Optical Fiber – Enabler of Wireless Devices in the Palms of Your Hands

A Presentation to
EE1001 Class of
Electrical Engineering Department
at University of Minnesota Duluth

By

Professor Imran Hayee

Smartphone vs. Crystal Ball

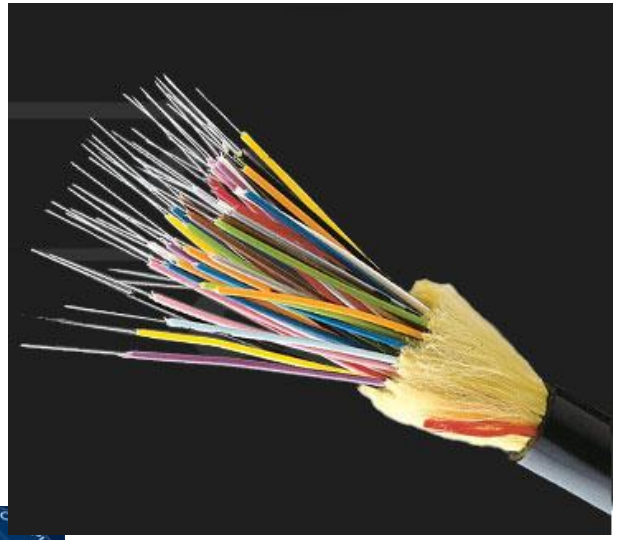
Crystal Ball gives information regardless of space and time

