# Internet: Past, present, future

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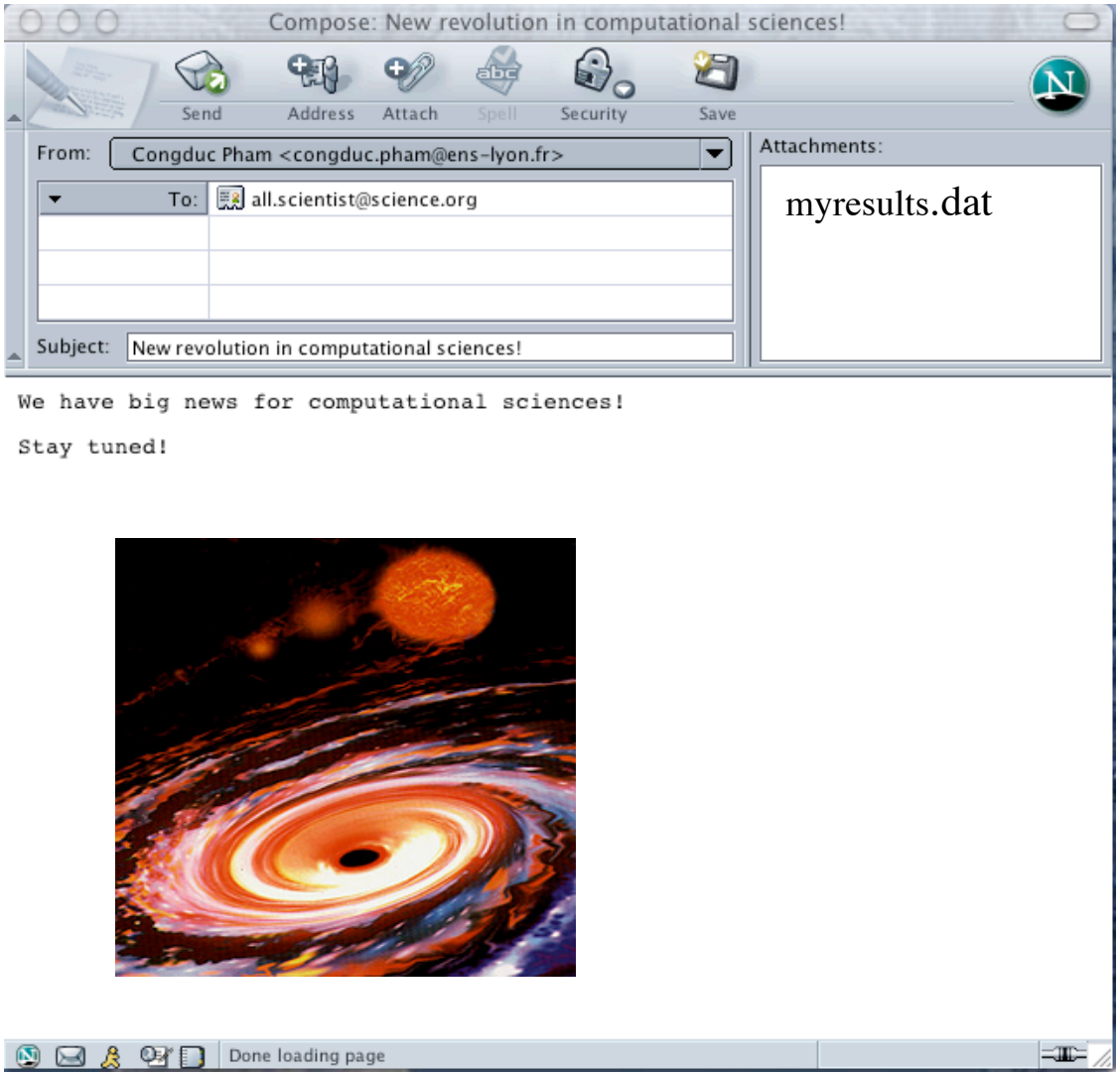
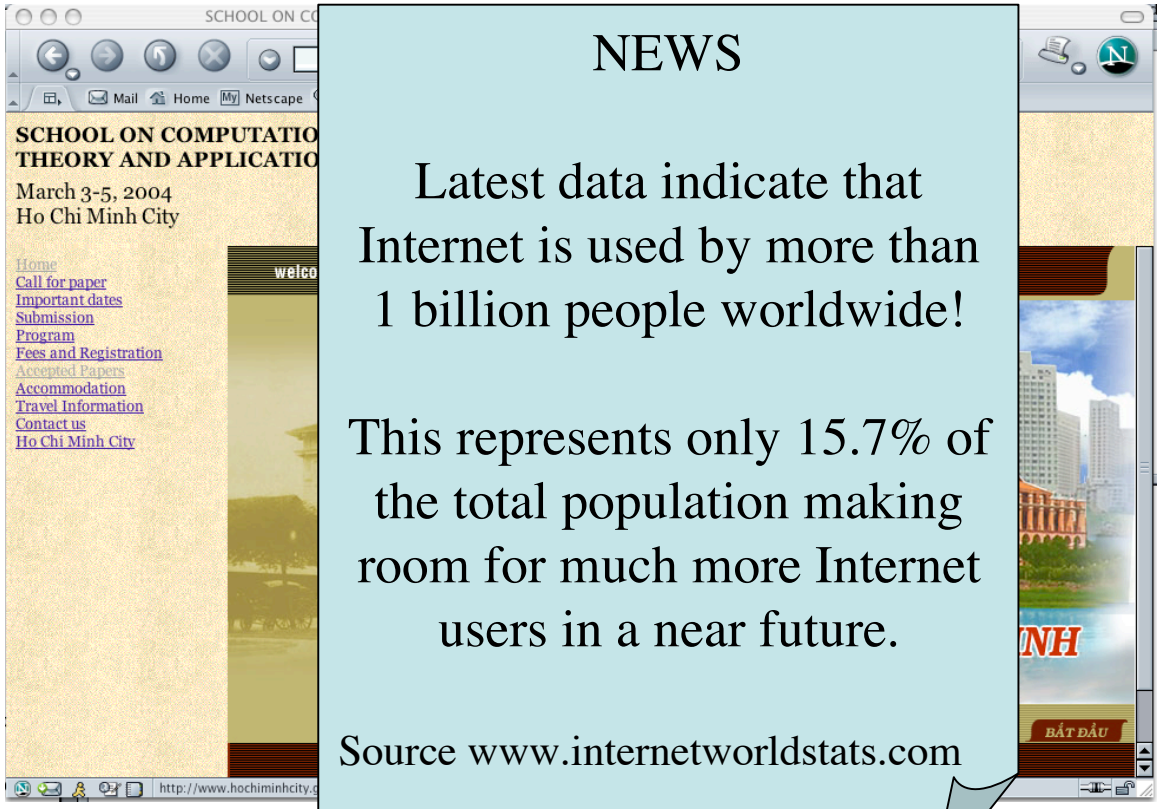
# Internet usage: e-mail…

- Convenient way to communicate in an informal manner
- Attachments as a easy way to exchange data files, images…



# ...and surfing the web

- A true revolution for rapid access to information
- Increasing number of apps:
  - e-science,
  - e-commerce, B2B, B2C,
  - e-training, e-learning,
  - e-tourism
  - ...



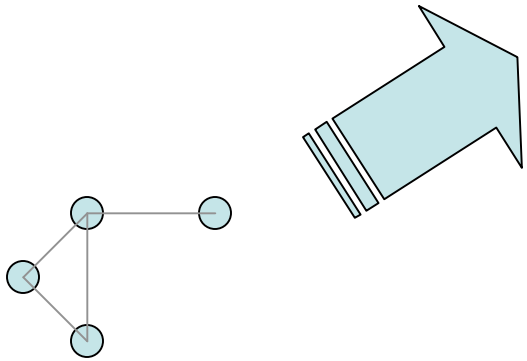

NEWS

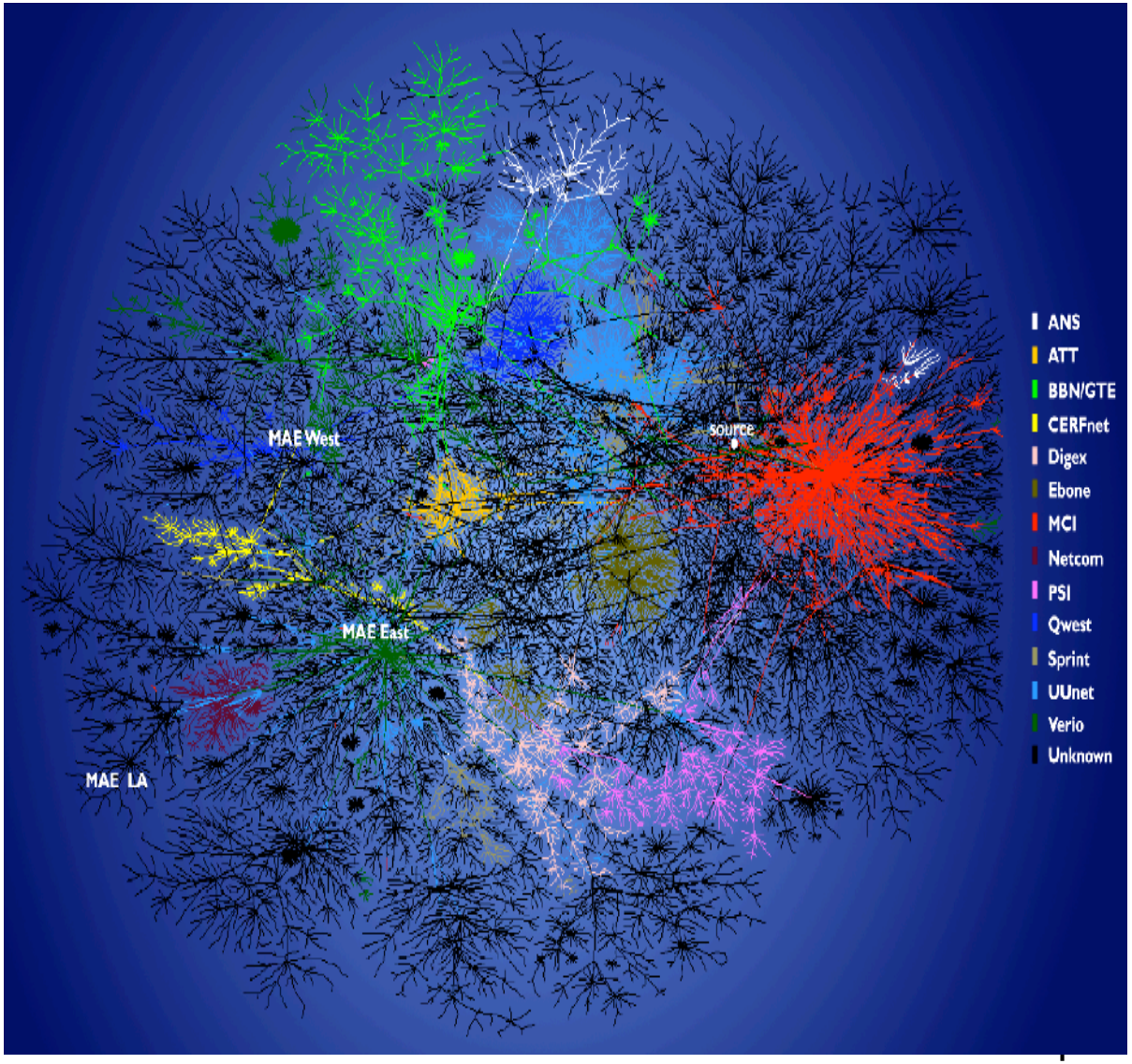
Latest data indicate that Internet is used by more than 1 billion people worldwide!

This represents only 15.7% of the total population making room for much more Internet users in a near future.

