

# **A High Level Overview of Optical Fiber Communications Systems**

*A Presentation to  
ECE1001 Class of  
Electrical and Computer Engineering Department  
at University of Minnesota Duluth*

*By*

*Professor Imran Hayee*



# Outline

- 1. What is an Optical Fiber?**
- 2. Why it Matters?**
- 3. How it Works?**
- 4. What do I do?**
- 5. Summary/Questions**



# Smartphone vs. Crystal Ball



**Crystal Ball**  
gives  
**information**  
regardless of  
**space and**  
**time**

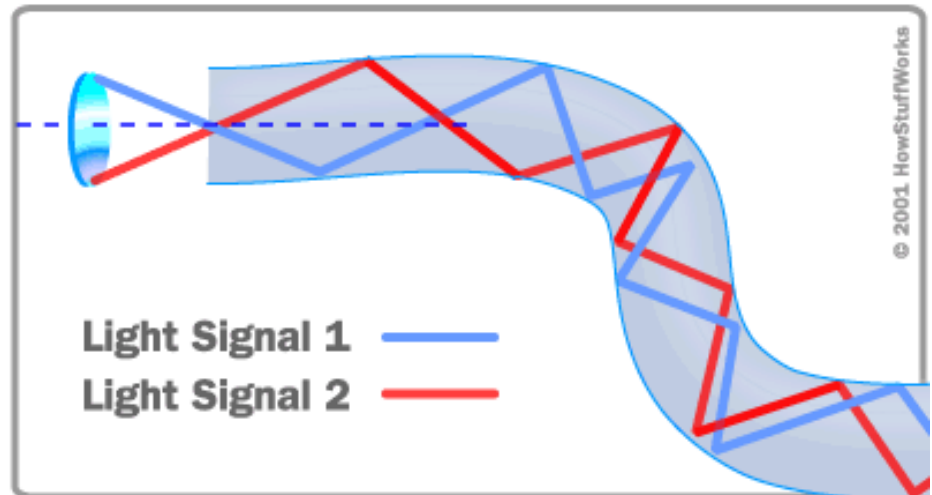
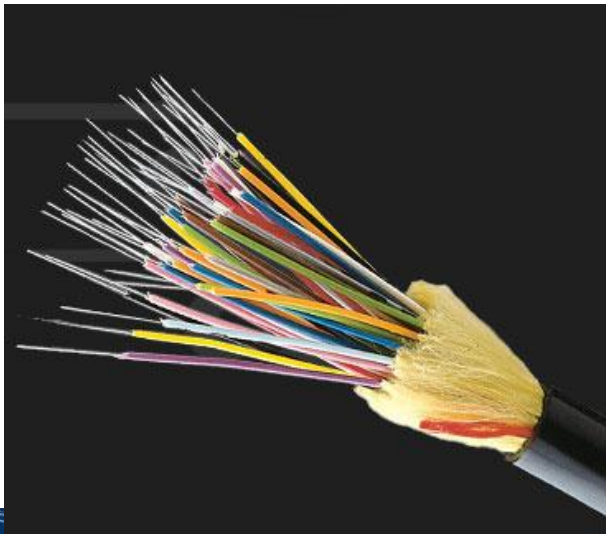


