Welcome to: ES011WS01

An eSeminar on

DWDM Optical Networking **R/Evolution**

The Magic of Photonics

M. T. Fatehi, Ph.D.
Stevens Institute of Technology
mfatehi@stevens.edu or fatehi@ieee.org

Ground Rules, Housekeeping and Preface

- Your instructor for this eCourse is Prof. M. T. **Fatehi** (Moh), Pronounced as: **Fa' te hee**
- During the week, if you have questions or comments:
  - you can send me e-mails at:
    1. my WebCT mail (preferable) ,
    2. my Stevens Email: mfatehi@stevens.edu,
    3. or at fatehi@ieee.org (a forwarding address).
  - Or at you can call me at +1 949-733-3468. You can leave voice message a message if I am not available.
  - If you know an easy way to send voice files via email, let us try that. It will be more personal than text email.

- The Goals of this experience are:
  - Learn
  - Have fun
  - Look back on this as a positive and worthwhile experience

Ground Rules, Housekeeping and Preface 2

- You may advance or backup the slides (or follow the pdf presentation files) during the lecture to view the picture or the text. You may also advance/backup the sound player at any time (if available).
- Read the **assigned texts** to facilitate understanding of the slides.
- If you read the assigned texts the slides would be, for the most part, self-explanatory for you.
- If voice is available for any of the modules AND you are interested in following a more audiovisual learning strategy by listening to my voice, then please activate the sound by pressing the icon (in the tool bar) suitable for your system to hear the lecture. If so, from time to time, I will read the slide number so that we can synchronize the sound and the slide together.
- From time-to-time, I will have links to some material that are entirely unrelated to this course objectives. This will add more reality to this virtual classroom.
- Optional demos and other material may be added to this course later.

"Understanding Is Ecstasy,"

wrote Dr. Dale Dubin in his book "Rapid Interpretation of EKG's" .

So try to understand and **enjoy**.

Ground Rules, Housekeeping and Preface 3

- The lecture material in this course is developed based on:
  - Short courses/workshops/tutorials presented over the past few years by the author in many conferences and workshops in the united stats and abroad.
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  - I have attempted to reference, acknowledge or note other sources and originators of presented material where possible
- Interactive presentation: This virtual course is intended to be an interactive one. Do not be passive
  - Ask any questions - Active participation
  - Let us synchronize our speeds from time-to-time
  - The unanswered questions (mostly in green font) are left for student as an exercise. If you can not answerer them, ask me or click if linked to answer.

- And Yes: Have Fun Learning

To Students and Attendees

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M. T. Fatehi

Background/Preview

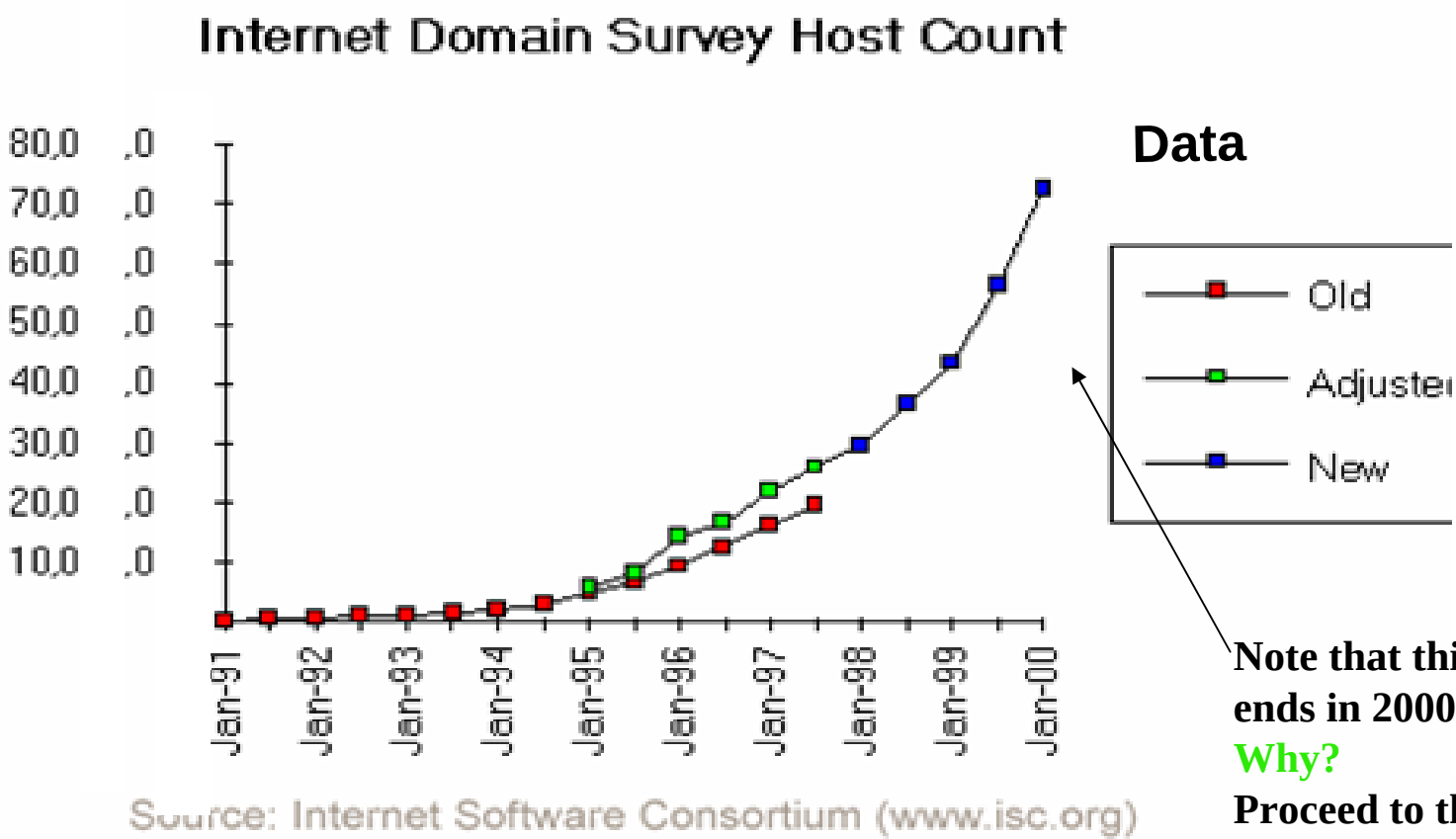
- Explosive growth in Internet has created need for large capacity (Bandwidth or BW) in backbone
  - Growth to continue (is there a BW glut or a BW shortage?)
- Installing new fiber is expensive
  - We would like to use existing fibers as much as possible.
- Ideal mechanism: Dense Wavelength Division Multiplexing (DWDM)
  - Increased capacity at relatively low cost
- DWDM carry multiple streams of signals over a single optical fiber by transmitting them at different wavelengths (colors)
- Conventional systems use single wavelength
- "Virtual fiber" can be added
- Systems introduced in 1996 (8 and 16 channels)… now up to 132 or more

