

The Internet

Dr. Vincenzo Mancuso
Electronics Engineer
PhD in Telecommunications

Università di Palermo
2007/2008

Slides by courtesy of
prof. Bianchi and Dr. Neglia

Traditional approach to Internet Teaching

1. Transmission technologies
 - physical carriers, modulation, etc
2. Data link protocols
 - reliable transfer of bits from point to point
3. Packet switching
 - Historical perspective, then technologies, routing, protocols, *finally IP*
4. Packet forwarding
 - Glue IP routing with layer 2, ARP,...
5. Transport protocols, application protocols
 - In a rush!! *(just a bit of TCP, HTTP, ...)*

Approach adopted in this course

□ **(almost) Top-Down**

- Applications are indeed important
- What you see is what you learn first

□ **Start focusing on internet application programming**

- Notion of sockets (no Java programming)
- Transport layer as application development platform

□ **Web as driving application**

- Limited details on other apps

Course objectives & limits

□ OBJECTIVES:

- Understanding what type of network the Internet really is.
- Understanding why protocols have been designed as they are
- Achieving capability to respond to layman (the most critical) questions
- Knowing what to read, when tech problems arise

□ LIMITS:

- Scope limited to “just” inter-networking; no networking (no mention to what’s below the internet protocol - dealt with in past courses)
- Limited to basic classical Internet (no mention to recent developements)

Teaching Material

□ Textbooks and notes

- Nicola Blefari Melazzi
 - Internet, Architettura, principali protocolli e linee evolutive (Jan. 2006, in Italian)
- *James F. Kurose, Keith W. Ross*
 - *Italian version: RETI DI CALCOLATORI E INTERNET
Un approccio TOP-DOWN,
Addison Wesley (PEARSON), approx 45 €*
 - *top-down approach*

□ Additional reference books & material

- Stevens (vol. 1), 1994
 - to dip into technical issues
 - a VALUABLE book (though a bit too old)
- RFCs: the real stuff...

□ Sites:

- www.ietf.org → Internet standardization
- www.w3.org → Web standardization

Class contents

□ PART A: Applications

- Internet architecture, internet standardization, switching basics
- Application addressing, Internet applications development
- World wide web; HTTP details
- Domain Name System

□ PART B: Transport

- User Datagram Protocol
- Introduction to TCP, pipelining, performance issues
- TCP algorithms: (a) window flow control; (b) TCP error control; (c) TCP congestion control.

□ PART C: Network

- IP addressing
- IP packet forwarding (ARP), IP address assignment (RARP, DHCP)
- Advanced IP addressing: subnetting & supernetting (CIDR)
- IP and ICMP details
- IP routing (**BGP, OSPF**)

□ extra Time? Never happened...

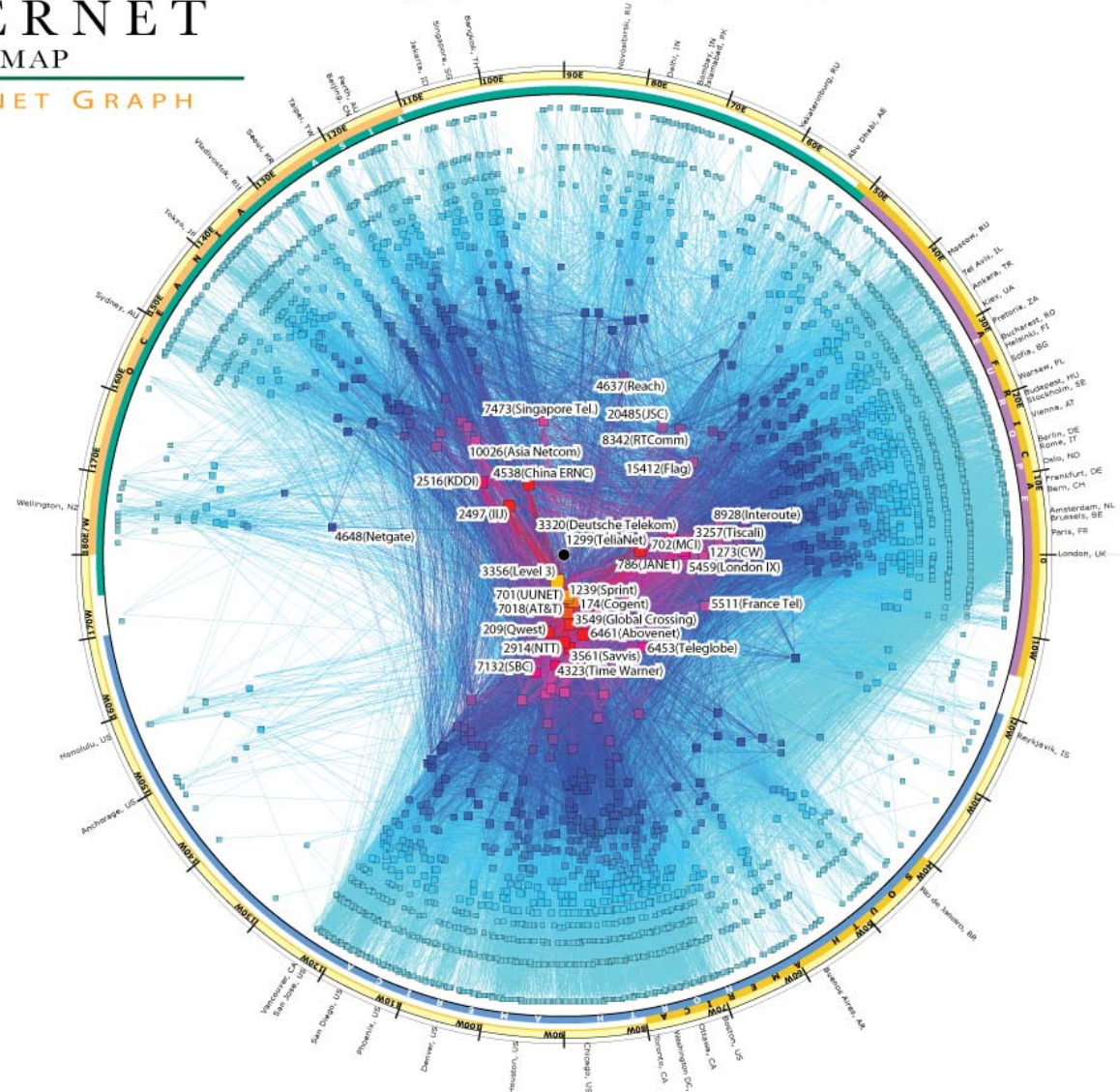
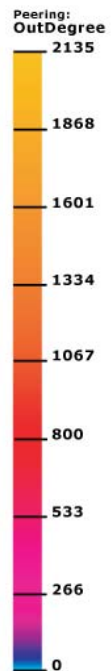
- **P2P applications, CDN network s...**