**Smart Phone**  
gives  
**information**  
regardless of  
**space and**  
**past time**

# What is an Optical Fiber

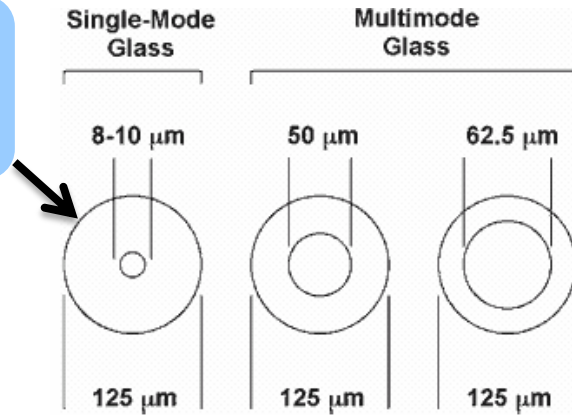


Optical Fiber is a thin long cylinder made of **Silica**

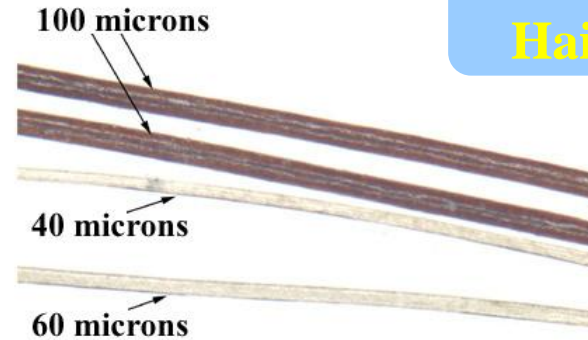


# Optical Fiber vs. Optical Cable

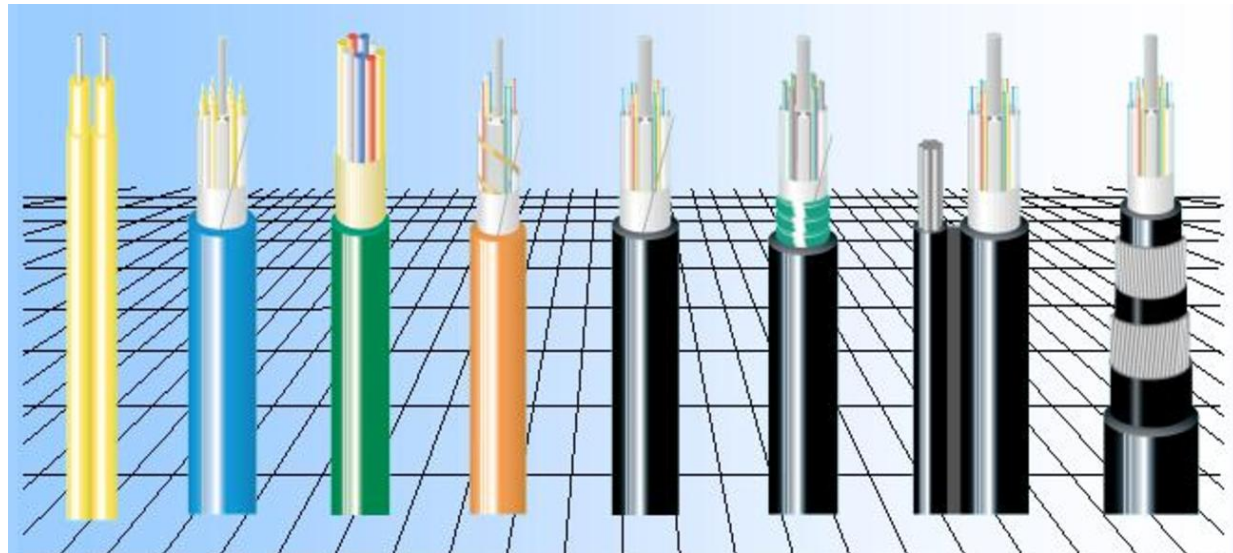
Today's  
Optical  
Fiber



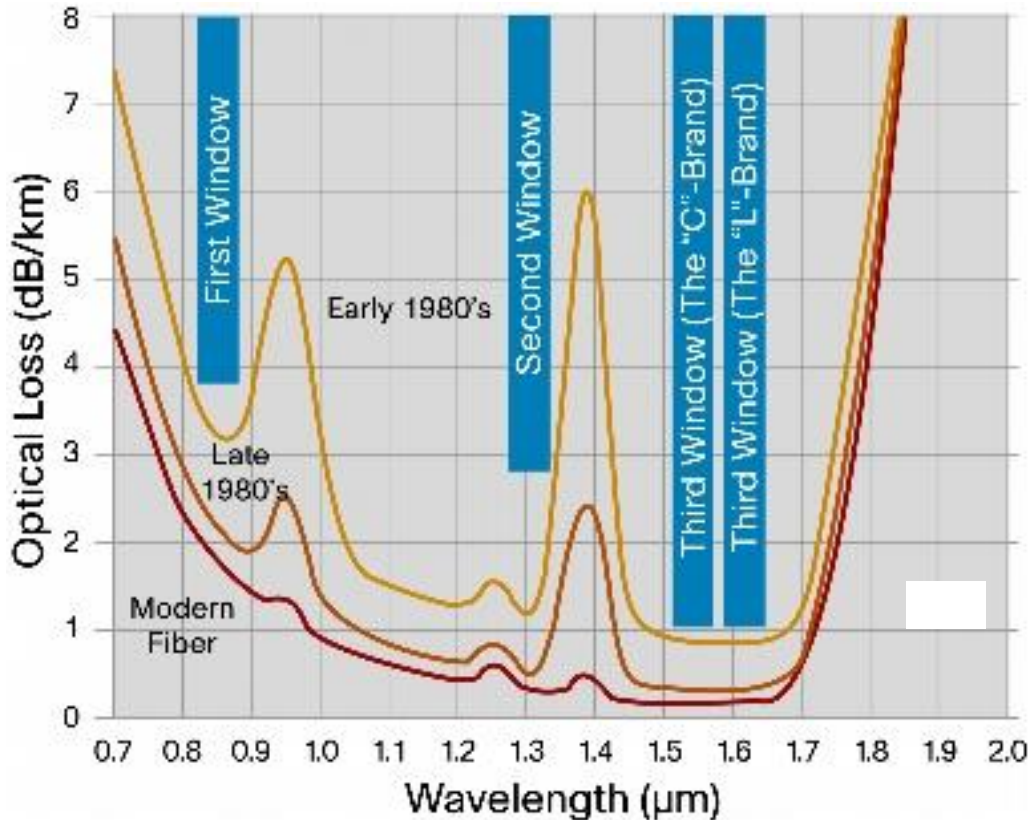
Human  
Hair



Optical  
Fiber  
Cables



# Why Optical Fiber?



**4 Billion bytes = 1 DVD**

**32 Billion bits = 1 DVD**

**1 Trillion bits ~ 31 DVDs**

**3 Trillion bits ~ 93 DVDs**

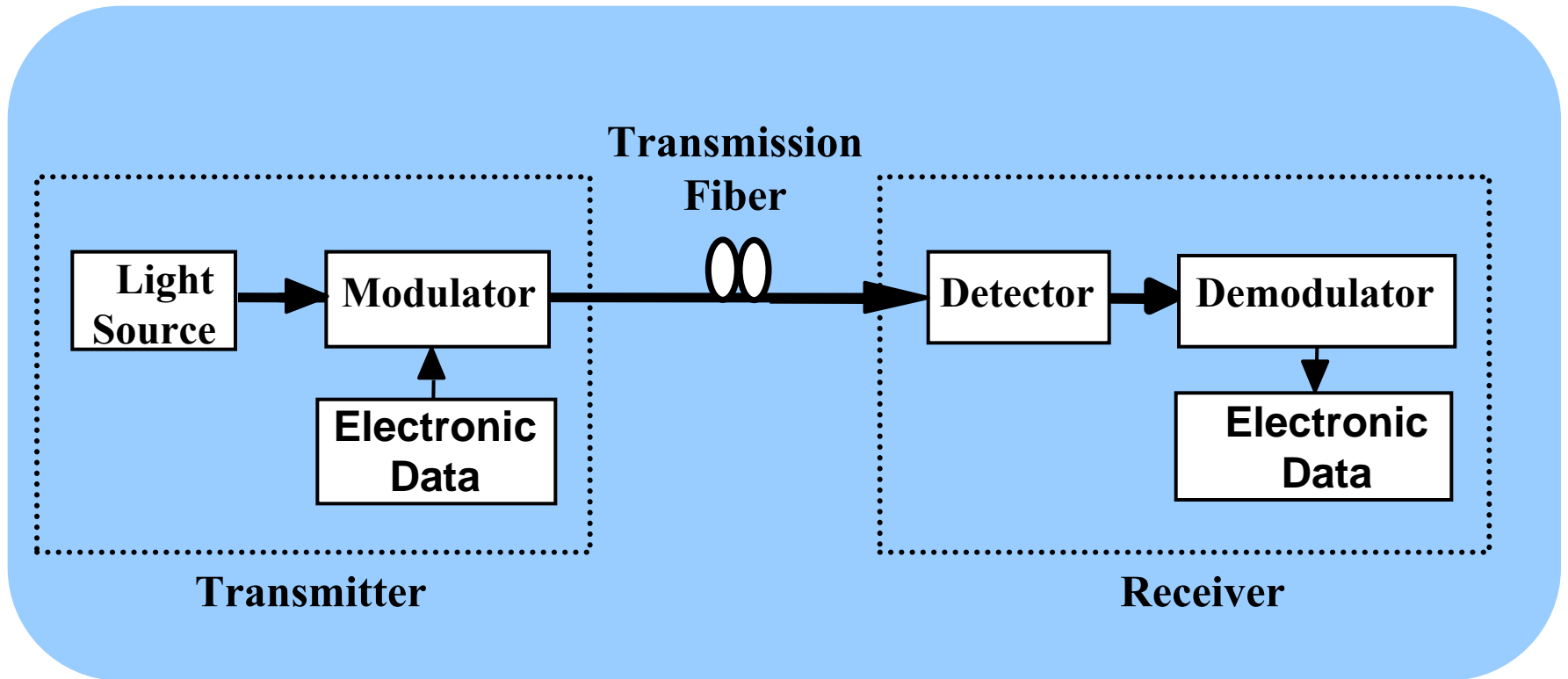
**25 Trillion bits ~ 775 DVDs**

**Huge but not Infinite  
Bandwidth**

**0.2 microns = 25 Tbit/sec**

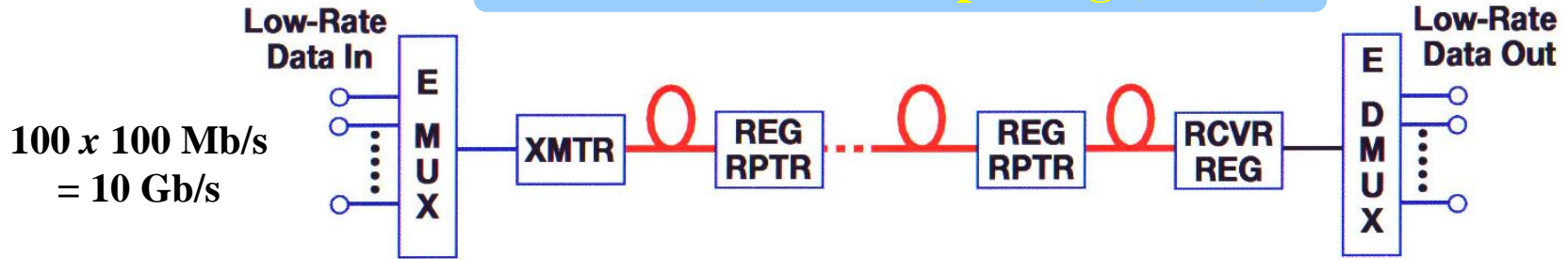
**Useable Today ~ 3Tb/s**

# How it Works?



# TDM vs. WDM

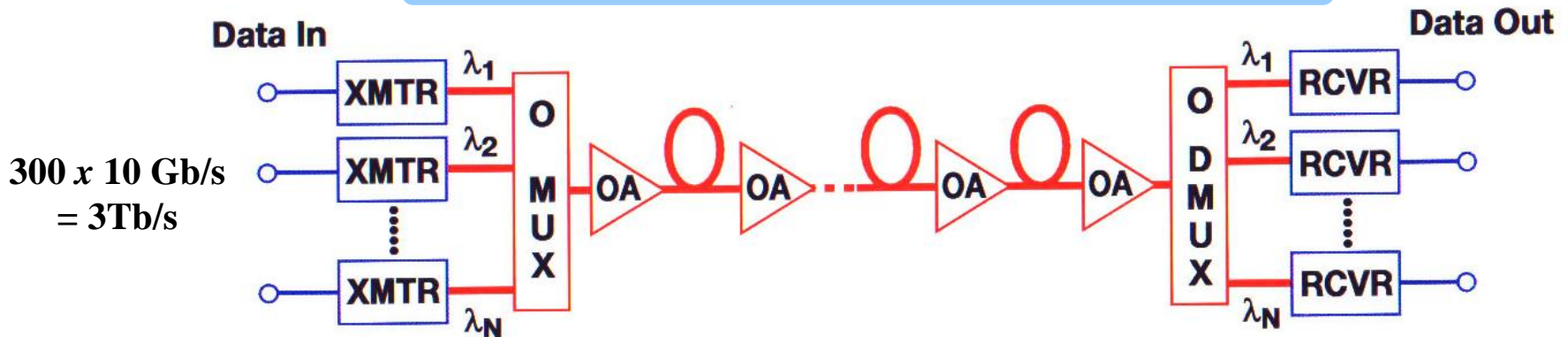
## Time Division Multiplexing (TDM)