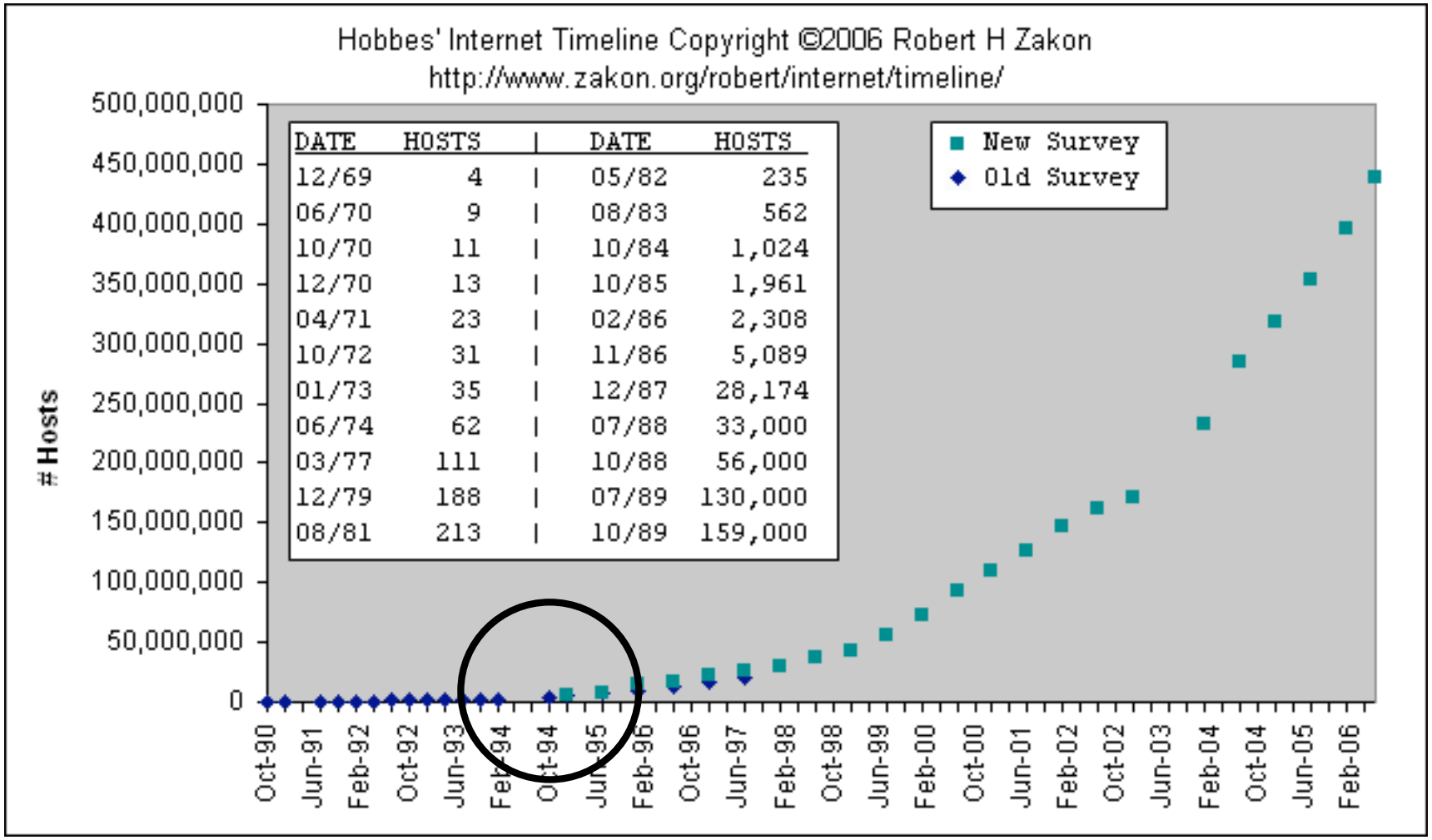
Source www.internetworldstats.com

# The big-bang of the Internet



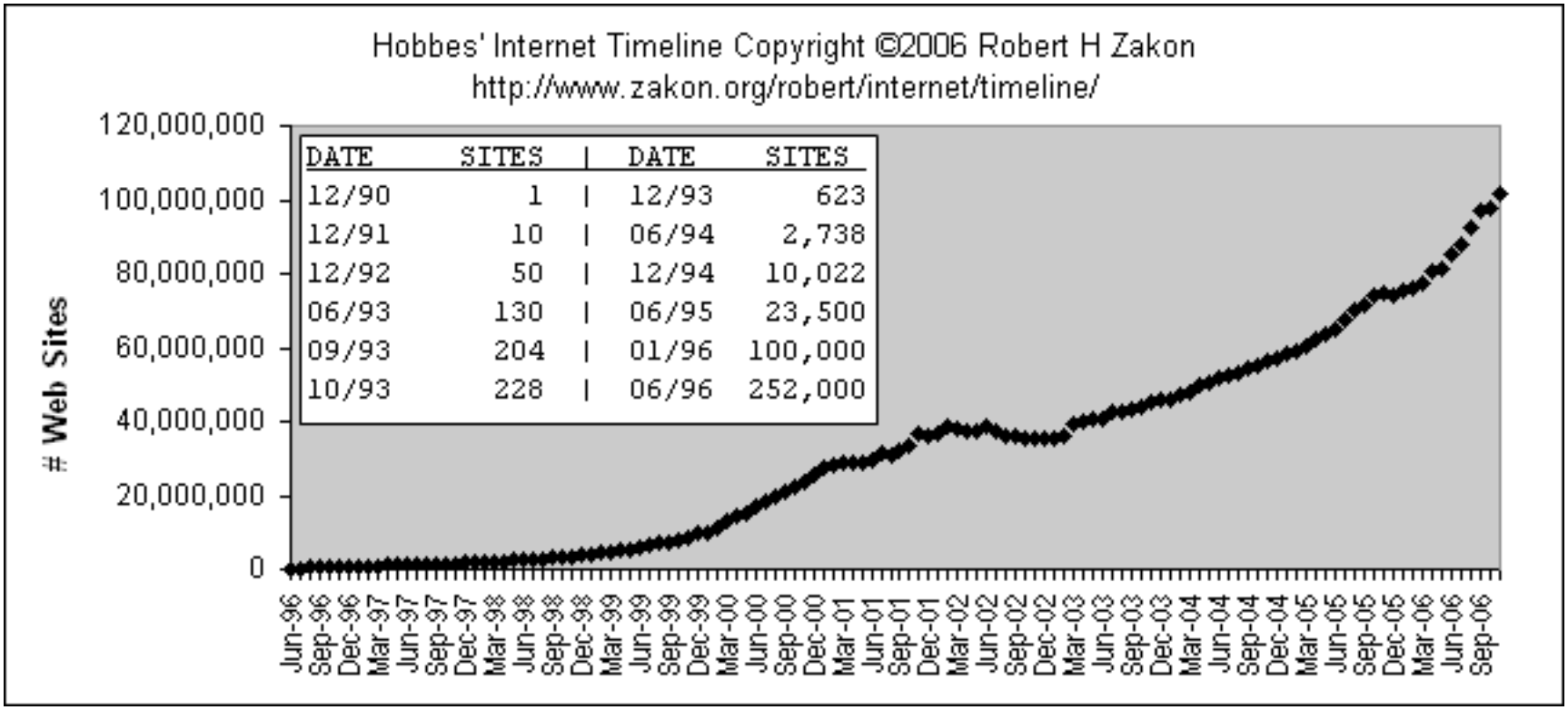


# # Internet host



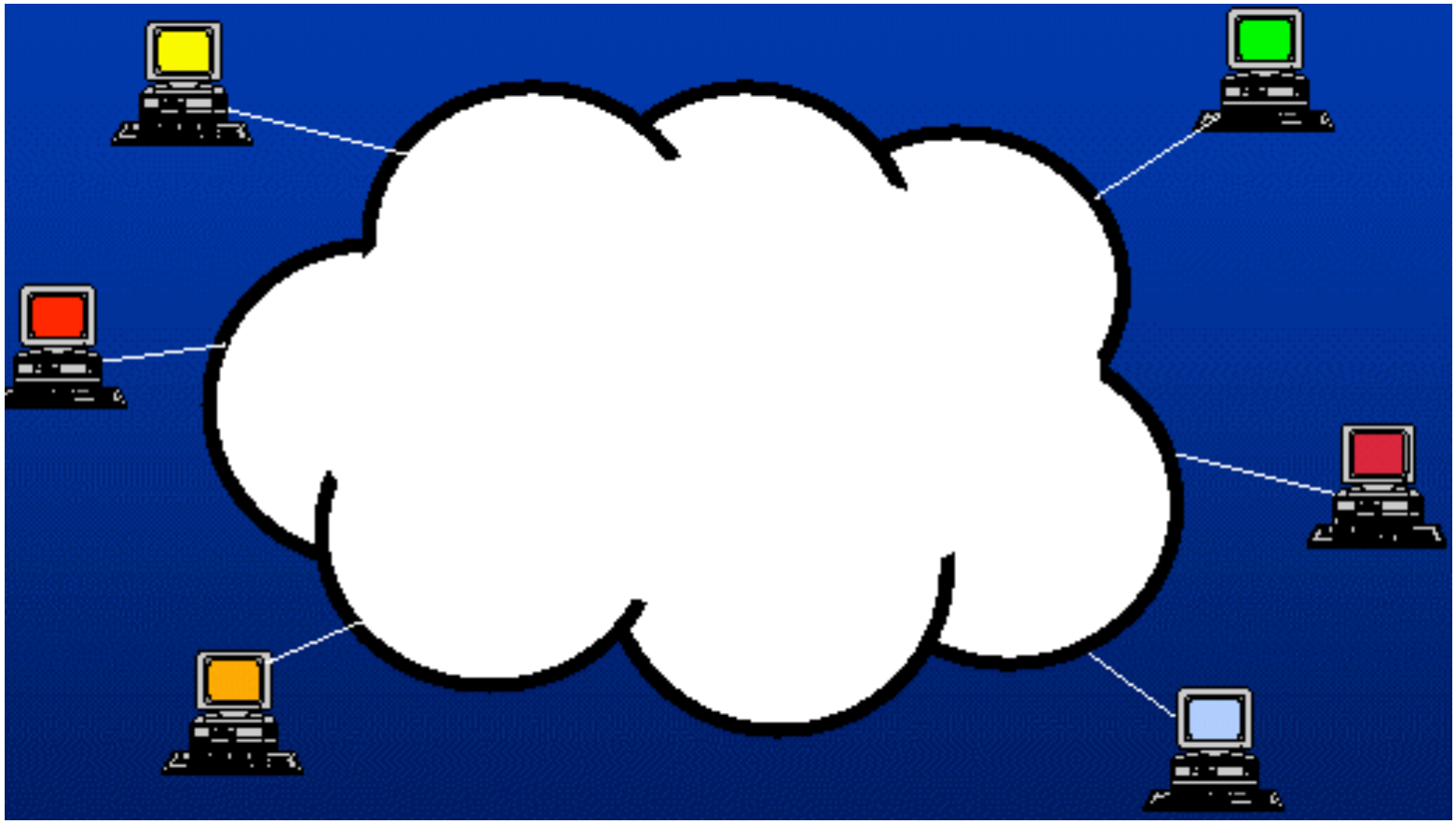

| DATE | HOSTS | DATE | HOSTS |
|---|---|---|---|
| 12/69 | 4 | 05/82 | 235 |
| 06/70 | 9 | 08/83 | 562 |
| 10/70 | 11 | 10/84 | 1,024 |
| 12/70 | 13 | 10/85 | 1,961 |
| 04/71 | 23 | 02/86 | 2,308 |
| 10/72 | 31 | 11/86 | 5,089 |
| 01/73 | 35 | 12/87 | 28,174 |
| 06/74 | 62 | 07/88 | 33,000 |
| 03/77 | 111 | 10/88 | 56,000 |
| 12/79 | 188 | 07/89 | 130,000 |
| 08/81 | 213 | 10/89 | 159,000 |

# www.web-the-big-bang.org

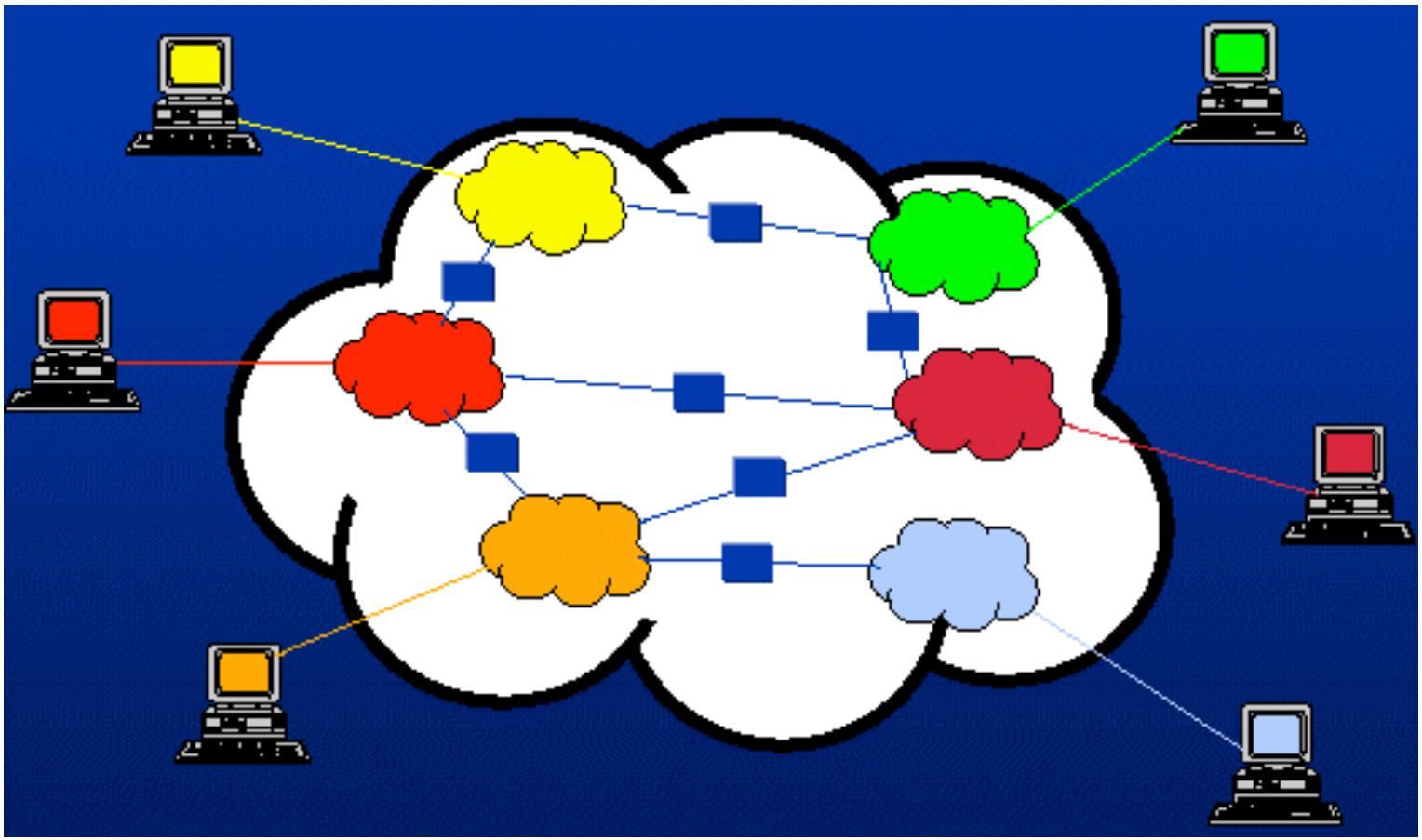



| DATE | SITES | DATE | SITES |
|---|---|---|---|
| 12/90 | 1 | 12/93 | 623 |
| 12/91 | 10 | 06/94 | 2,738 |
| 12/92 | 50 | 12/94 | 10,022 |
| 06/93 | 130 | 06/95 | 23,500 |
| 09/93 | 204 | 01/96 | 100,000 |
| 10/93 | 228 | 06/96 | 252,000 |

# A user's perspective of the Internet



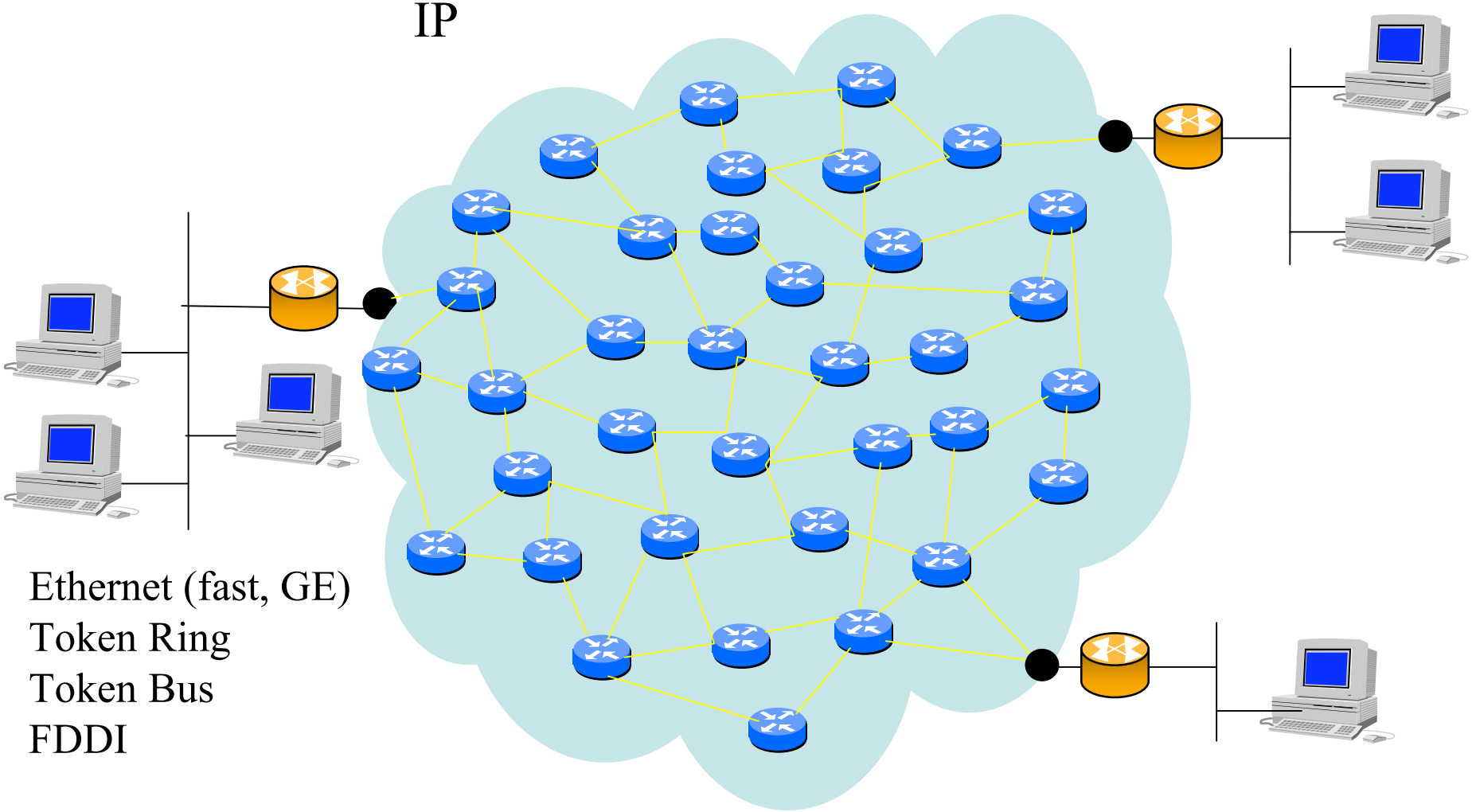
# Internet, in reality...