Basic Approach/Preview

- Multiple wavelenghts of light carry the data channels to an optical multiplexers, where they are combined for transport over a single fiber
- Optical amplifiers maintain continuity by amplifying the multiple signals simultaneously along the line
- Essential to WDM is optical amplifier … Erbium-Doped Fiber Amplifier (EDFA) initially
  - now new extended-band amplifiers being sought
- Carry the signal to optical demultiplexers, where they are split into the original channel

The Exploding Internet

. . . *and the Changing Traffic Mix*



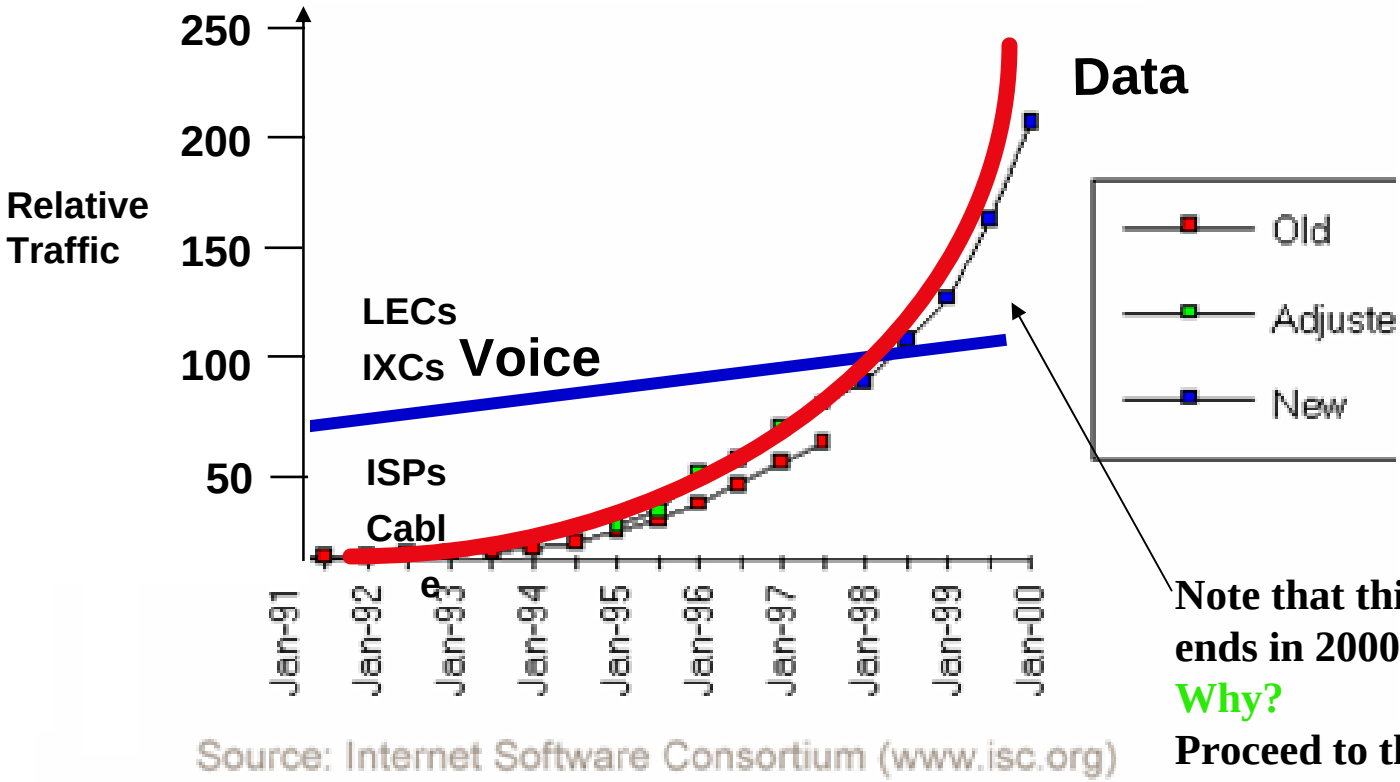
Note that this prediction ends in 2000.