Smart Phone gives information regardless of space and past time

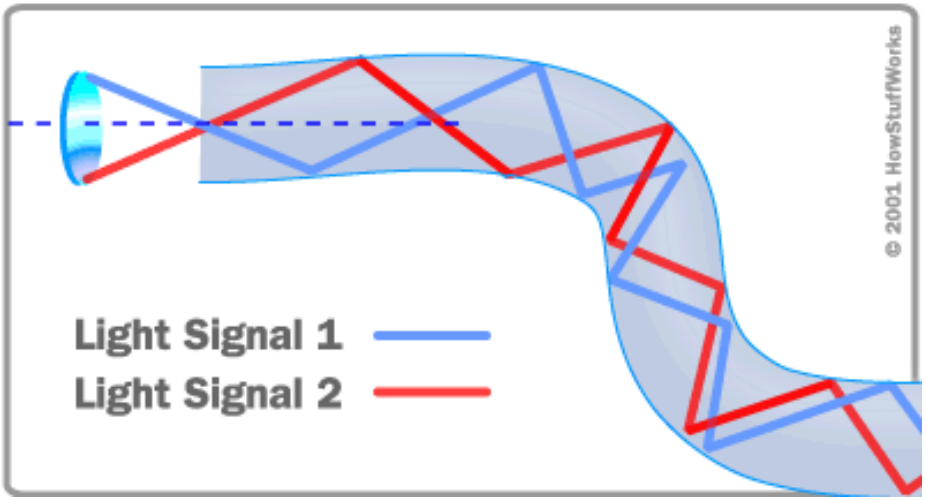
Outline

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

What is an Optical Fiber

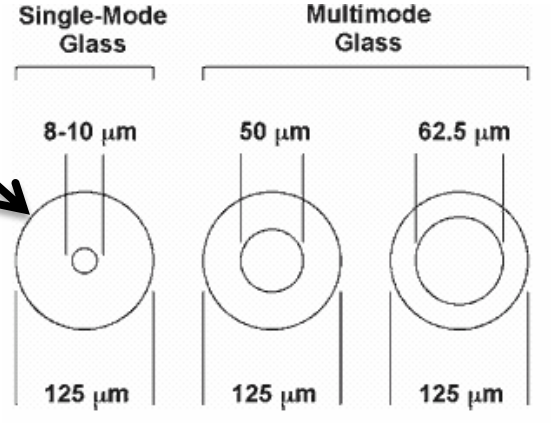


Optical Fiber is a thin long cylinder made of Silica

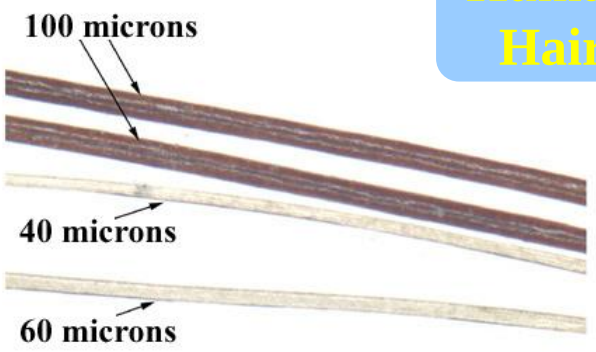


Optical Fiber vs. Optical Cable

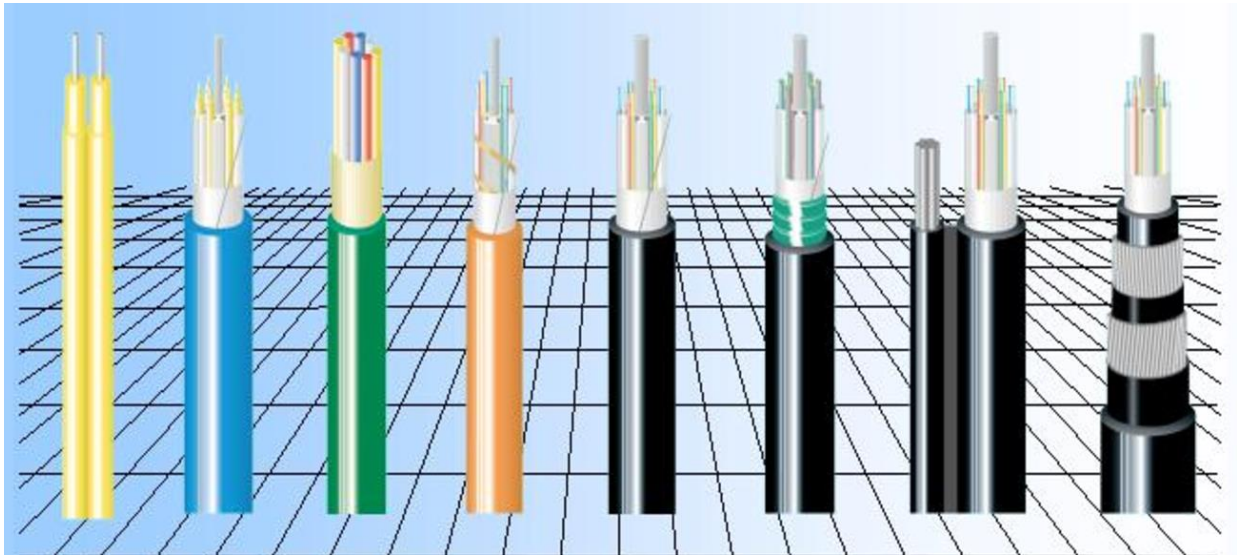
Today's Optical Fiber



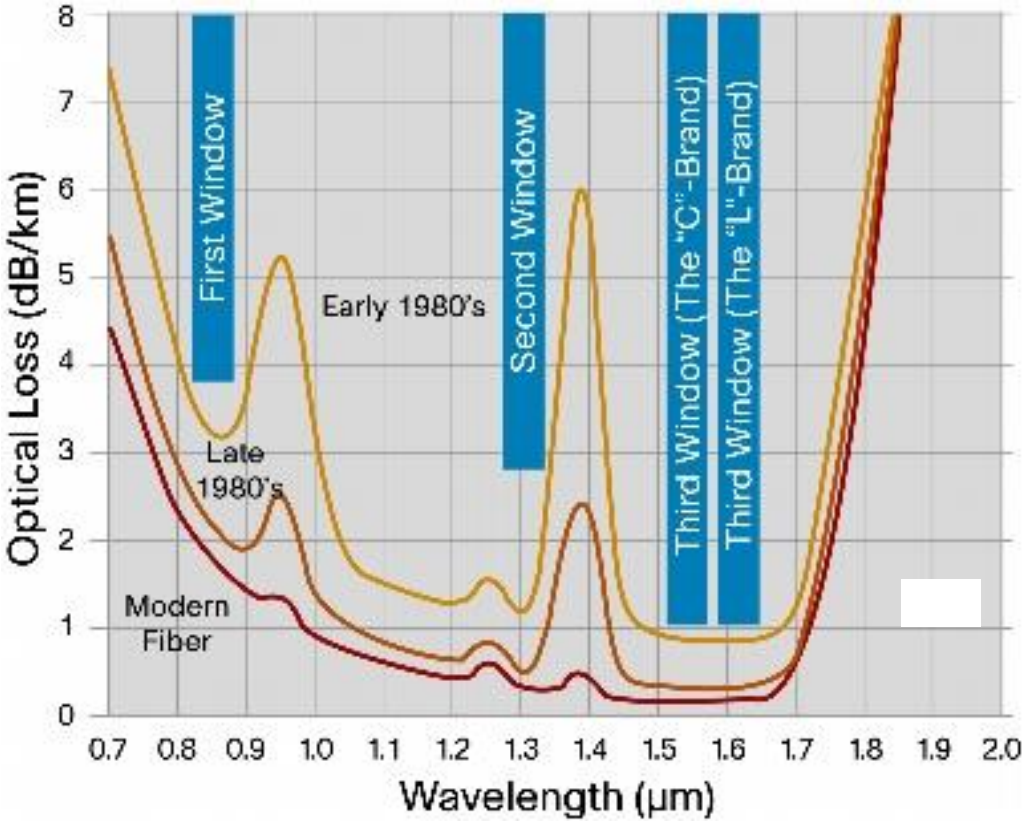
Human Hair



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

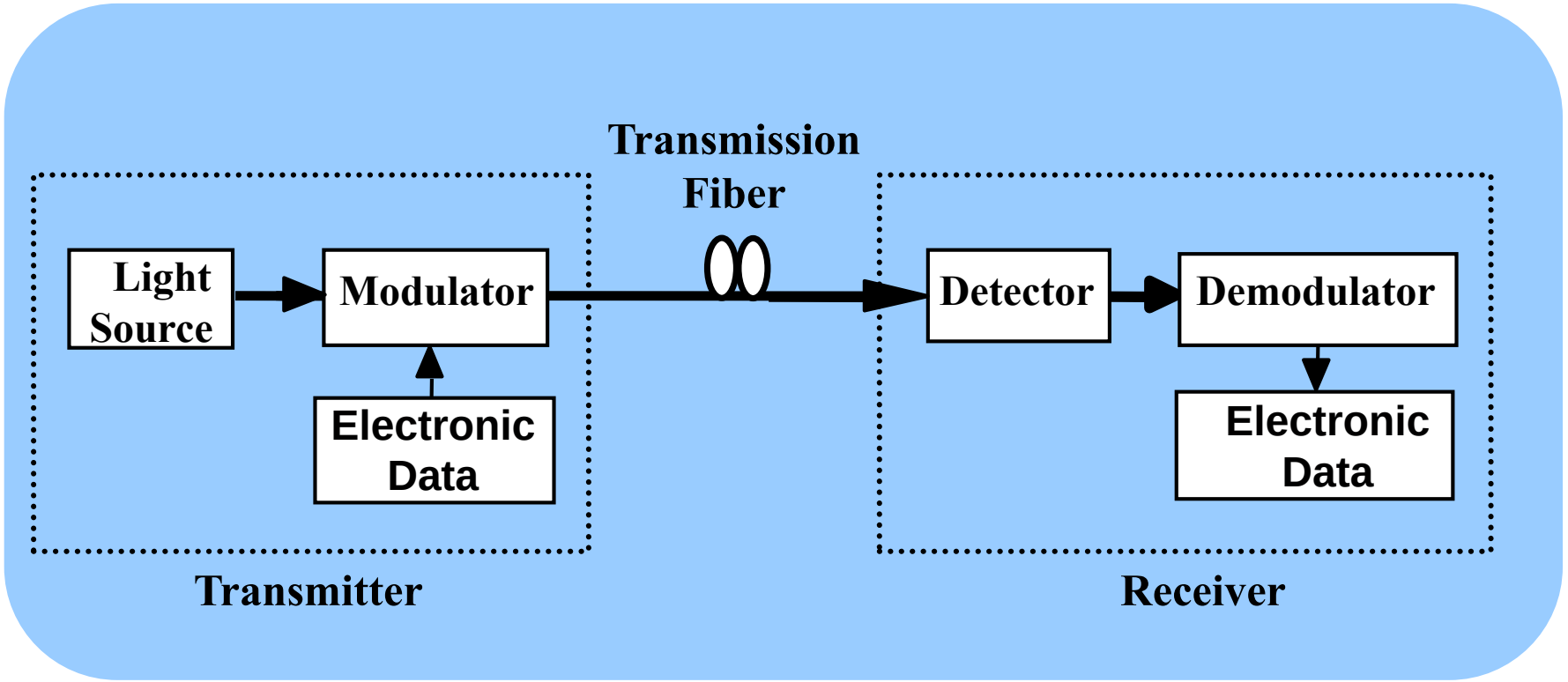
25 Trillion bits ~775 DVDs

Huge but not Infinite Bandwidth

0.2 microns = 25 Tbit/sec

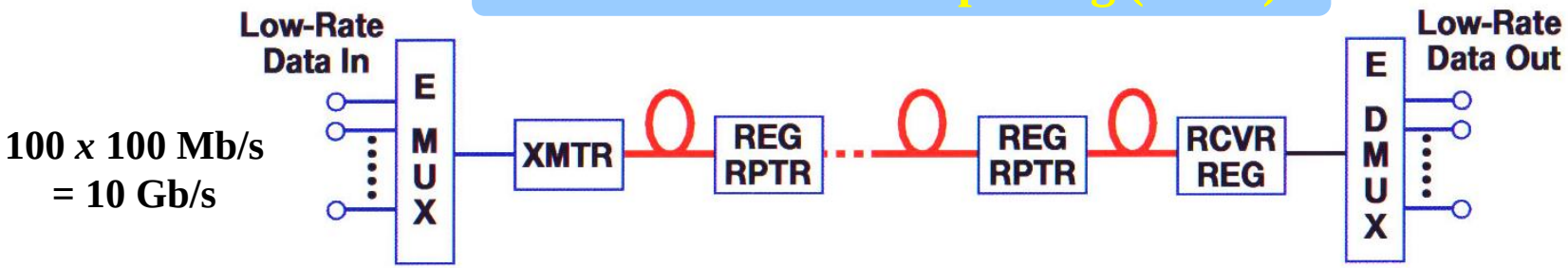
Useable Today ~ 3Tb/s

How it Works?


Transmission
Fiber
Light
Source
Modulator
Electronic
Data
Detector
Demodulator
Electronic
Data
Transmitter
Receiver

TDM vs. WDM

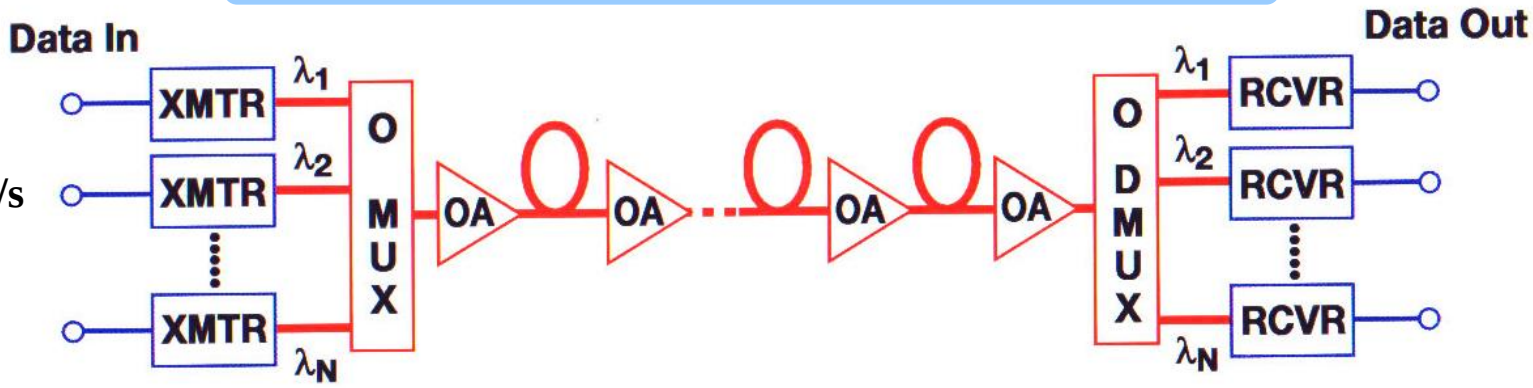
Time Division Multiplexing (TDM)



100 *x* 100 Mb/s
= 10 Gb/s

10Gb/s max - one color of light

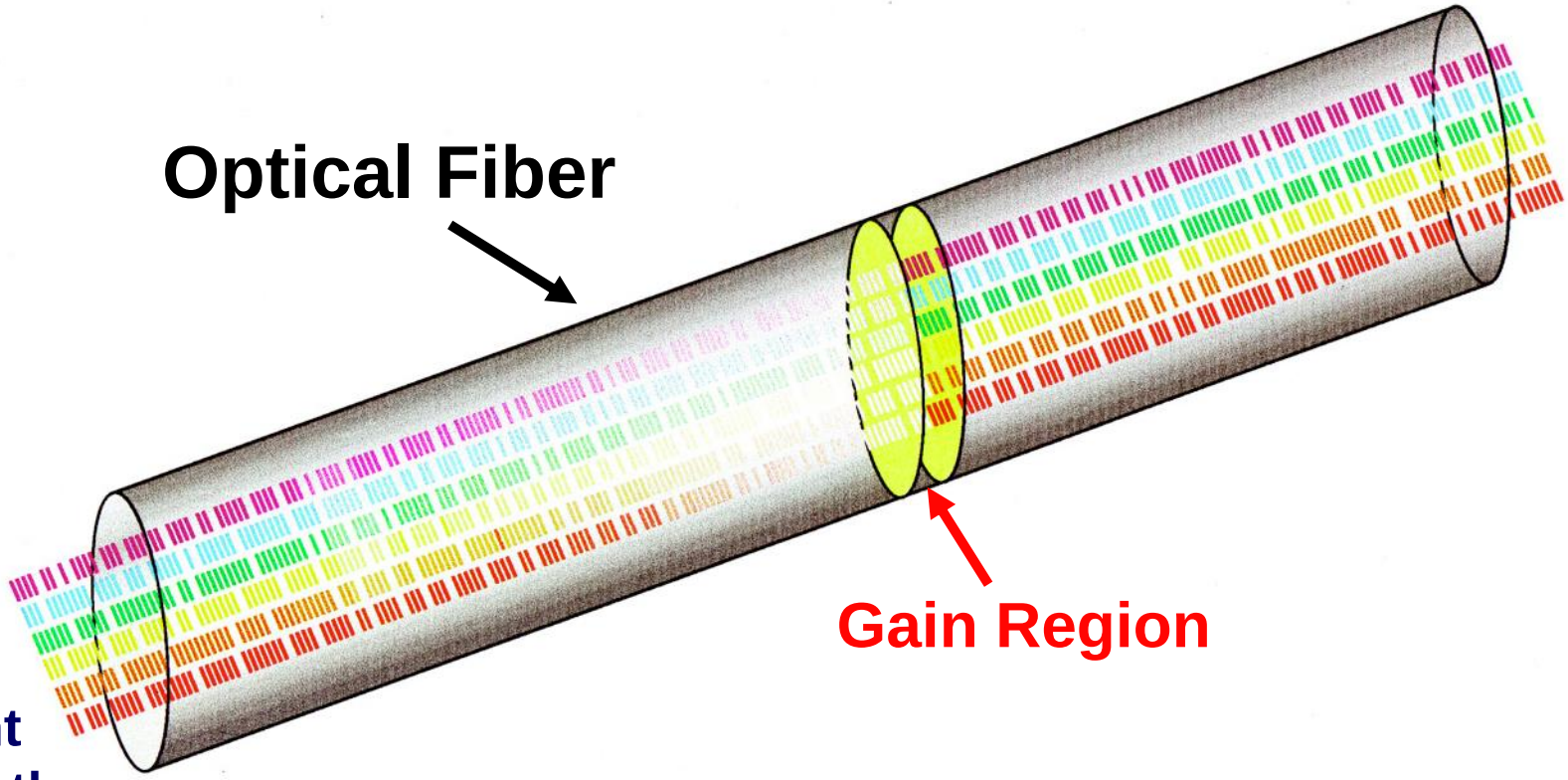
Wavelength Division Multiplexing (WDM)



300 *x* 10 Gb/s
= 3Tb/s

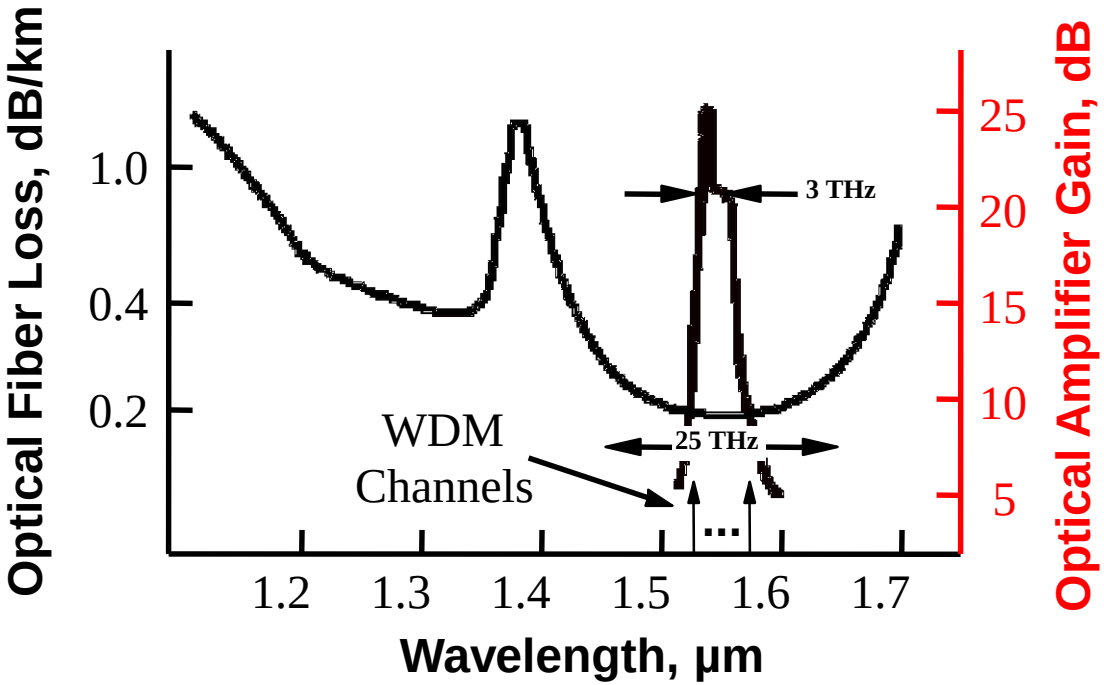
300 channels of 10Gb/s – many colors of light simultaneously

