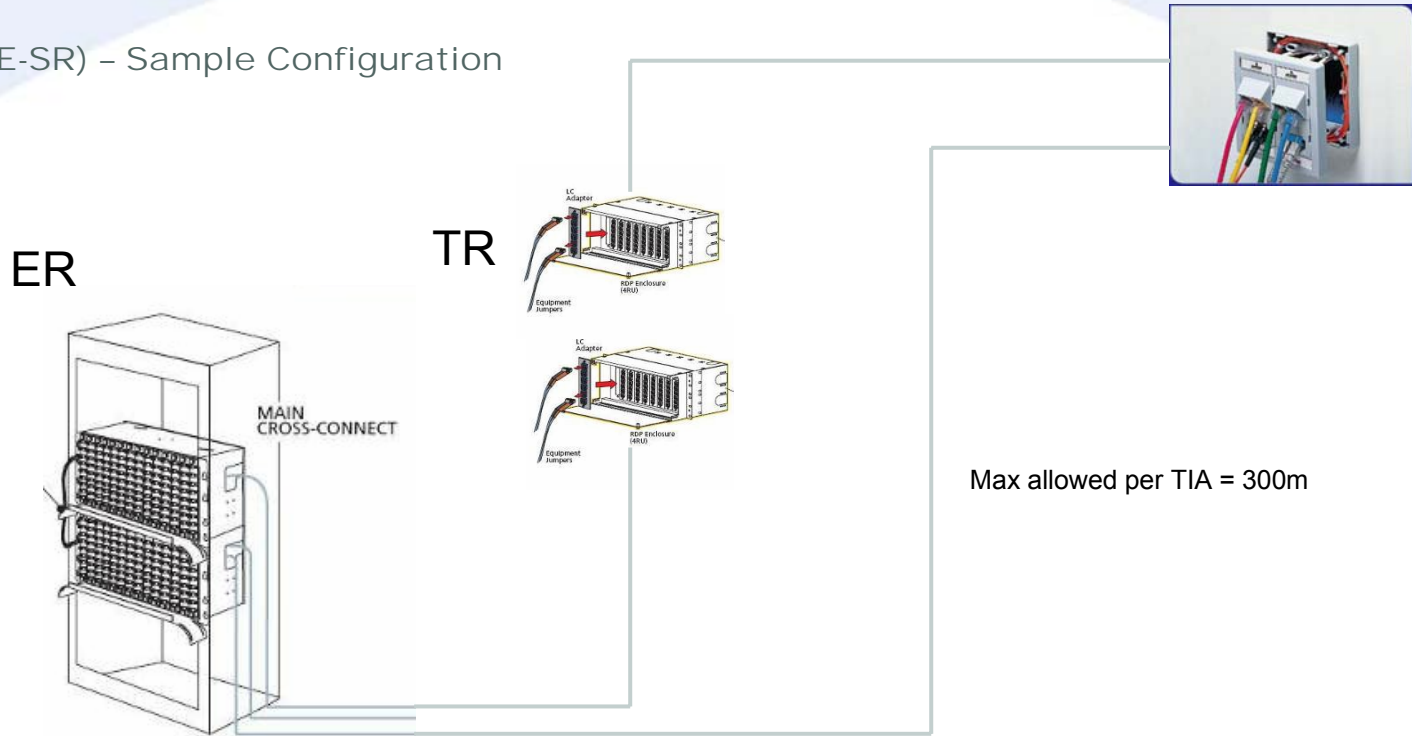


	POD 1 (db)		POD 2 (db)	Total (db)	Remaining Budget	Length Allowed (m)
<b>TIA</b>	<b>0.75</b>	<b>0.75</b>	<b>0.75</b>	<b>2.25</b>	<b>0.35</b>	<b>117</b>
<b>Premium</b>	<b>0.30</b>	<b>0.40</b>	<b>0.30</b>	<b>1.00</b>	<b>1.60</b>	<b>533</b>