Why?

Proceed to the next slide.

The Exploding Internet

. . . and the Changing Traffic Mix



Note that this prediction ends in 2000.

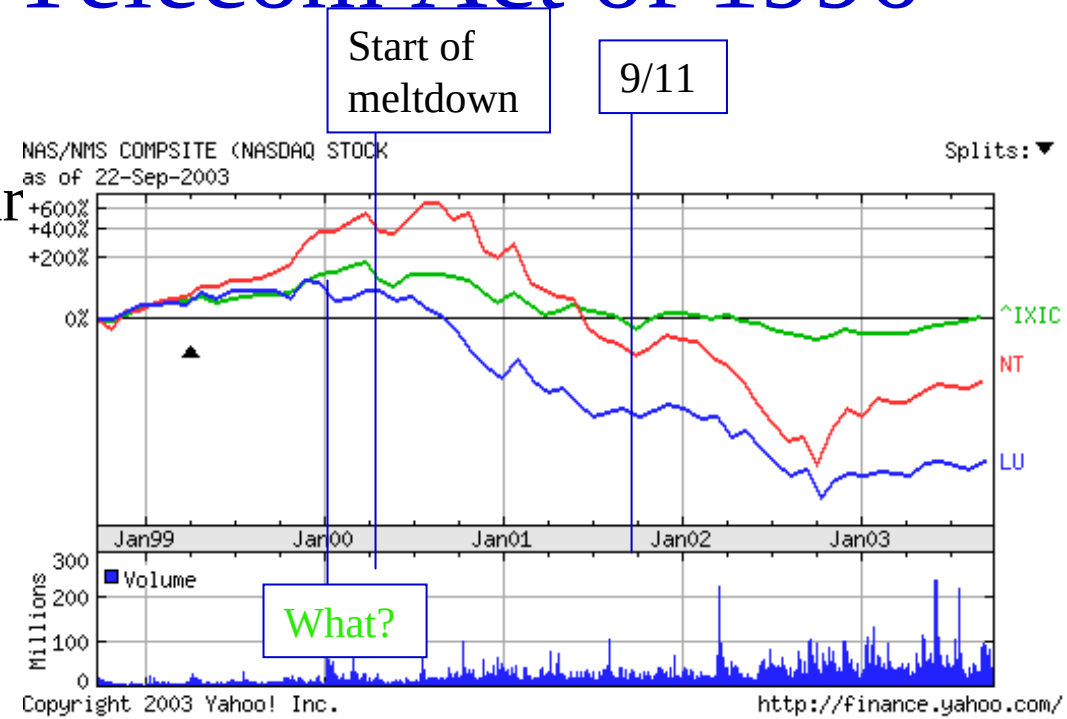
Why?

Proceed to the next slide.

Data over Voice Networks → **Voice over Data Networks**

Impact of the Telecom Act of 1996

- The previous graph was true up to the year 2000
- In 2000-2001, the trend suddenly broke down (temporarily I believe) due to the Telecom meltdown.



The stock market behavior from 2000 to present is indicative of what happened. Here, we List Lucent, Nortel and compare them with NASDAQ as the normalization factor.
Note the vertical scale is logarithmic.
Why do you think this happened to the industry? → Answer follows

Impact of the Telecom Act of 1996

- Telecom downtrend could be blamed on the Telecom Act of 1996.
- Telecom Act of 1996 has lead to band with mismanagements that analysts have interpreted as a bandwidth glut!
- What is it and why? →Answer follows

Question 1: What do you think? At this point in time is there a BW glut or a BW shortage? Click to next slide see my views on this.

Telecom act of 1996 and its impact

The Telecommunications Act of 1996 has led to a misdistribution of bandwidth between the edge of the network (access) and the core. This law, while intended to promote competition, requires local phone companies to lease out their network to competitors at below retail rates. As result, local phone companies did not invest in improving access infrastructure while long-haul was heavily invested in (by 2000) and was built to meet the expected capacity demand. This has led to a communication bottleneck**:** bandwidth shortage at the edge and glut at the core, and the consequential meltdown of the telecommunications industry.

The House recently passed "Tauzin-Dingell" bill, which will help bring high speed Internet access to metro access and rural areas. The analysts who expect a decision by mid February 2003 believe the FCC will propose phasing out wholesale access pricing over two years for new policies that favor direct investment by local telecommunications competitors.

As a result, the Local Carriers (LECs) would be **expected to invest in new high capacity equipment** to alleviate this telecommunication bottleneck at user interface.