# Why this presentation?

X25, FR, ATM, SONET/SDH

IP



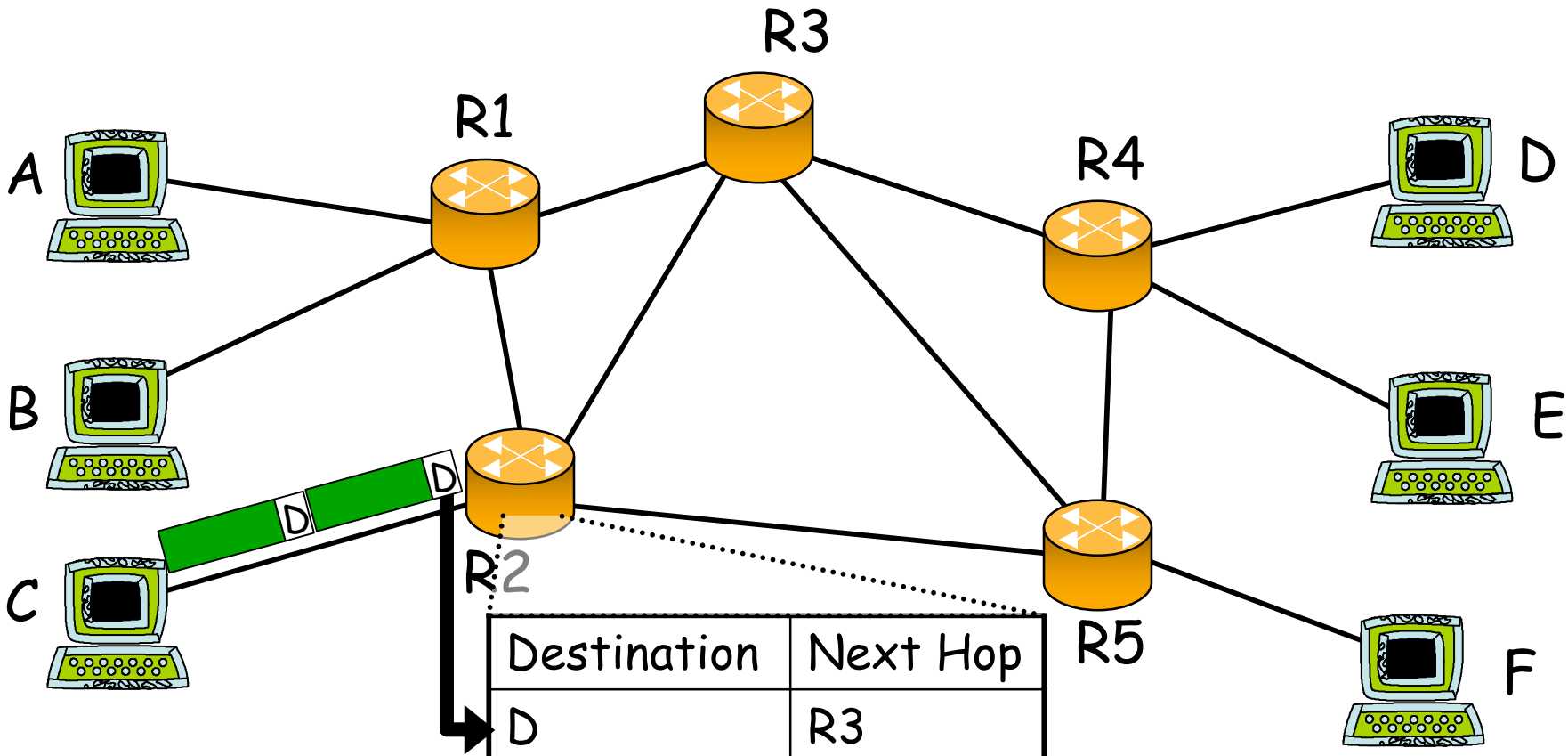
Ethernet (fast, GE)