The Internet Core (IPv4 2007)

copyright ©2007 UC Regents. all rights reserved.

IPv4 INTERNET
TOPOLOGY MAP

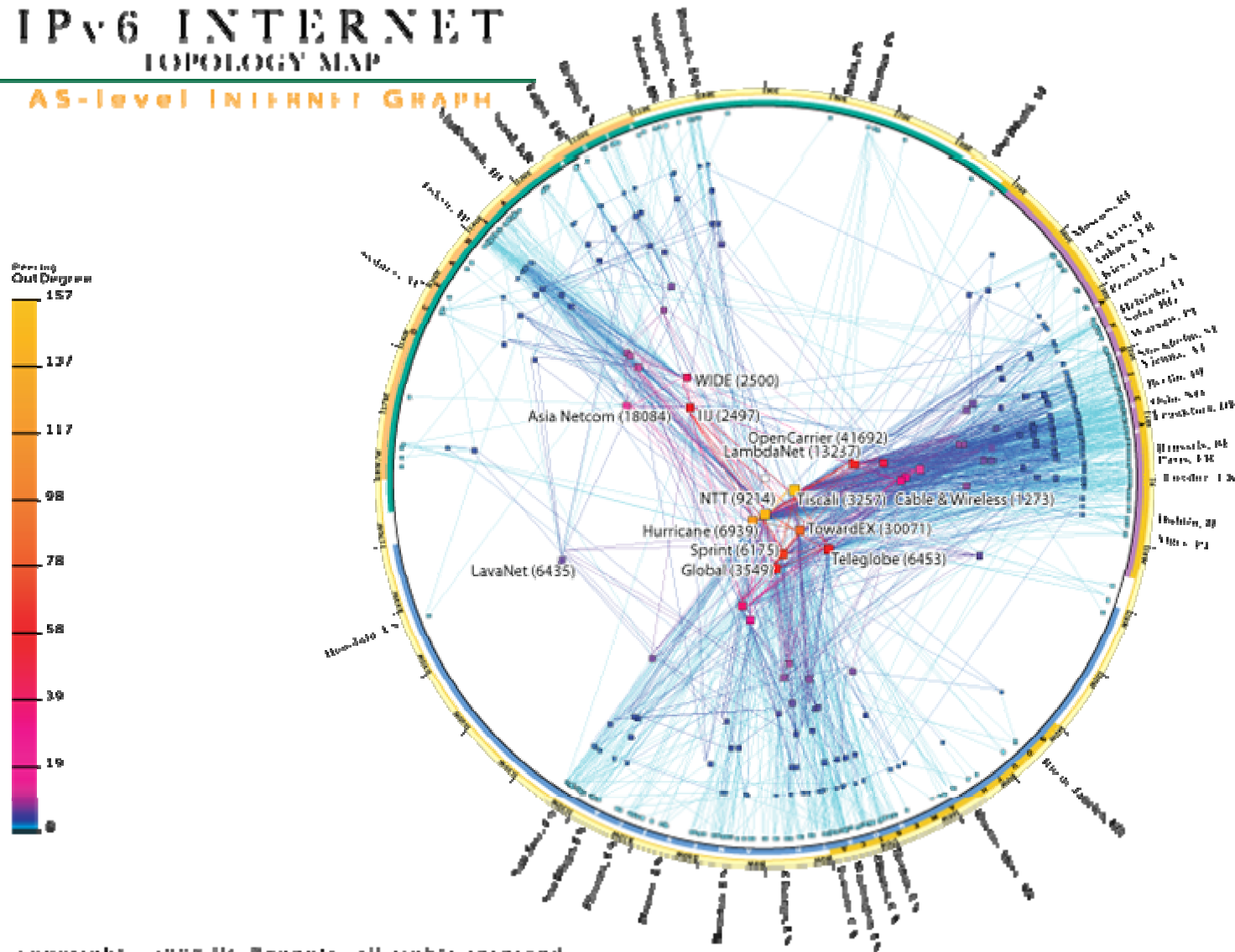
AS-level INTERNET GRAPH



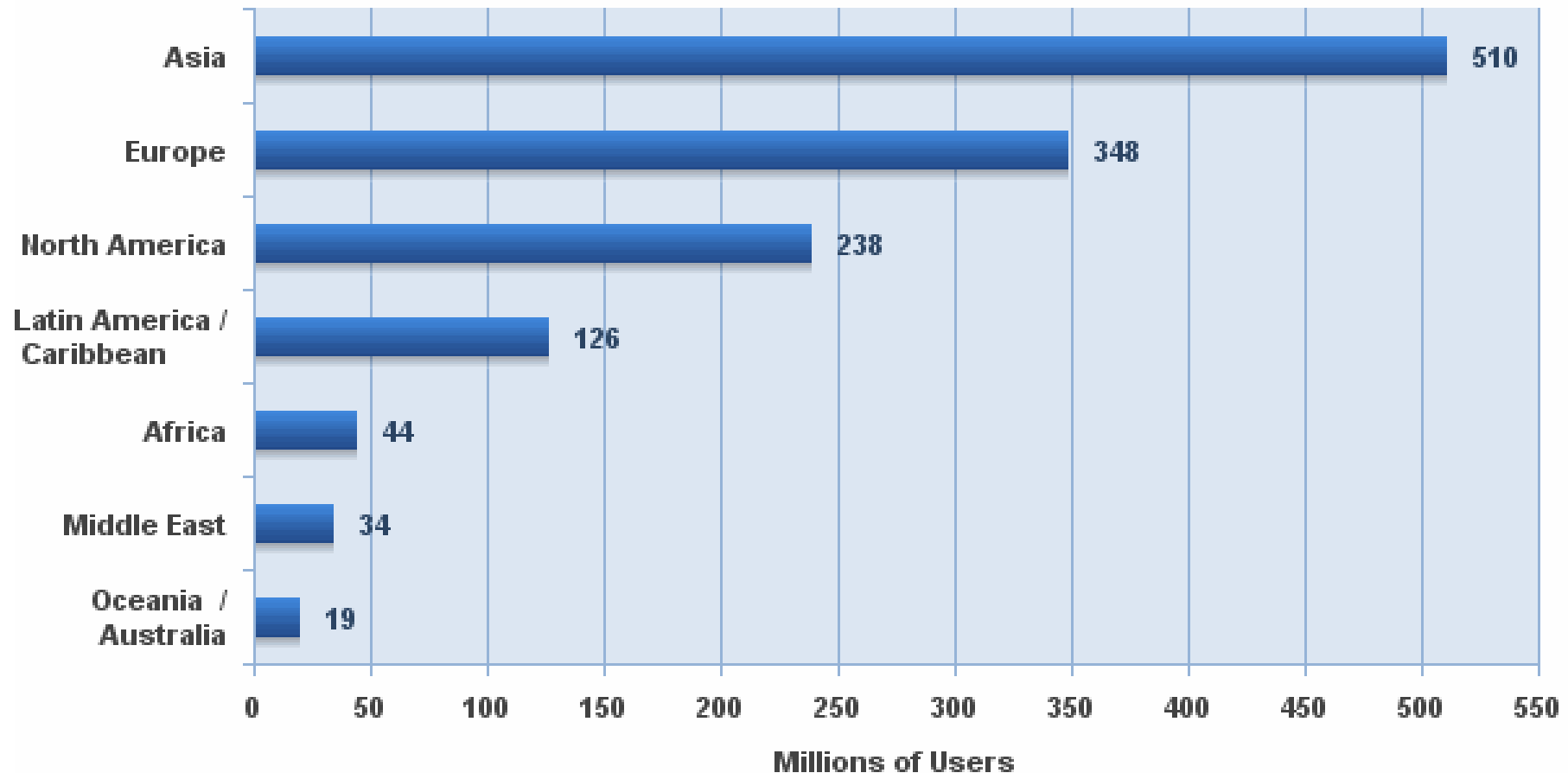
The Internet Core (IPv6 2008)