$100 \times 100 \text{ Mb/s}$   
 $= 10 \text{ Gb/s}$

10Gb/s max - one color of light

## Wavelength Division Multiplexing (WDM)

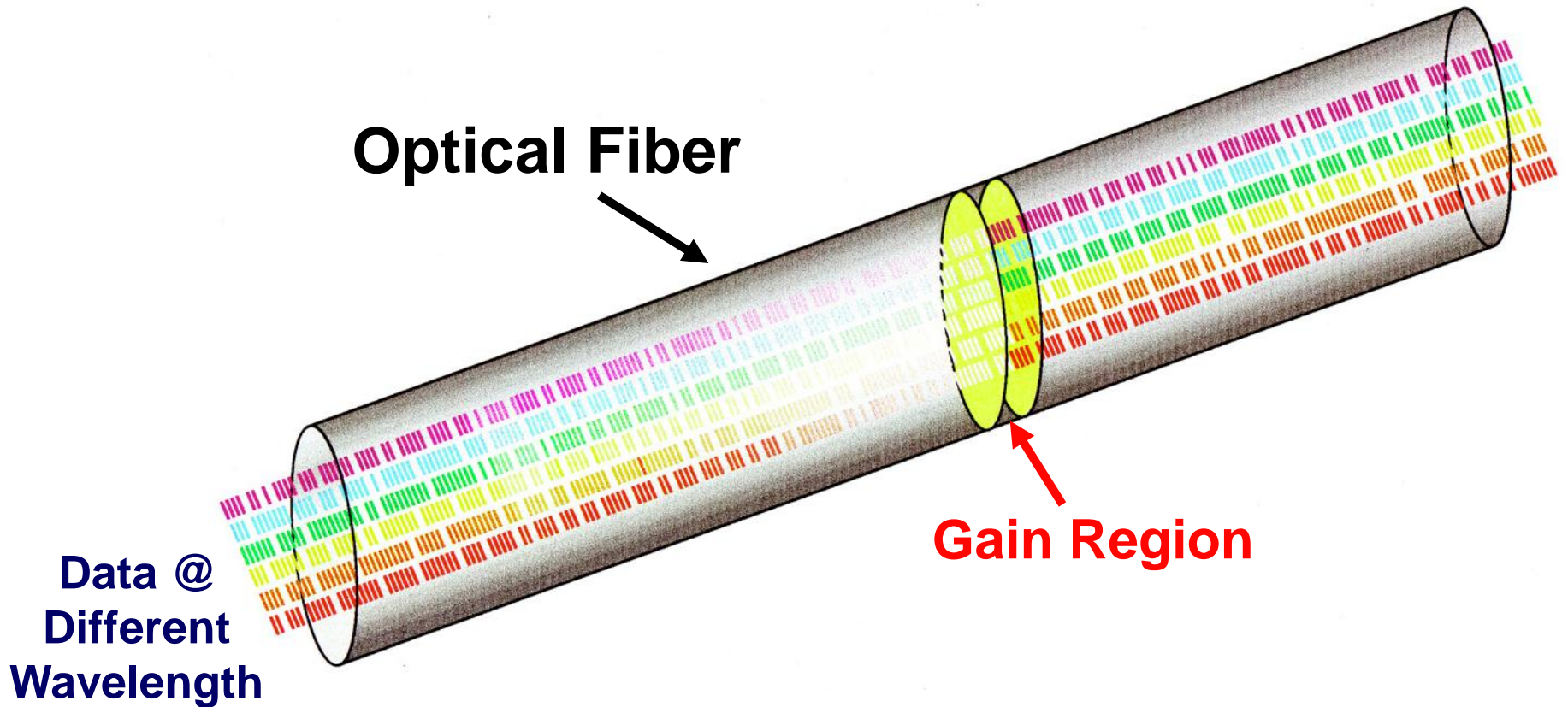


$300 \times 10 \text{ Gb/s}$   
 $= 3 \text{ Tb/s}$

300 channels of 10Gb/s – many colors of light simultaneously

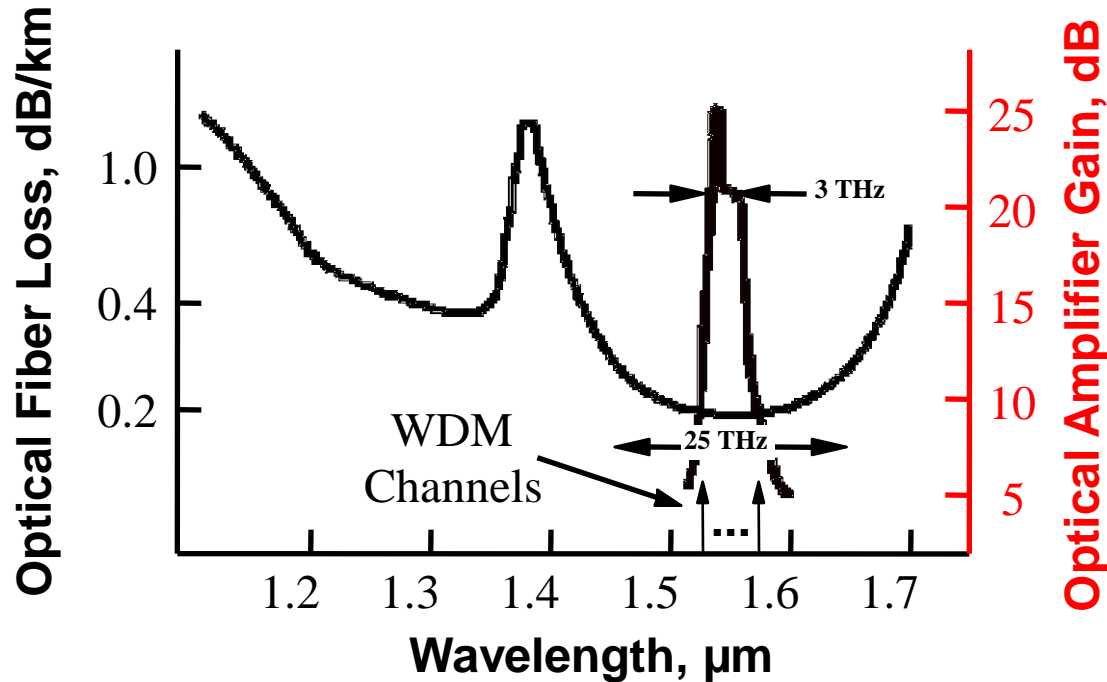


# Wavelength-Division-Multiplexing (WDM)



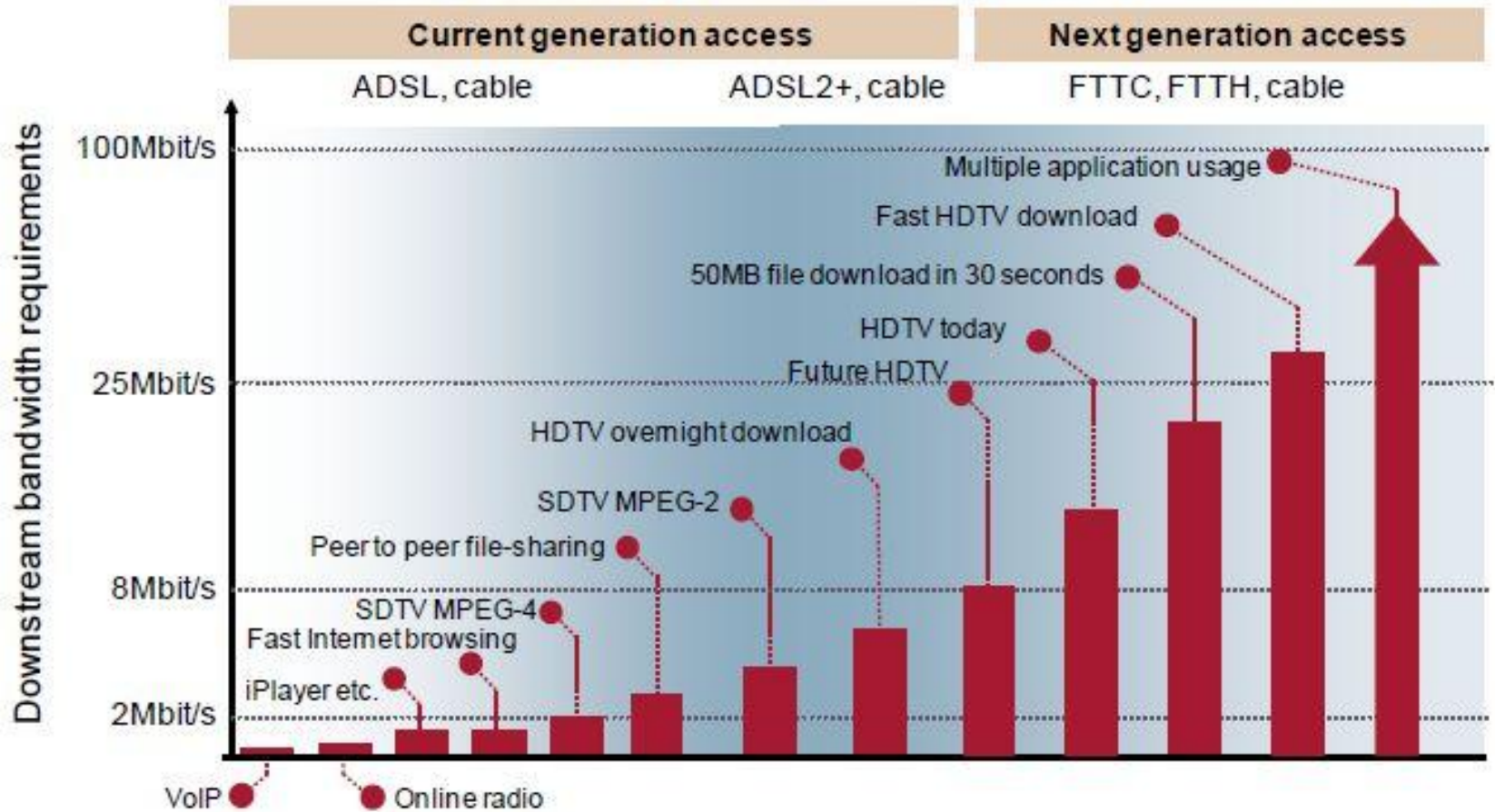
Multiple colors of light traveling through the optical fiber, interact with each other in very complex manner – that is the ultimate limitation of capacity usage of fiber

# Useable Optical Fiber Bandwidth



*About 3 Tbits/sec bandwidth could be used using EDFAs which is still ~12% of total fiber bandwidth*