Token Ring

Token Bus

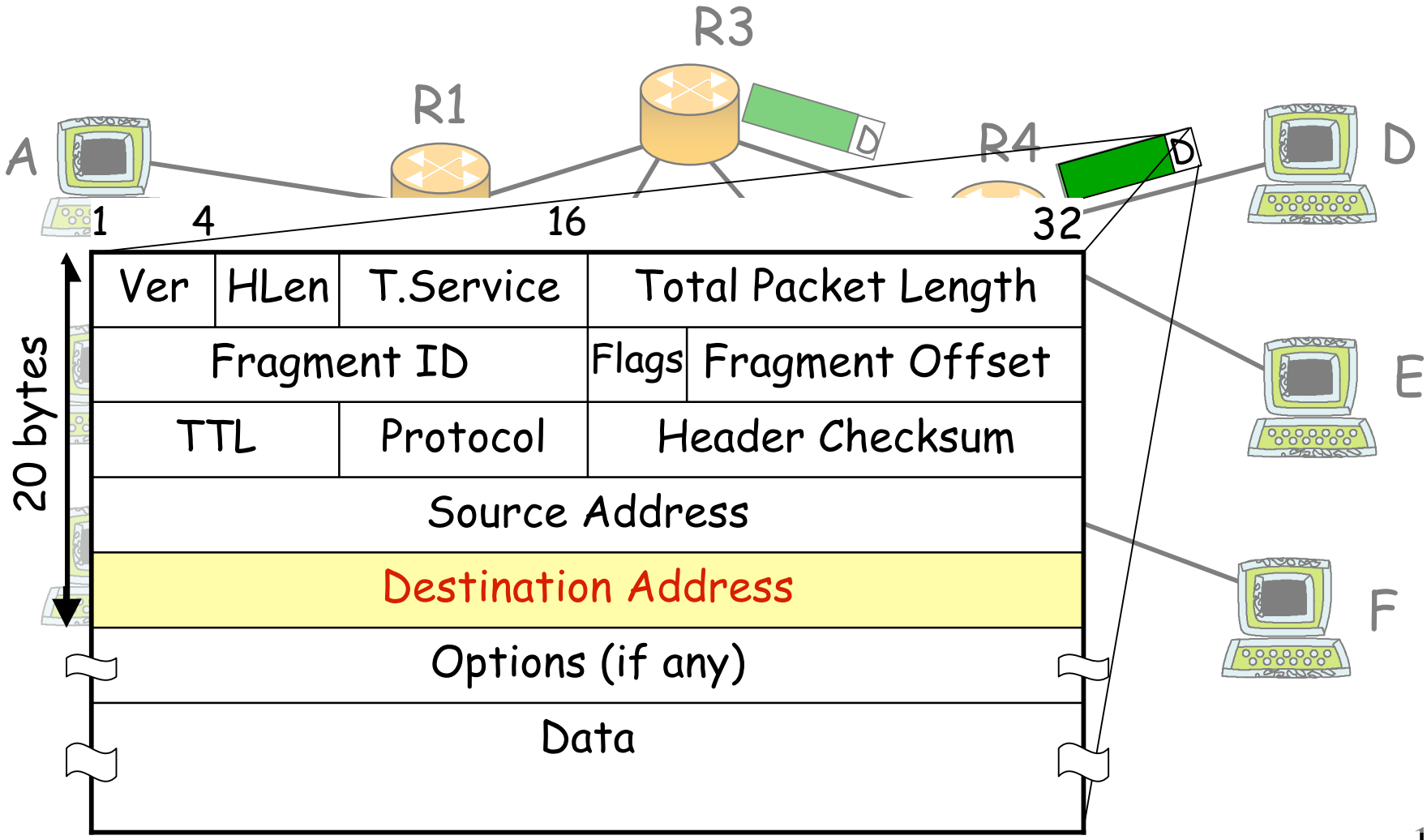
FDDI

# Hop-by-hop routing

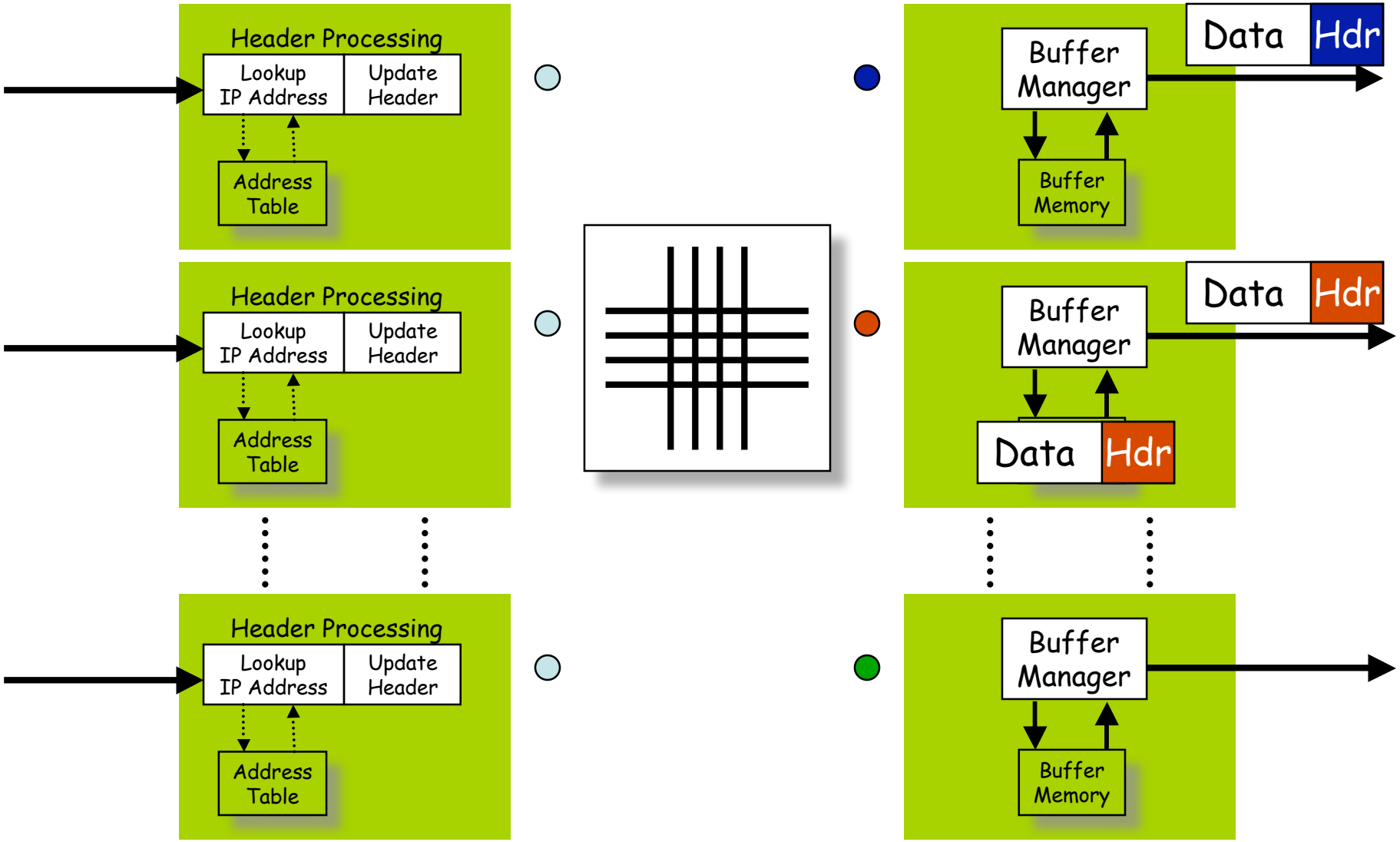



| Destination | Next Hop |
|---|---|
| D | R3 |
| E | R3 |
| F | R5 |

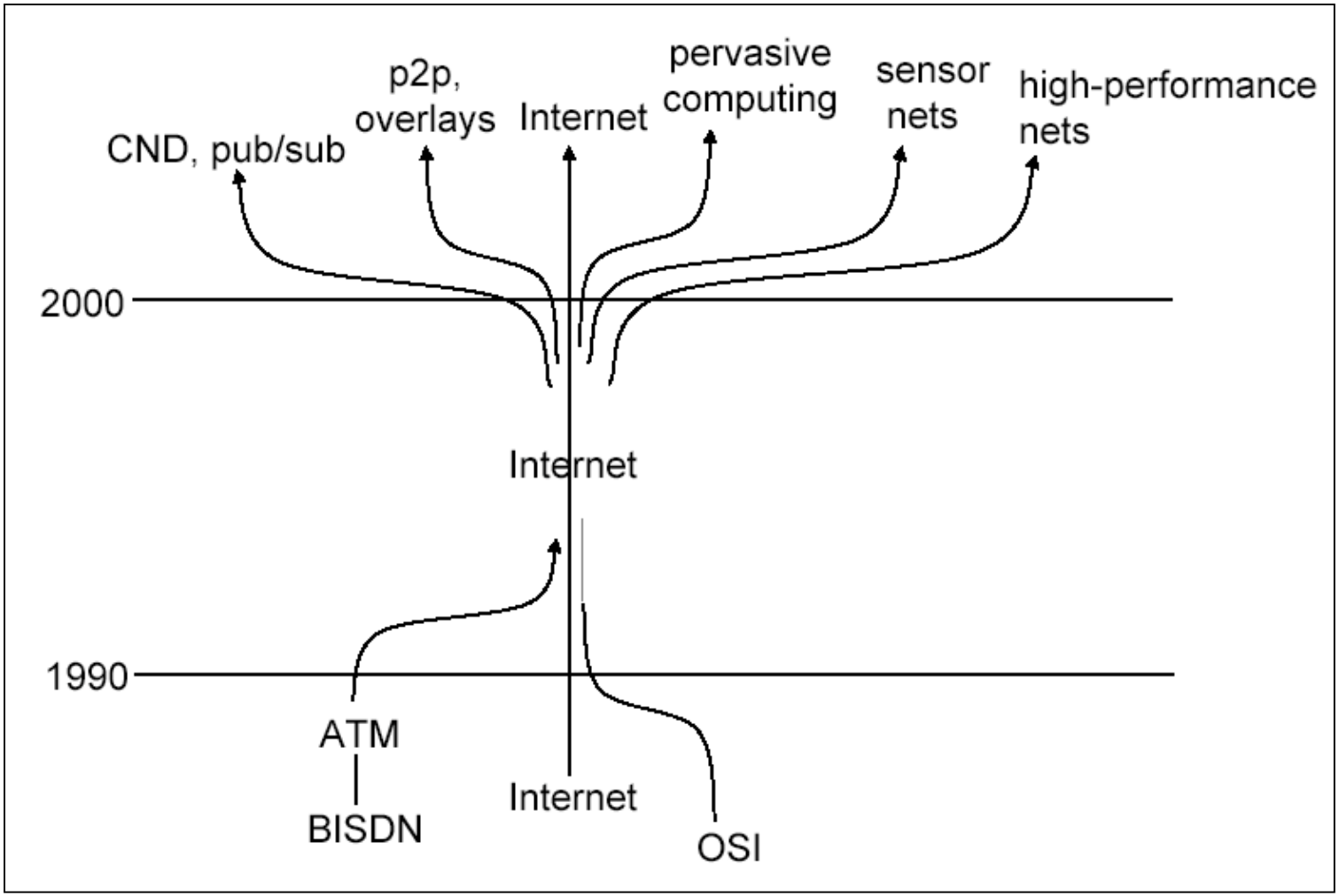
# IP-based routing



# General router architecture



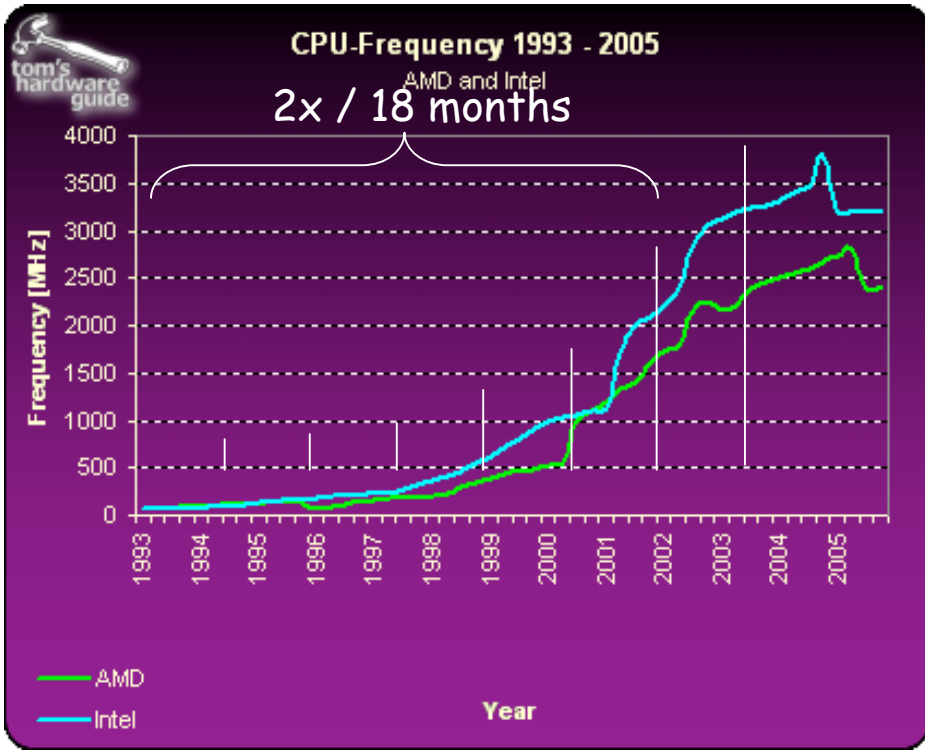
# Towards all IP

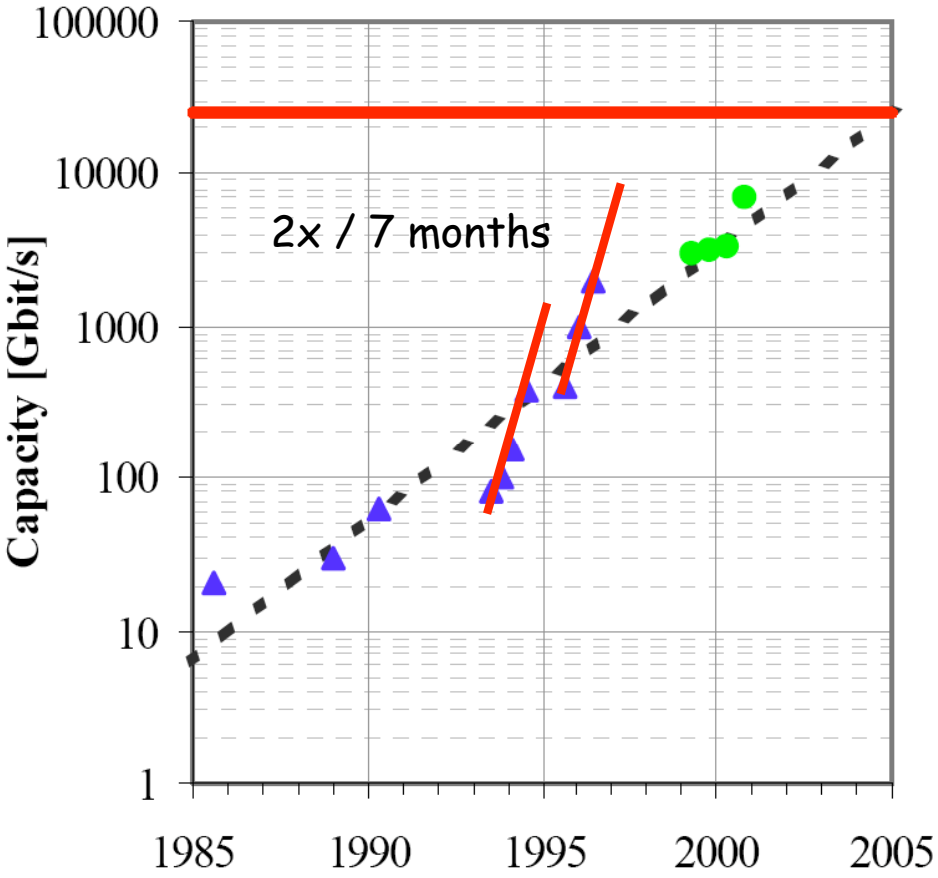



From Jim Kurose

# A whole new world for IP

# The optical revolution!

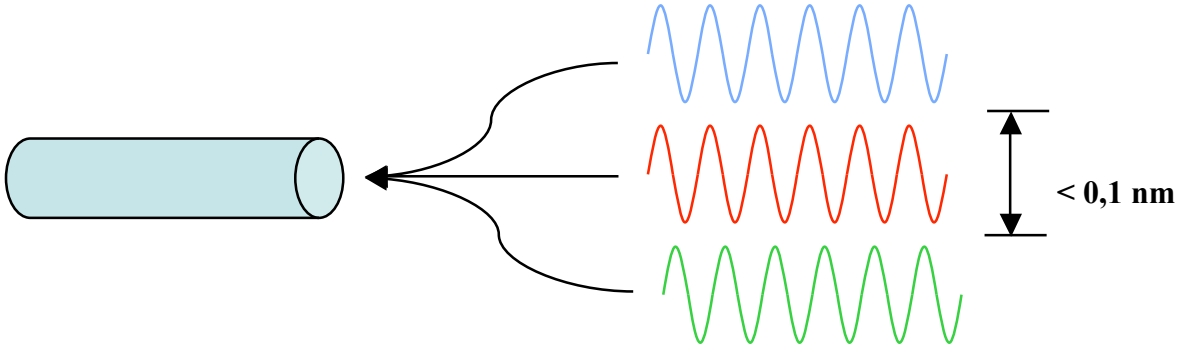


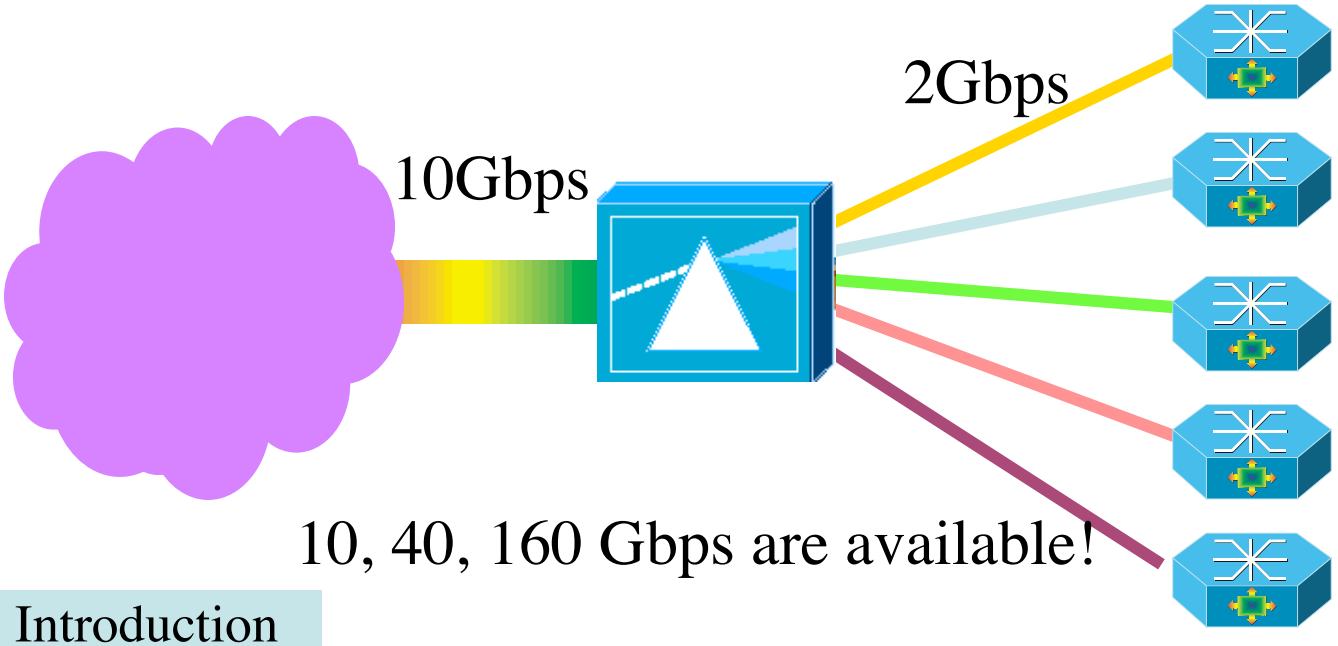




Source « Optical fibers for Ultra-Large Capacity Transmission » by J. Grochocinski

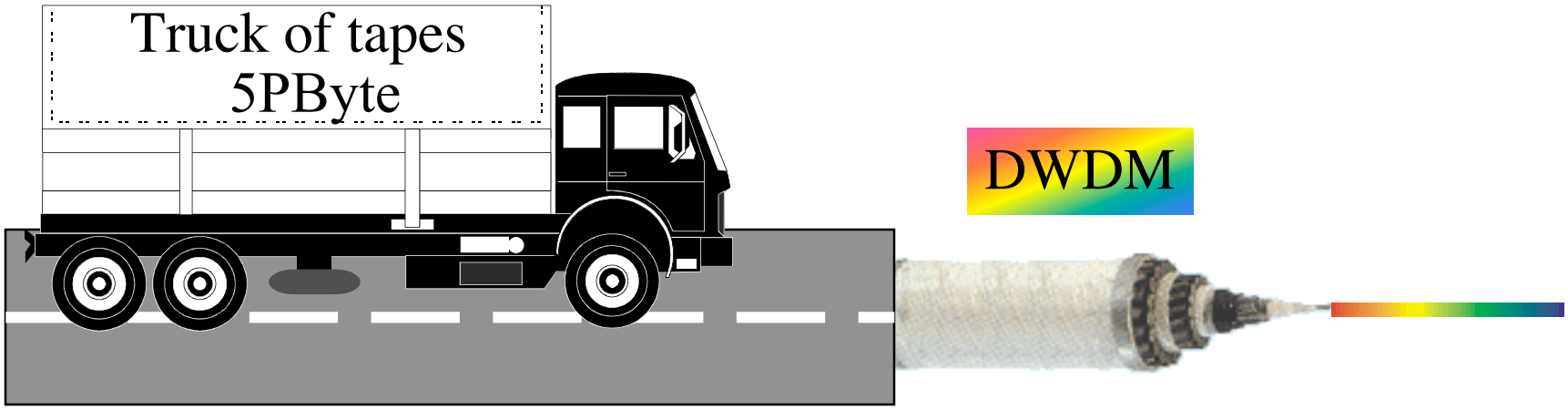
# DWDM, bandwidth for free?

DWDM: Dense Wavelength Division Multiplexing




# The information highways




NEWS of Dec 15th, 2004

A throughput of 1.28 Tbits/s has been achieved on a 430kms regular monomode fiber between France Telecom and Deutsch Telecom using 8 DWDM channels (EU project TOPRATE)

## Revisiting the truck of tapes

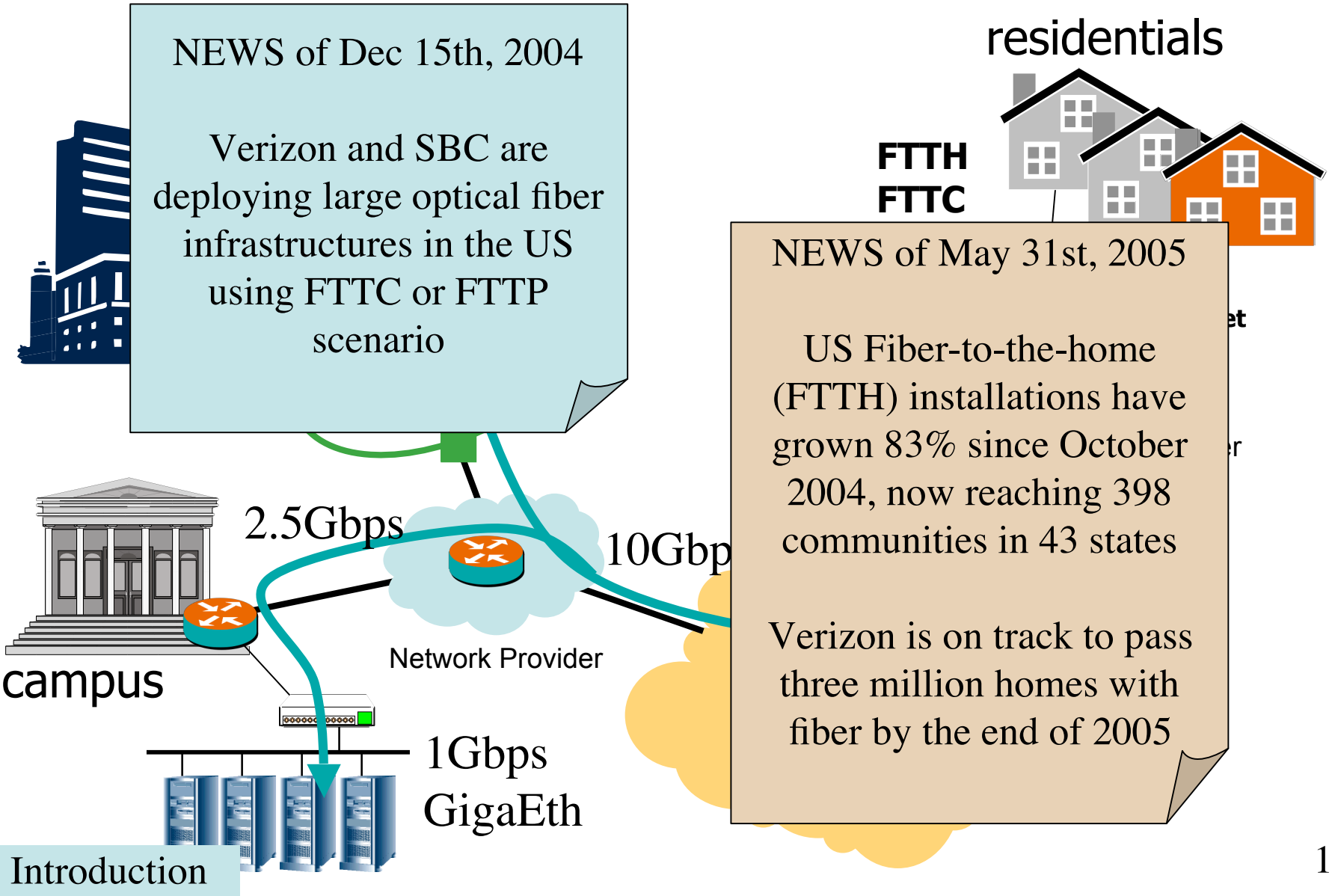
(18 of 18)

Consider one fiber

- Current technology allows for 320 λ in one of the frequency bands
- Each λ has a bandwidth of 40 Gbit/s
- Transport: $320 * 40*10^9 / 8 = 1600$ GByte/sec
- Take a 10 metric ton truck
- One tape contains 50 Gbyte, weights 100 gr
- Truck contains ( 10000 / 0.1 ) * 50 Gbyte = 5 PByte
- Truck / fiber = 5 PByte / 1600 GByte/sec = 3125 s ≈ one hour
- For distances further away than a truck drives in one hour (50 km) minus loading and handling 100000 tapes **the fiber wins!!!**