Wavelength-Division-Multiplexing (WDM)



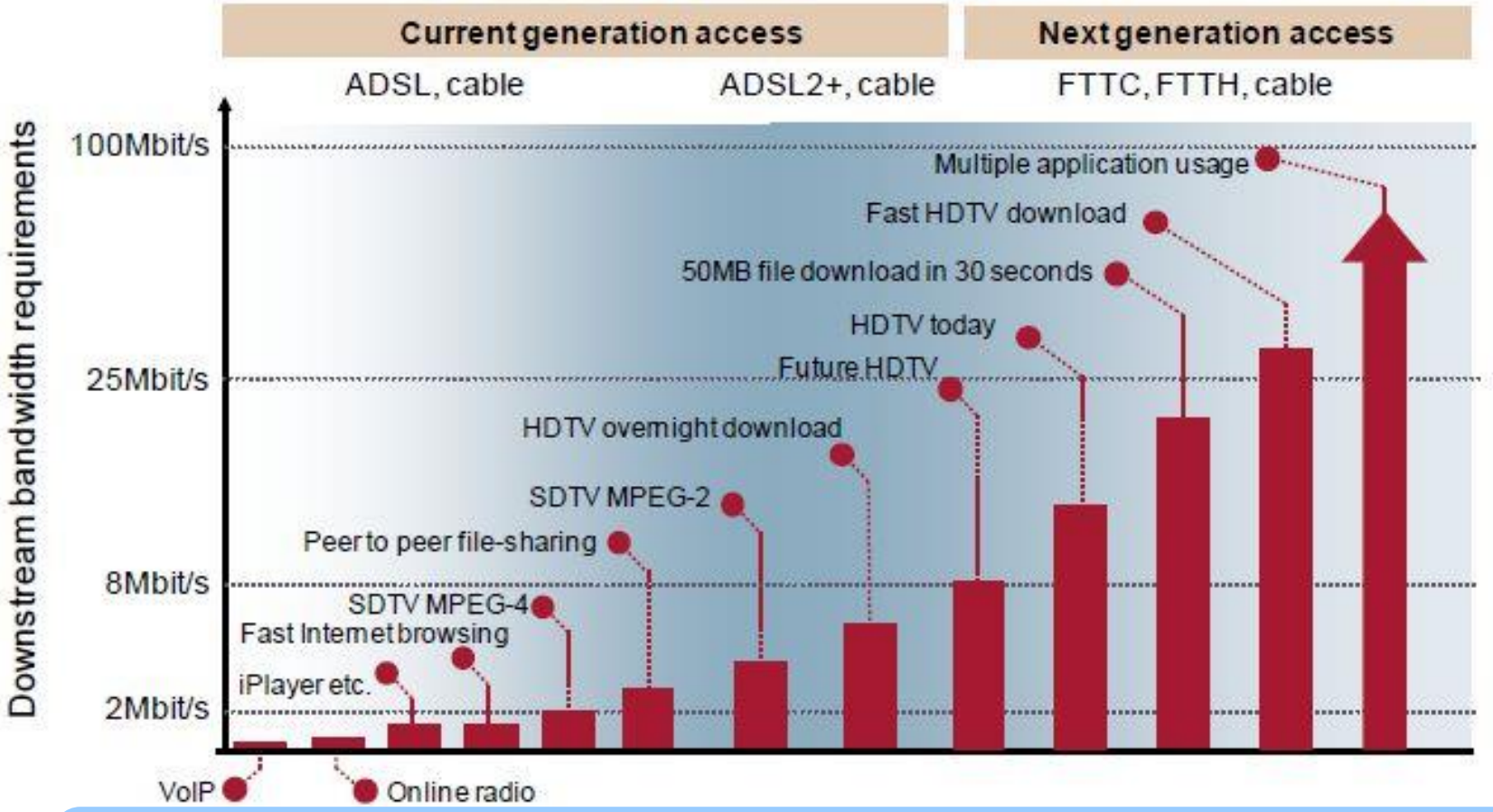
Multiple colors of light traveling through the optical fiber, interact with each other in very complex manner – that is the ultimate limitation of capacity usage of fiber