3.0db/km MM LO Fiber

# Applications – FTTH

10Gb (10GBASE-SR) – Sample Configuration

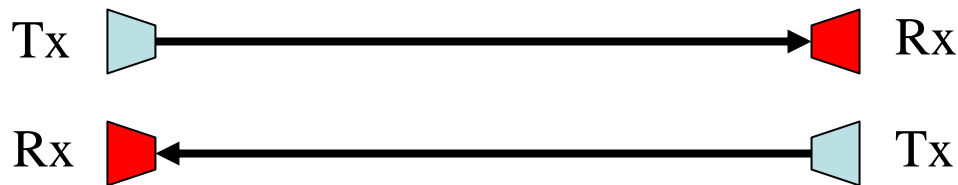


	ER (db)		TR (db)		Workstation (db)	Total (db)	Remaining Budget	Length Allowed (m)
Standard	0.75	0.75	0.75	0.75	0.75	3.75	-1.15	-383
Premium	0.30	0.30	0.30	0.30	0.30	1.50	1.10	367 3.0db/km MM LO Fiber

# Polarity

# Polarity

- TIA 568B.1-7 – Guidelines for Maintaining Polarity Using Array Connectors – Jan 2006
  - Methods A, B and C
- Support bi-directional communication systems that use separate fibers in each direction



- Polarity cabling accounts for this configuration
  - A to B – reverse polarity
  - A to A – straight polarity

# Polarity

- Method A

Jumper

A to B

Transition

Key Up  
Key Down

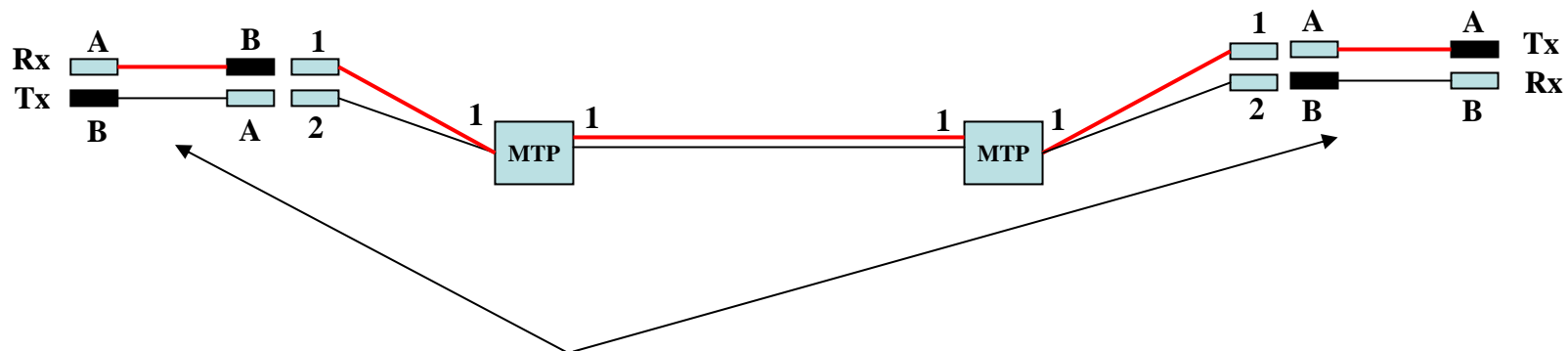
Trunk Cable (straight)

Transition

Key Up  
Key Down

Jumper

A to A



Disadvantage:

Need to keep/use two types of patch cords.

# Polarity

- Method B

Jumper

A to B

Transition

Key Up  
Key Up

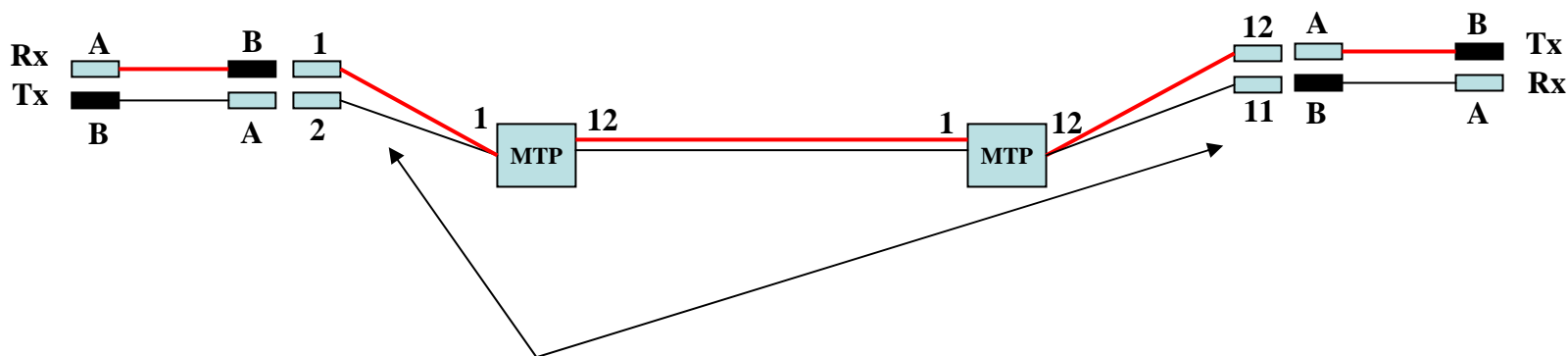
Trunk Cable (flipped)