IPv6 INTERNET TOPOLOGY MAP

AS-level INTERNET GRAPH

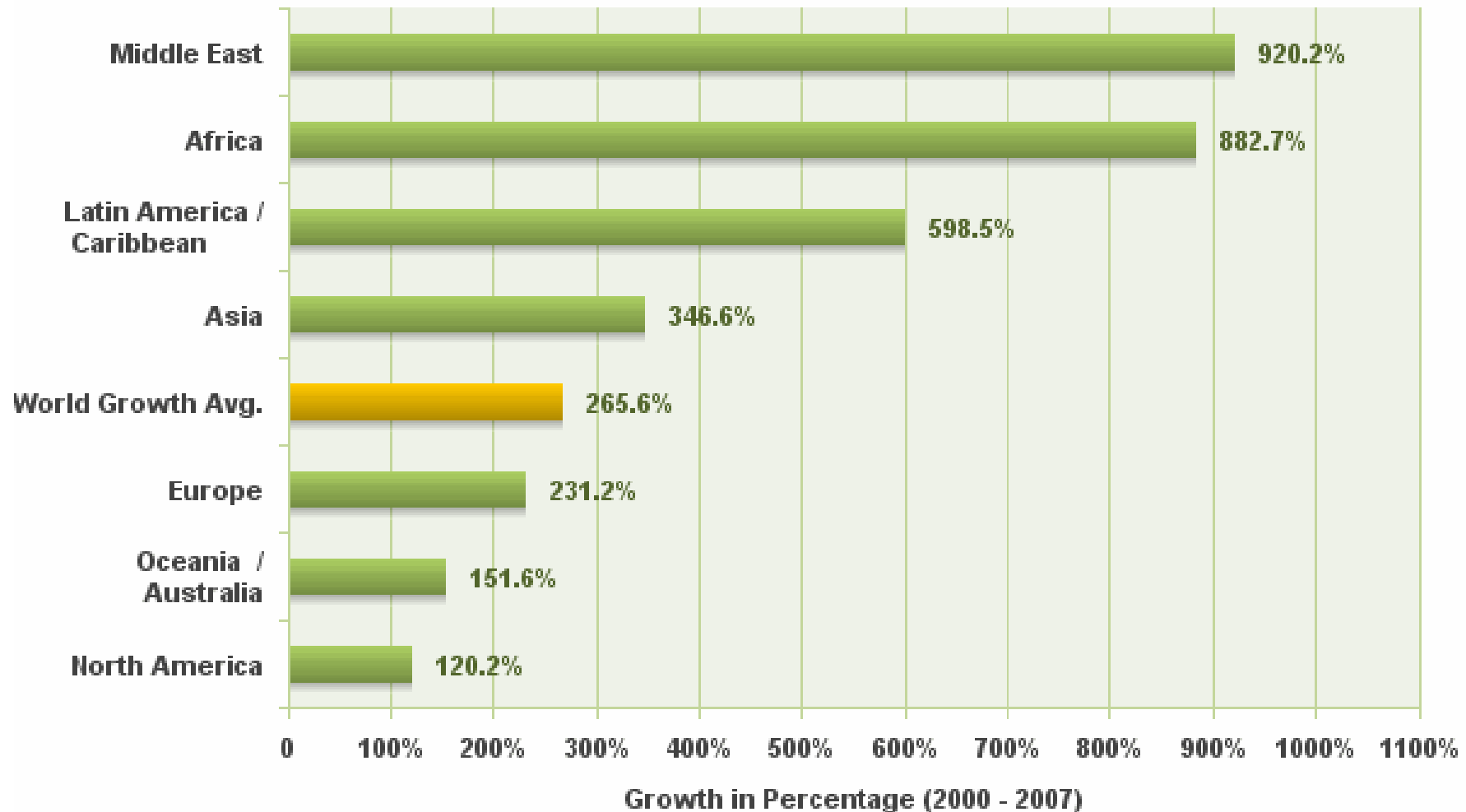


Internet Users in the World December 2007



Note: Total World Internet Users estimate is 1,319,872,109 for year-end 2007
Copyright © 2008, Miniwatts Marketing Group - www.internetworldstats.com

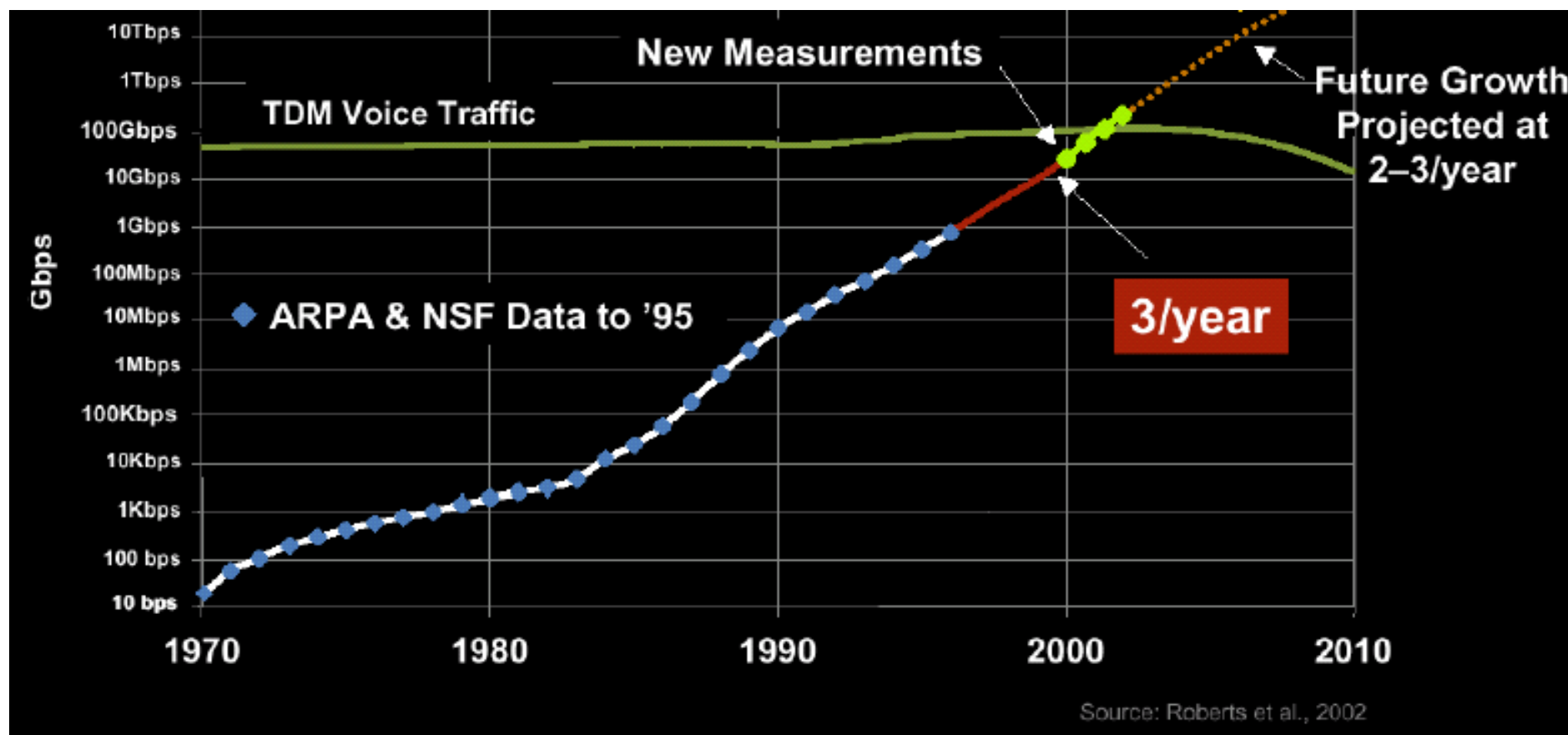
Internet Users in the World Growth Between 2000 and 2007