Additionally, if this bottleneck is alleviated as a result of this wholesale access pricing phase out, the bandwidth demand in the core is also expected to grow which will, in turn, lead to the recovery of the entire telecommunications industry by 2005.

Source: FCC websites

Optical Communication System Overview

First, a Brief Historical Review:

You can Skip this section if you are not interested.

A Brief Historical Overview

480 BC	**Ancient Persians conceived of optical signaling with mirrors and torches [3,4]**
1880	**A.G. Bell invented the "Photophone" [5] See the "Photophone" slide.**
1945	**Heartly and 1951 Tyrell of BTL proposed optical frequencies for communication**
1950's	**--move from analog to digital transmission**
	--fiber bundles for imaging
1958-61	**--laser development (Ali Javan, et.al.)**
1966	**Kao & Hockman suggested low-loss fiber (<20 dB/Km) was possible**
1969	**Semiconductor injection laser announced**

Source:

3. Gowar, John,"Optical Communications Systems," pp. 1-2, "Prentice Hall, 2nd ed, 1993, ISBN 0-13-638727-6

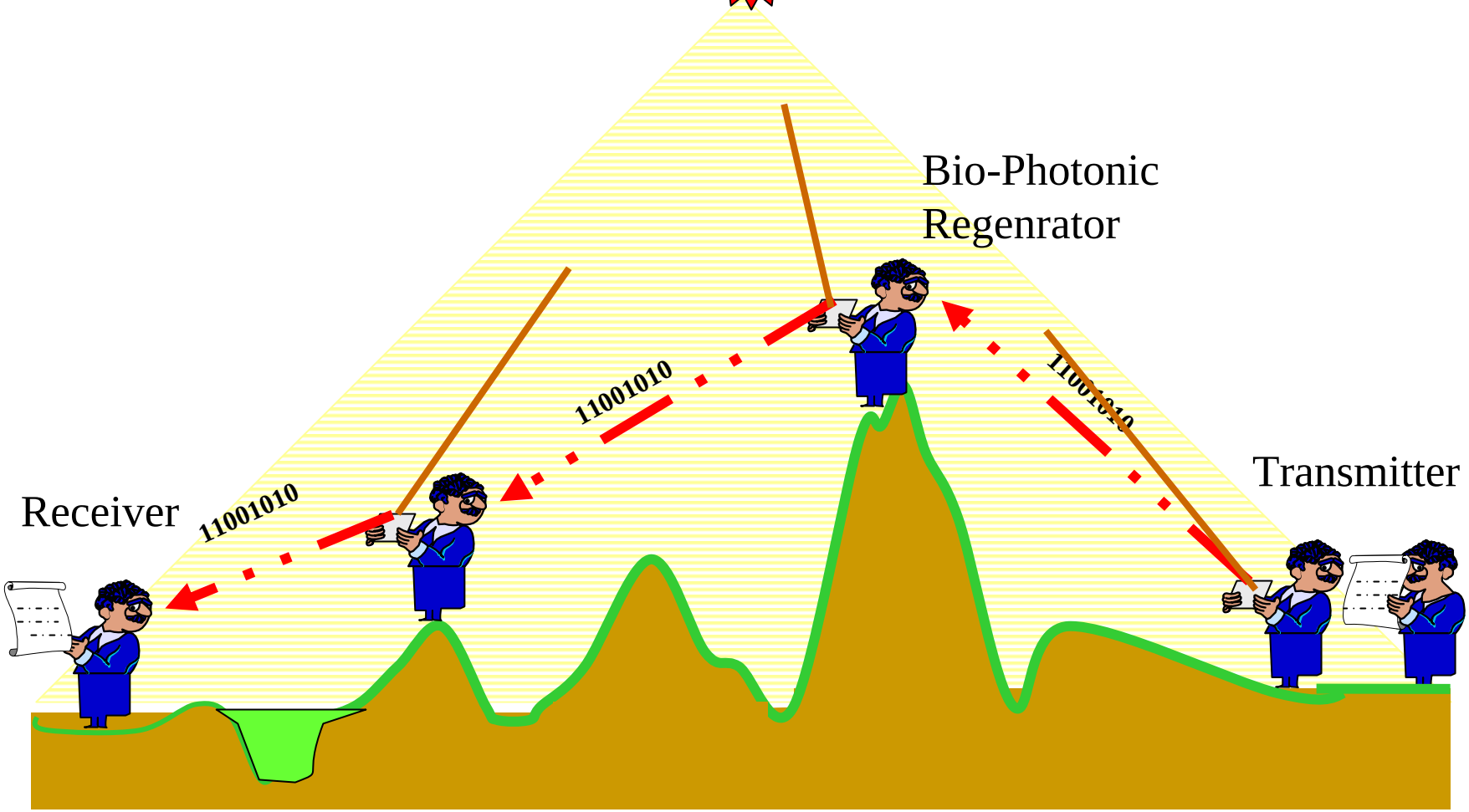
4. No 22, National UNESCO committee, "Iran-Shahr", published by Tehran Univ Press, 1965 (1343 Shamsi) , Vol. 2 , pp 1078-1081, pp 1084-1087, pp 1497-1498.

5. US patent N0. Bell & 235,496, Issued on 1880/12/14

Historical Overview Cont.