Transition

Key Down  
Key Down

Jumper

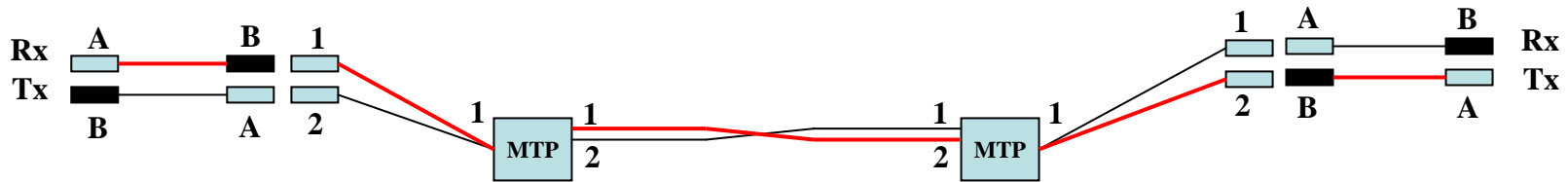
A to B



Disadvantage:  
Circuits end-up reversed.

# Polarity

- Method C



No need for different patch cords or reverse circuits.

# Polarity

Table 1: Summary of Components Used for **Duplex** Signals

Connectivity Method	Array Connector Cable Type	Array Adapter Type	Duplex Patch Cord Type
A	A	A	A-B and A-A
B	B	B	A-B
C	C	A	A-B

Table 2: Summary of Components Used for **Parallel** Signals

Connectivity Method	Array Connector Cable Type	Array Adapter Type	Duplex Patch Cord Type
A	A	A	Type A and Type B
B	B	B	Type B

Source: TIA-568-B.1-7 – Jan 2006

# Colors

## TIA 568.C-3

### Cables

- Standard SM fiber: yellow
- Standard MM 50 $\mu$ m and 62.5 $\mu$ m fibers: orange
- OM3 (Laser Optimized) fiber: aqua

### Connectors

- SM: blue (where applicable – e.g. LC, SC)
- Standard MM 62.5 $\mu$ m: beige
- Standard MM 50 $\mu$ m: beige or black (optional)
- OM3 (Laser Optimized) fiber: beige or aqua (optional)