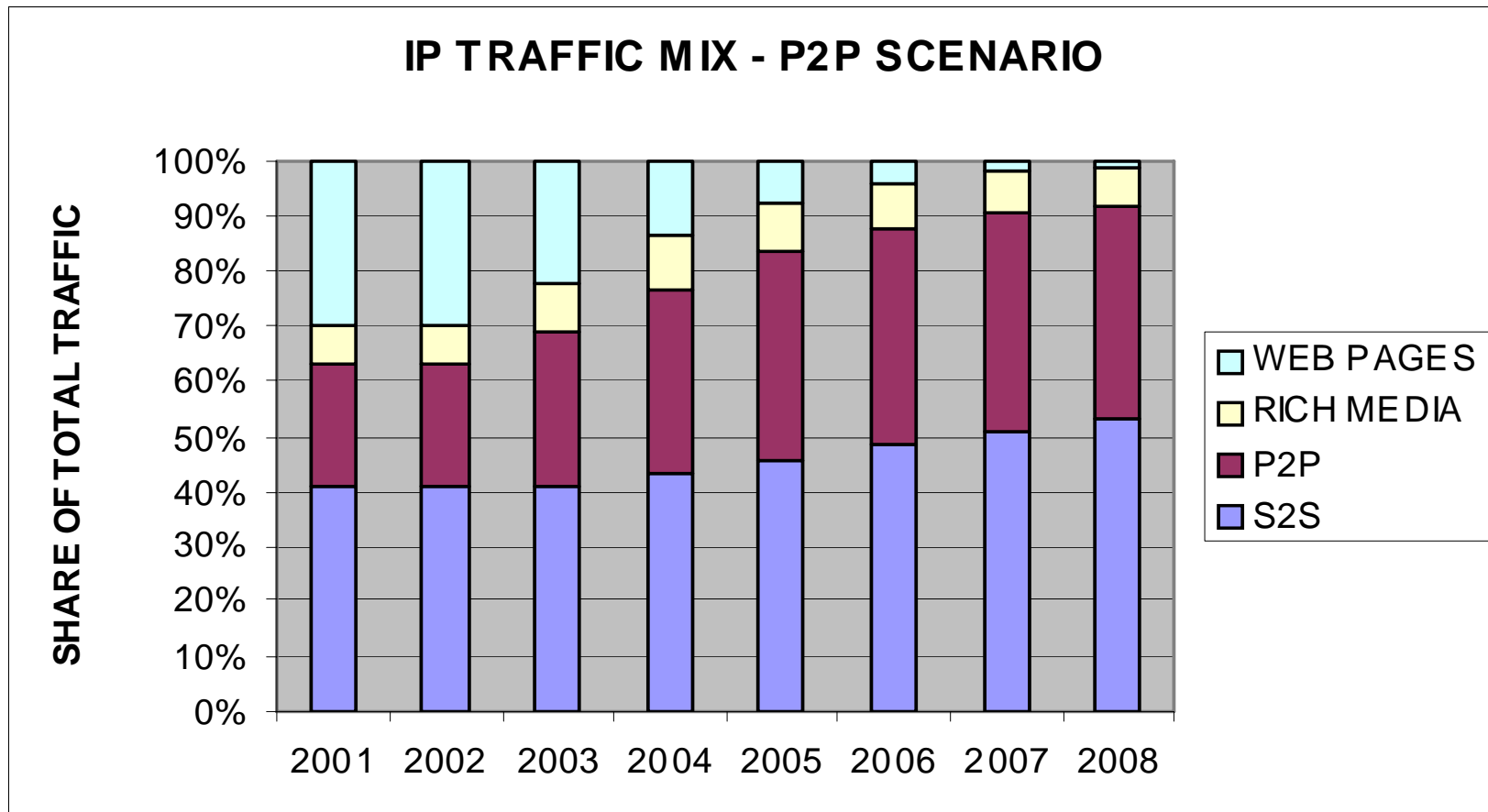
Note: Total World Internet Users estimate is 1,319,872,109 for year-end 2007.

Copyright © 2008, Miniwatts Marketing Group - www.internetworldstats.com

Internet traffic growth (USA – non-recent measurements)