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 Feb. 21

THE SPECTRUM CRUNCH

Sorry, America: Your wireless airwaves are full

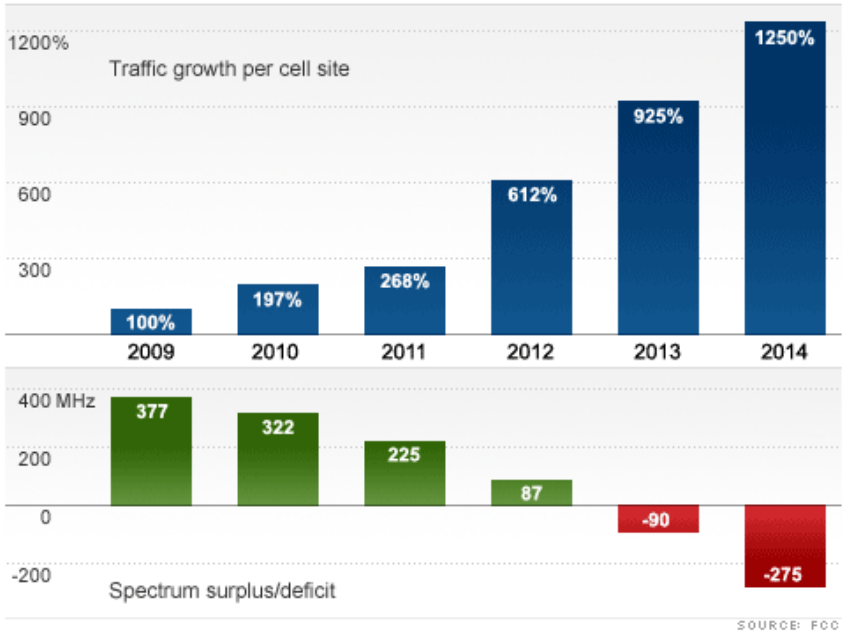
CNNMoney

1,395 comments

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

Recommend 3k Tweet 68 Share 18 +1 93 Email Print

WIRELESS DATA GROWTH LEADS TO SPECTRUM DEFICIT

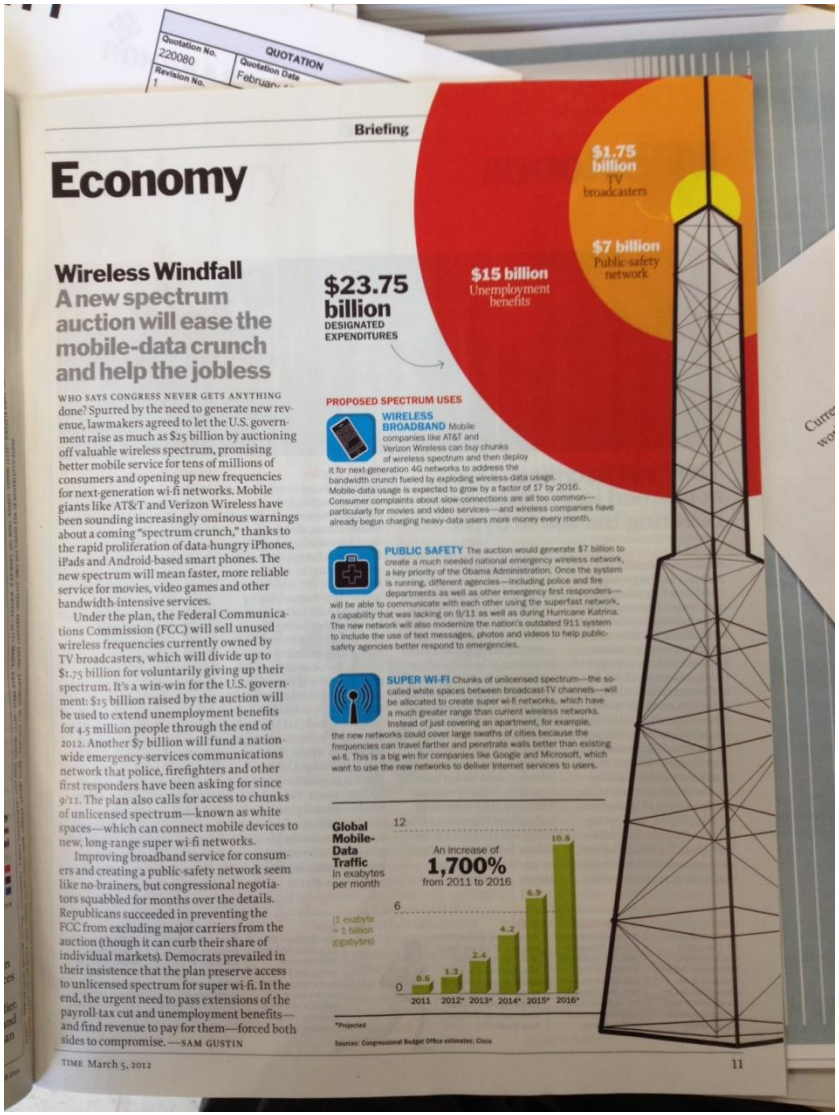


SOURCE: FCC

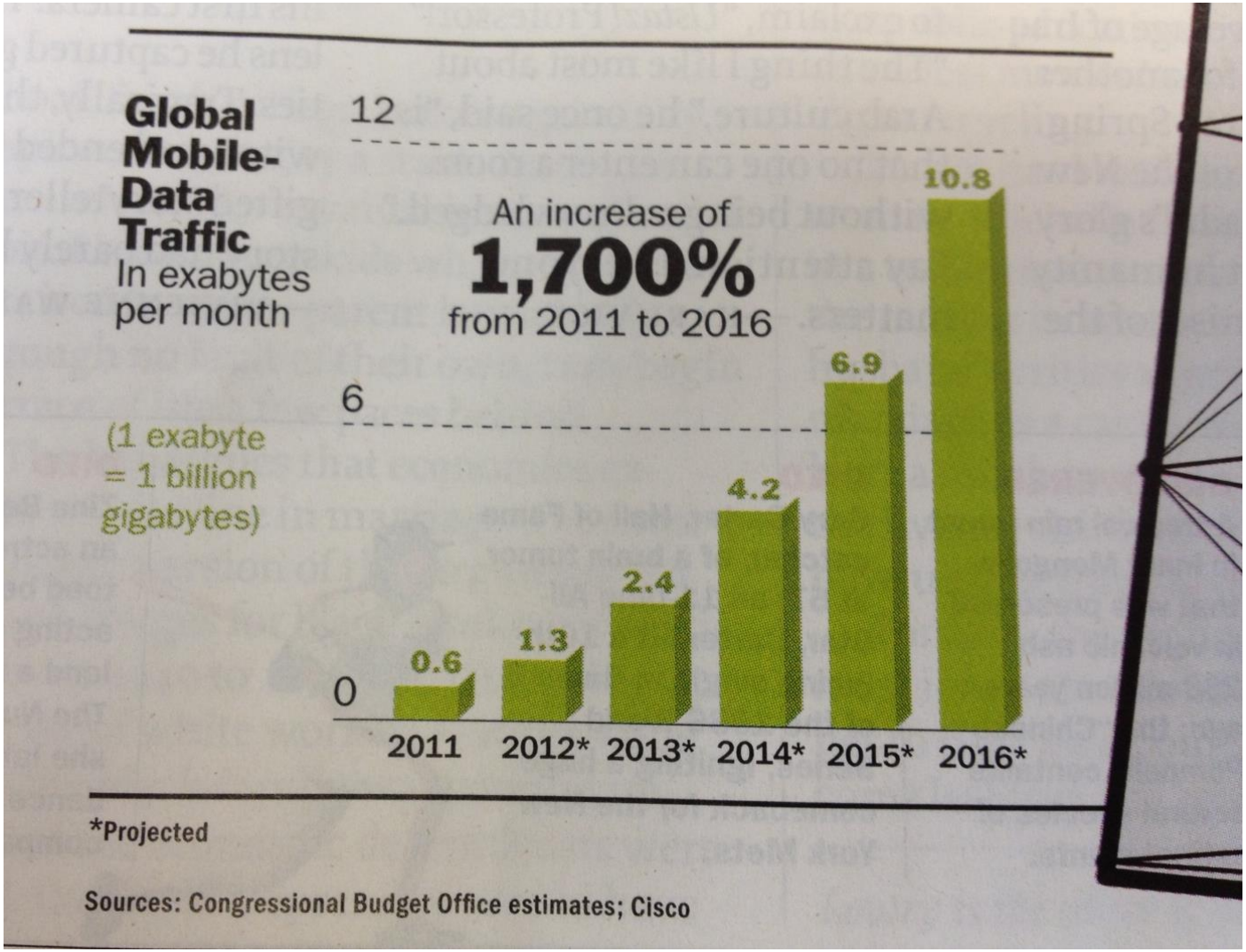
*This is **part one of a week-long series** on the cell phone capacity crunch.*

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.