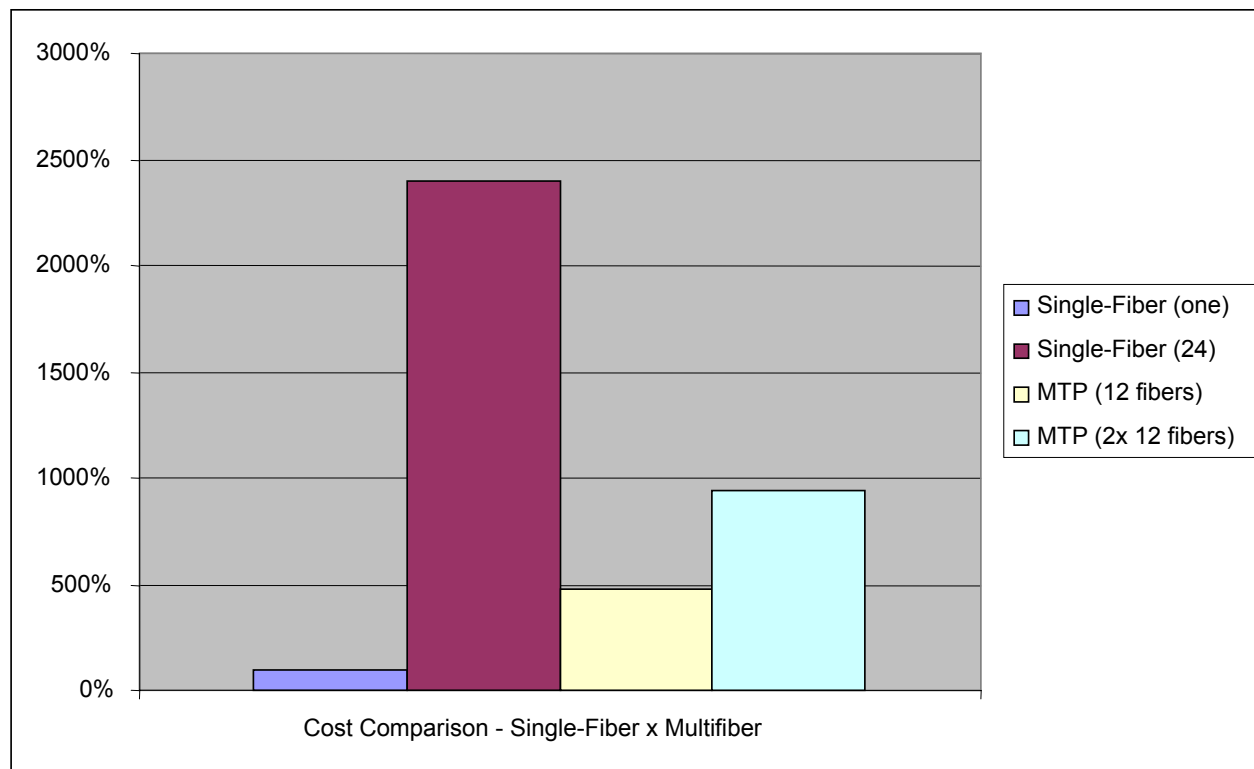
# Economics

# Economics

- Which Plug-and-Play solution is more economical?
  - Array X Single-fiber Connectors
  - Cassettes
  - Transitions (Harnesses)
  - Single-fiber terminations
  - Zero-U Brackets

# Economics

- Trunk Cables
  - Single-fiber X Array Connectors (Factory Installed)



Costs referenced to a single-fiber connector termination on a 12-fiber cable.

# Economics

## Are Array Connectors the Answer?

### Pros

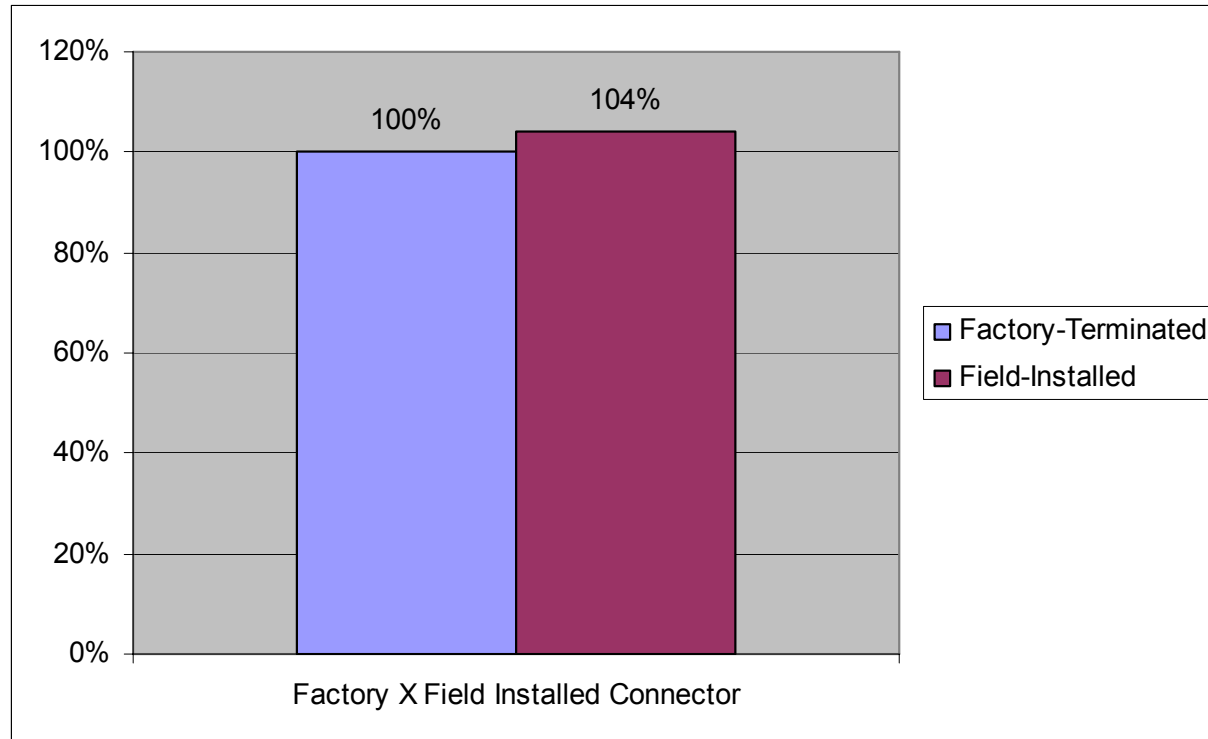
- Fast and easy to connect/disconnect
- Very high density – save rack/floor space
- Lower overall cost