Example from A. Tanenbaum, slide from Cees De Laat

# Fibers everywhere?



# SONET/SDH in the core

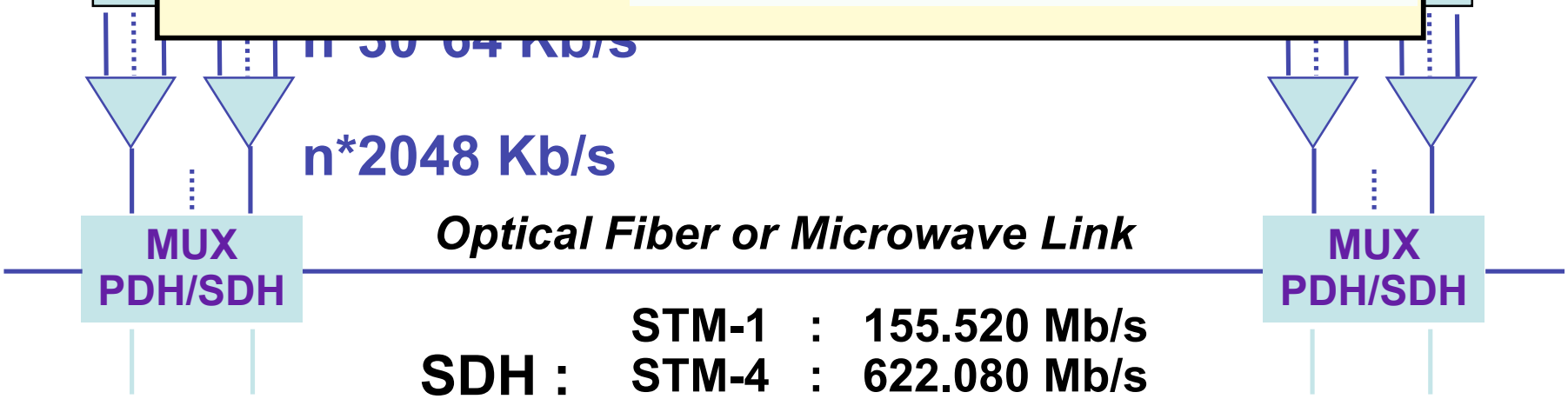
## 95% of exploited OF use SONET/SDH

**STS:**
Synchronous Transport System

**STM:**
Synchronous Transport Module

**OC:**
Optical Carrier

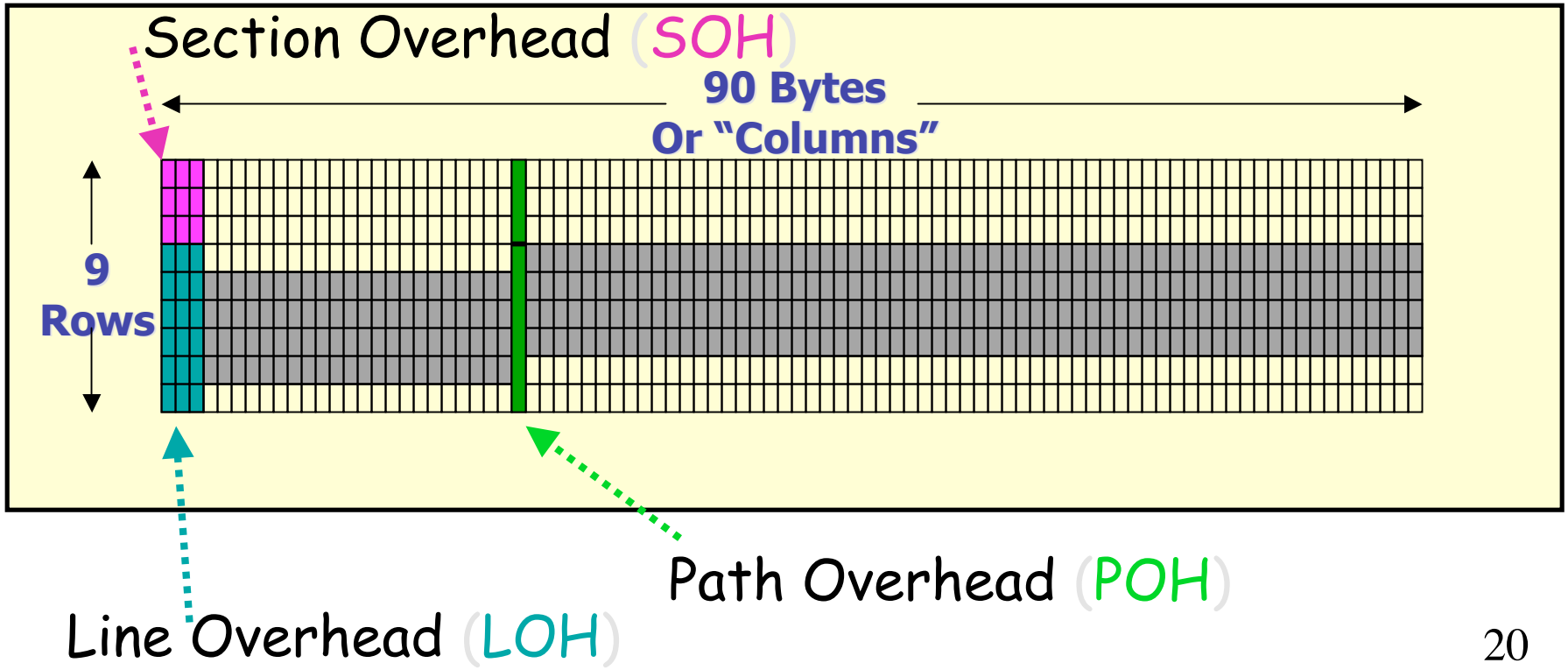
| SONET | SDH | Débit (Mbits/s) |
|---|---|---|
| STS-1/OC-1 | | 51.84 |
| STS-3/OC-3 | STM-1 | 155.52 |
| STS-9/OC-9 | | 466.56 |
| STS-12/OC-12 | STM-4 | 622.08 |
| STS-18/OC-18 | | 933.12 |
| STS-24/OC-24 | | 1244.16 |
| STS-36/OC-36 | | 1866.24 |
| STS-48/OC-48 | STM-16 | 2488.32 |



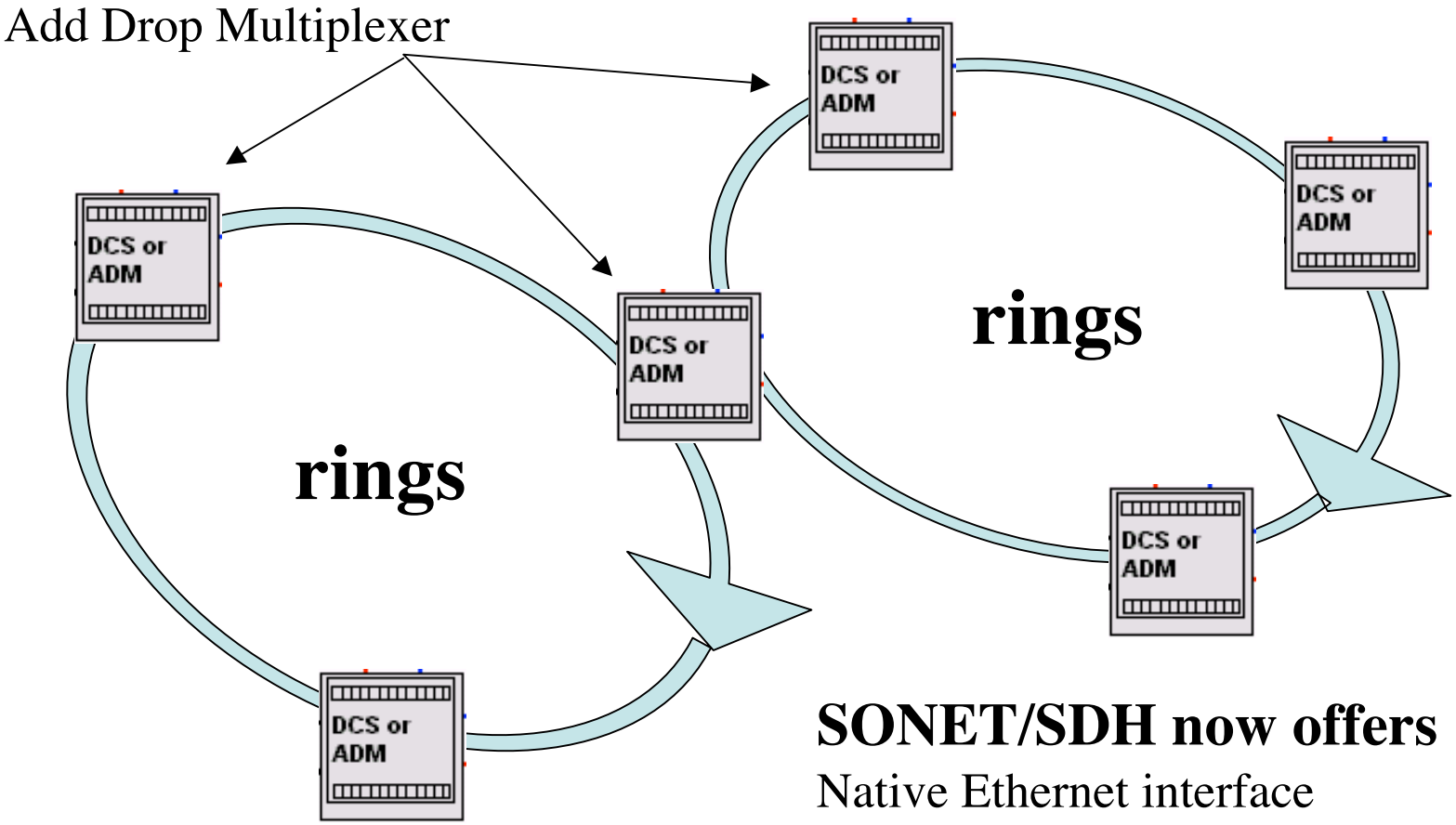

**SDH :** **STM-1 : 155.520 Mb/s**
**STM-4 : 622.080 Mb/s**
**STM-16 : 2488.320 Mb/s**

# The SONET frame

- Basic frame length is 810 bytes (TDM)
  - Sent every 125us, raw throughput of 51.84 Mbits/s (STS-1)
  - Better seen as a block with 90 colomns and 9 lines



# SONET/SDH transport network infrastructure




**SONET/SDH now offers**

Native Ethernet interface

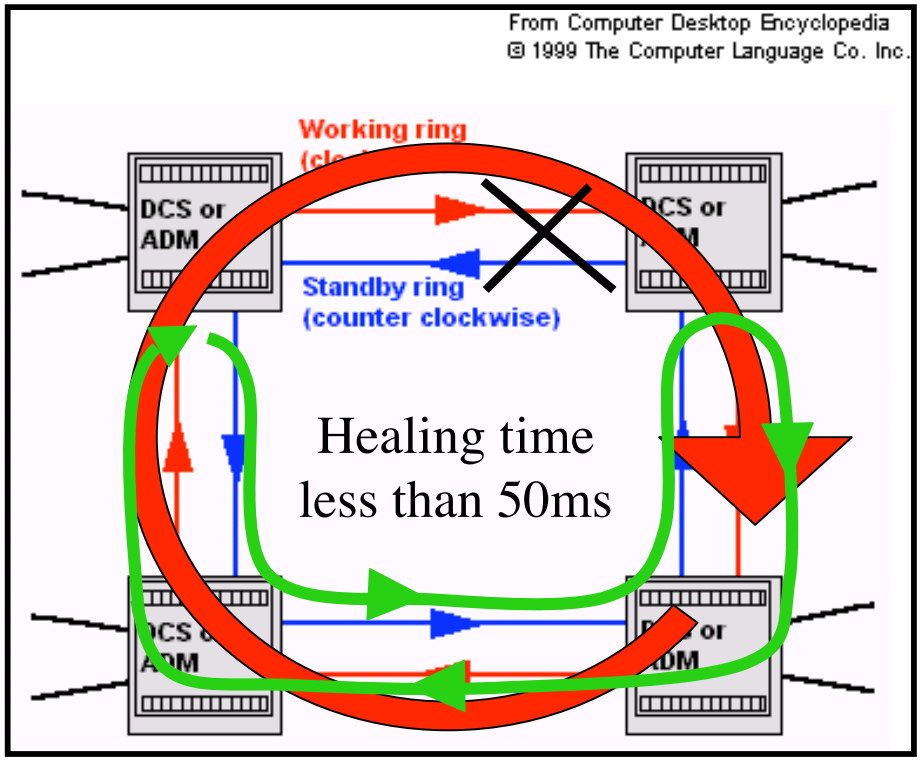
Generic Framing Procedure

Virtual Concatenation

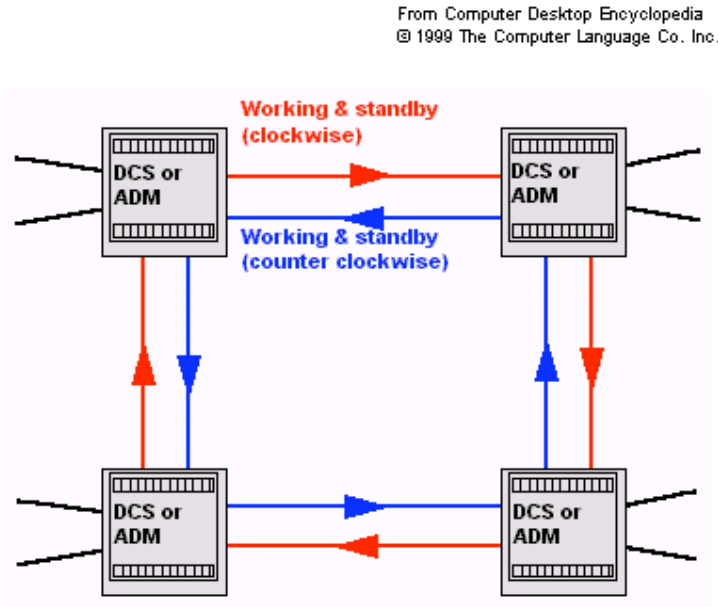
# SONET/SDH and resiliency

- SONET/SDH has built-in fault-tolerant features with multiple rings
- Ex: simple case

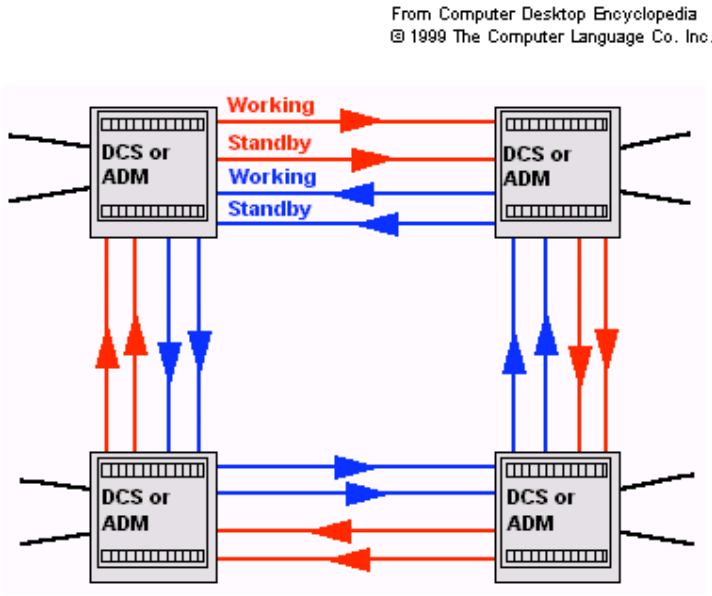
DCS
(Digital Cross-Connects)