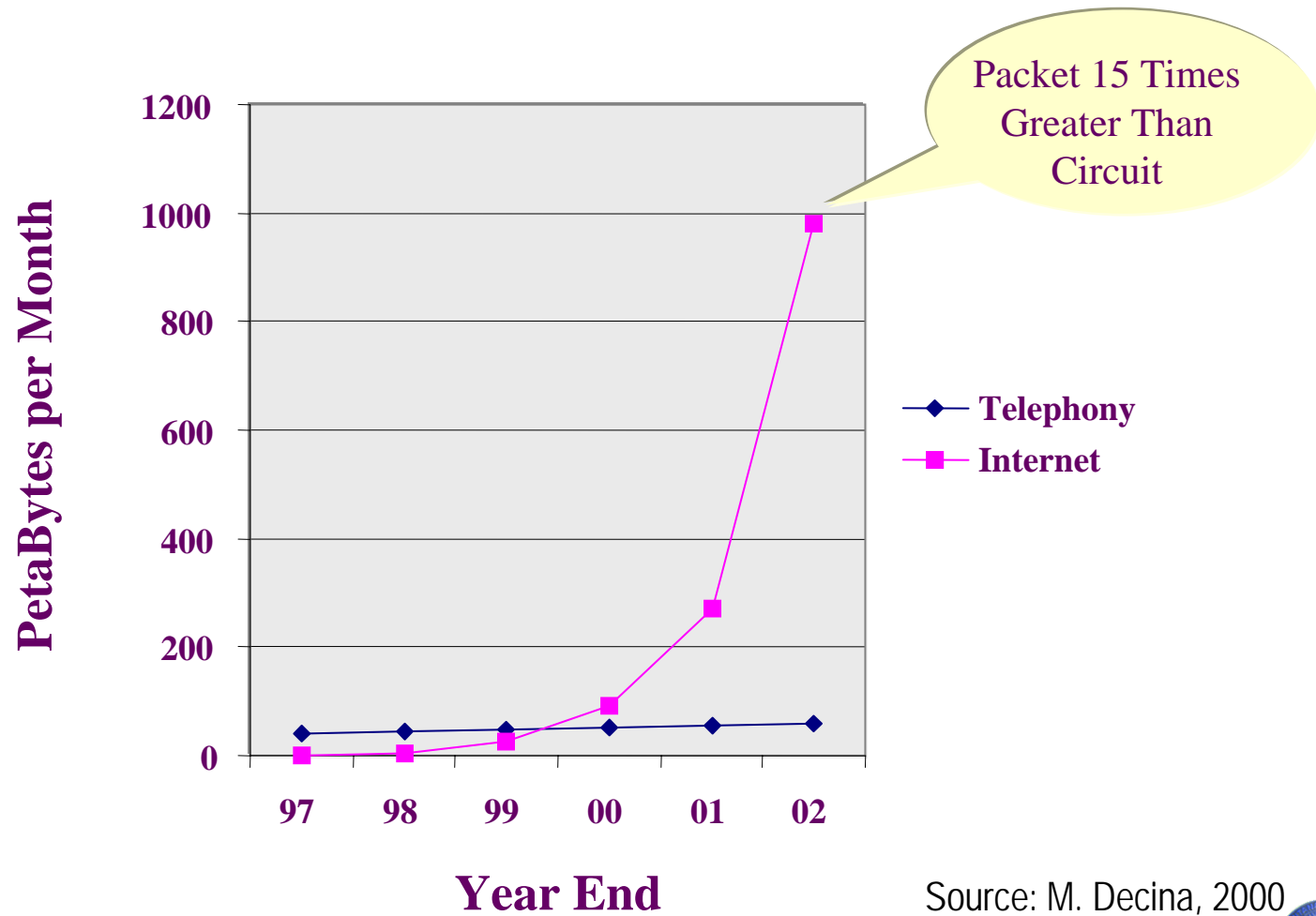


Traffic share - projections



source: Cohen Communications Group

Why “All” over IP?



Source: M. Decina, 2000

Voice over IP – deployment

(source: F. Carlini, november 2003)

❑ ITA: Fastweb

- All-IP Voice service

❑ ITA: Telecom Italia

- 100% (!!) Telephone traffic, MI-RM-NA backbone is IP
 - Did you know?

❑ International traffic

- 12% of whole international traffic is IP

❑ Ongoing direction:

- User VoIP awareness (e.g. Fastweb)

What was the Internet

(for the mass-media, a few years ago)

□ Internet synonymous of WWW (World Wide Web) sites & pages:

- millions of documents
- Spreaded worldwide
- mostly written in **HTML** language
(*HyperText Markup Language*)
- mostly accessible via the **HTTP** protocol
(*HyperText Transfer Protocol*)

What was the Internet (for the scientist in the 80s)

□ Internet synonymous of FTP (File Transfer Protocol) and e-mail:

- Scientists were the only ones having a presence on the Internet (unix logins)
 - » contacts via email, talk program
- Research documents archived in FTP sites
 - » accessible via FTP, gopher
- Scientific (and cultural) forums: Usenet news

What is the internet (for the mass media, today)

□ Huge marketplace for e-business

- B2B and B2C portals with full-fledged transaction capabilities

□ Virtual communities

- Chat & messaging
- Peer to peer applications

□ Communication network

- IP Telephony / Multimedia commun.

What will be the Internet (in 2015?)

- High speed unique integrated telecommunication network and business services platform**
 - High Speed = Broadband
 - Unique = integrated services network
 - Services = from communication to distributed systems
 - IMS (IP Multimedia Subsystem)
 - ???
- Worldwide operating system?**
- Content delivery network?**
- p2p?**
- Internet Appliances, the real revolution?**
- Overlay networks?**

What is the Internet

(For networking engineers: We!)