### Cons

- Higher loss than single-fiber connectors
- One bad circuit compromises the others
  - Limit maximum number of fiber/connector to 12.

# Economics

## Factory-Terminated vs. Field-Terminated Connectors

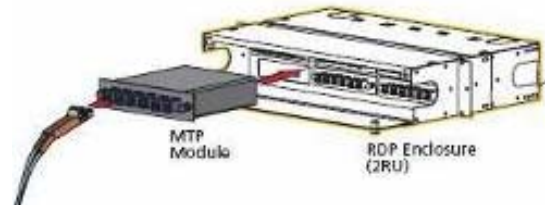


### Assumptions:

- LC MM connector
- Average 2.5min per field terminated connector
- Adhesive-type connector
- Field labor rate: \$40/hour
- Waste (lost connectors, etc. not considered)
- Pre-measurement for factory-terminated not considered

# Economics

## Module Systems

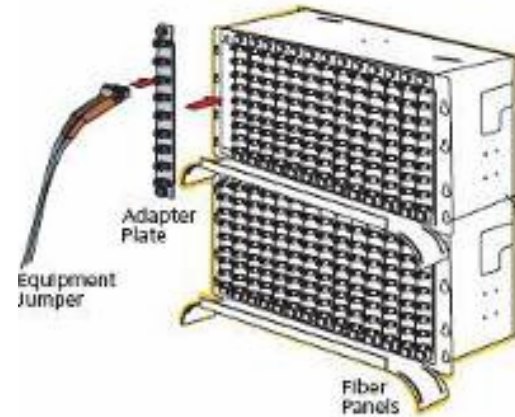


- Pros
  - Easy and fast termination of many fibers
  - Easy and fast connector type exchange
- Cons
  - Adds extra penalty on optical power budget
    - one extra connection point: uses array connector

# Economics

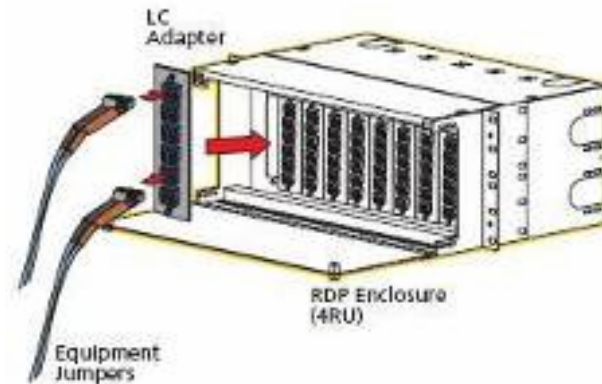
## Single-Fiber Termination + High-Density Panels

- Pros
  - Save floor space
  - Easy access
- Cons
  - Limited connector flexibility
    - not a major factor if used in a central cross-connect point