# High availability in SONET/SDH networks



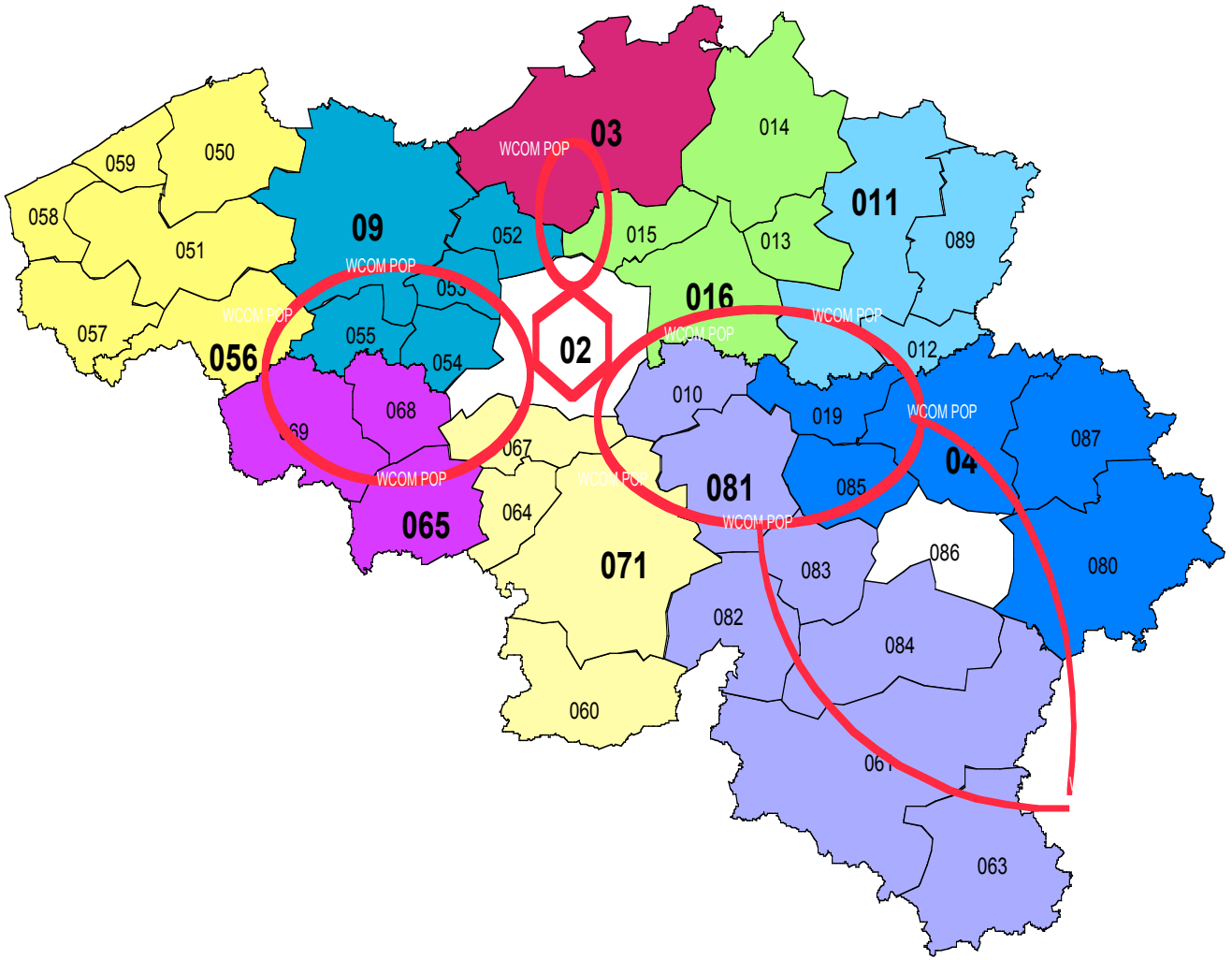

bi-directional



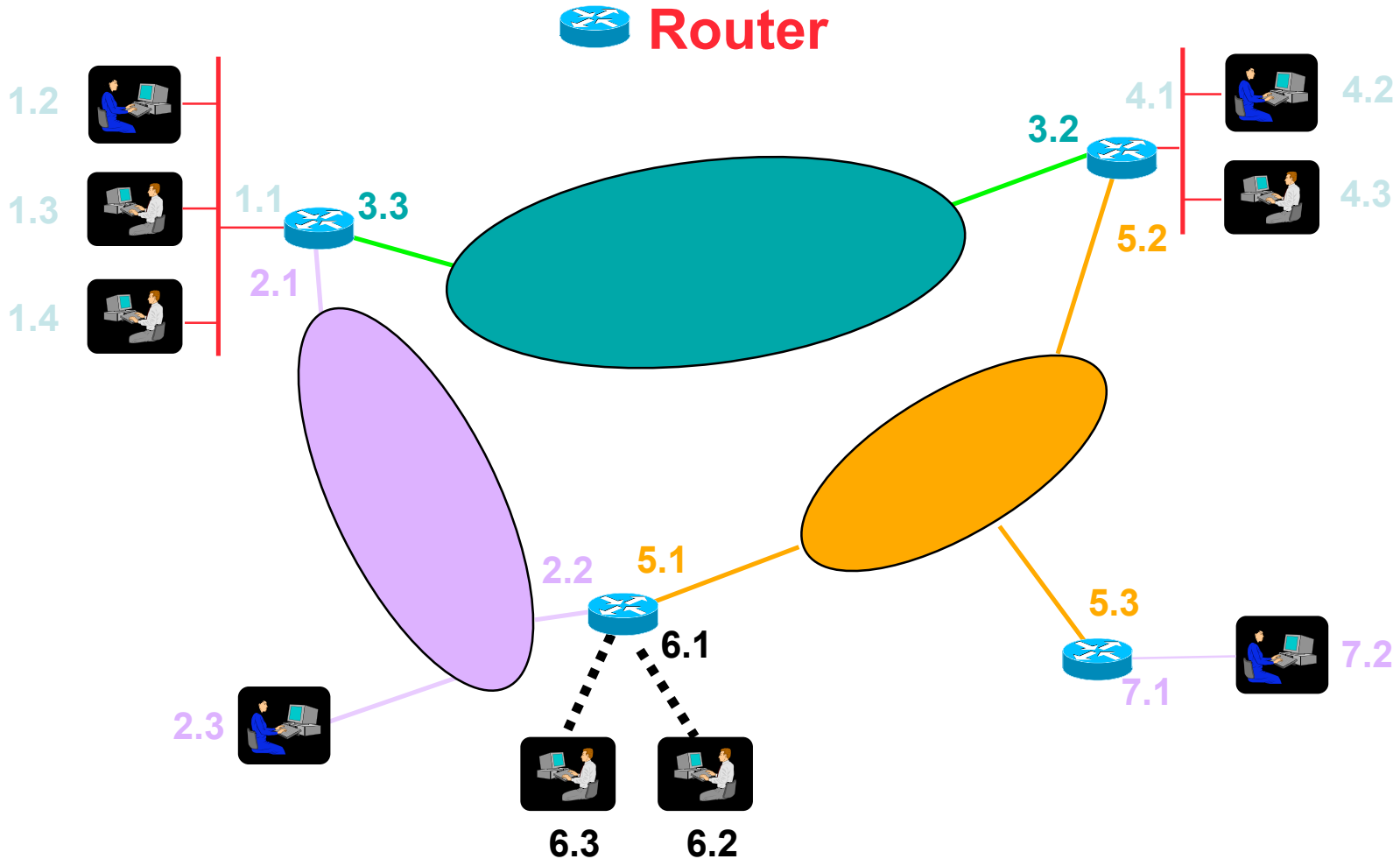

Found in most operators' networks

# SDH Rings

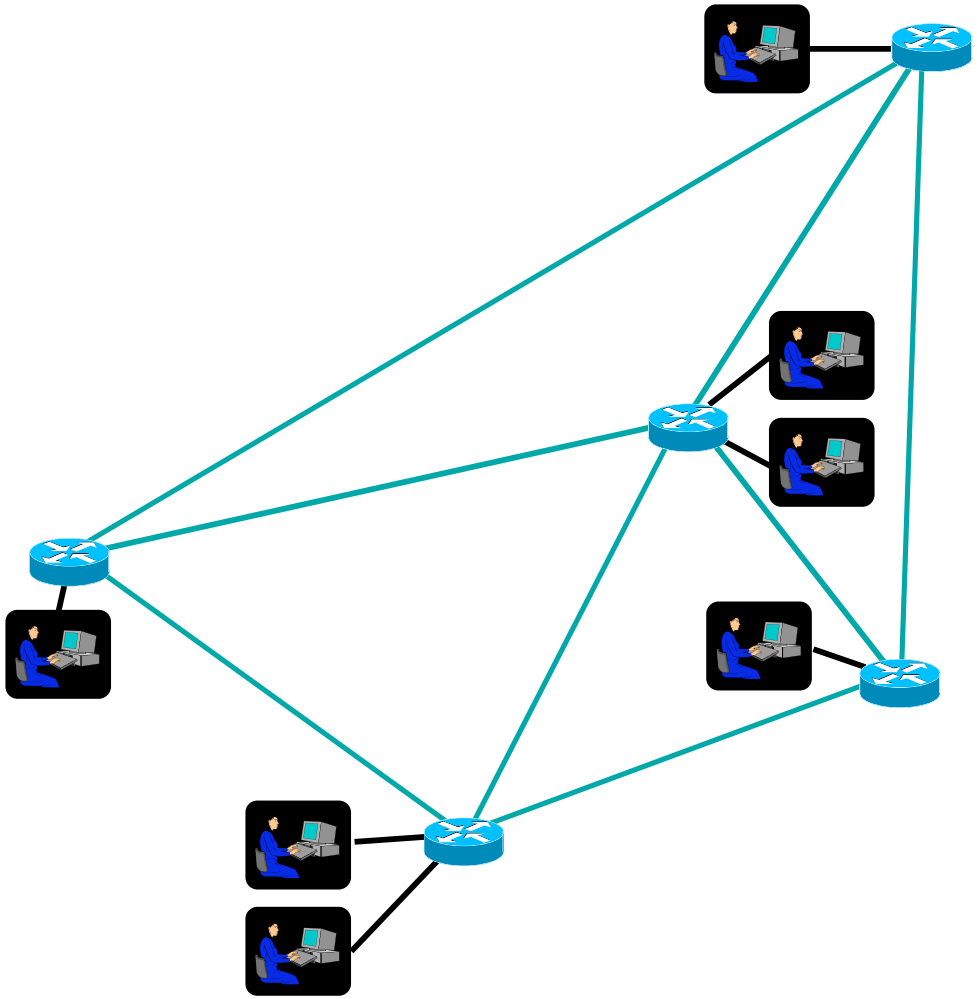
## The Worldcom Belgian Network



# Example: IP Networks



# Directly linked Routers



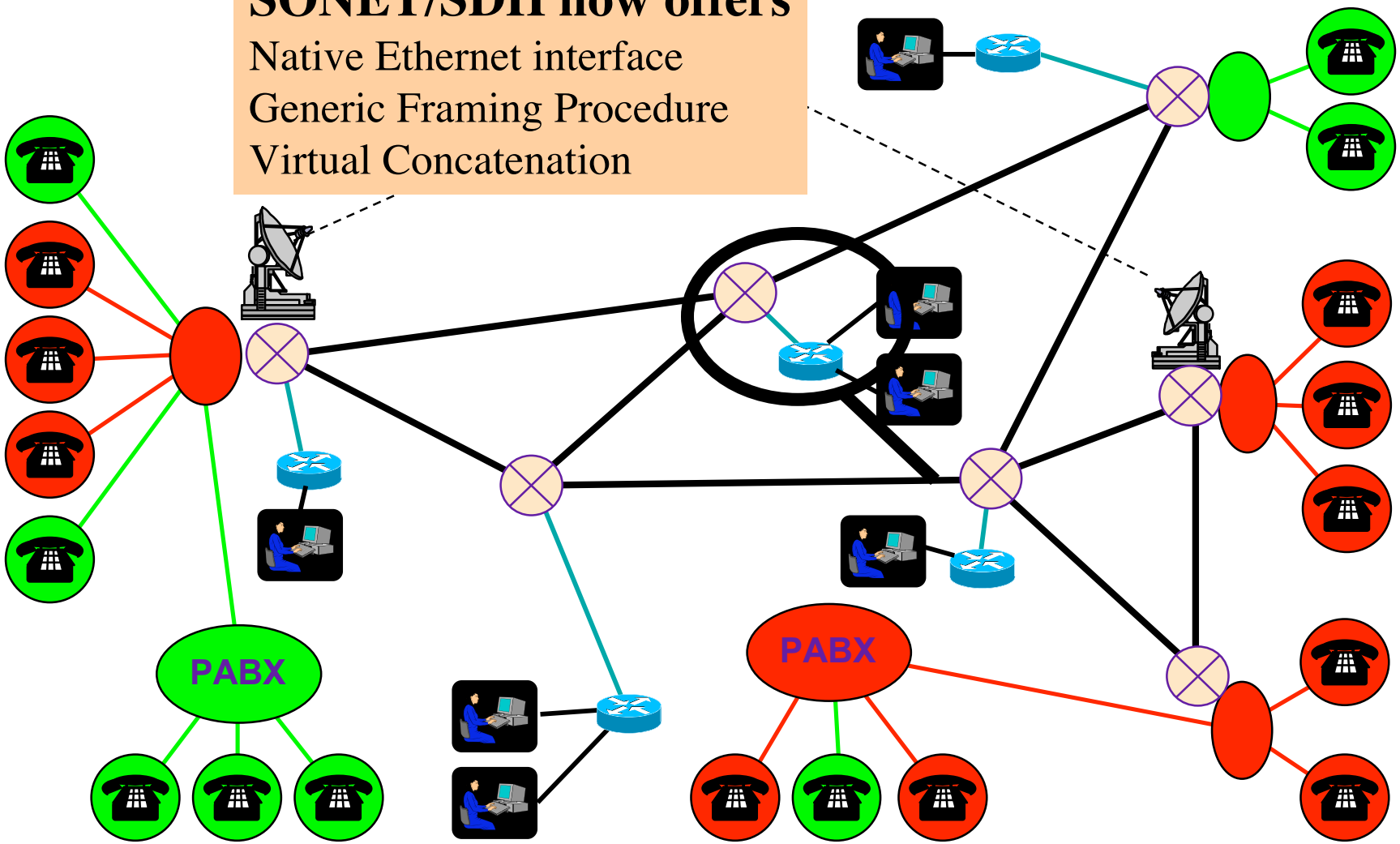
# General Purpose SDH Networks

**SONET/SDH now offers**

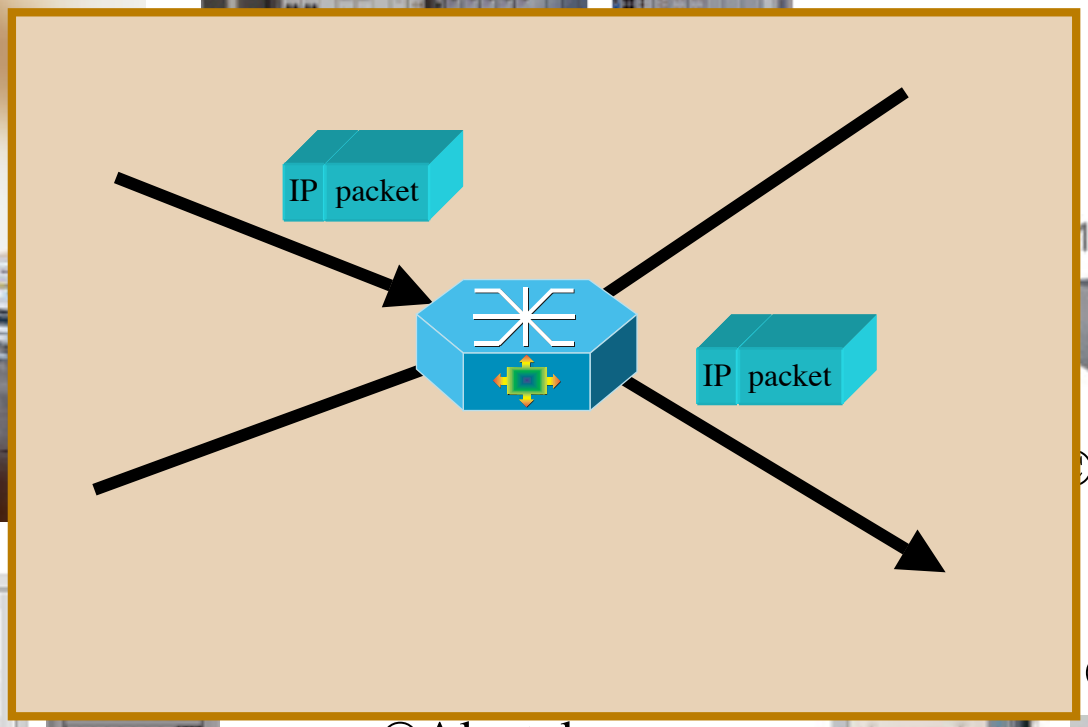
Native Ethernet interface

Generic Framing Procedure

Virtual Concatenation



# High Performance Routers



©Procket Networks

©Nortel Networks

©Alcatel

©Lucent

**and more…**

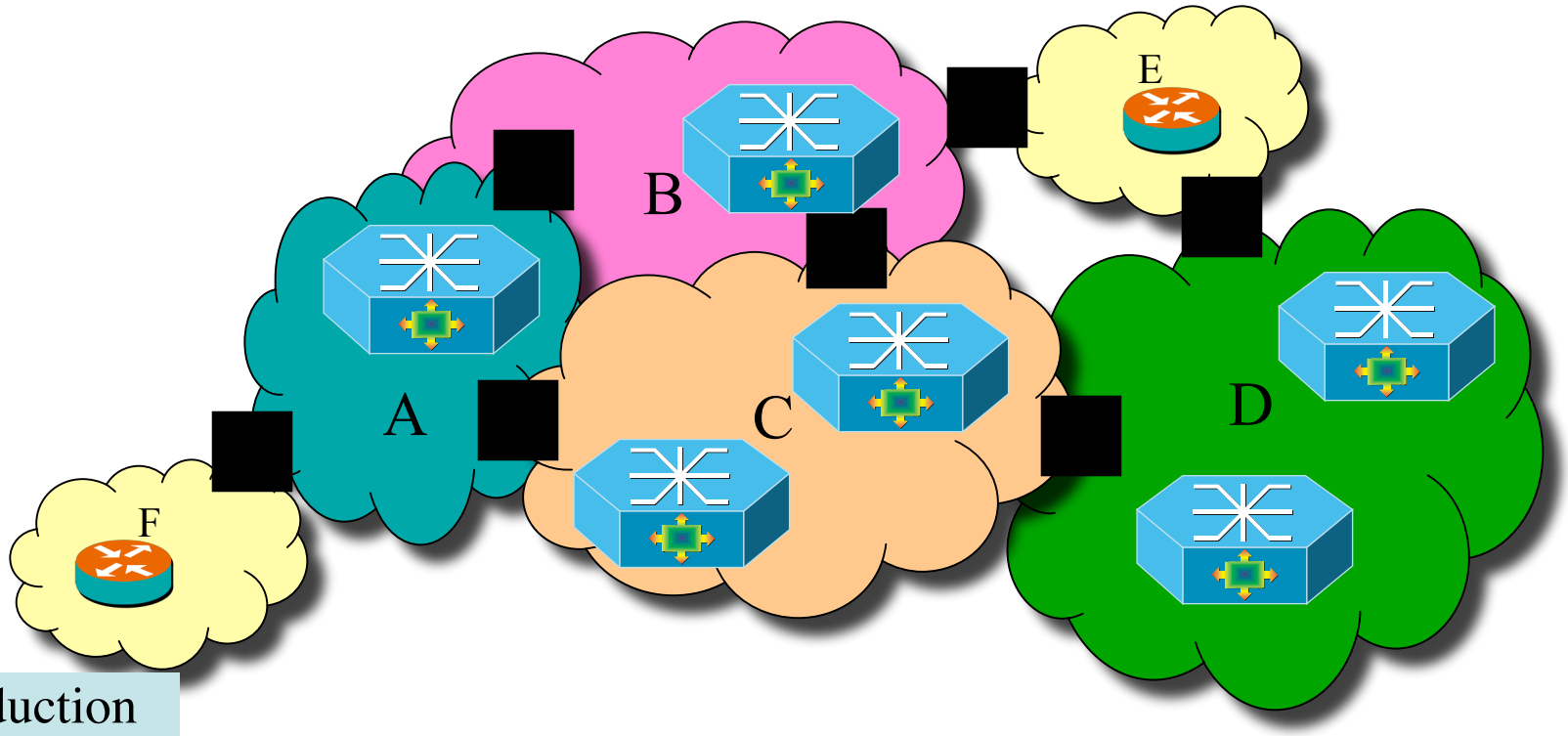