1. A worldwide computer network

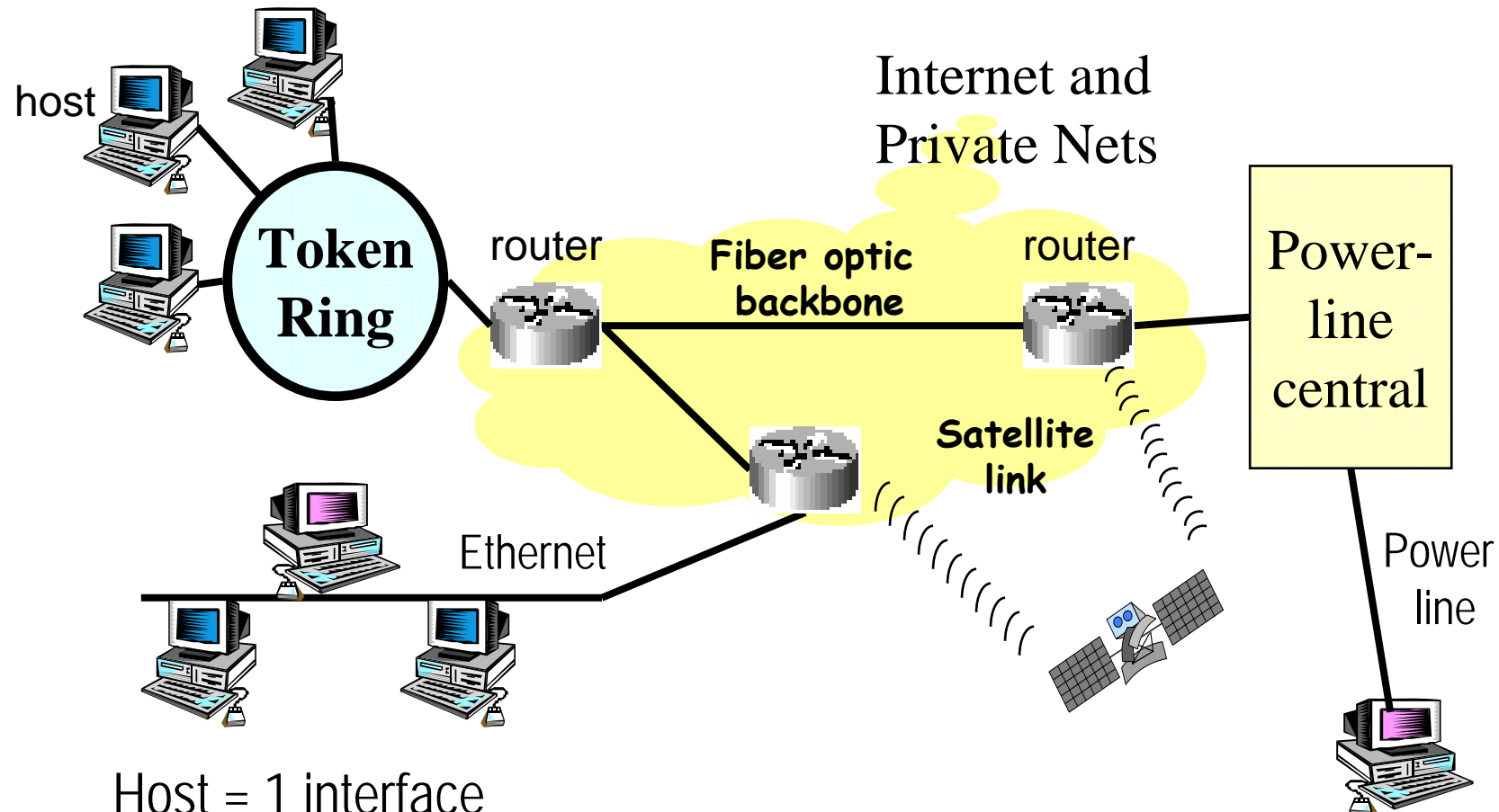
- Connecting end-systems (host, servers)
- Each uniquely identified by a numeric address (IP address)

2. the world wide group of networks combined with TCP/IP

- TCP/IP synonymous of the entire suite of networking protocols.
 - The name comes from the two most important:
 - » TCP = Transmission Control Protocol
 - » IP = Internet Protocol