# Economics

## Single-Fiber Termination + Standard Enclosures

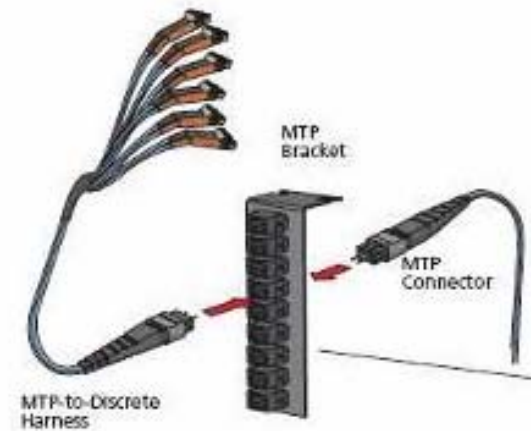


- Pros
  - Easy access
  - Lockable doors prevent unauthorized access
- Cons
  - Lower density than panels
  - Same limited connector flexibility as panels

# Economics

## Harness (Trunk-Transition Termination) + Zero U Brackets

- Pros
  - Very high density
  - Save rack space for active equipment
  - Save optical power budget
  - Very fast exchange of connector type or repair
- Cons
  - Fiber cable more exposed, requires more careful handling



# Economics

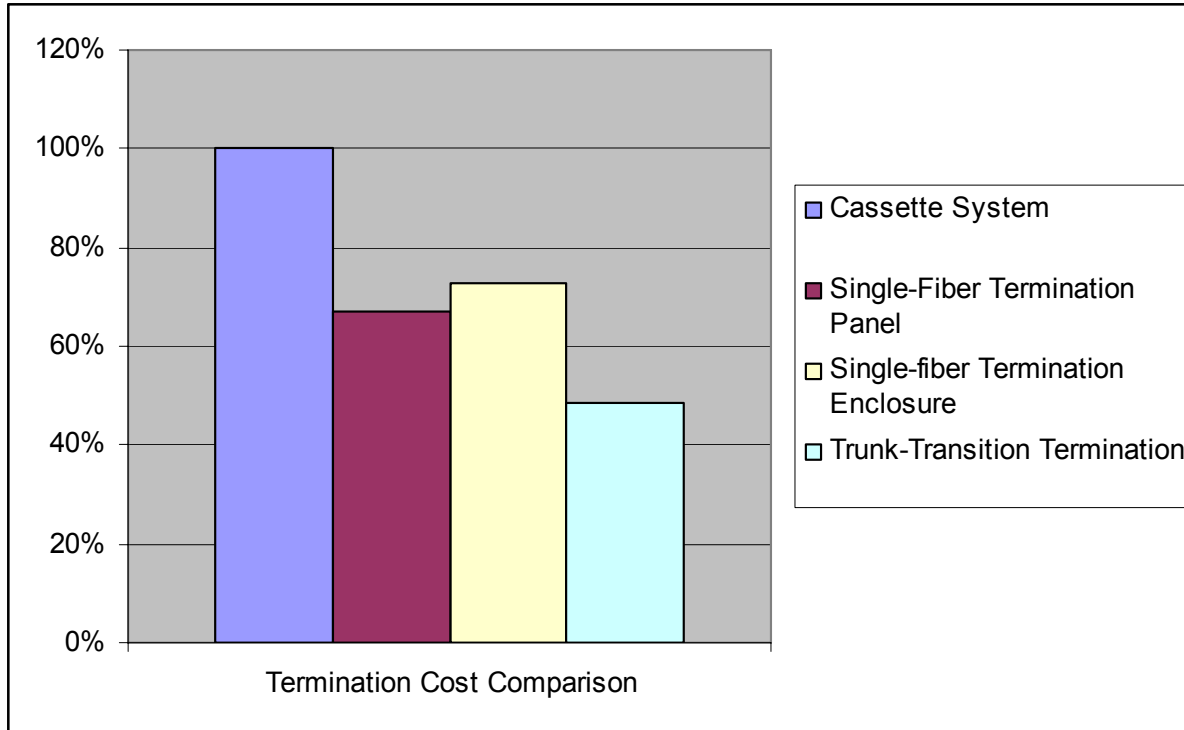
How much do they cost?