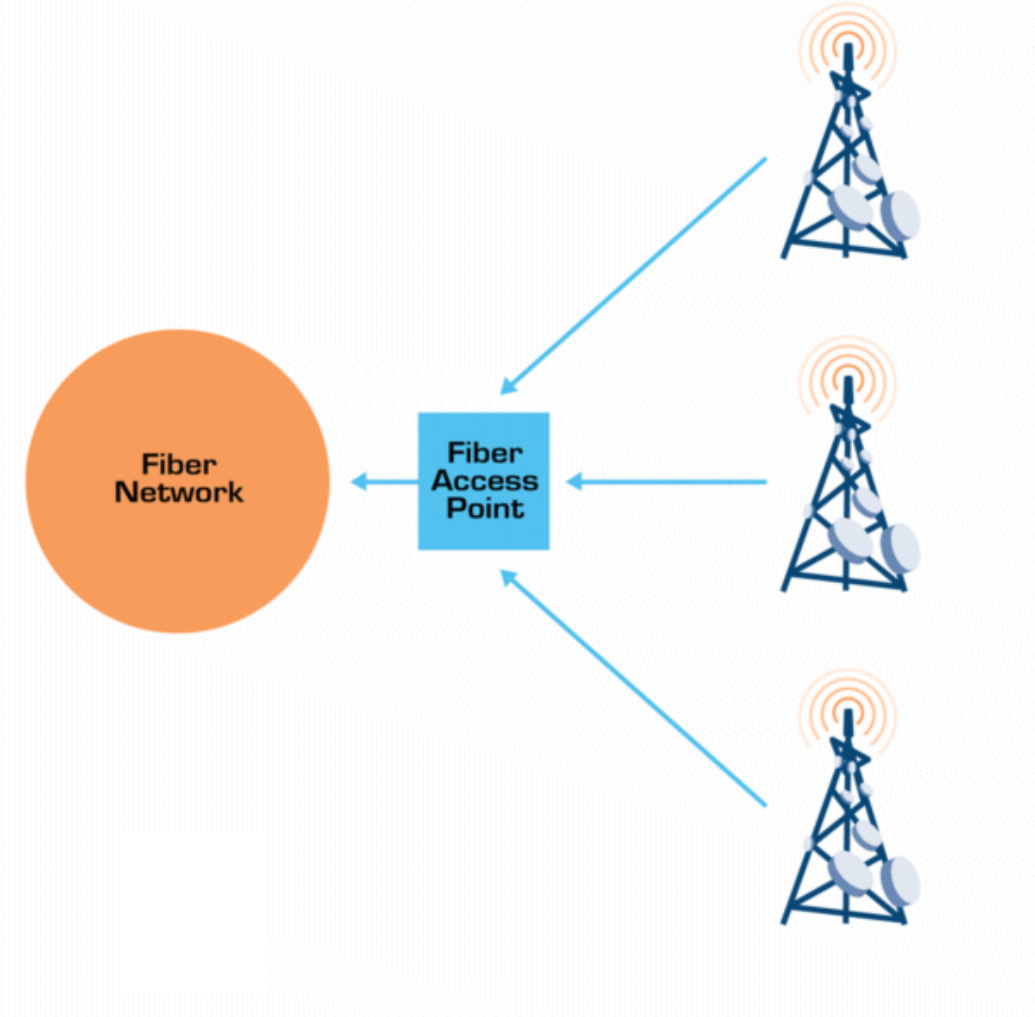
March 5 Time Magazine – Page 11



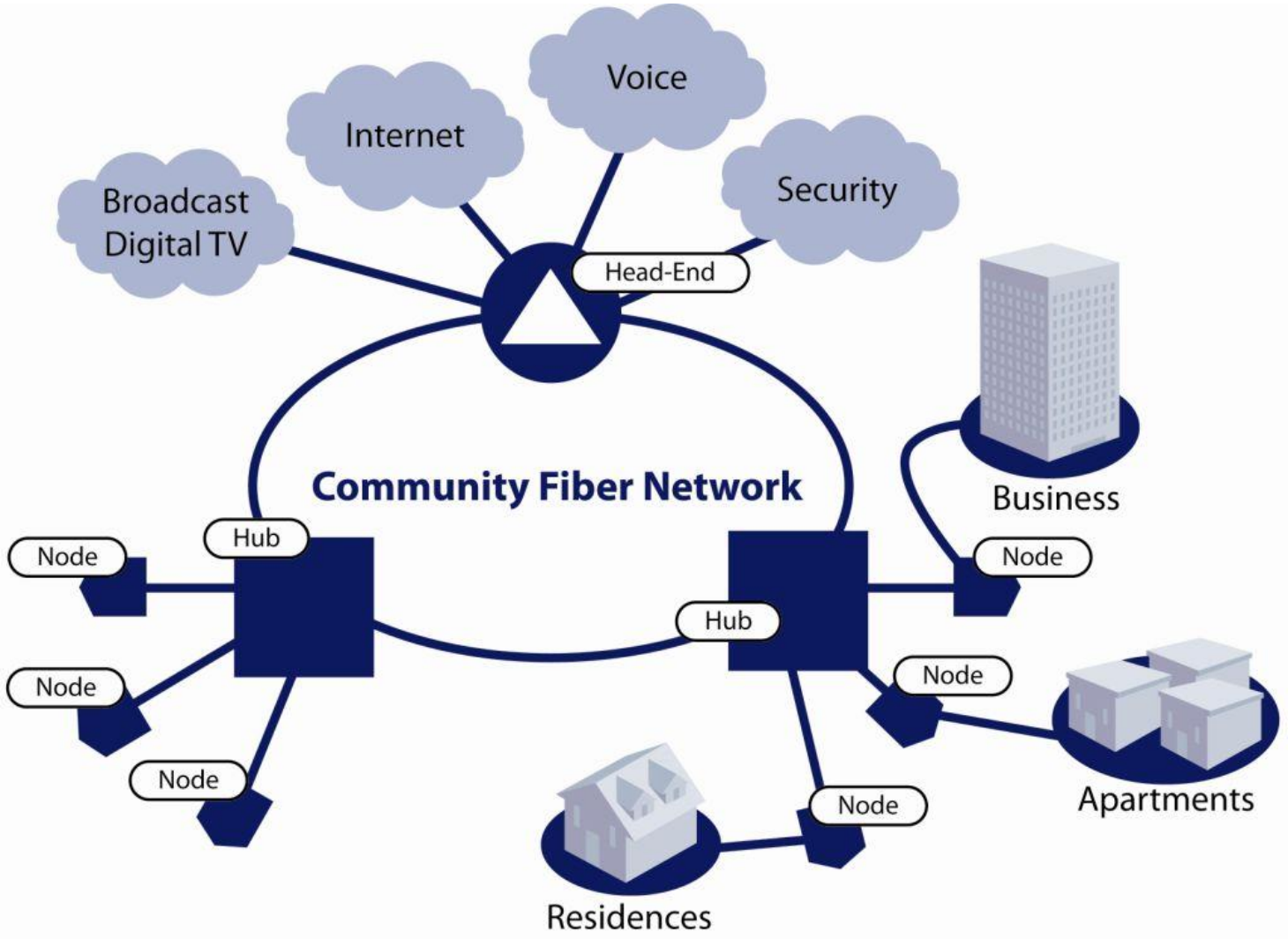
Wireless Demand is Exploding



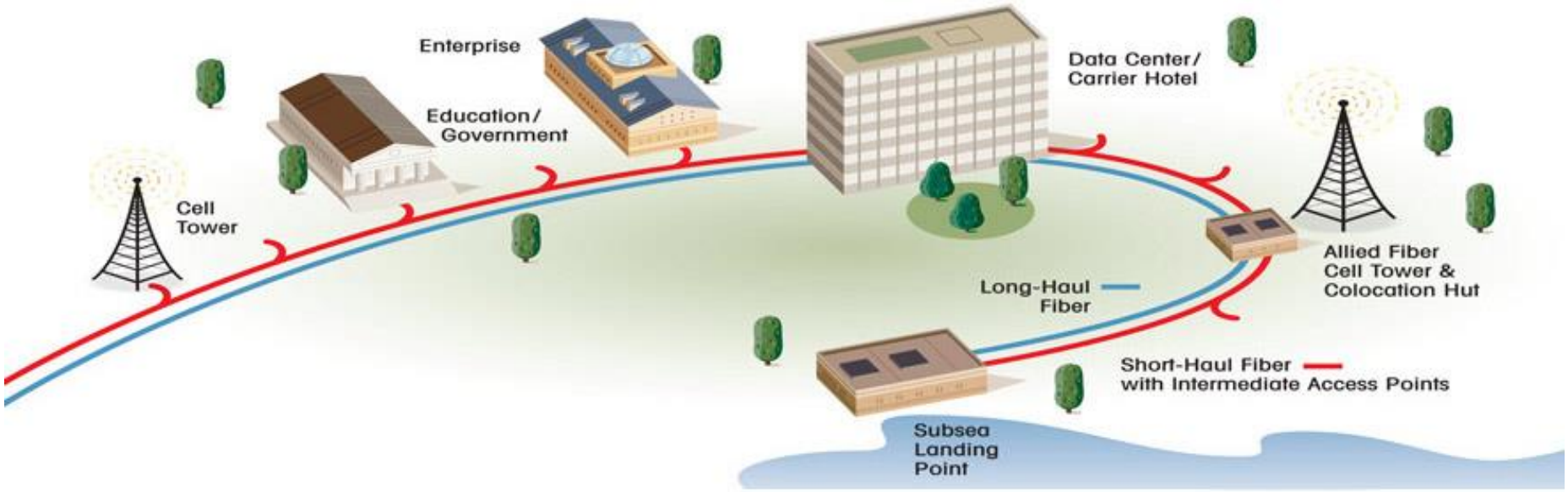
Cell Towers are Connected to Fiber



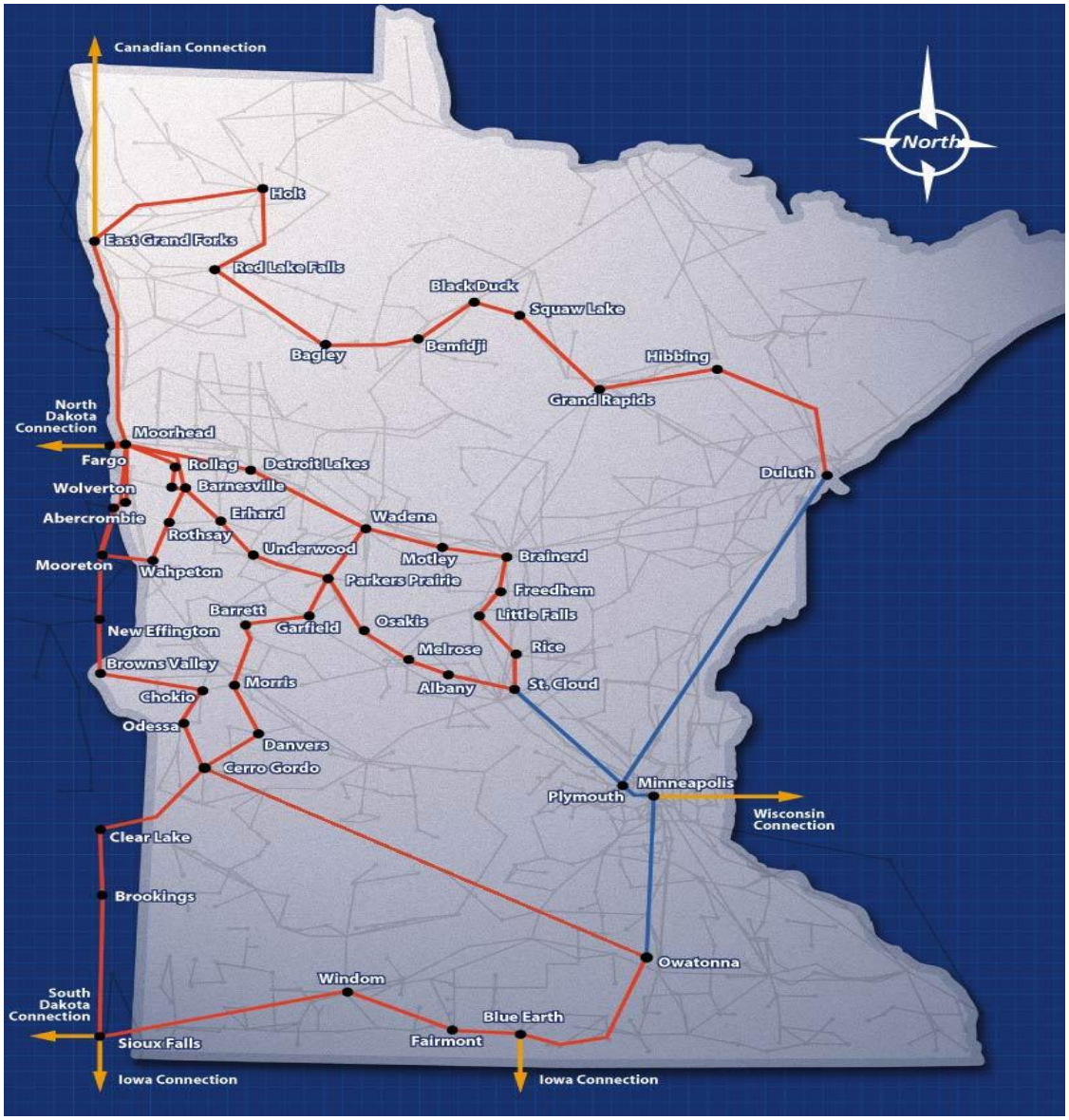
Optical Fiber – Backbone of Information Highway