1977	**first field trial of AT&T lightwave system**
1980	**first commercial lightwave system (45 Mb/s, MM, 0.820 micron)**
1985	**first 0.820μ, 417Gb/s fiber optic transport (Philadelphia-Chicago), upgraded to 1.7 Gb/s in 1987**
1988-90	**1.3m-1.5 WDM deployment, evolution of SONET**
1990-94	**introduction and evolution of optical amplifiers, DWDM (see Chapter xx), Optical switching concepts, RACE Project in Europe**
1994-96	**MONET Project in US, concept of transparent optical networking,**
1995	**first submarine optical amplifier network**
1998-2001	**mushrooming Optical Networking start-ups**
2001-	**Telecom Industry Meltdown**
Near future	**transparent all-optical networking concepts**
Future	**Optical Internet, Optical computing and data processing**

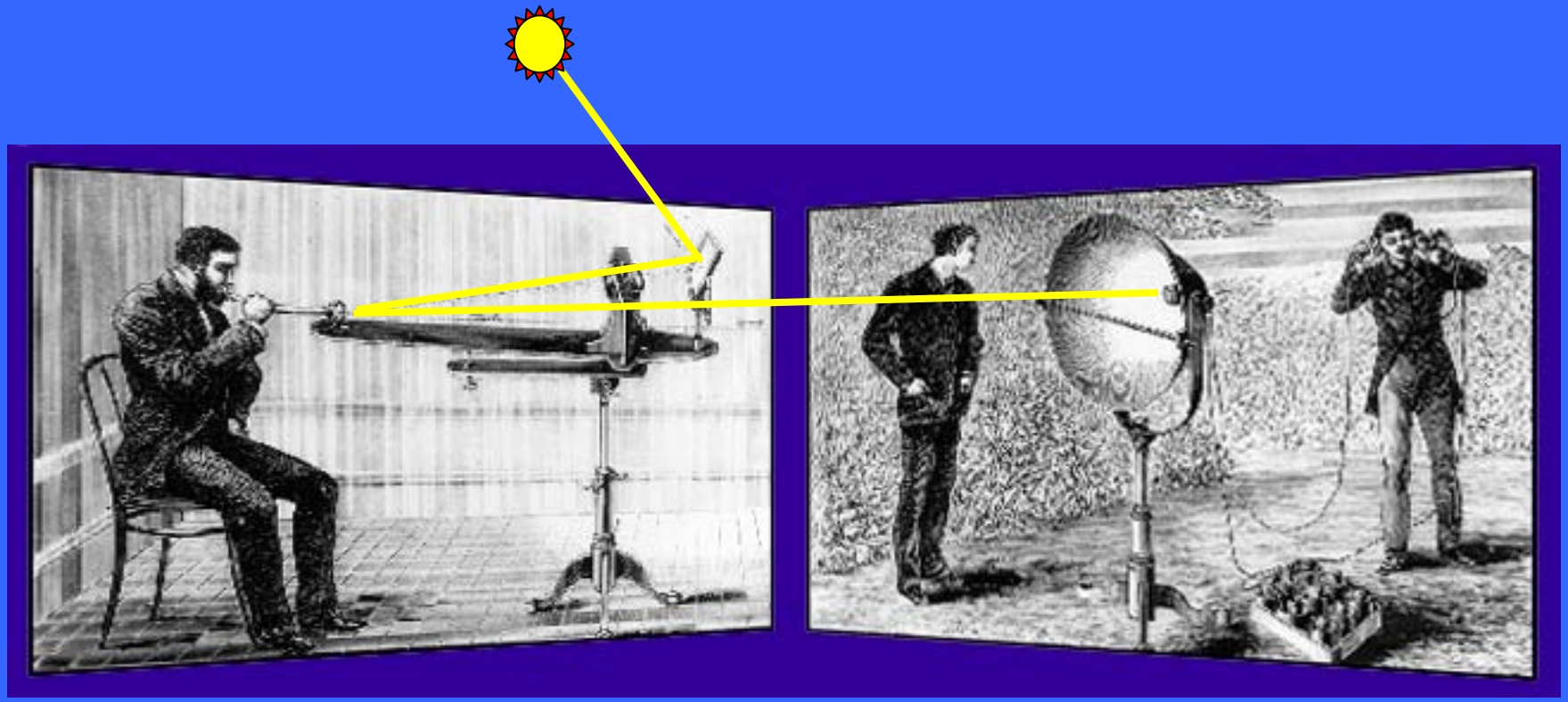
$$\sum_{\iota=1}^{N} \lambda \iota$$



An Ancient Persian Optical Digital Communications System Using Unguided Transmission Medium

3. Gowar, John,"Optical Communications Systems," pp. 1-2, "Prentice Hall, 2nd ed, 1993, ISBN 0-13-638727-6
4. No 22, National UNESCO committee, "Iran-Shahr", published by Tehran Univ Press, 1965 (1343 Shamsi) , Vol 2 , pp 1078-1081, pp 1084-1087, pp 1497-1498.