# Performance constraints

- At gigabit rate, millions of packets must be routed per seconds!

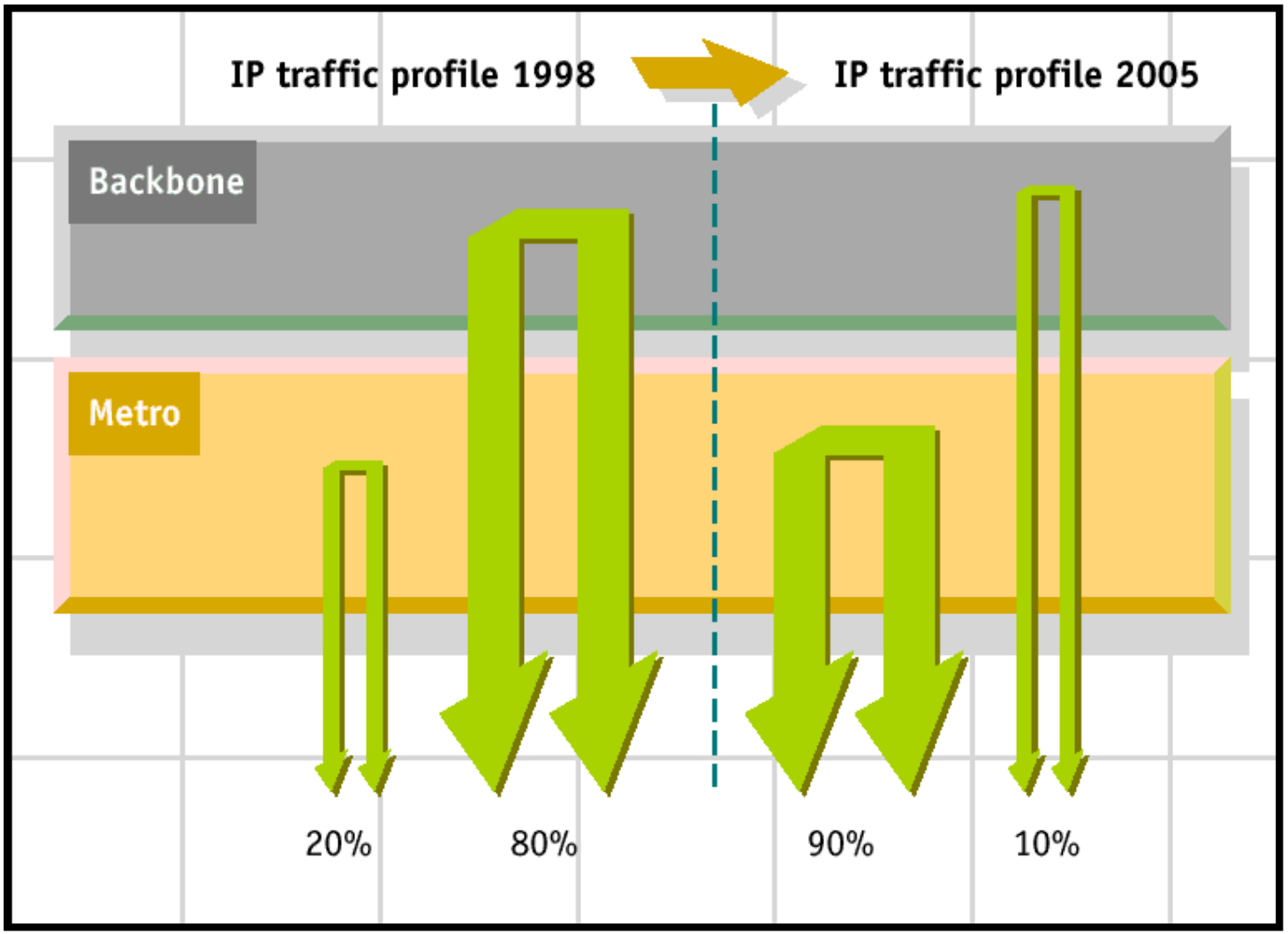
| Year | Line | Linerate (Gbps) | 40B (Mpps) | 84B (Mpps) | 354B (Mpps) |
|---|---|---|---|---|---|
| 1997-98 | OC3 | 0.155 | 0.48 | 0.23 | 0.054 |
| 1998-99 | OC12 | 0.622 | 1.94 | 0.92 | 0.22 |
| 1999-00 | OC48 | 2.5 | 7.81 | 3.72 | 0.88 |
| 2000-01 | OC192 | 10.0 | 31.25 | 14.88 | 3.53 |
| 2002-03 | OC768 | 40.0 | 125 | 59.52 | 14.12 |
| | 1GE | 1.0 | 3.13 | 1.49 | 0.35 |

# Operator's infrastructure

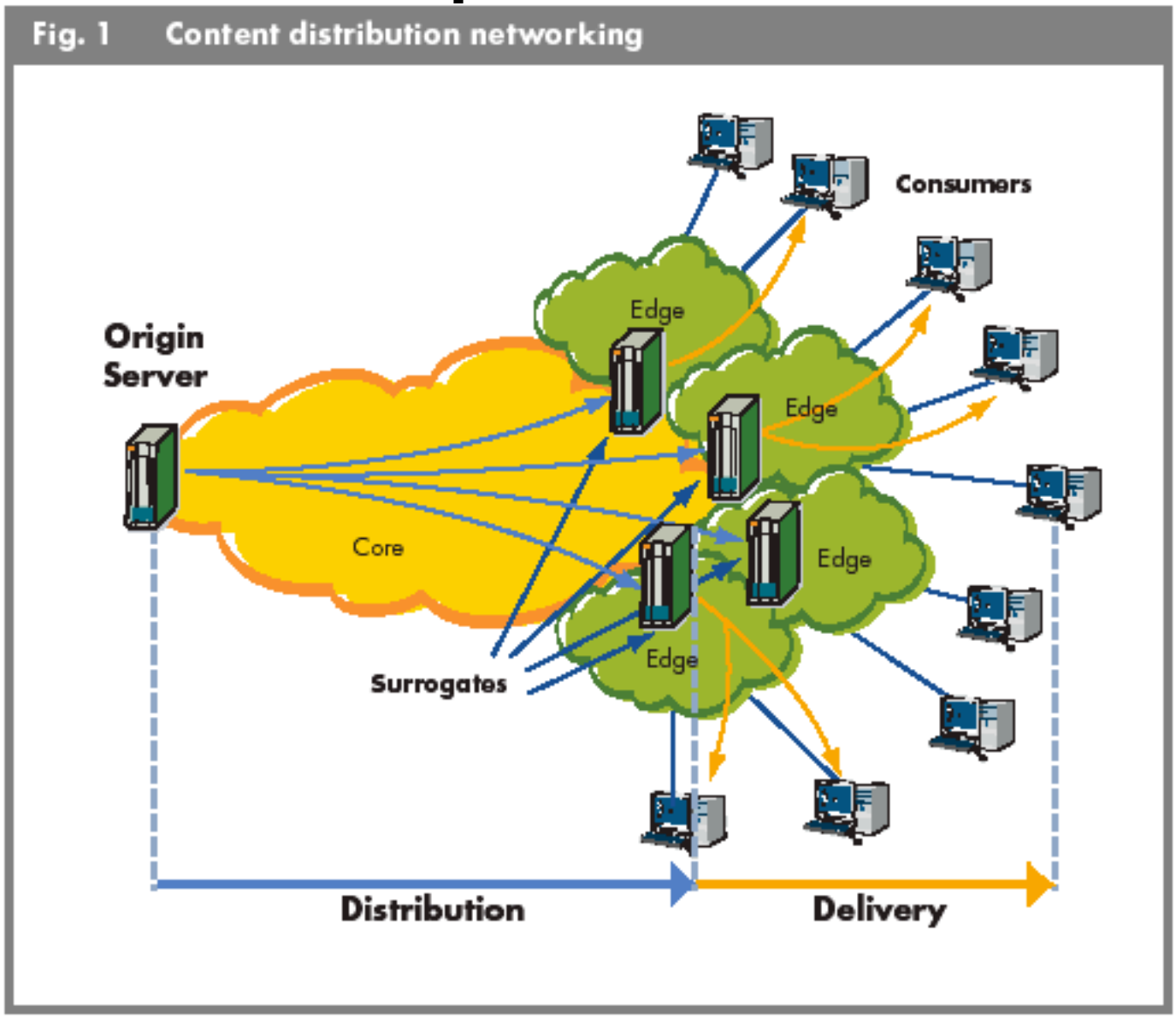
- Backbones are optical: OC48 (2.5Gbps), OC192 (10Gbps), OC768 (40Gbps), OC3072(160Gbps)
- New technologies deployed by operators, POPs available worldwide