The Bigger Picture

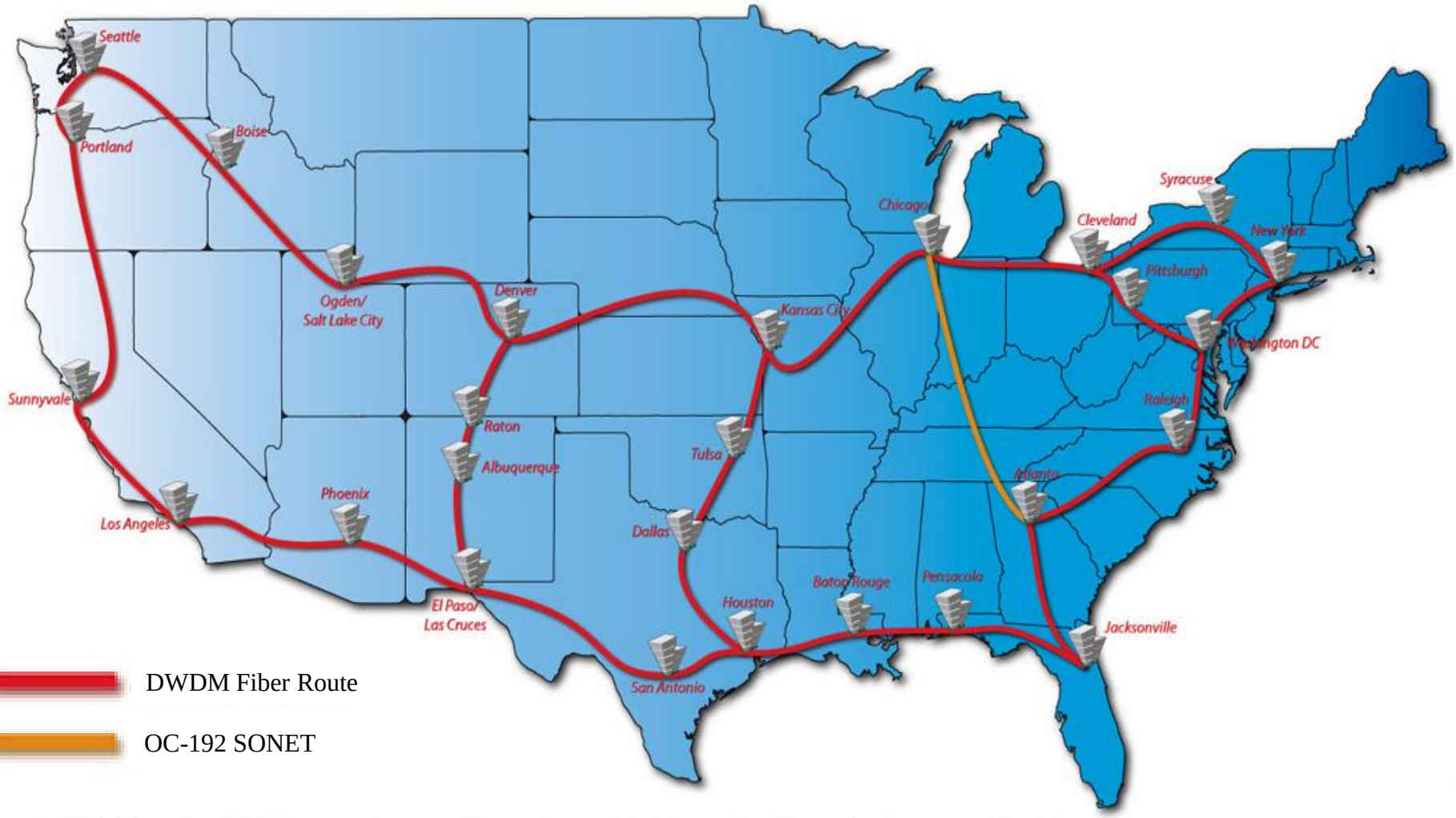


Metropolitan Network



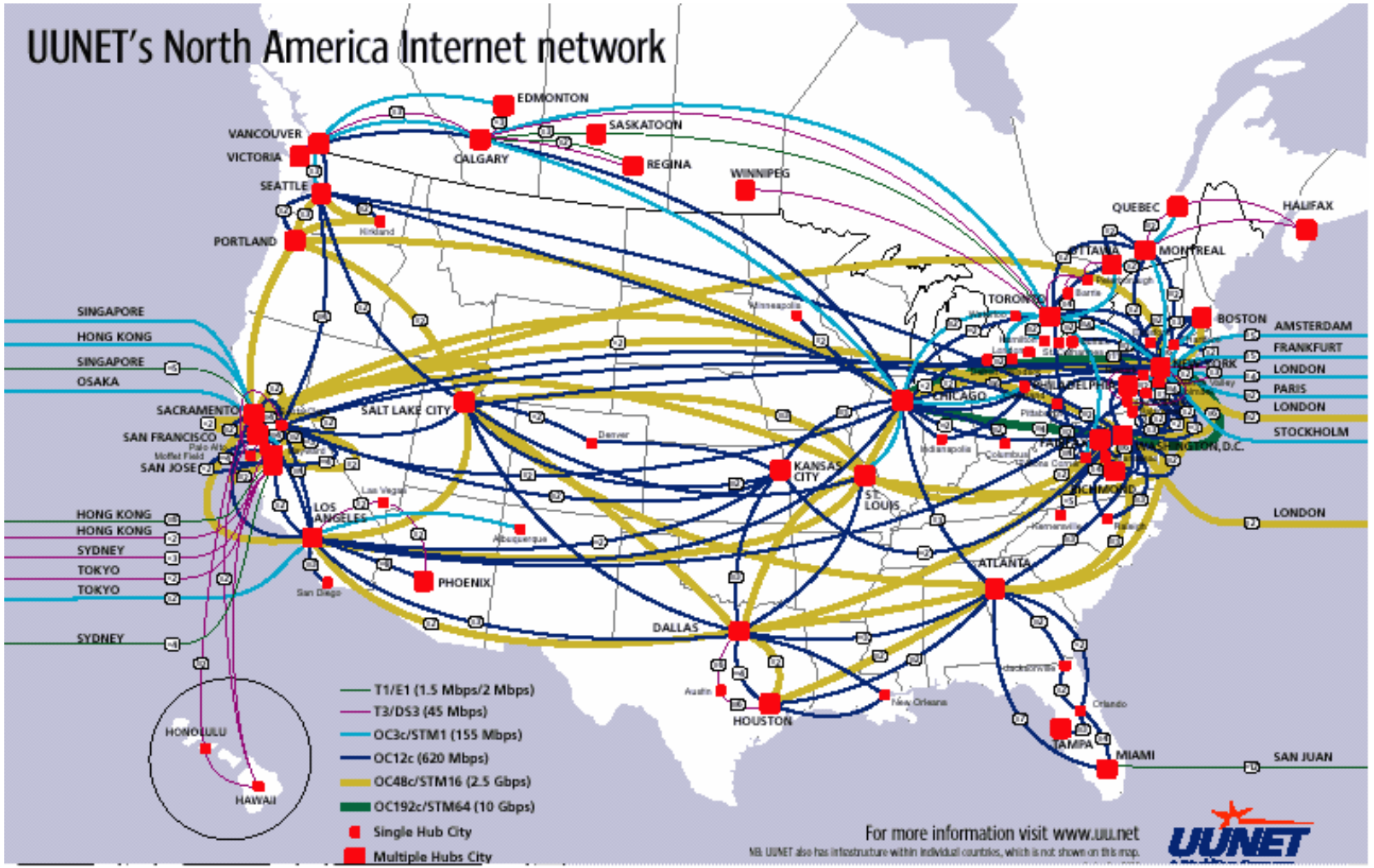
Aurora Fiber Optics Networks

Long Haul Network

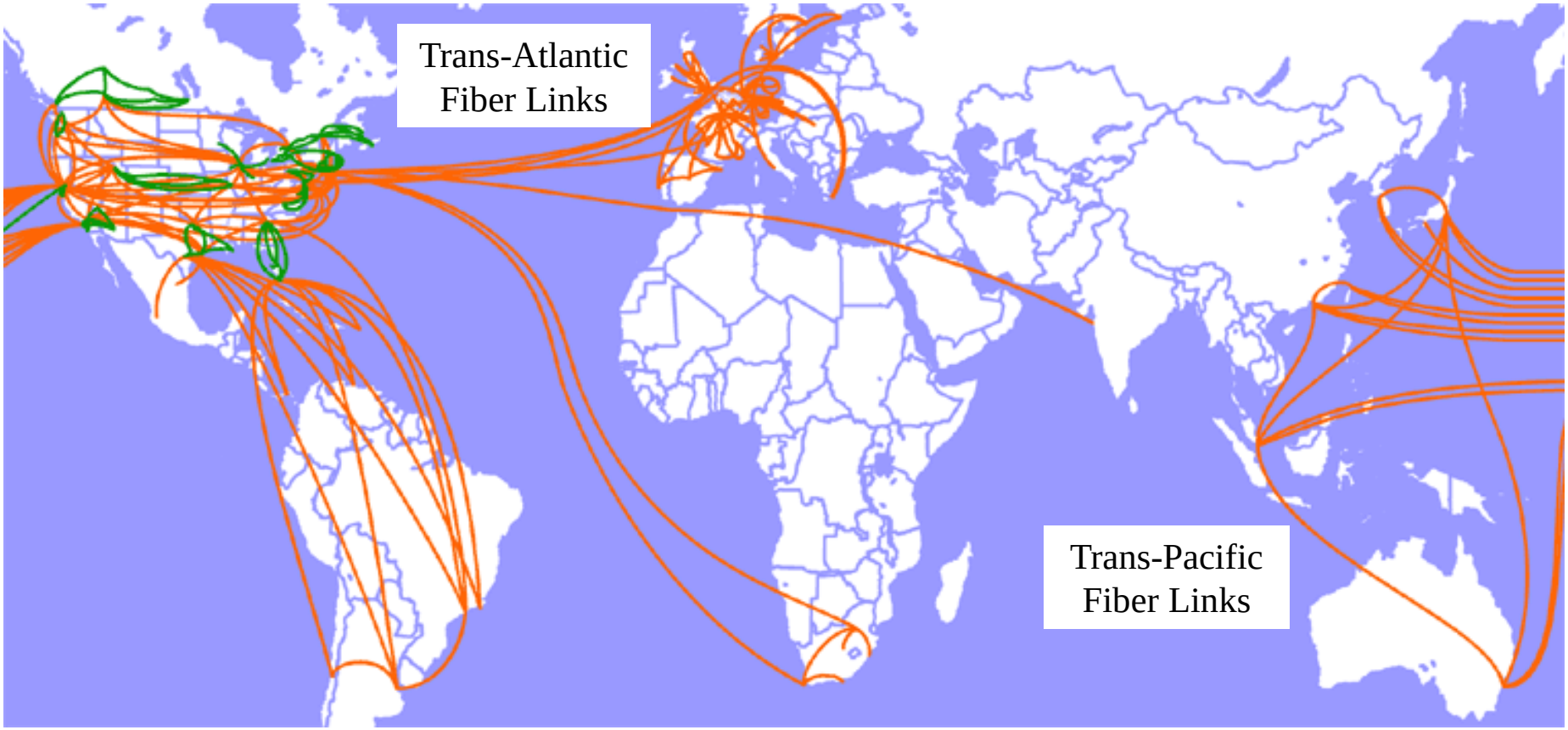


For more information regarding NLR see http://www.nlr.net or contact info@nlr.net