# Is 3 Tb/s Enough?



**100 users x 100 Mbit/s = 10Gb/s (1 Fiber Channel)**

**300 users x 10Gb/s = 3Tb/s (useable Fiber BW)**

# Most Popular Headline of CNN on February 21, 2012

THE SPECTRUM CRUNCH

## Sorry, America: Your wireless airwaves are full

CNNMoney

1,395 comments

By David Goldman @CNNMoneyTech February 21, 2012: 5:30 PM ET

Recommend 3k

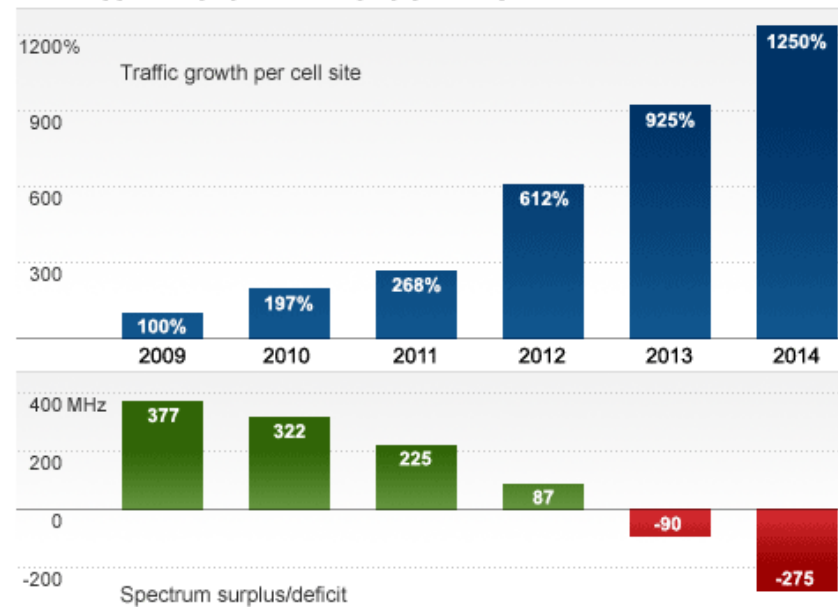
Tweet 68

Share 18

+7 93

Email Print

### WIRELESS DATA GROWTH LEADS TO SPECTRUM DEFICIT



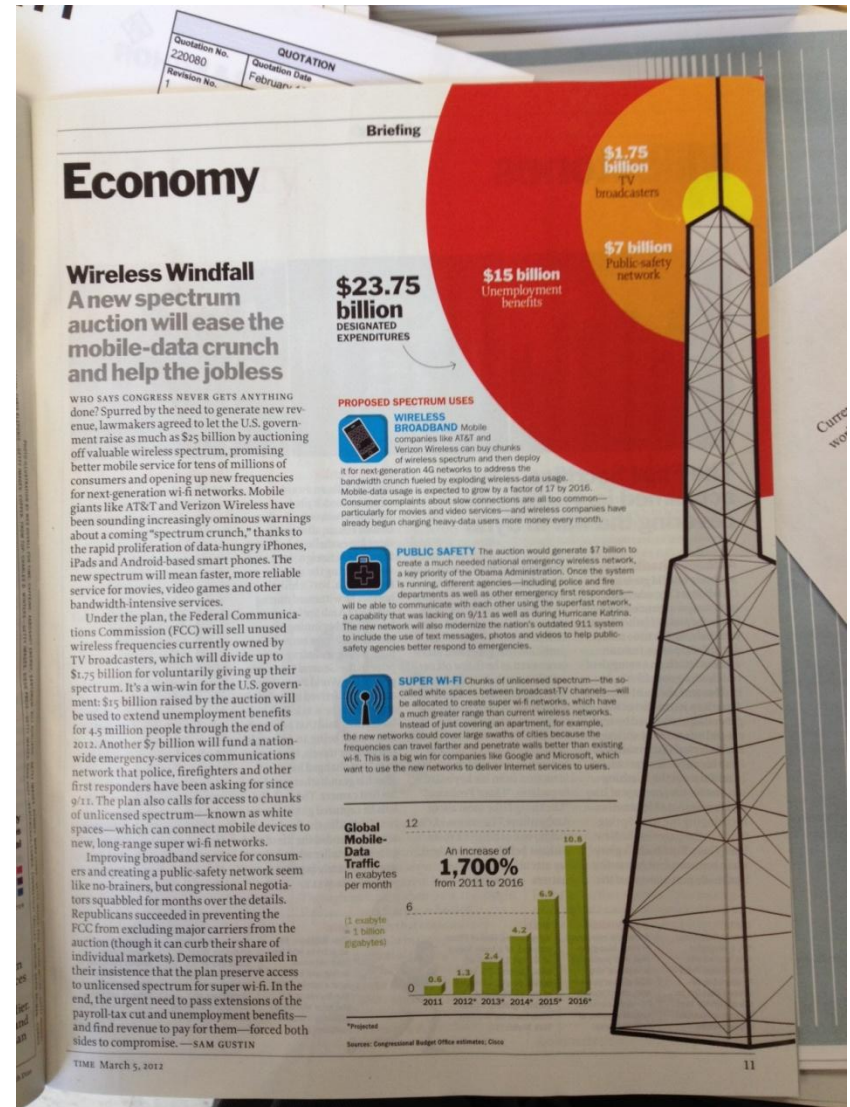
SOURCE: FCC

This is **part one of a week-long series** on the cell phone capacity crunch.

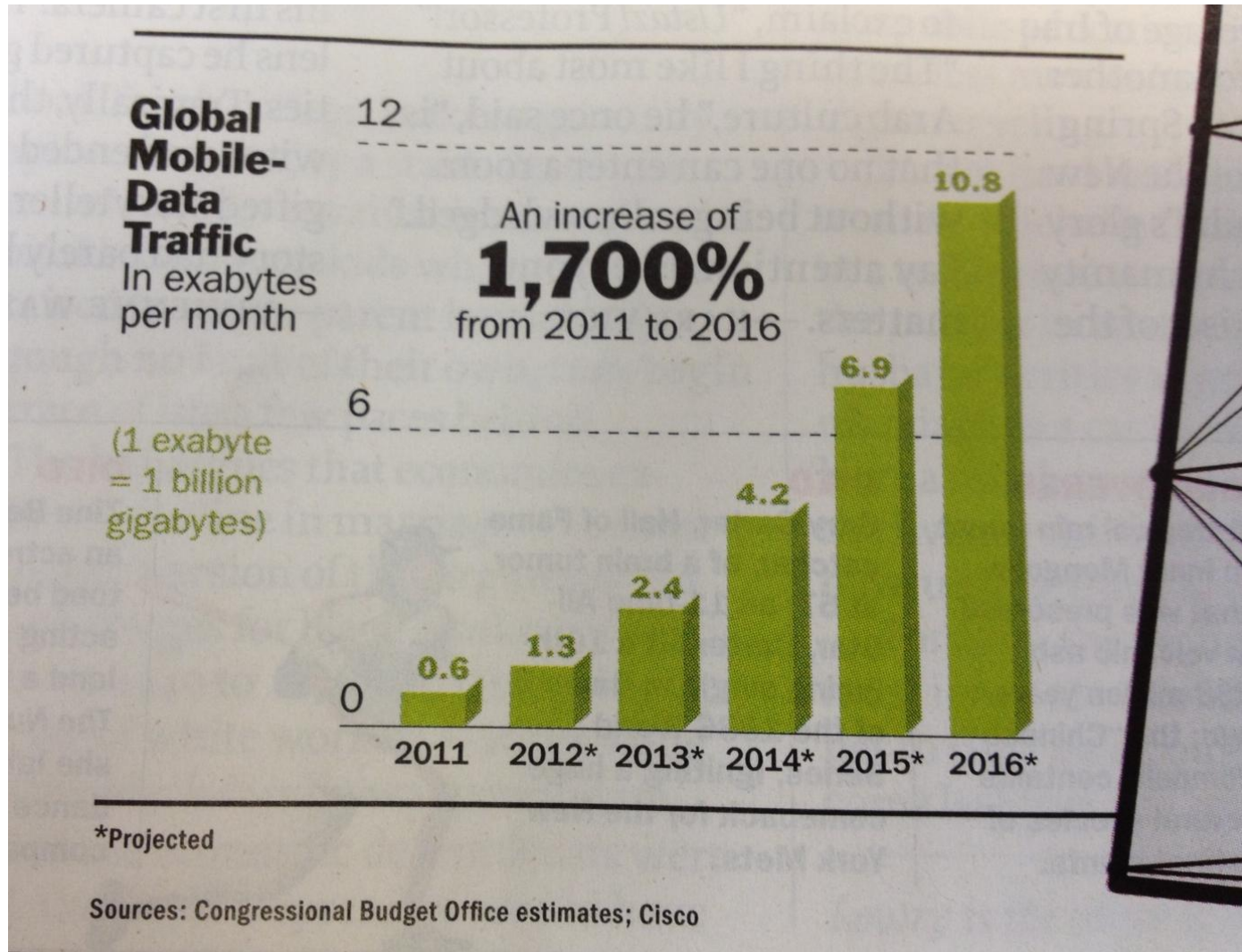
NEW YORK (CNNMoney) -- The U.S. mobile phone industry is running out of the airwaves necessary to provide voice, text and Internet services to its customers.