Bell/Tainter's Photophone[5]

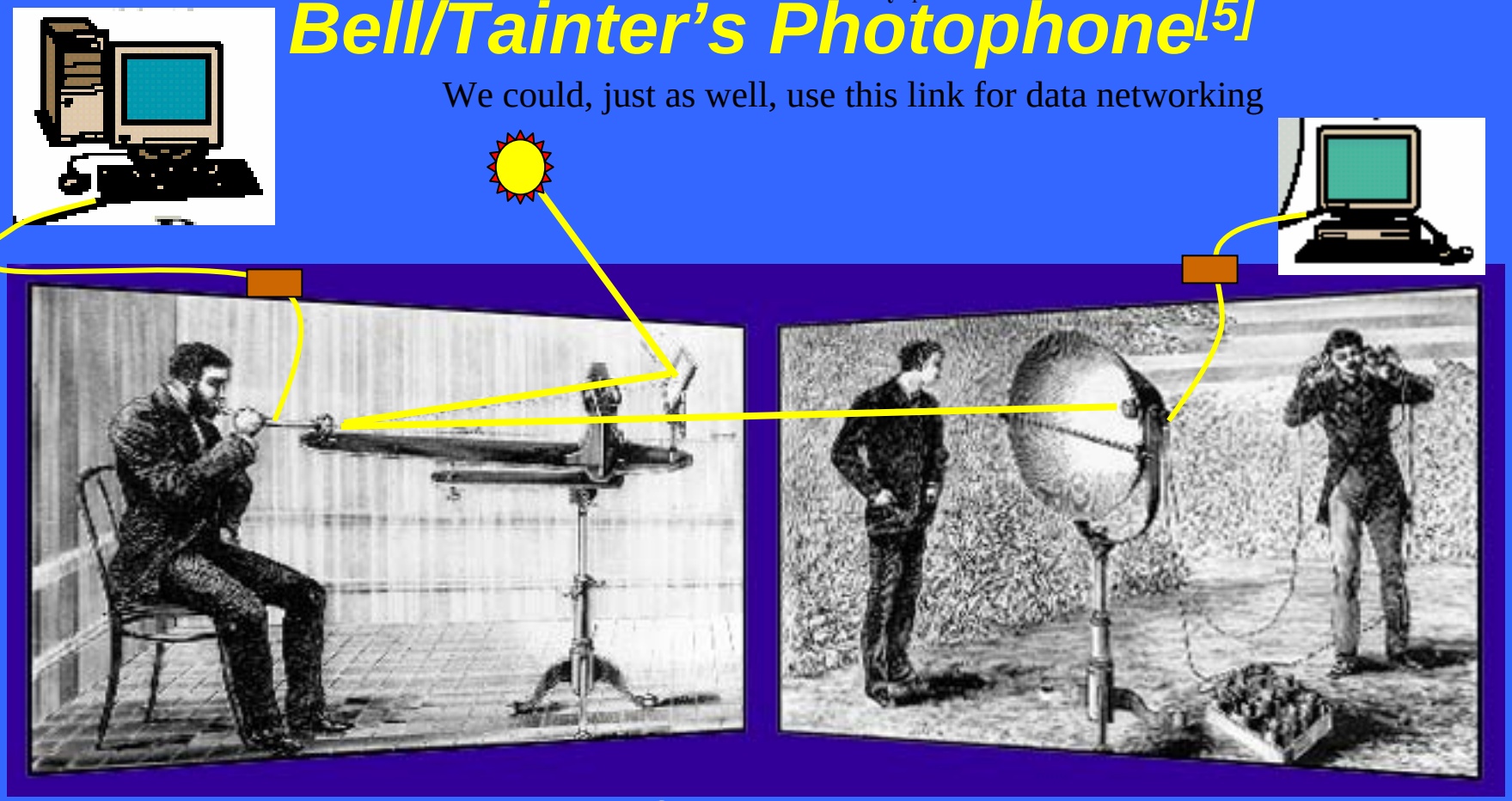


I have **seen** a ray of sun laugh, cough, and sing."
- **Alexander Graham Bell** after sending words over a beam of light, 1880.

5. Bell & Tainter patent 235,496 granted 1880/12/14*

Bell/Tainter's Photophone[5]