Metropolitan and Long Haul Networks

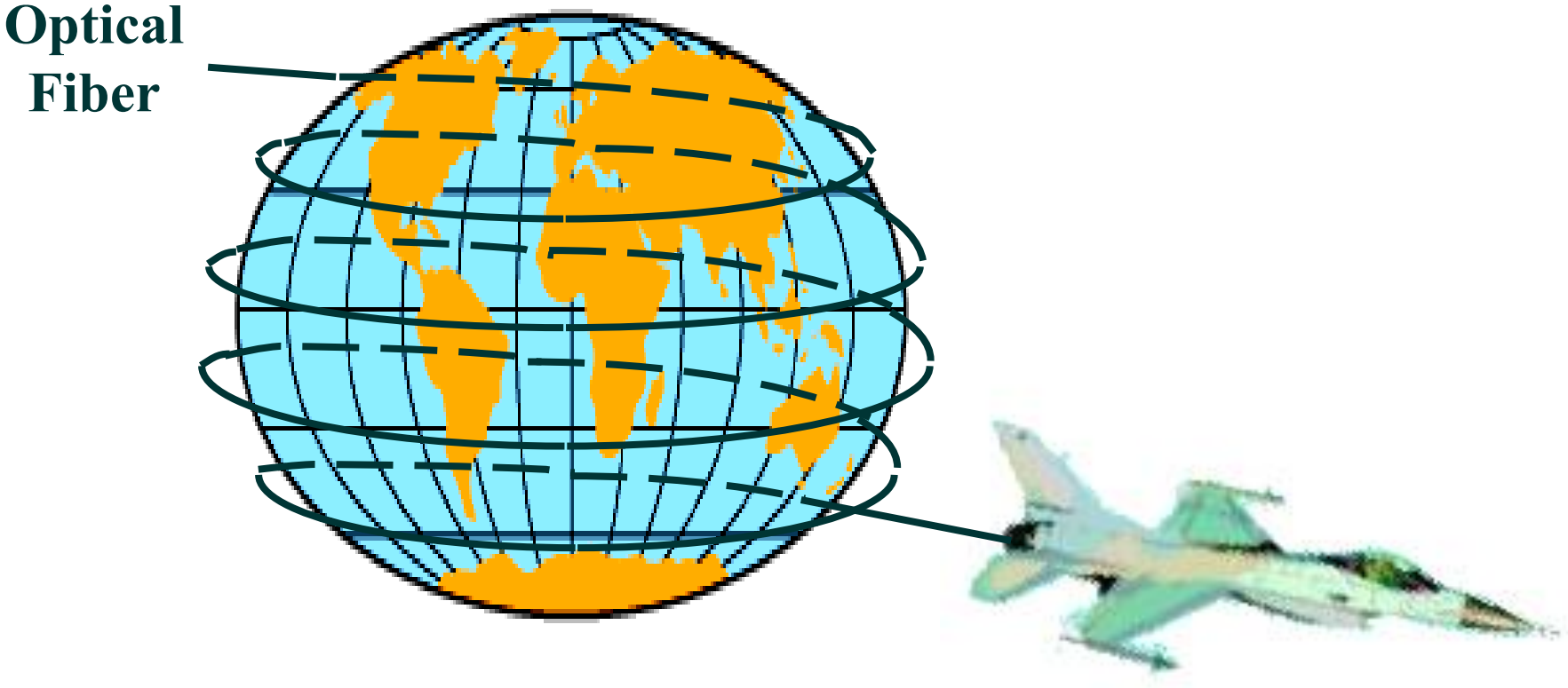


Long Haul and Transoceanic Network



Worldwide Fiber Deployment

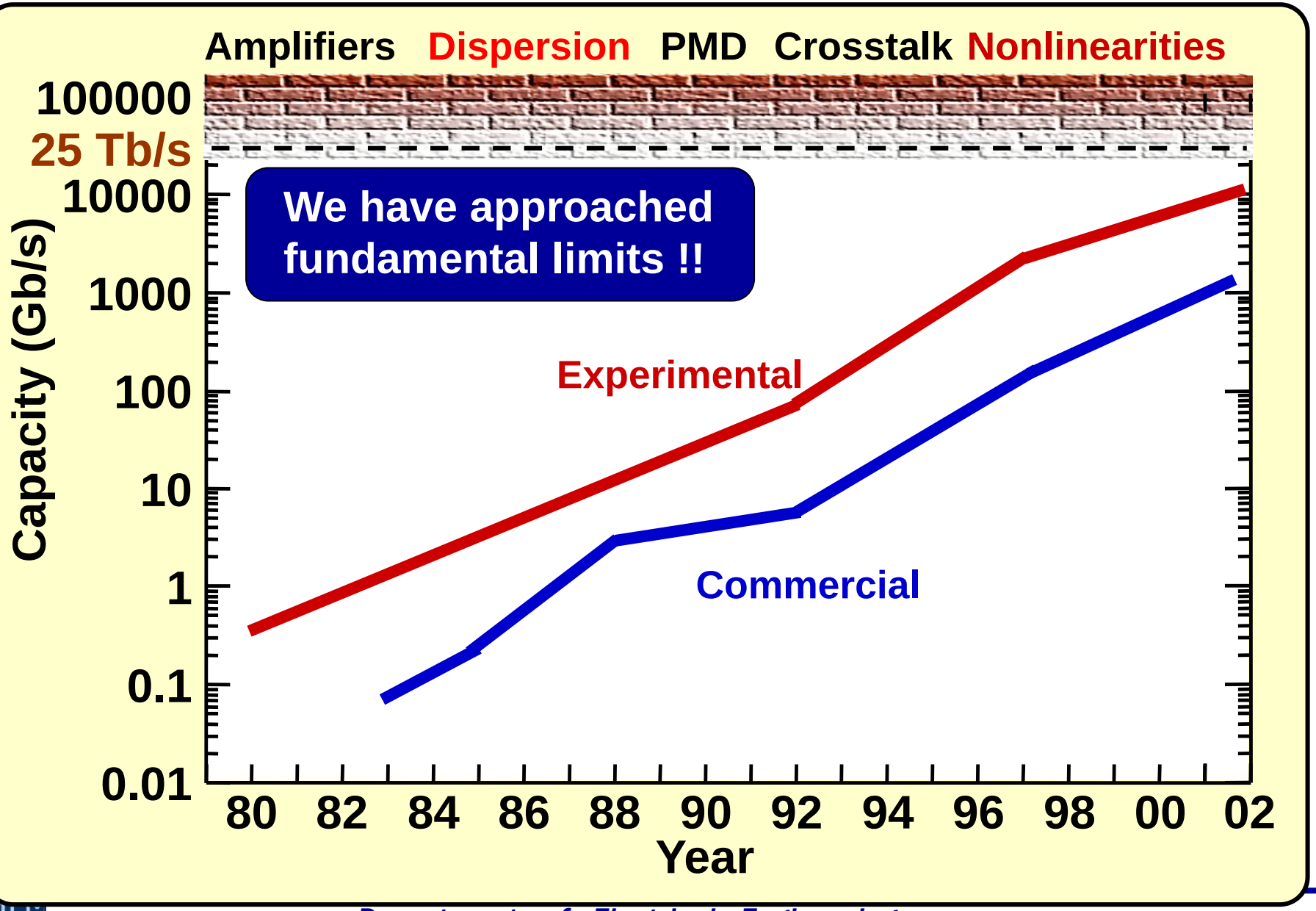
Deploying Fiber at the speed of Mach 3



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

T. Li & A.R. Chraplyvy, 2001

Limitations of Fiber Systems

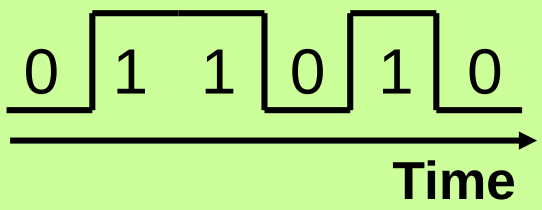


Origin of Fiber Dispersion

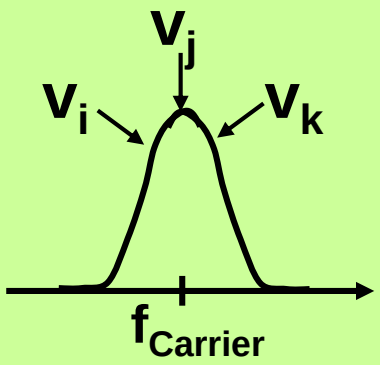
$$\text{Photon Velocity } (\lambda) = \frac{\text{Speed of Light in Vacuum}}{\text{Index of Refraction } (\lambda)}$$

Different wavelengths in the fiber travel with different speeds

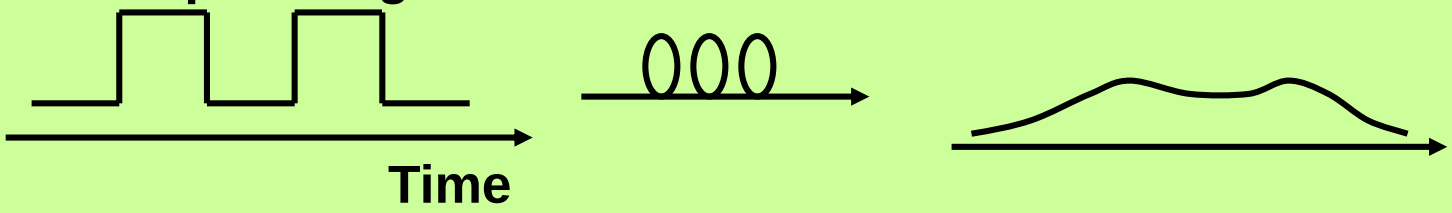
Information Bandwidth of Data



Fourier transform



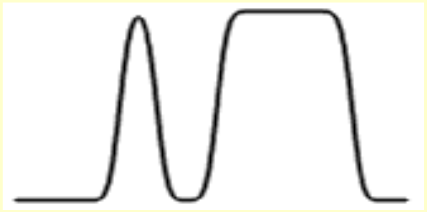
Temporal Pulse Spreading → **F *[distance, (bit rate)²]*** → **ps/nm km**



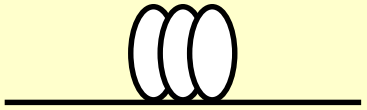
Chromatic Dispersion and Achievable Bit Rate

No distortion of output bit stream

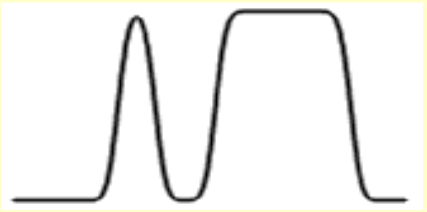
2.5 Gbit/s



Distance = 0 km



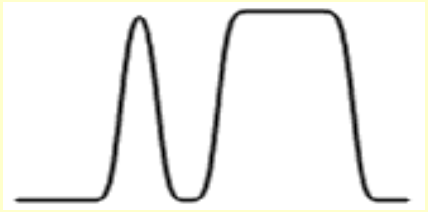
Optical fiber



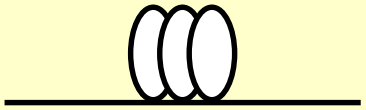
100 km

Large distortion of output bit stream

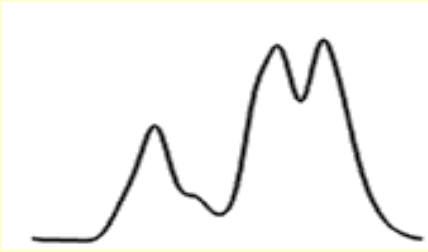
10 Gbit/s



Distance = 0 km



Optical fiber

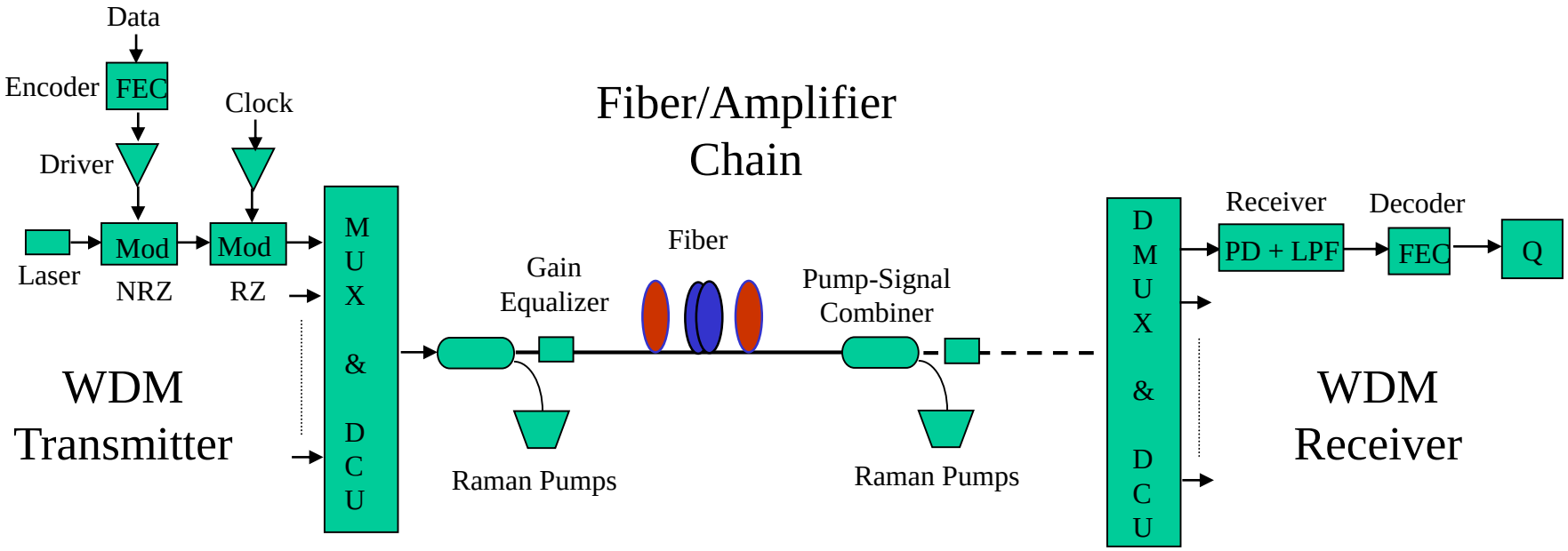


100 km

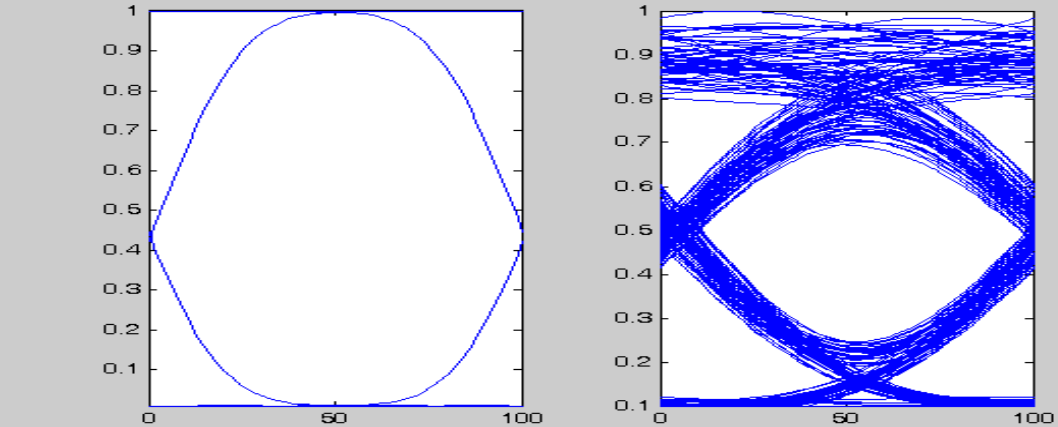
Dispersion induced 1-dB Power Penalty:

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?