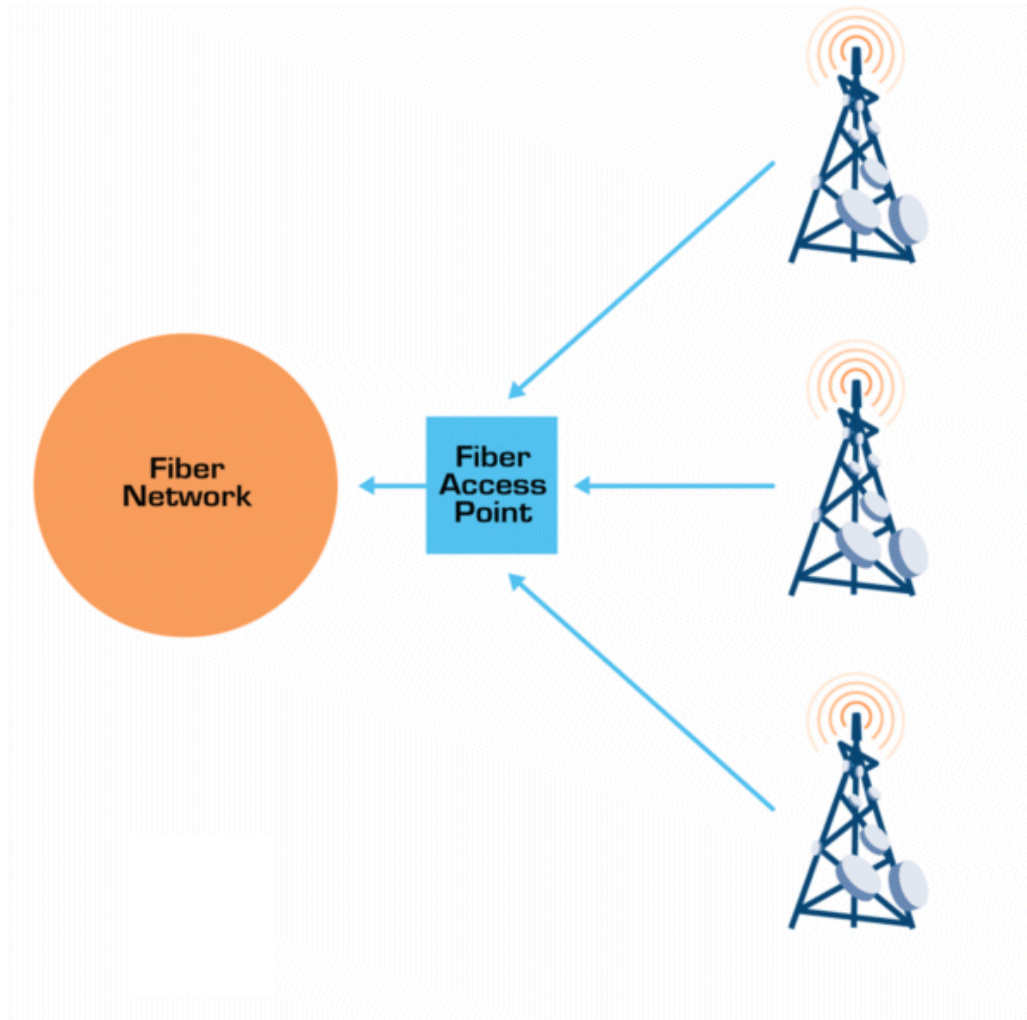
# March 5 Time Magazine – Page 11



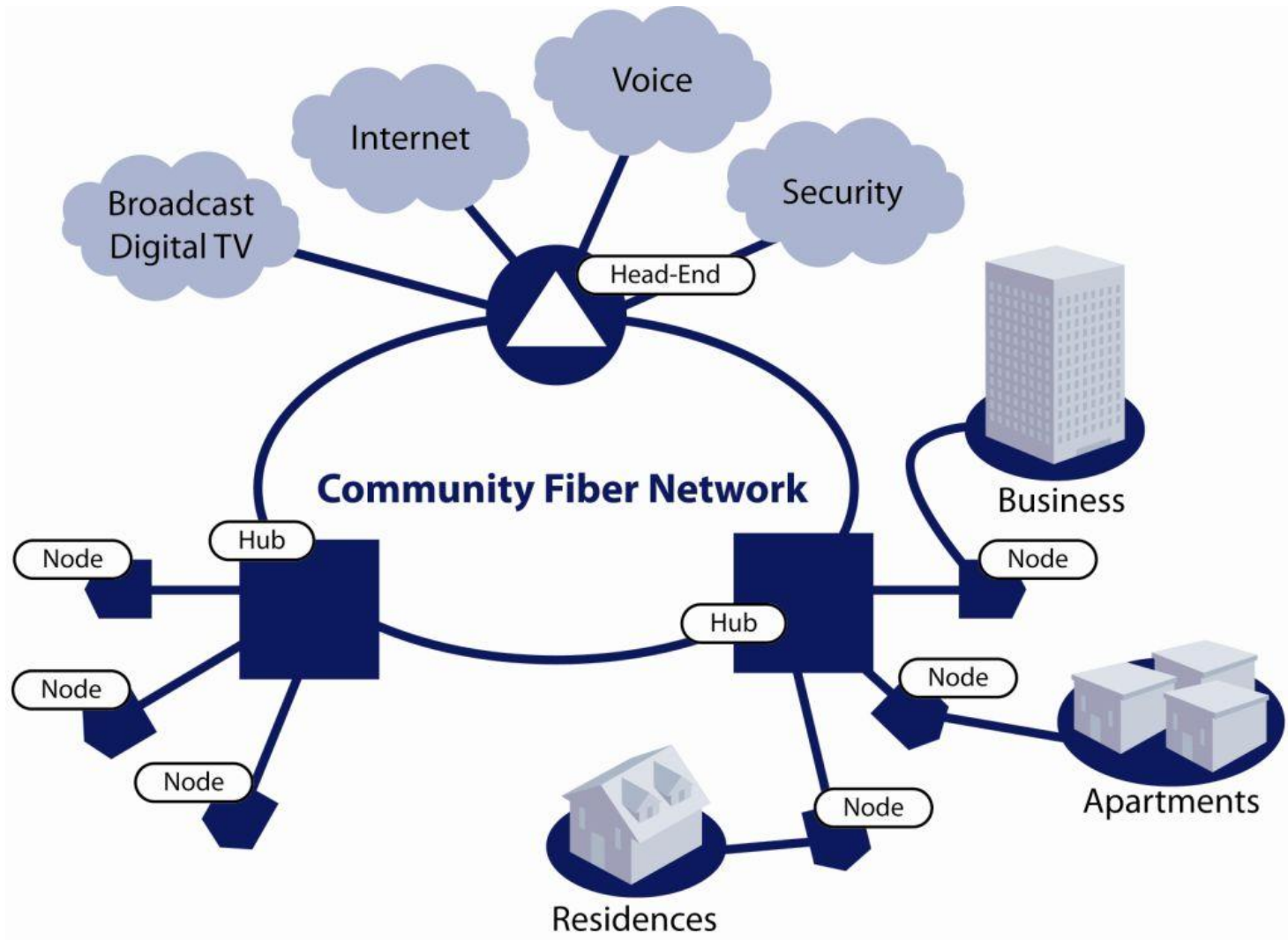
# Wireless Demand is Exploding



# Cell Towers are Connected to Fiber

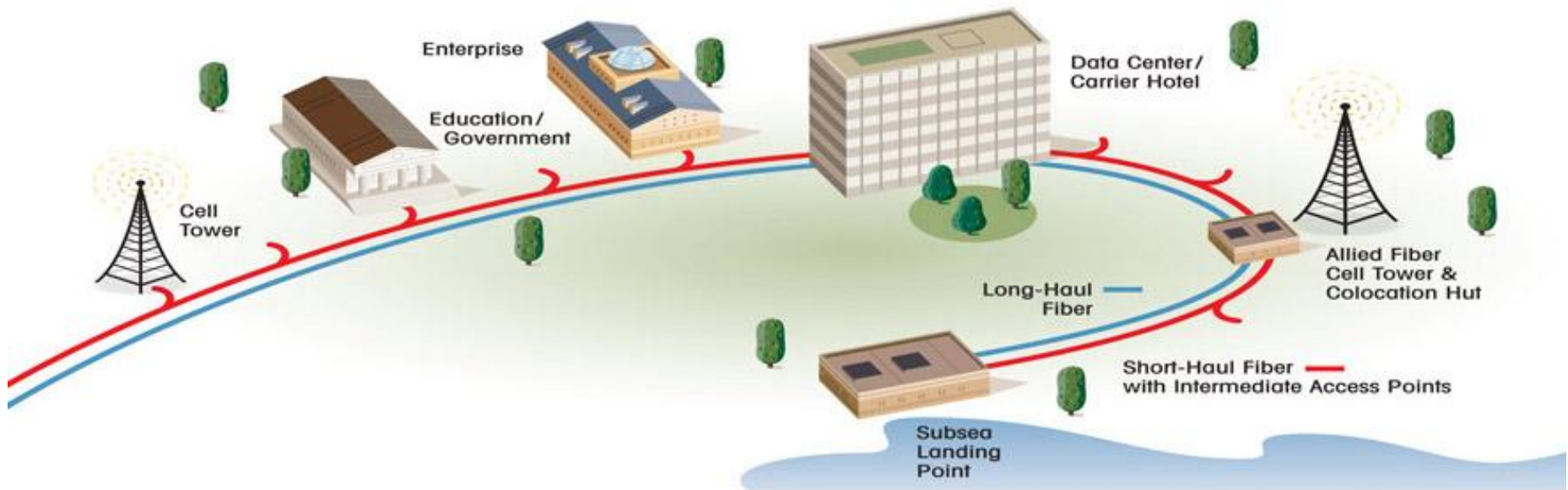


# Optical Fiber – Backbone of Information Highway

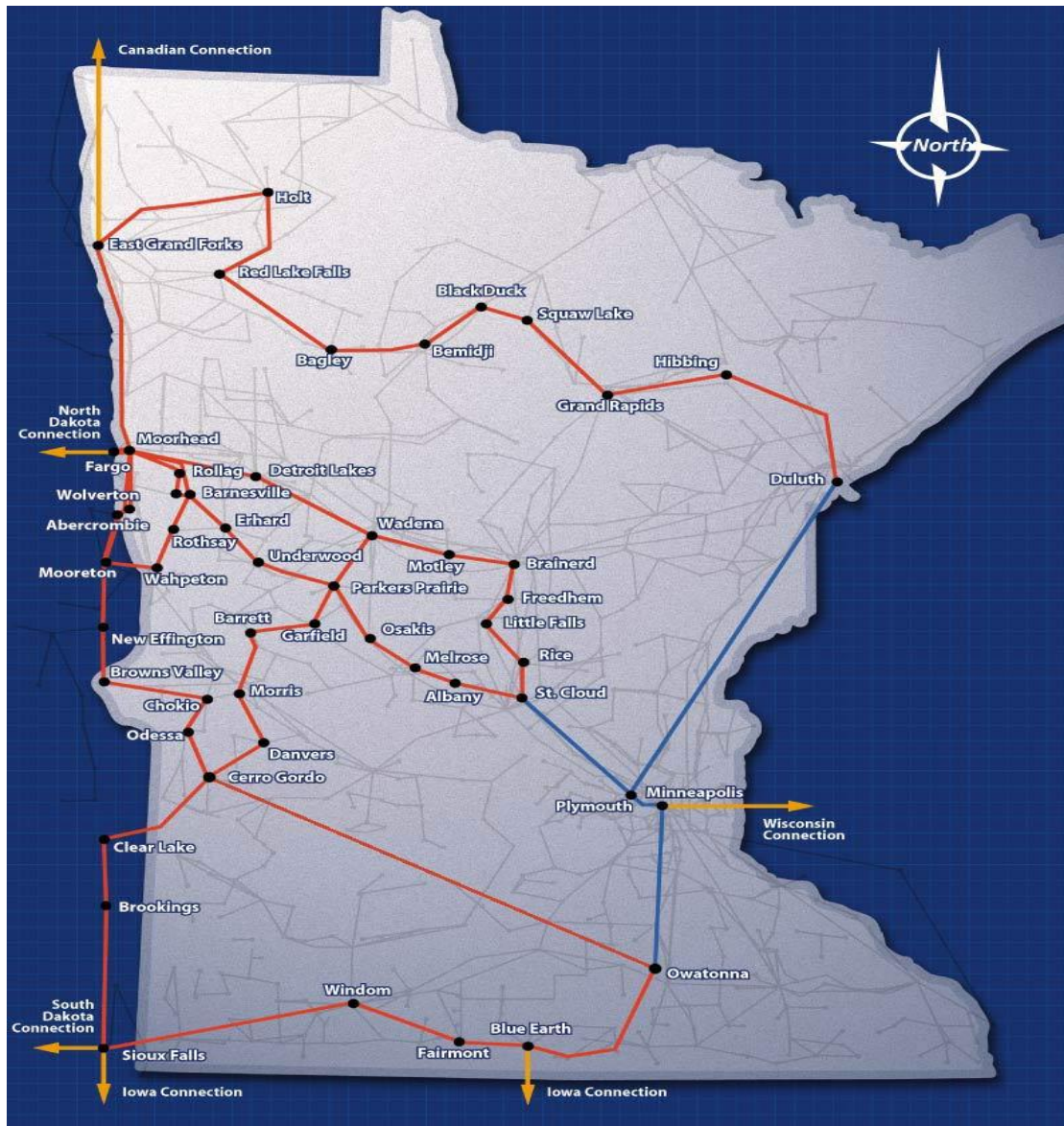