## Assumptions

- 50 $\mu$ m MM optical fiber
- LC duplex and 12-fiber array connectors
- 19in ANSI/EIA/TIA Standard Enclosures
- One port = two optical fibers

# Economics

## Relative Cost per Port

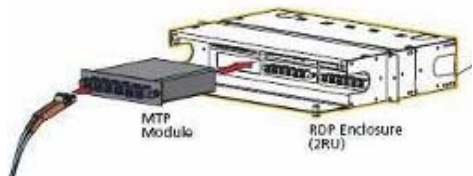


Costs referenced to the Cassette System

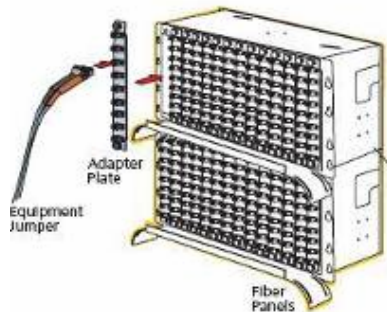
# Economics

## Which solution is the best?

- **Cassette Systems**



- **Single-Fiber Termination + High-Density Panels**

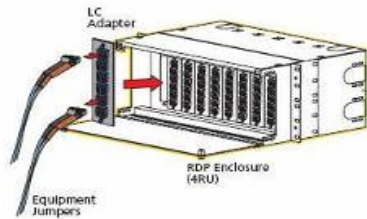


- Ideal for areas where equipment changes are common
  - offered with different connectors
  - eliminate hybrid patch-cords
- Ideal for central cross-connect
  - high density
  - single connection lowers optical power loss
  - custom panels can match special applications (e.g. mainframes)

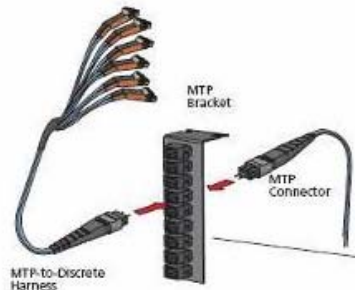
# Economics

## Which solution is the best?

- Single Fiber Termination + Standard Enclosures



- Harness + Zero-U Bracket



- Ideal for extra-security areas and where very low optical power loss is required

- lockable door
- single connection

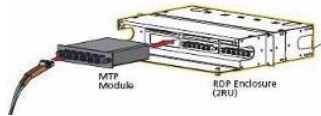
- Ideal for “no-space” areas and where equipment changes are common

- ultra-high density
- single connection lowers optical power loss

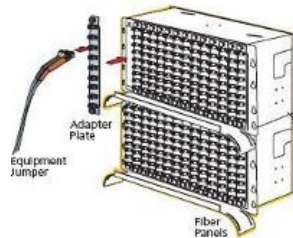
# Economics

## Comparing costs:

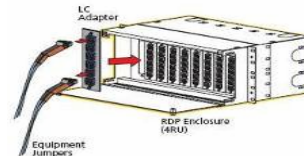
### Solution 1



Module System



Cross-Connect Panel



Standard Enclosure

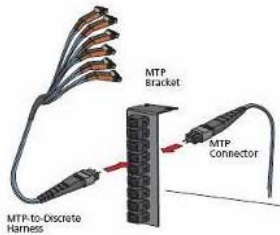
## Assumptions:

- 288 ports in central cross connect
- 144 ports in each remote (zone) interconnect