# From backbone to metro

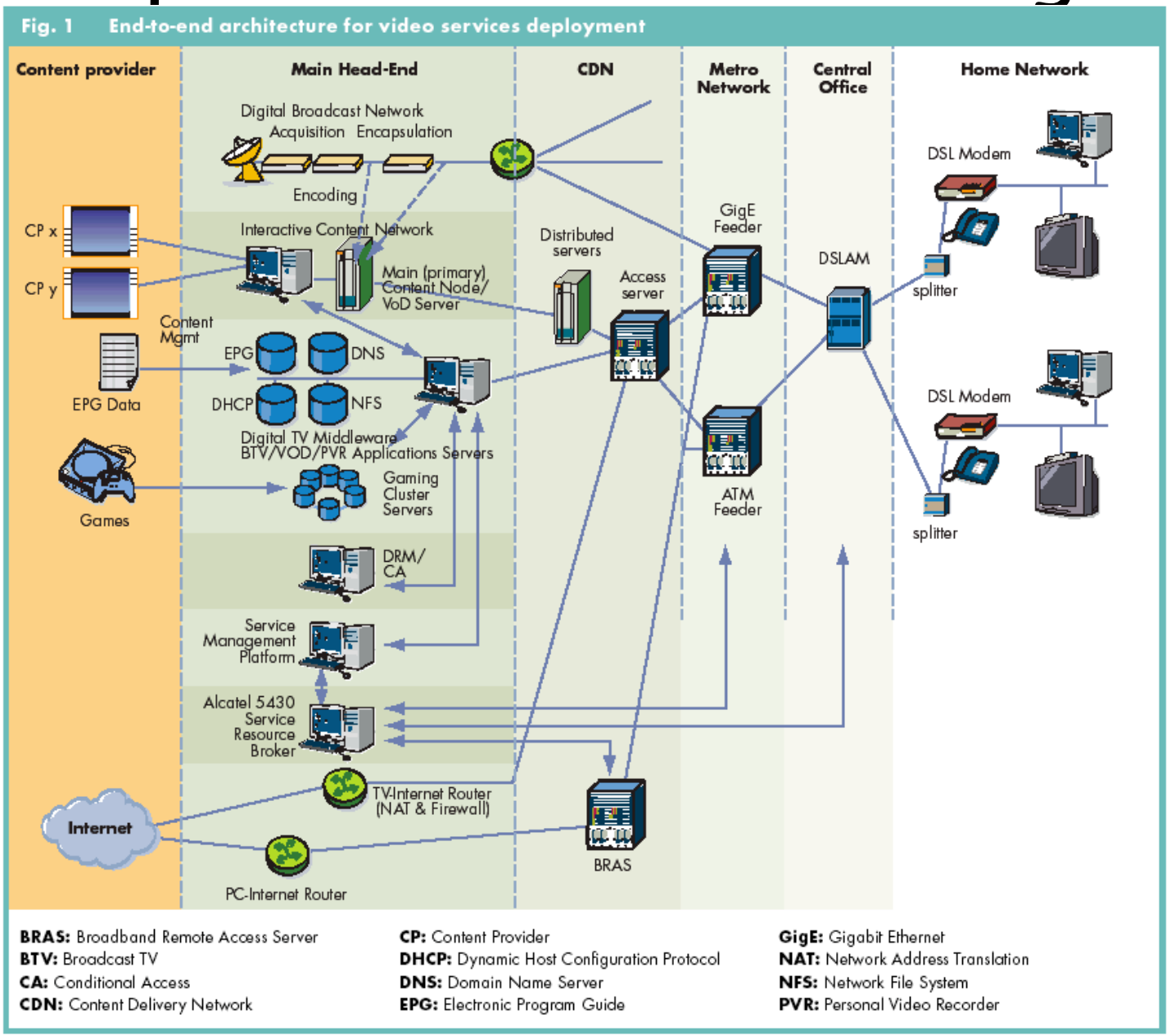


# Example: CDNs




From Alcatel

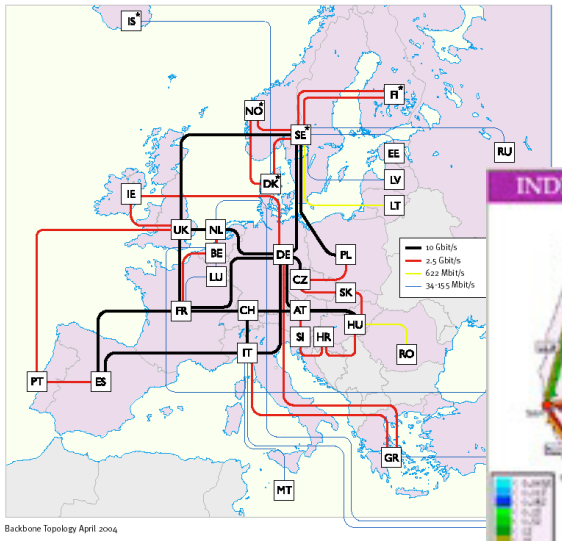
# Example: video broadcasting

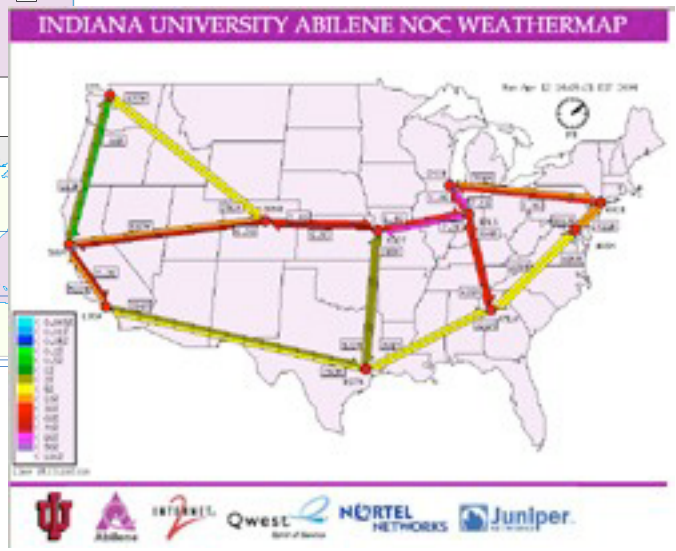



From Alcatel

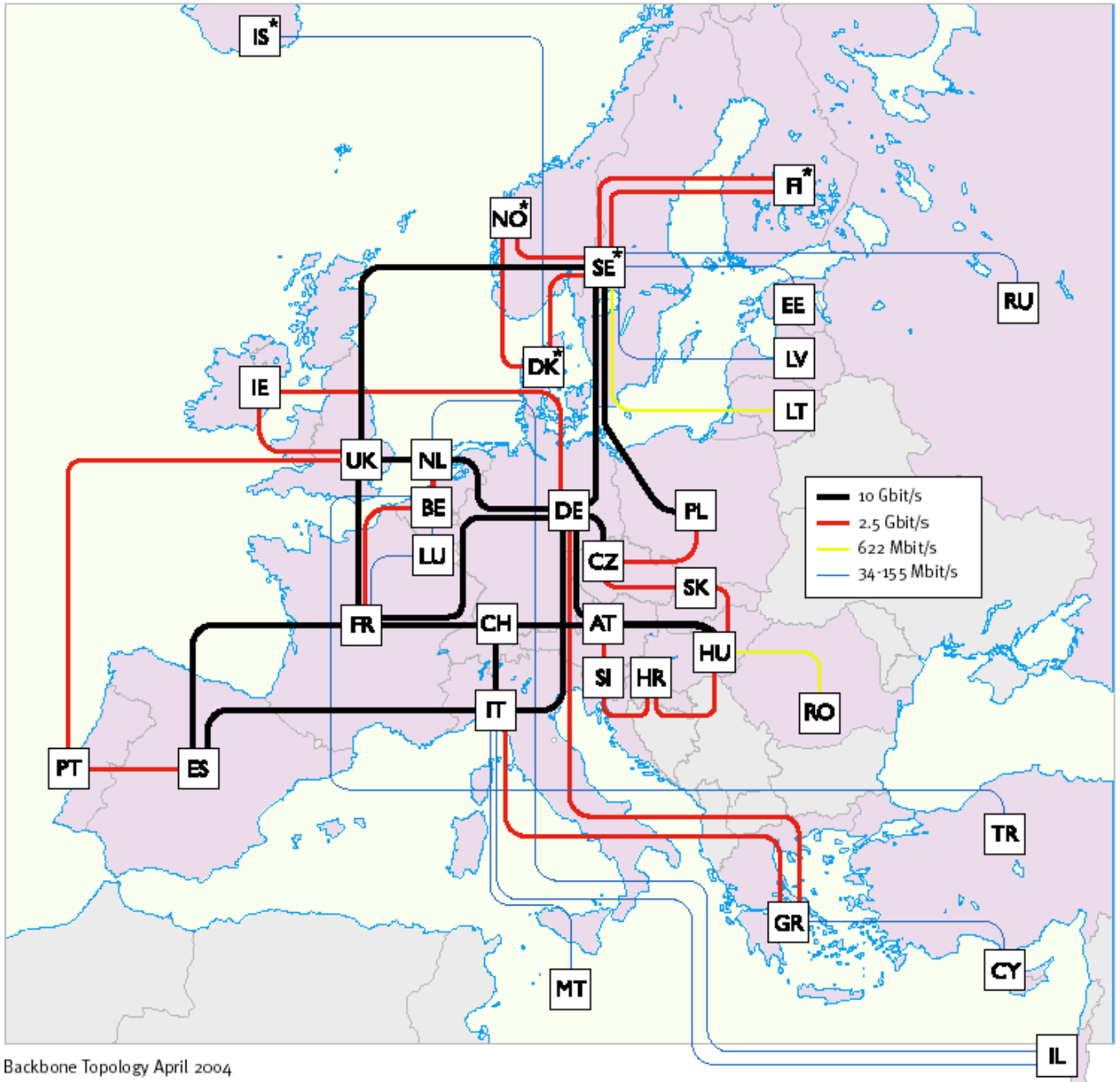
# The new networks

- vBNS
- Abilene
- SUPERNET
- DREN
- CA*NET
- GEANT
- DATATAG
- …much more to come!




# GEANT



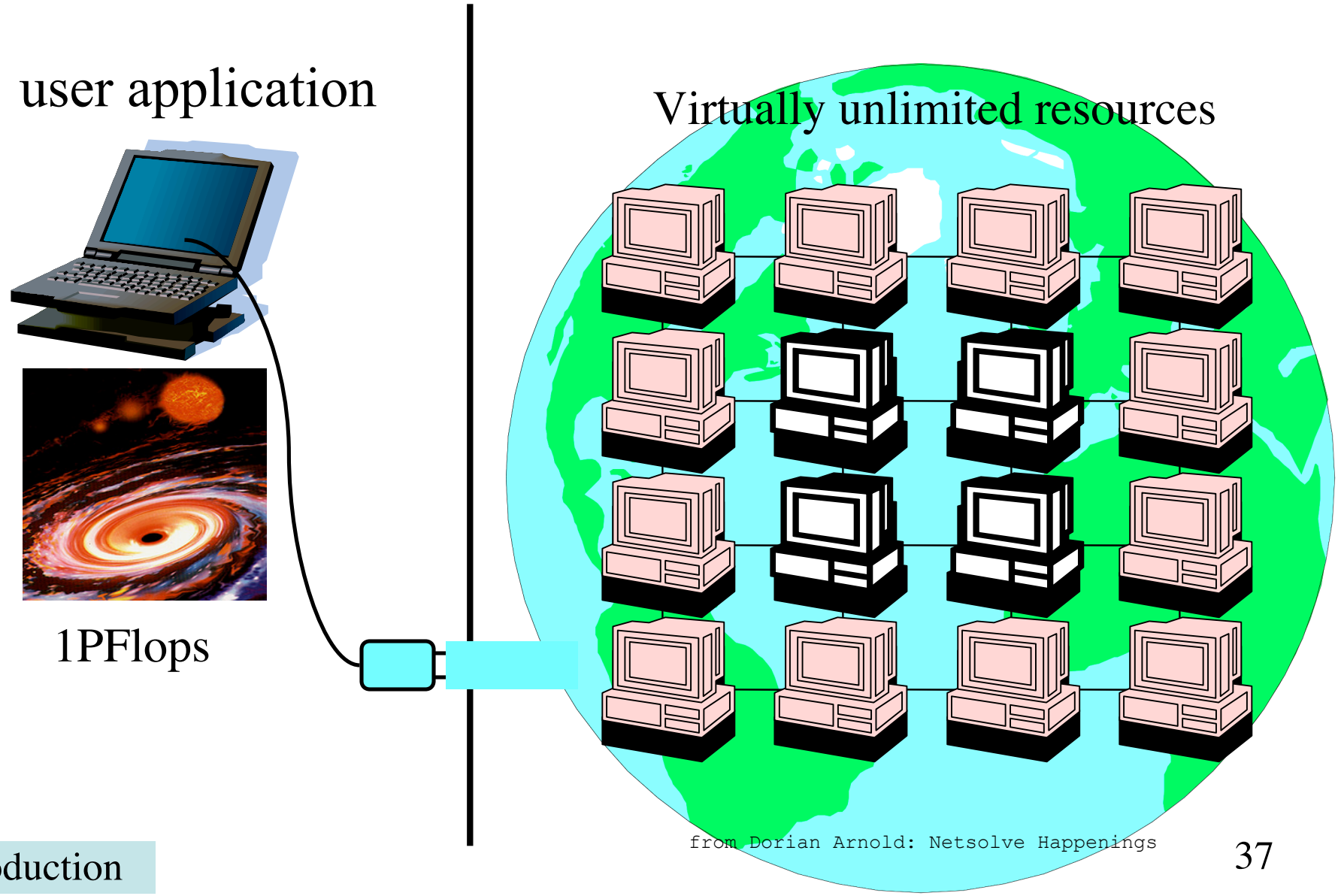

Backbone Topology April 2004

# New applications on the information highways

**Think about…**

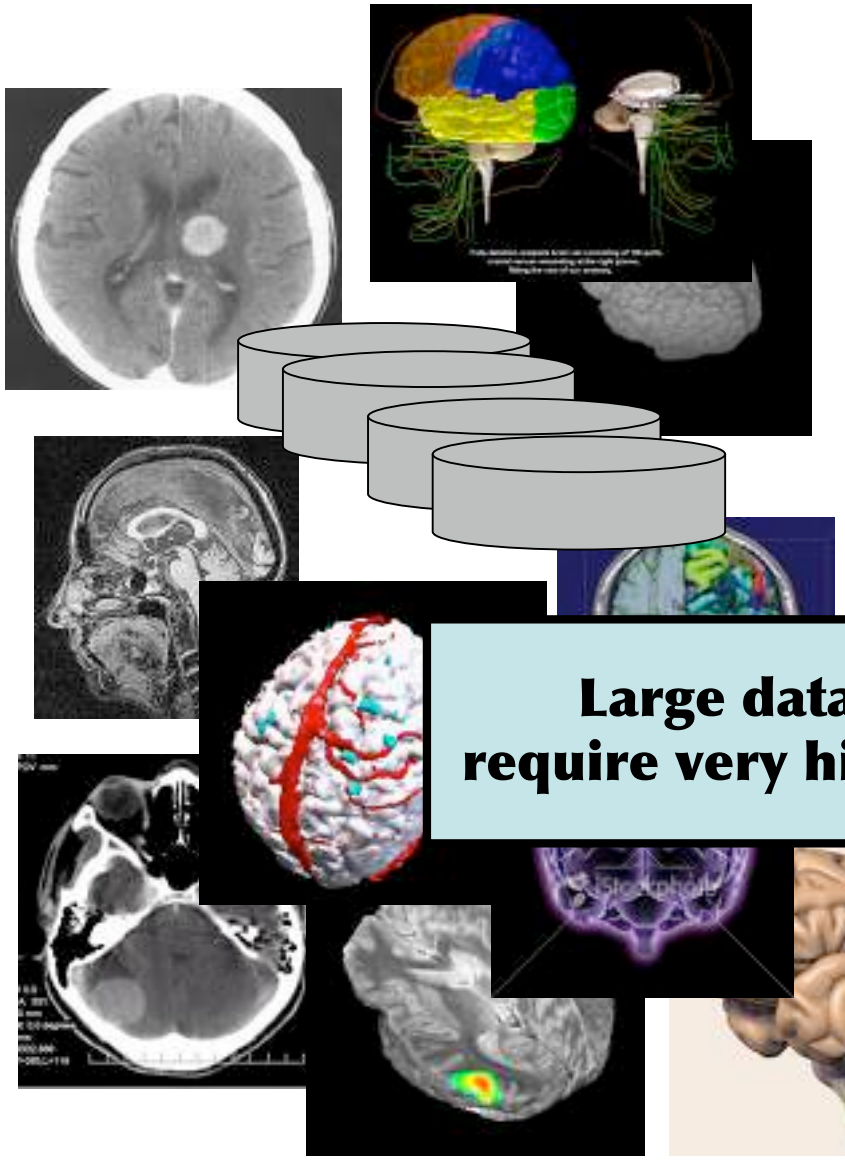
- video-conferencing
- video-on-demand
- interactive TV programs
- remote archival systems
- tele-medecine
- virtual reality, immersion systems
- high-performance computing, grids
- distributed interactive simulations

# Computational grids




from Dorian Arnold: Netsolve Happenings

# Real-time interactive large-scale scientific collaborations

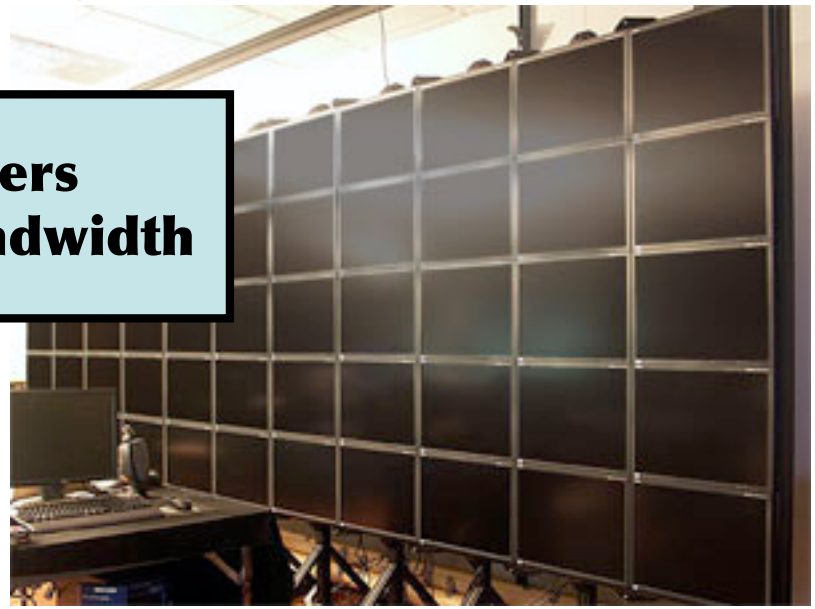


**Large data transfers require very high bandwidth**

**Multimodality brain mapping**

**require the ability to process, share, and interactively visualize multiple 100Gbytes datasets!**

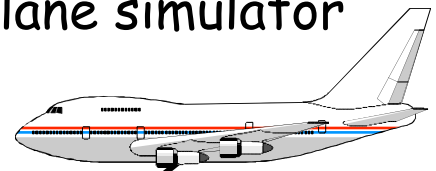
**Today, to visualize and explore eight 3D images require 64Gb/s !**



# Wide-area interactive simulations

display

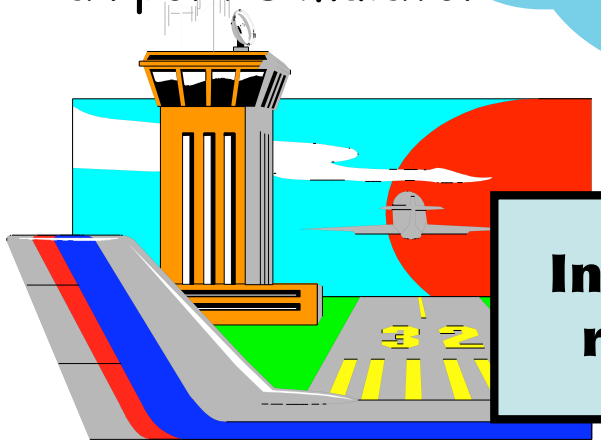
computer-based plane simulator

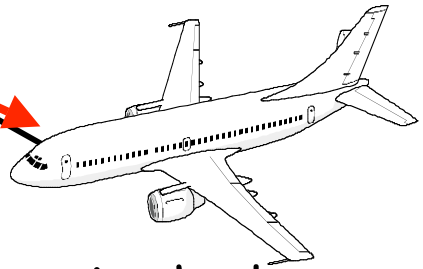


(x,y,z,t)

INTERNET

airport simulator





human in the loop flight simulator

**Interactive applications require low latencies**