# The Bigger Picture



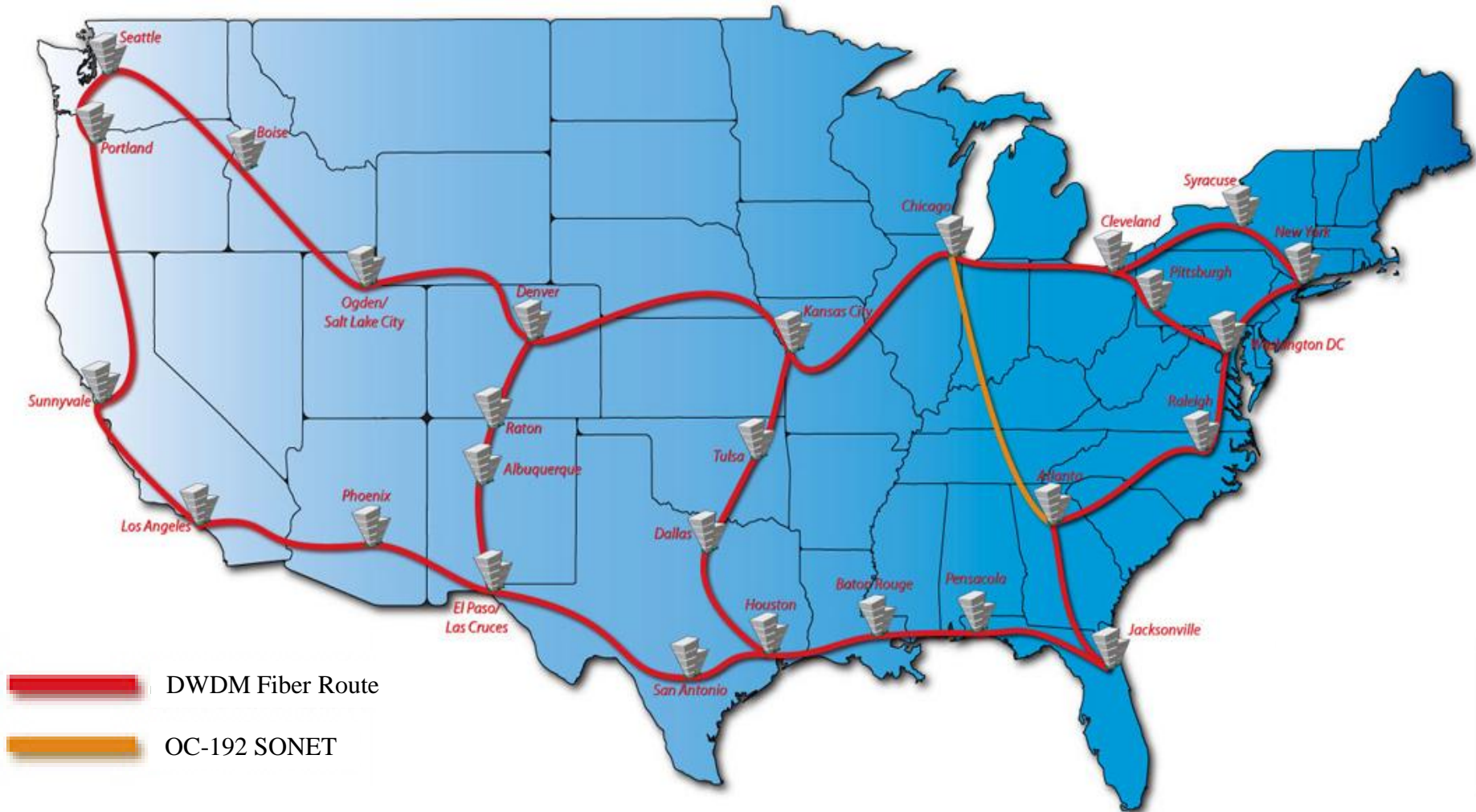
# Metropolitan Network



Aurora Fiber Optics Networks



# Long Haul Network

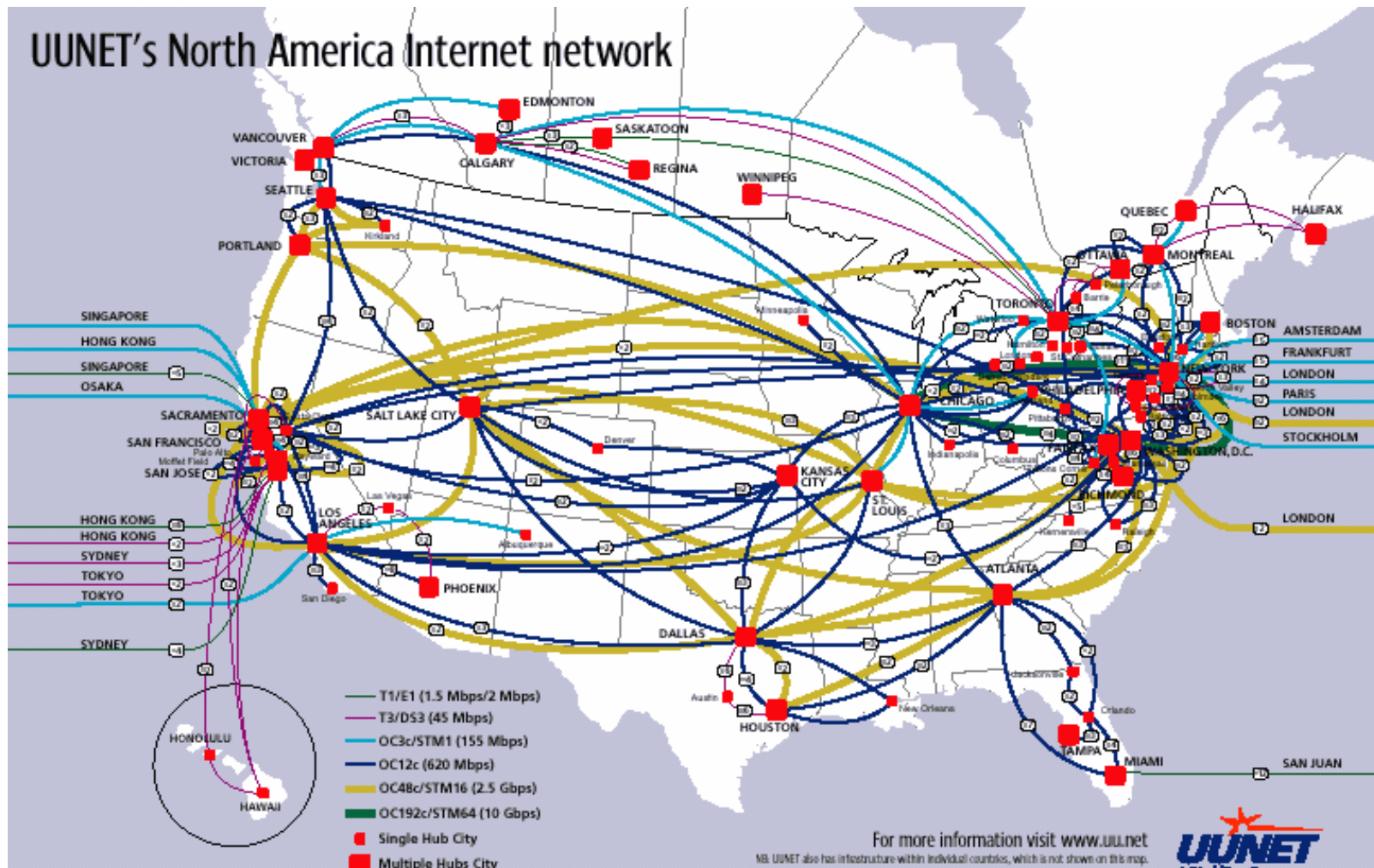


© 2005 National LambdaRail™

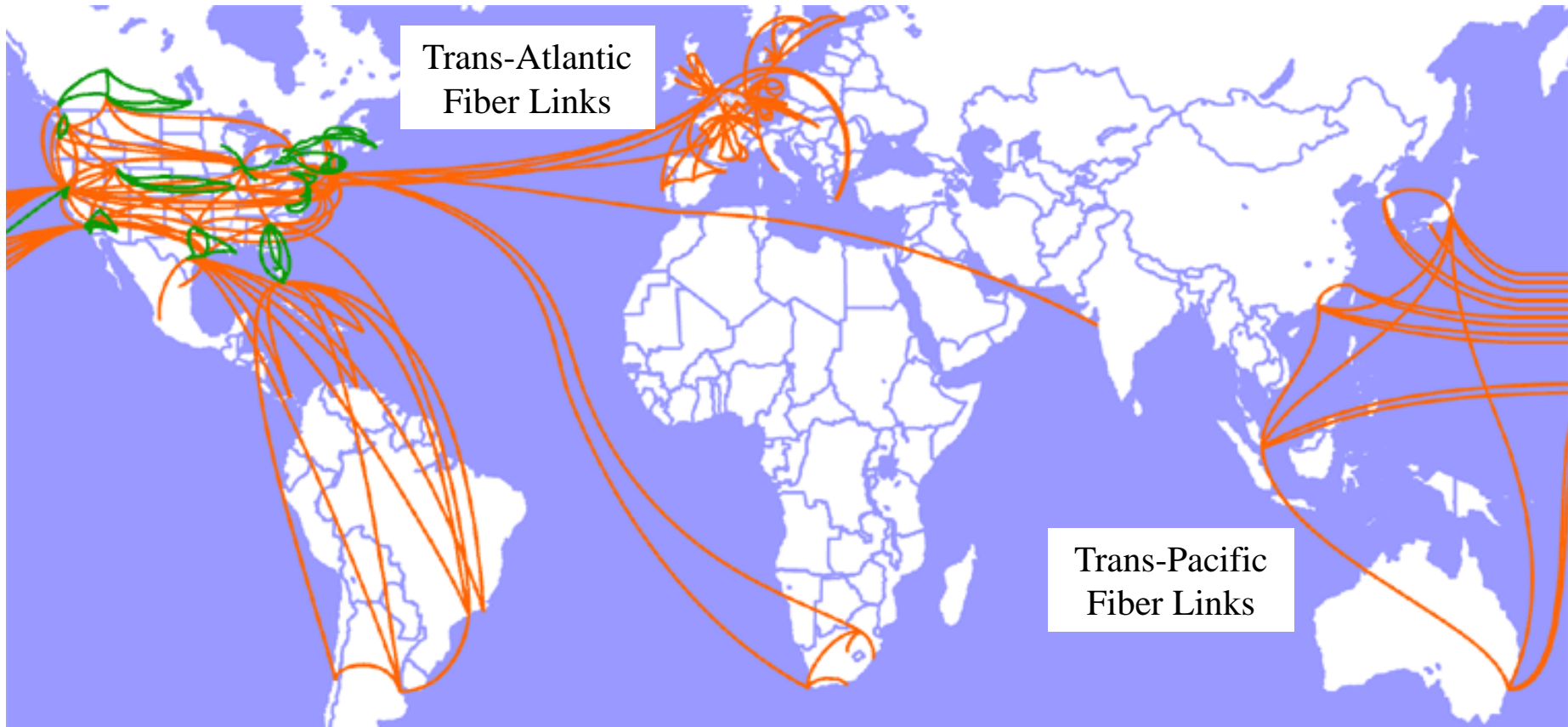
For more information regarding NLR see <http://www.nlr.net> or contact [info@nlr.net](mailto:info@nlr.net)