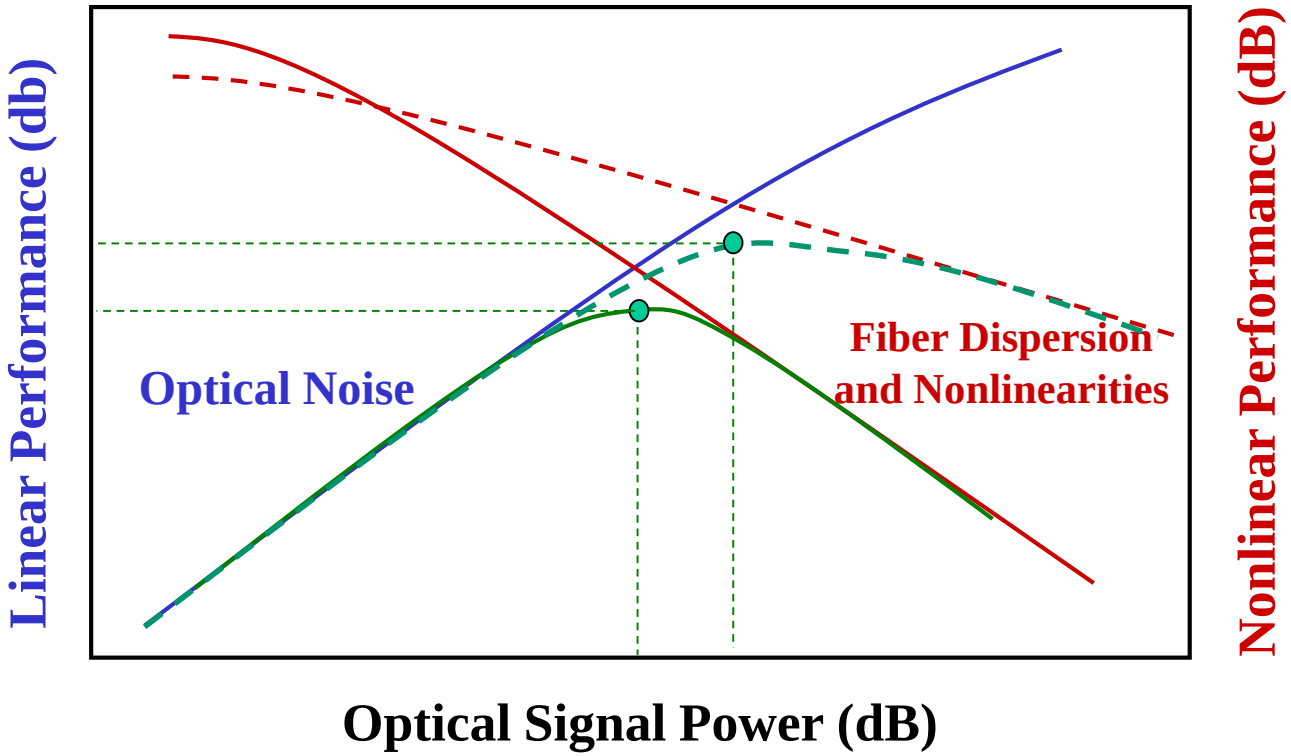


Input Eye



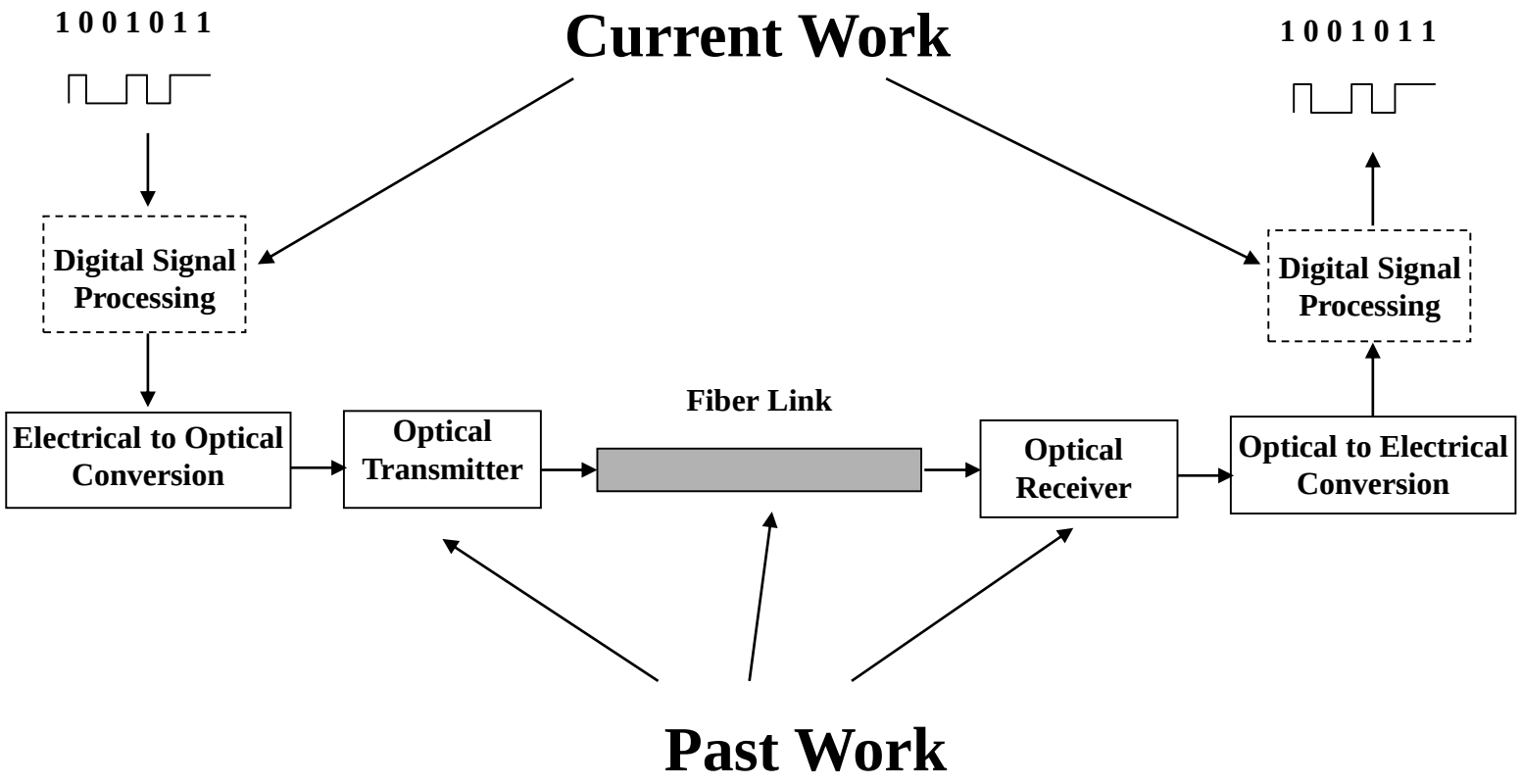
Output Eye

Fiber Nonlinearity Imposes Ultimate Capacity Limit

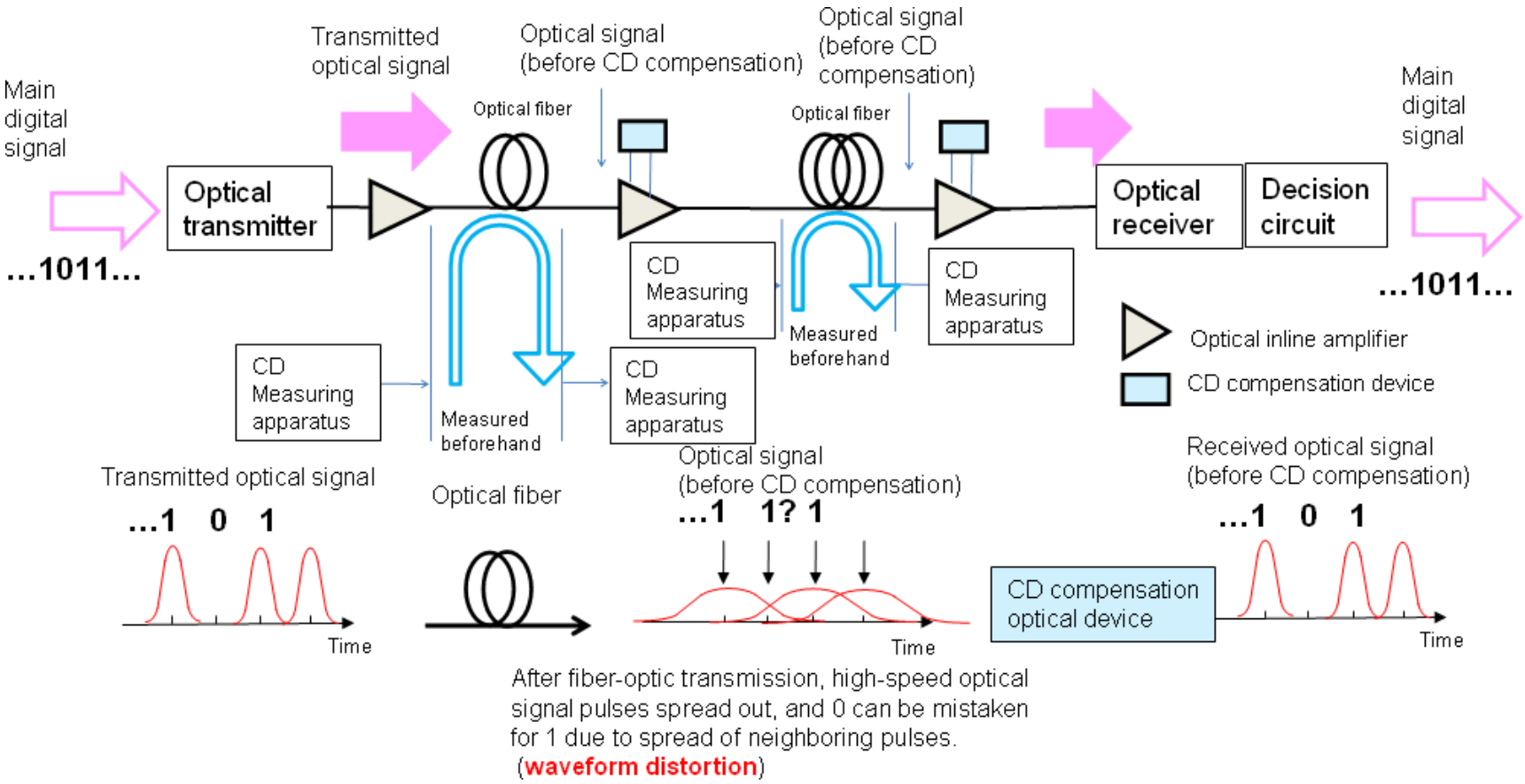


Fiber nonlinearity puts the ultimate limit on the capacity to be used in an optical fiber communication system

What do I do?


1 0 0 1 0 1 1
Current Work
1 0 0 1 0 1 1
Digital Signal Processing
Digital Signal Processing
Fiber Link
Electrical to Optical Conversion
Optical Transmitter
Optical Receiver
Optical to Electrical Conversion
Past Work

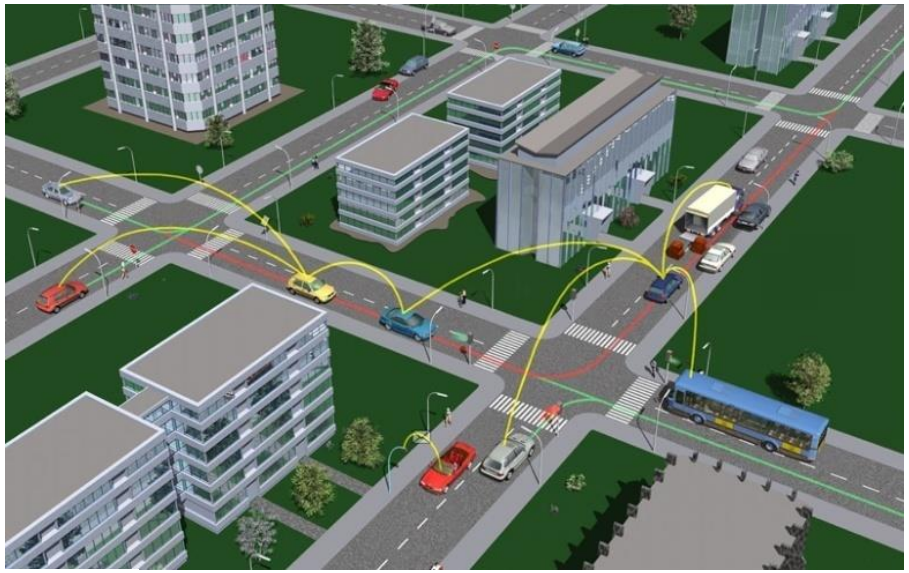
In color, I do this?



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 Transportation System



Electronic Heart Murmur Detection

Summary/Questions

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