We could, just as well, use this link for data networking



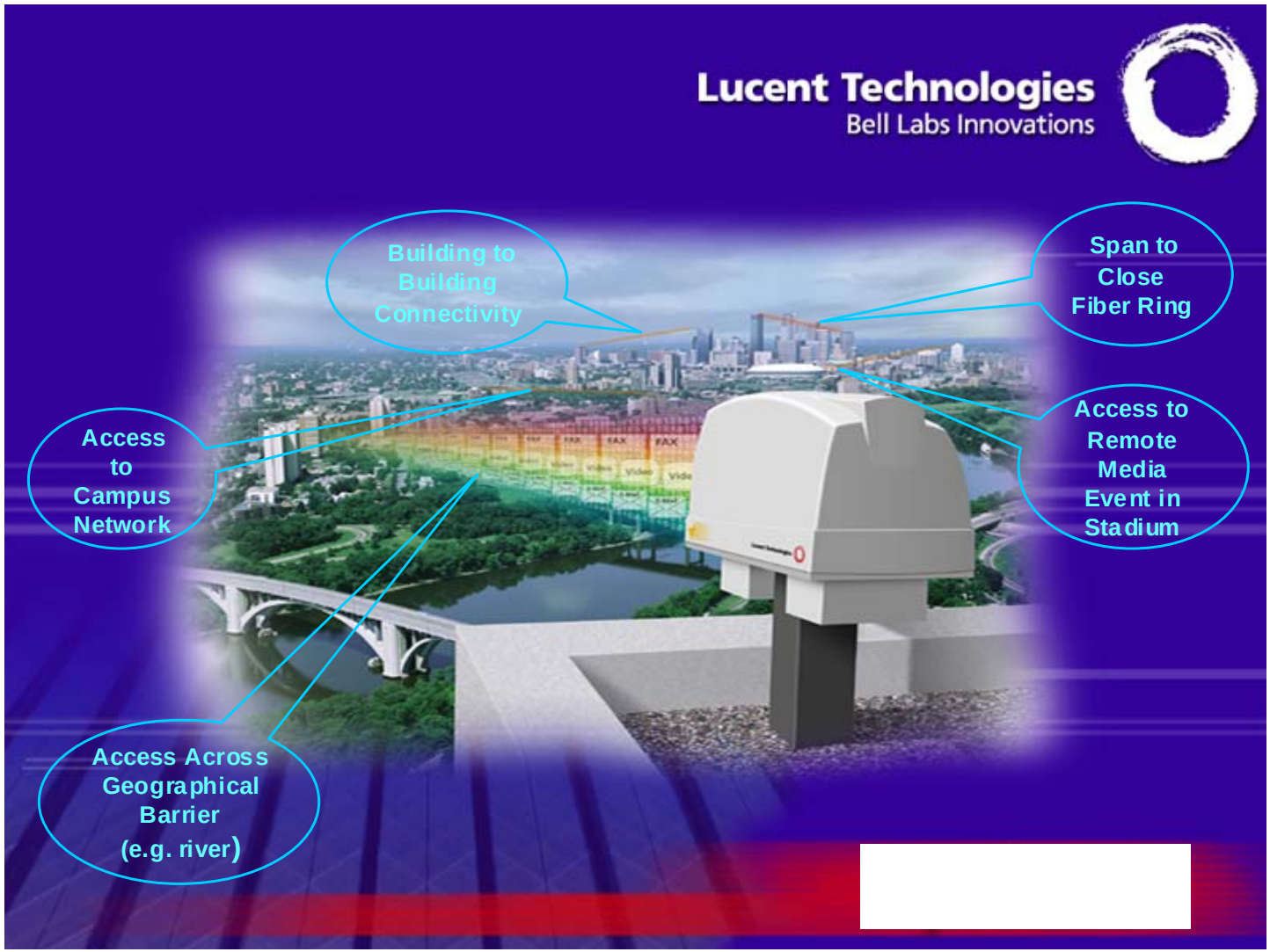
I have **seen** a ray of sun laugh, cough, and sing."
- **Alexander Graham Bell** after sending words over a beam of light, 1880.

"I have **seen** WDM transmission over an Optical Network.
It is so simple to understand
–**Our reader** at the completion of this tutorial