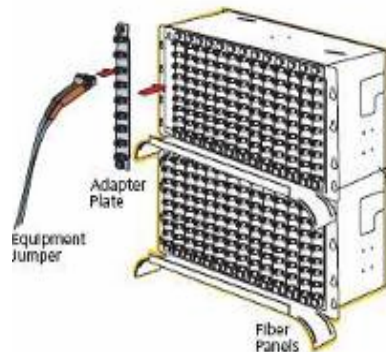
# Economics

## Comparing costs:

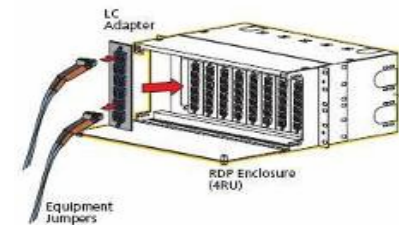
### Solution 2



Harness



Cross-Connect Panel



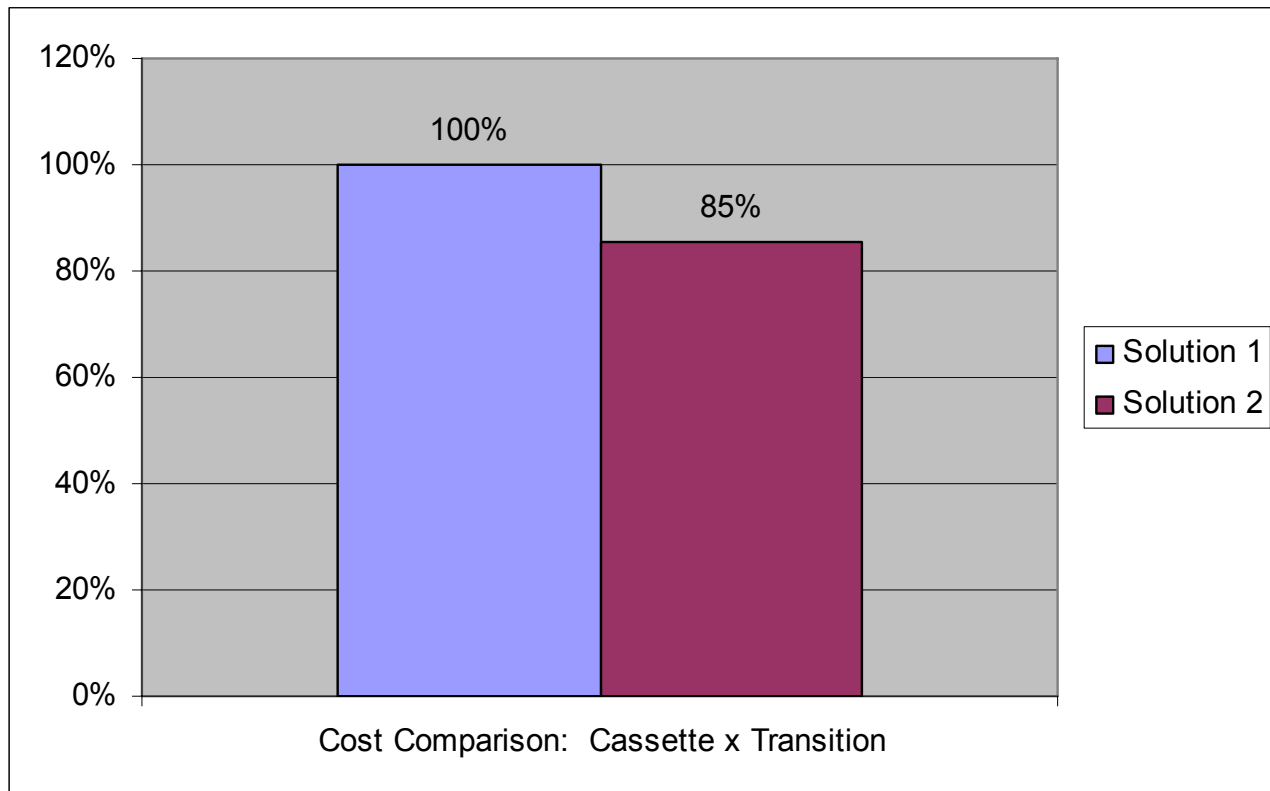
Standard Enclosure

## Assumptions:

- 288 ports in central cross connect
- 144 ports in each remote (zone) interconnect

# Economics

## Cost Comparison



# Summary

# Summary

- Data Center Definitions and Requirements
- Standards
- Optical System Performance
- Typical Topologies and Configurations
- Polarity
- Economics
- Summary

# Summary

- Main Standards
  - EIA/TIA 568-B, 942, 862
  - IEEE 802.11ae
- Performance
  - Plan for the future
    - *“640K ought to be enough for anybody.”*

# Summary

- **Topologies**
  - Zones (PODs) most common
- **Polarity**
  - Follow TIA standard - Avoid proprietary solutions
  - Choose one method (A, B or C) and stay with it
- **Economics**
  - Business Continuity
  - Criticality
    - Time to Recovery vs. Cost of Recovery
  - Which Solution is the Best?
    - Consider the application and criticality vs. cost

# TIA Fiber Optics LAN Session (FOLS)

- Founded in 1993 as a Section of the TIA's Fiber Optics Division.
- Mission: to educate system designers, architects, consultants, engineers, contractors, end users and the media about the technical advantages that optical transmission brings to customer-owned networks.
- FOLS also stimulates the development of new fiber standards and the promotion of optical-based applications in customer-owned networks.



# TIA Fiber Optics LAN Session

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Thank You!

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