# Metropolitan and Long Haul Networks



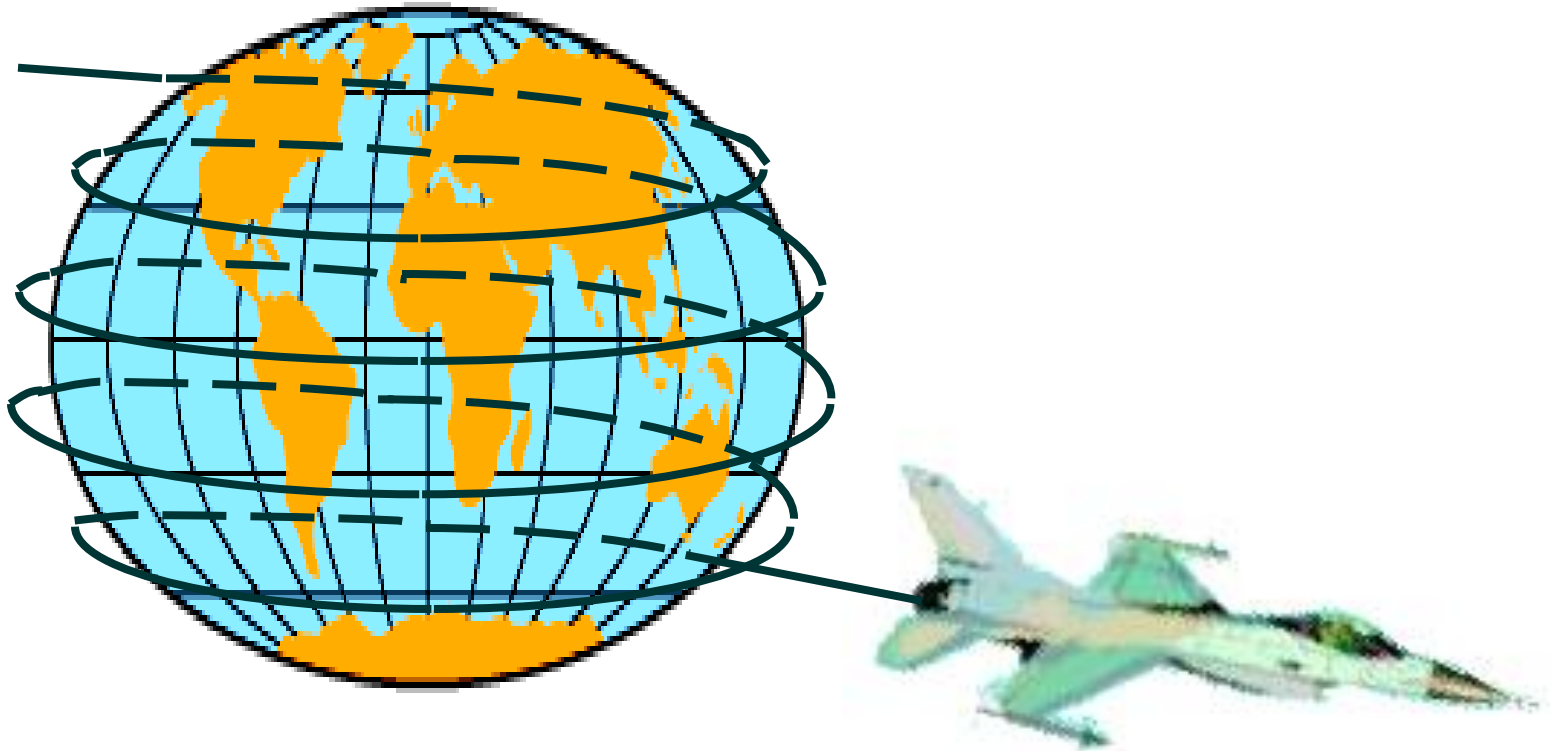
# Long Haul and Transoceanic Network



# Worldwide Fiber Deployment

*Deploying Fiber at the speed of Mach 3*

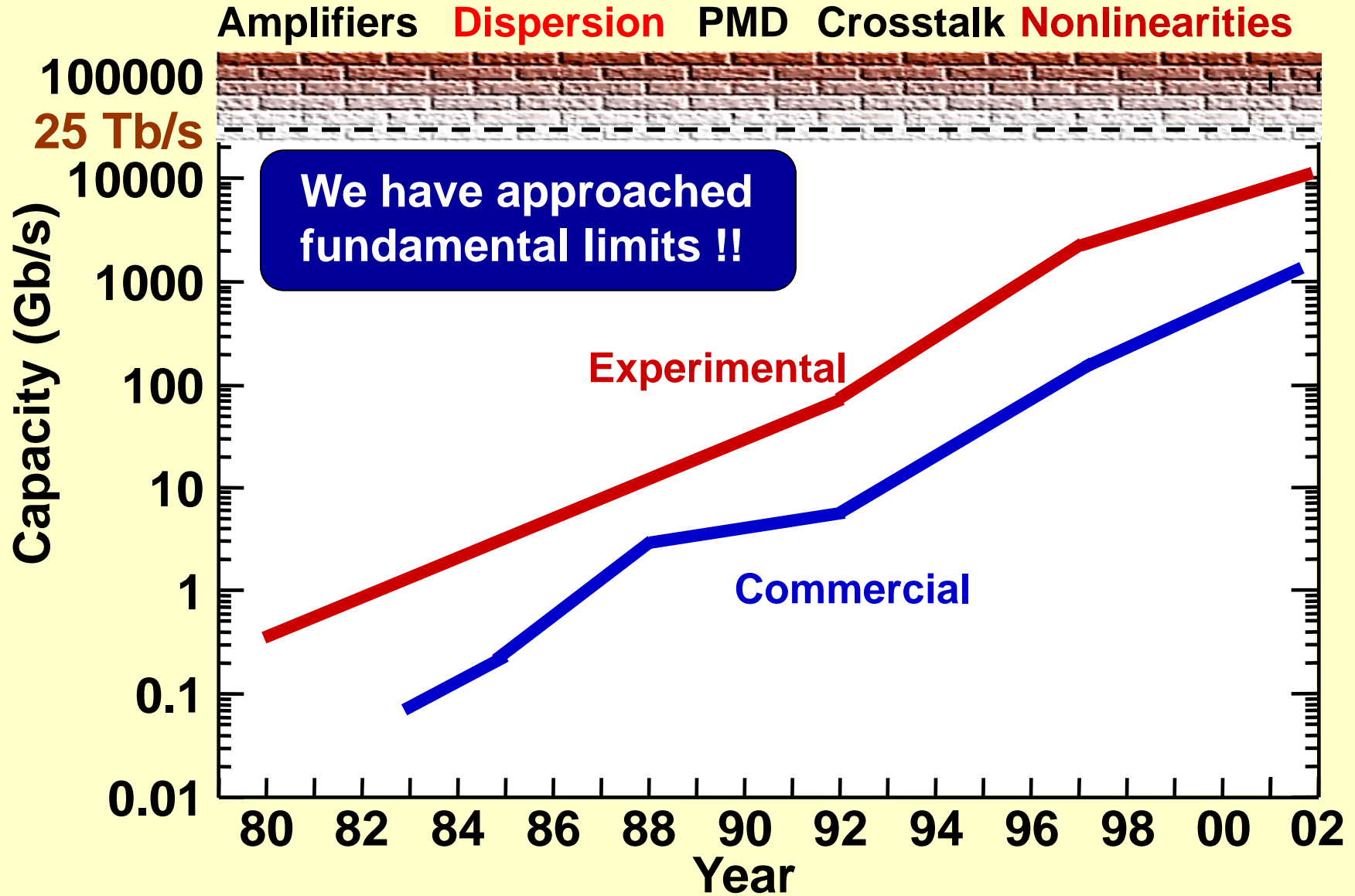
**Optical  
Fiber**



**In 2001, fiber was deployed at a rate of ~ 2000 miles every hour**

T. Li & A.R. Chraplyvy, 2001

# Limitations of Fiber Systems

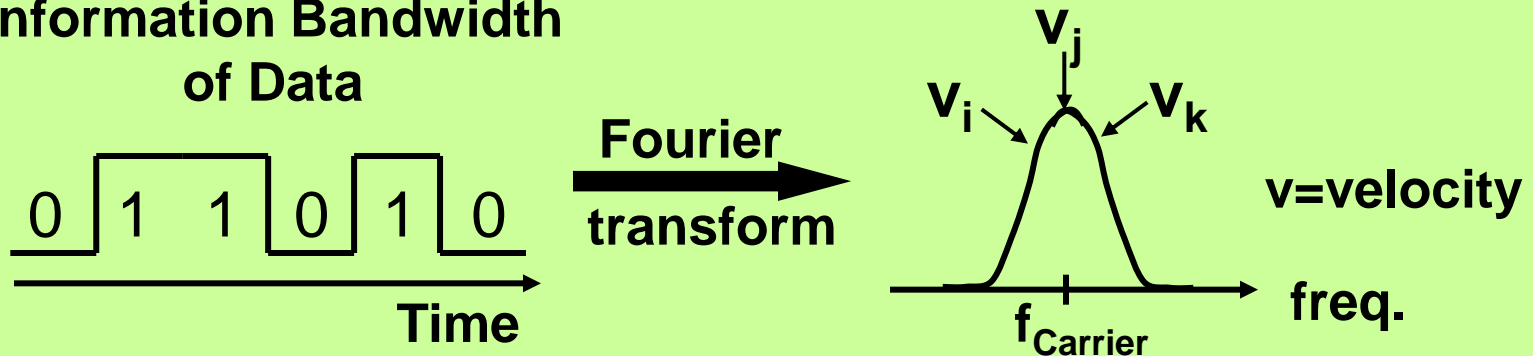


# Origin of Fiber Dispersion

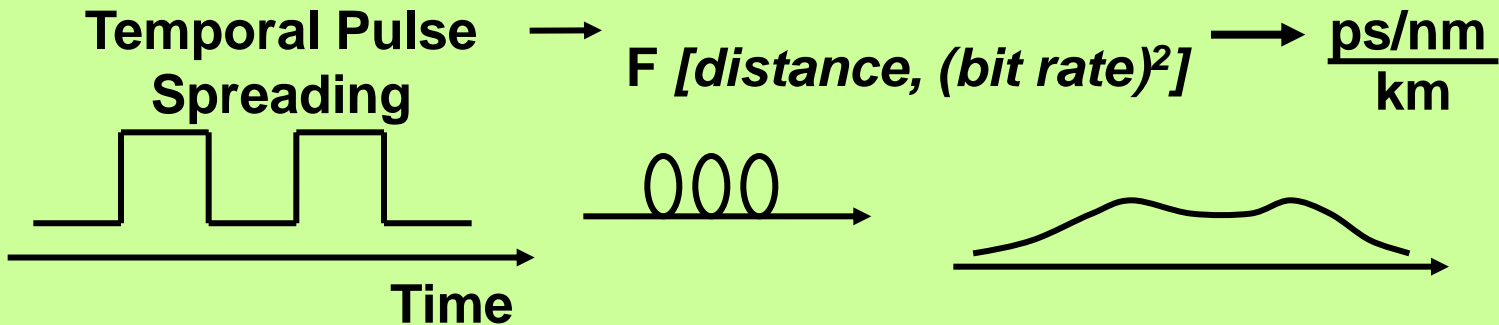
$$\text{Photon Velocity } (v) = \frac{\text{Speed of Light in Vacuum}}{\text{Index of Refraction } (n)}$$

Different wavelengths in the fiber travel with different speeds

Information Bandwidth  
of Data



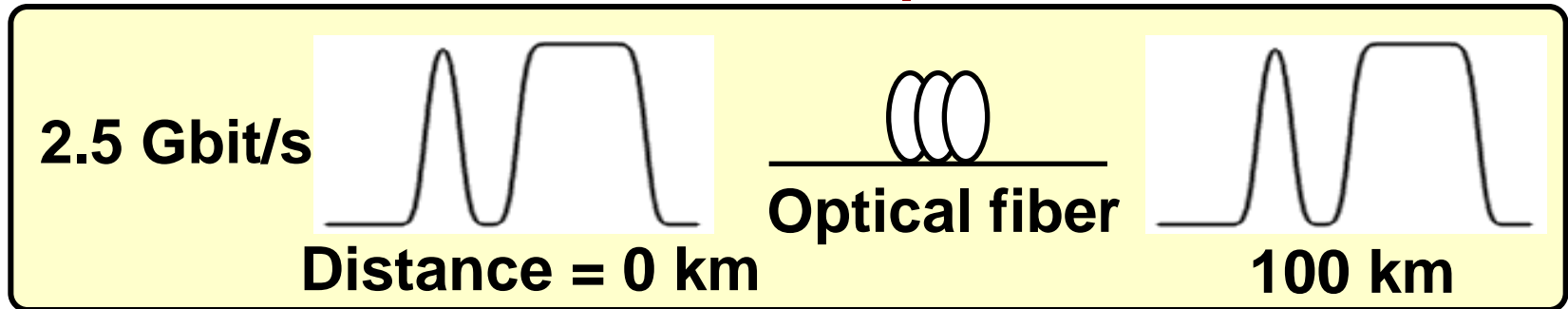
Temporal Pulse  
Spreading



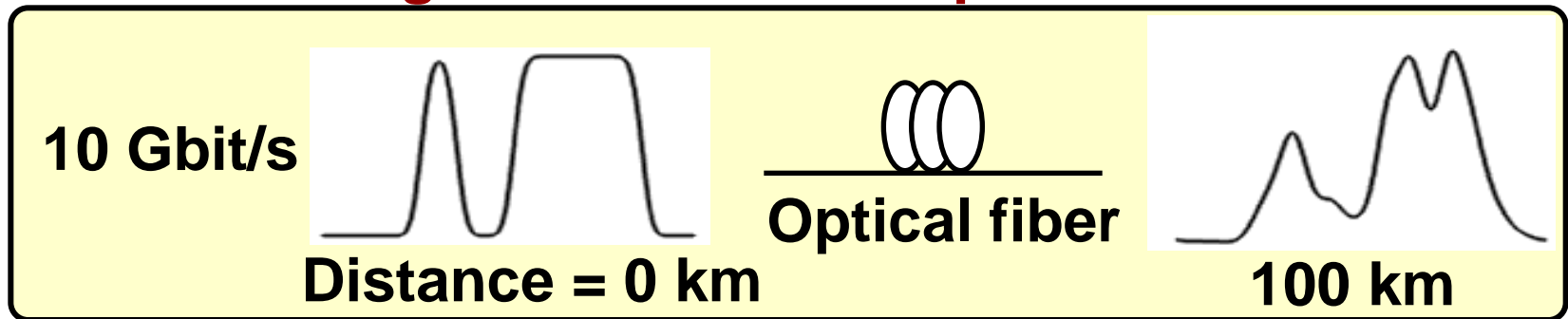


# Chromatic Dispersion and Achievable Bit Rate

**No distortion of output bit stream**



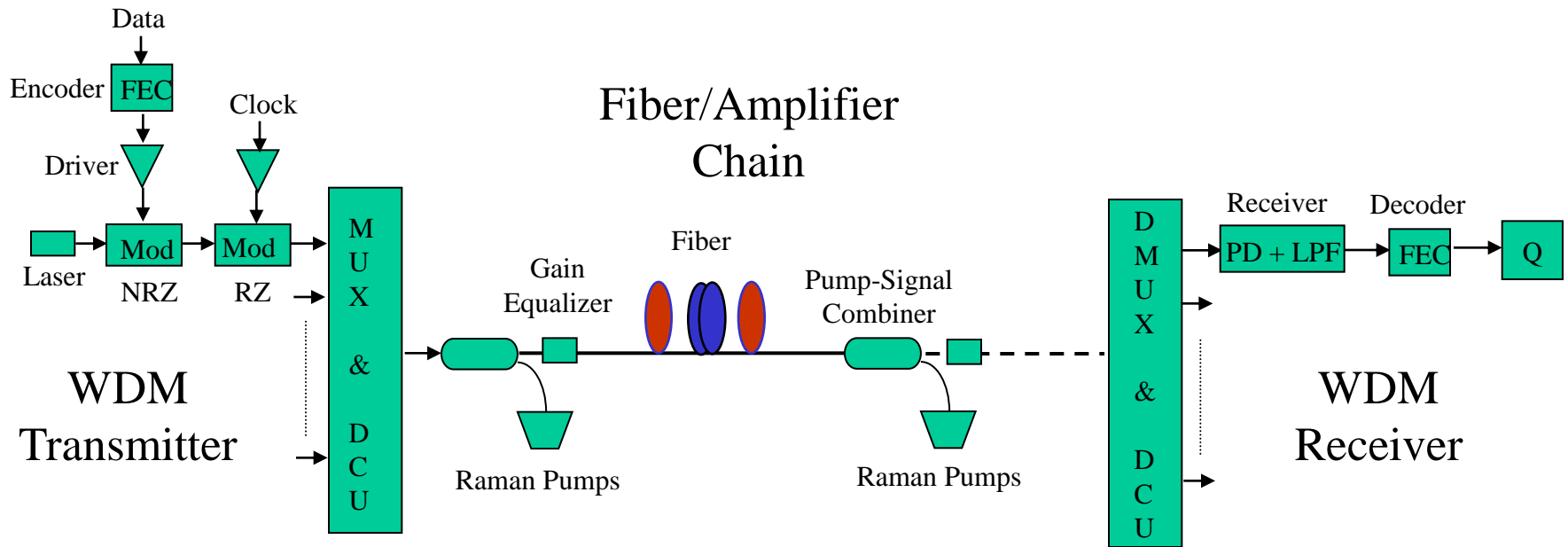
**Large distortion of output bit stream**



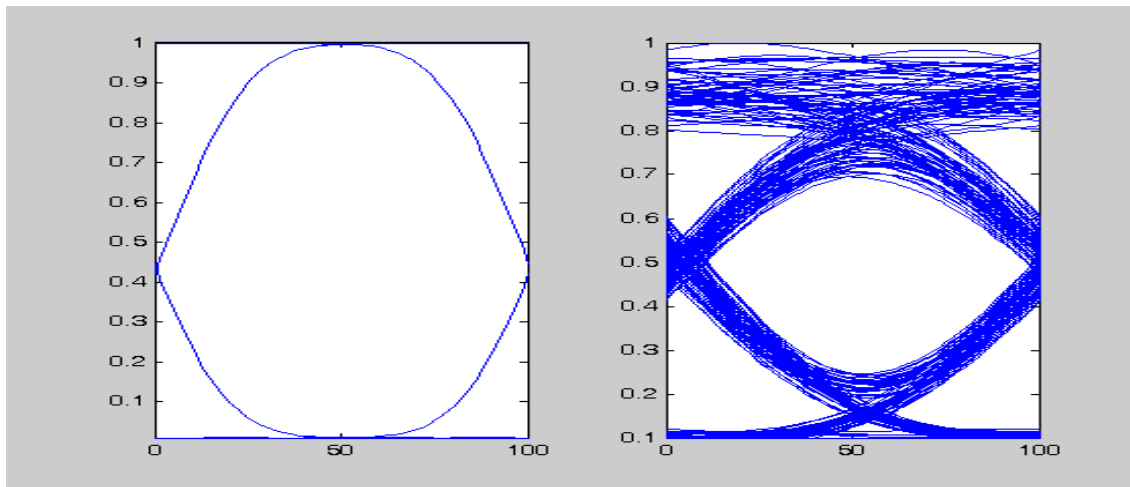
**Dispersion induced 1-dB Power Penalty:**