And Now: DWDM IN THE AIR

Lucent Technologies
Bell Labs
Innovations

WaveStar™
OpticAir OLS

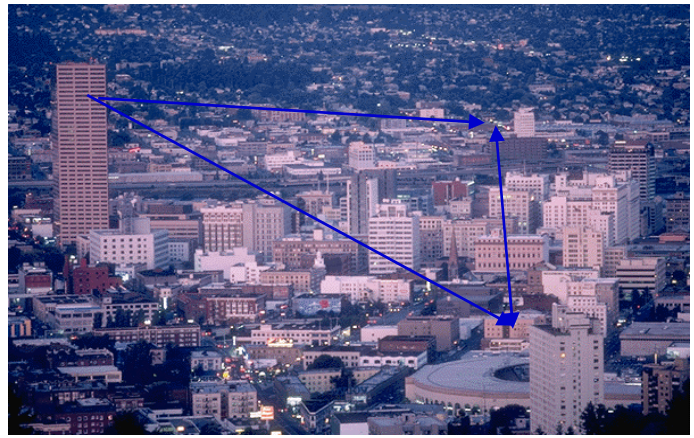


OpticAir was Developed at Lucent Technologies, a decedent of Bell System Systems

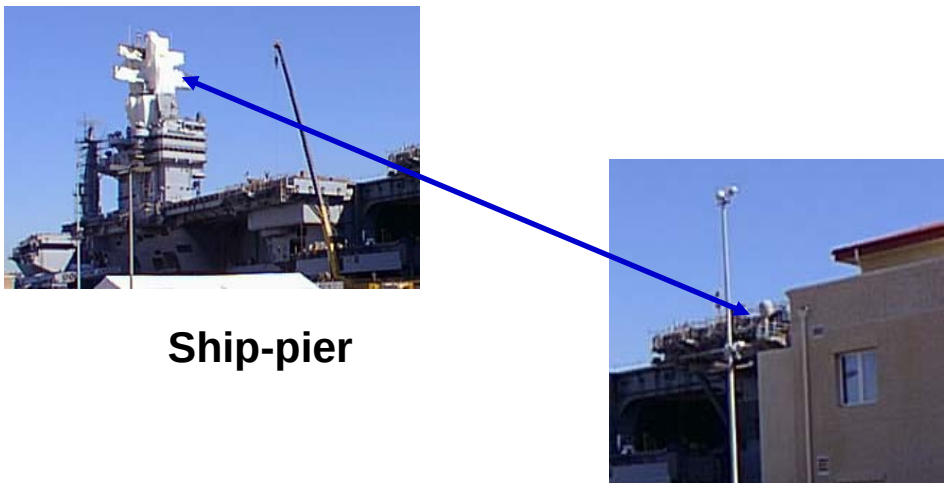
DWDM IN THE AIR

Lucent Technologies
Bell Labs
Innovations

- Alternative when fiber is not available/difficult
- Protection Link
- Temporary Link
- Metropolitan Link
- Access POP
- Other applications
  - Campus LAN
  - Data downloading from mobile transport e.g. ship/pier, car/site, oil rig



Metropolitan



Ship-pier

Market Segments

- Federal Government
  - Navy e.g. Ship/Pier
- Commercial Market
  - CLECs
  - Large Businesses

OpticAir was Developed at Lucent Technologies, a decedent of Bell System Systems

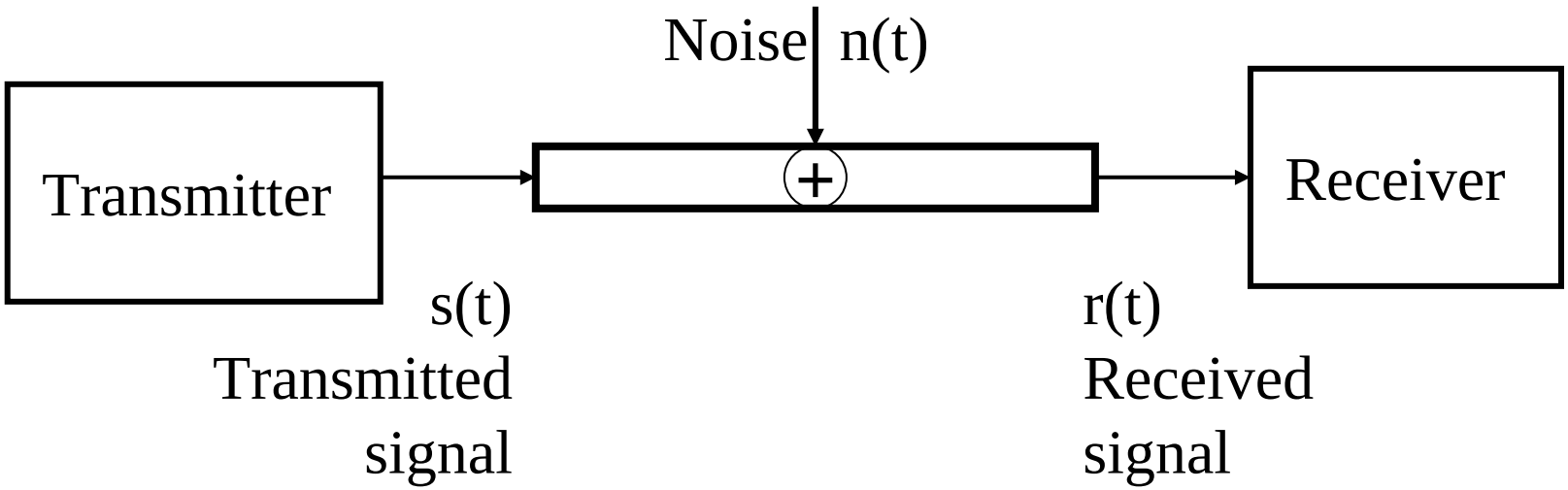
Review of a Generalized Communication System (Model)

some convention/ terminology

- **Information**
  - what one end user wants to exchange with another end user
  - examples:
    - e-mail message between computers
    - Telephone conversation between people
- **Signal**
  - What is applied to the transmission system
  - Optical, electrical, even mechanical (example?), other
  - Caries the information (above) through the transmission system
- **Transmission system**
  - Connects source and destination
  - can be a simple transmission line or a complex network (e.g. wide area network WAN, local area network LAN, etc.)

A Simplified Communications Model (cont.)

Consider this simple communications model



Intuitively conclude that: $r(t) = s(t) + n(t)$

This carries a lot of implications

Simplified Communications Model (cont.)

- **Role of transmitter**
  - Generate proper signal and send it into the transmission system.
  - Observation: Many types of signals are possible
    - What are they? -- there will be discussed later
    - How to design the signal? Need to match the signal characteristics to that of the transmission system
- **Role of receiver**
  - to receiver the received (contaminated)signal r(t), and recover the original signal s(t), in presence of noise n(t).
- **Role of transmission system**
  - to provide connectivity between the transmitter and the receiver during the period of communications.
  - May be dedicated or shared
  - May be connection oriented or message oriented
  - There are variety of transmission systems -- more on that later

End of Module 1

- Do you have any questions?
- Homework assignments:
  - Reflect on this module before moving on to the next.
  - Provide a summary slide for this module
  - Draw a detailed diagram showing the communication network in your organization. No right or wrong answer. It is probably an Ethernet network. What is the maximum connection speed?
- Next module deals with Fiber Optic Communication Fundamentals.