2.5 Gb/s:	16,640 ps/nm	~980 km SMF
10 Gb/s:	1,040 ps/nm	~60 km SMF
40 Gb/s:	65 ps/nm	~4 km SMF

# What Does Fiber Nonlinearity Do?

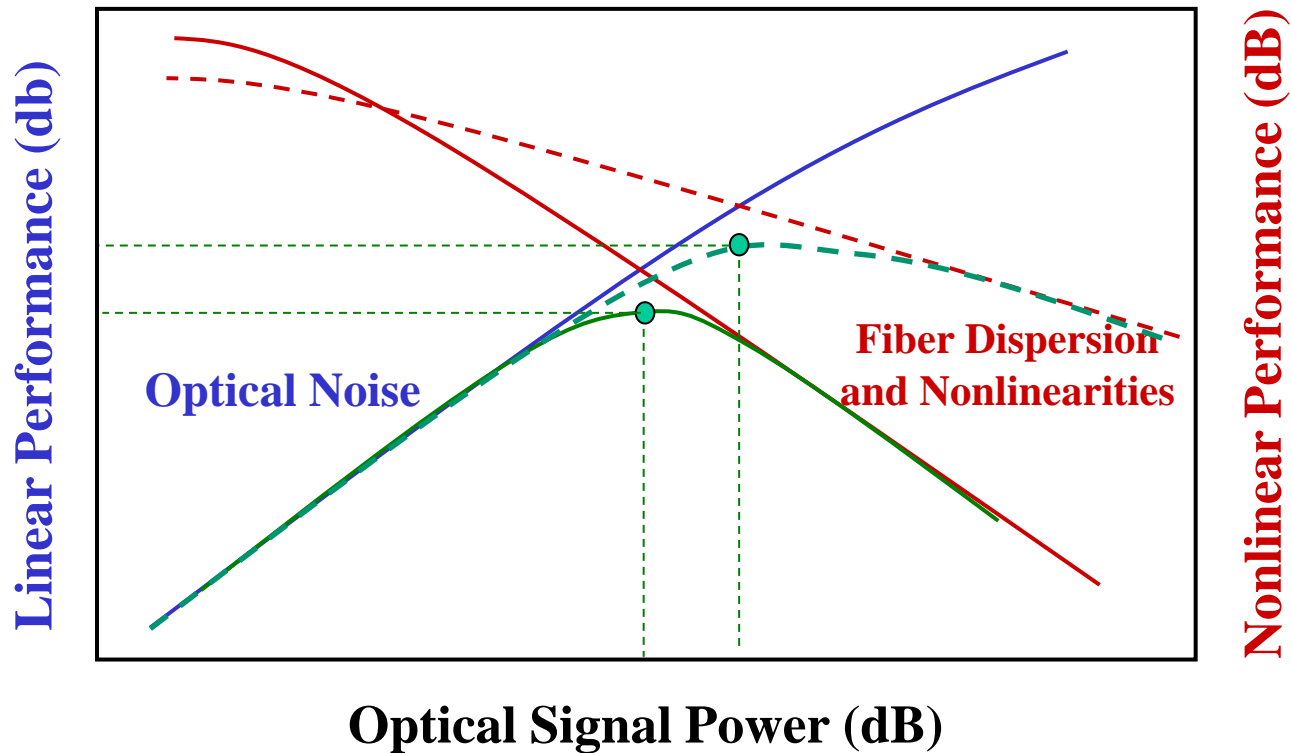


Input Eye



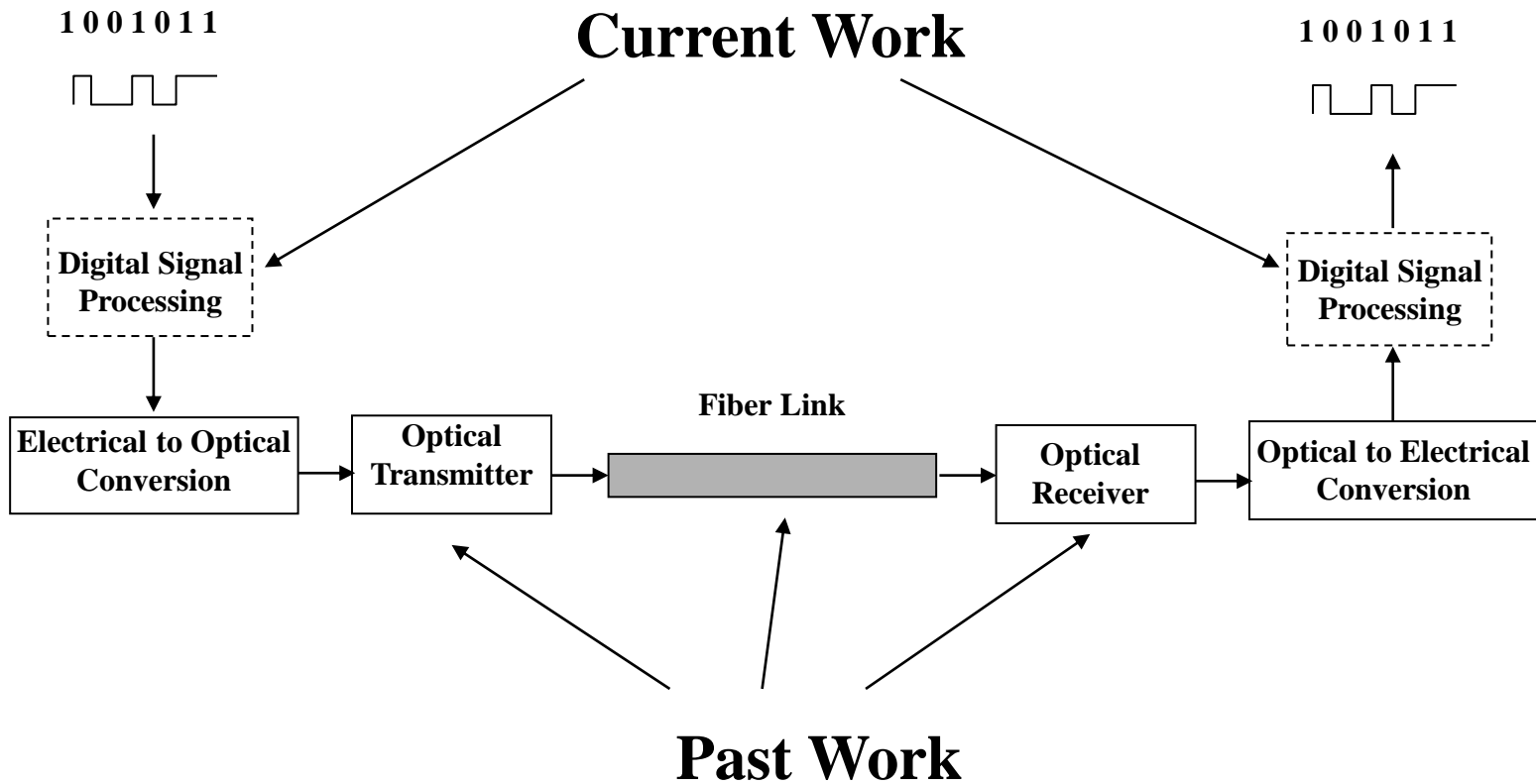
Output Eye

# Fiber Nonlinearity Imposes Ultimate Capacity Limit

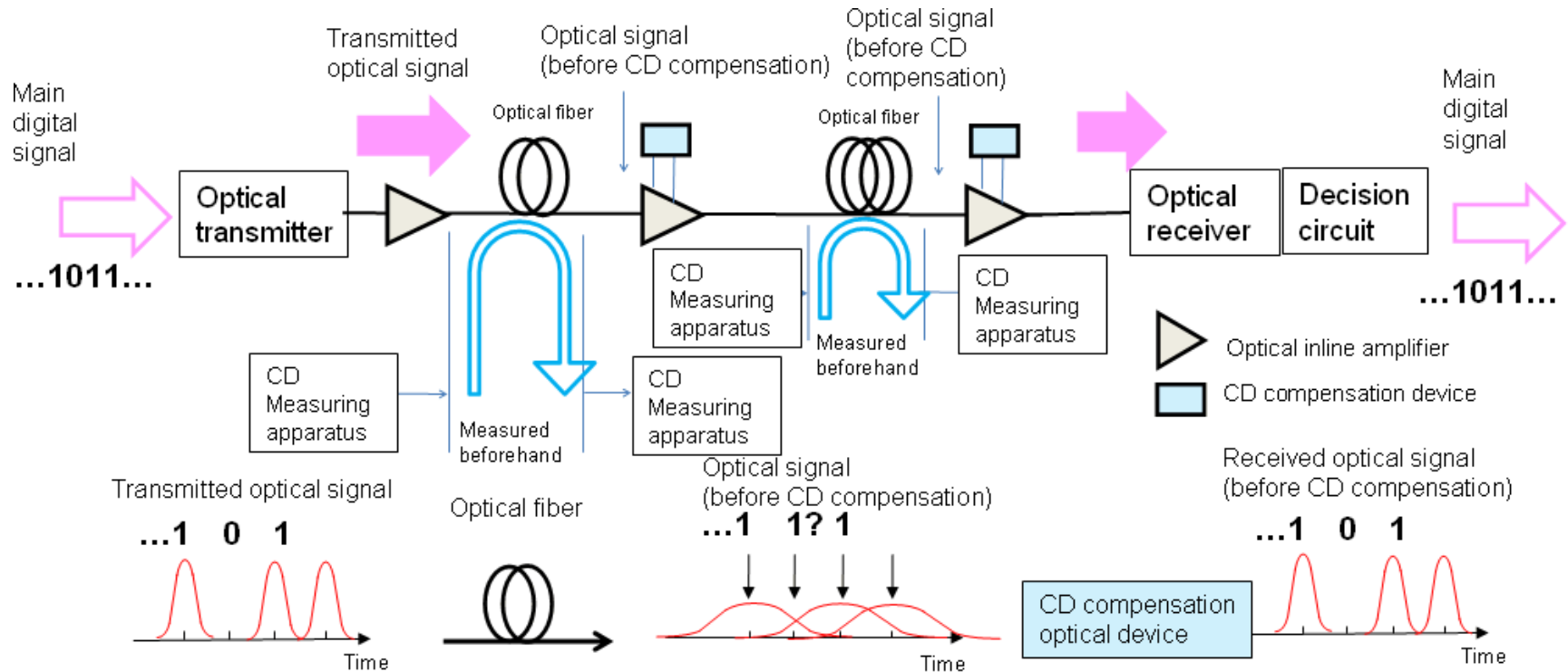


**Fiber nonlinearity puts the ultimate limit on the capacity to be used in an optical fiber communication system**

# What do I do?



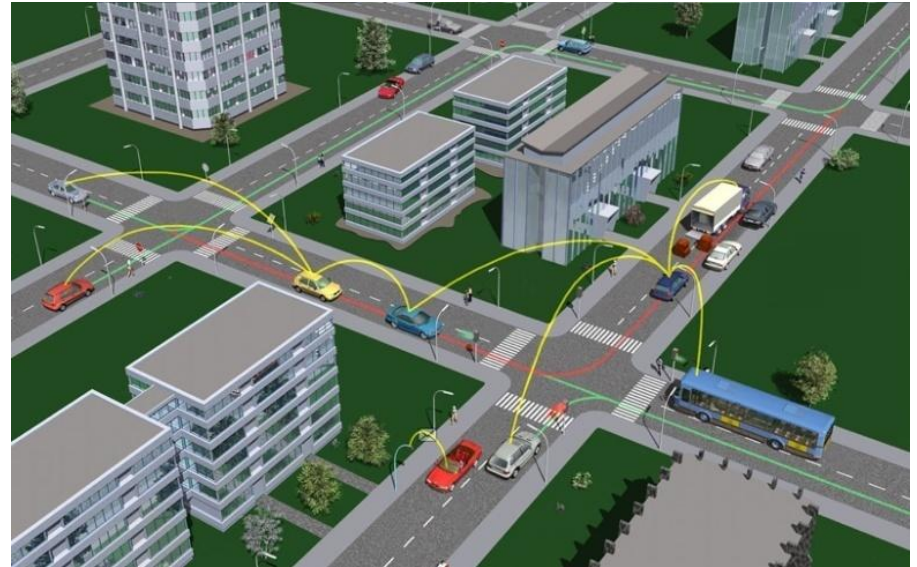
# In color, I do this?



After fiber-optic transmission, high-speed optical signal pulses spread out, and 0 can be mistaken for 1 due to spread of neighboring pulses.  
(**waveform distortion**)

# What else do I do?

**Intelligent  
Transportati  
on System**



**Electronic  
Heart  
Murmur  
Detection**

# Summary/Questions

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