3. A packet switching network

What Internet is: a network of heterogeneous networks

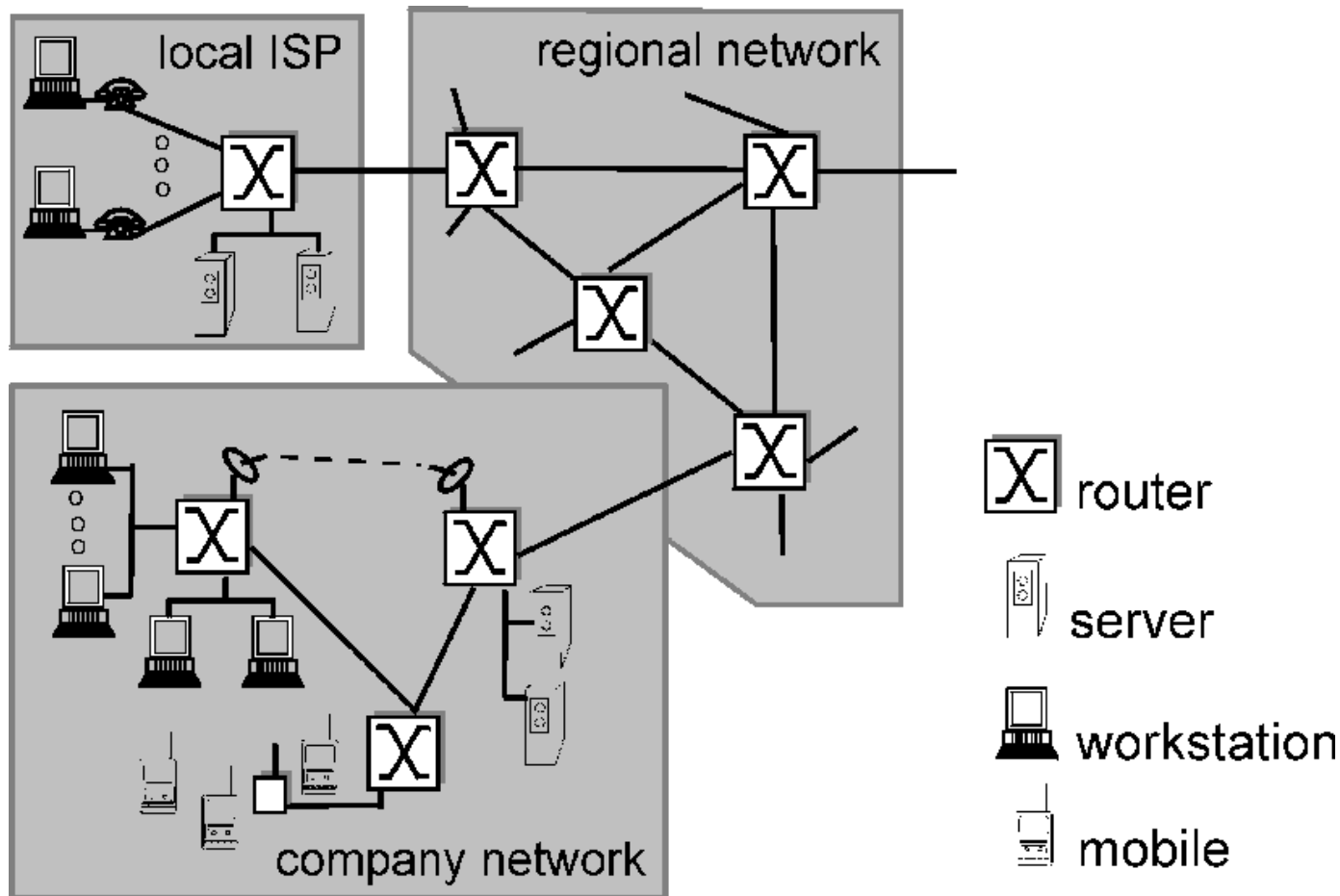


Host = 1 interface
Router = 2+ interfaces

TCP/IP characteristics

- TCP/IP provides services necessary to create the Internet, by:
 - interconnecting computers
 - &
 - interconnecting networks
- Independence from underlying network topology, physical network hardware, Operating Systems, etc
- Universal connectivity throughout the network
- Standardize High Level protocols

What Internet attempts to be (but only loosely is): a hierarchical network...

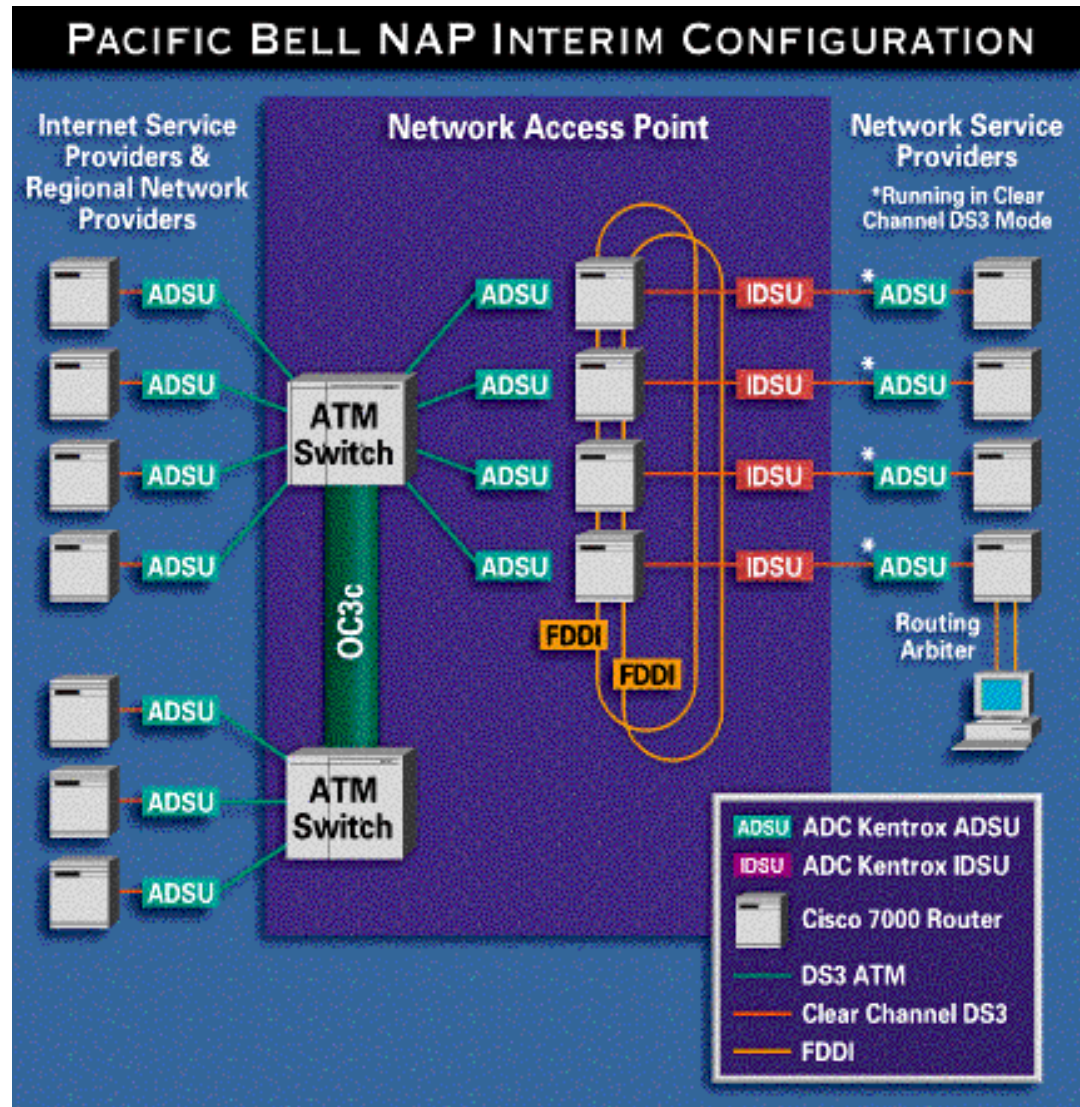


Architecture Hierarchy - USA

- ❑ **Local ISPs**
- ❑ **Regional ISPs**
- ❑ **National & International Backbone Providers (NBPs)**
 - InternetMCI, Sprintlink, PSINet, UUNet, Technologies, AGIS, ...
 - interconnected via big switching centers called Network Access Points (NAPs), or Metropolitan Area Exchanges (MAEs)
 - or private peering points (Point of Presence, PoP)

A NAP: just another router...?

Pacific Bell S. Francisco NAP



The core: Digital Transmission Hierarchy Levels

SDH (Europe): Synchronous Digital Hierarchy → STM-N: Syn. Transport Module, level N
SONET (USA): Synchronous Optical NETWORK → STS-N: Syn. Transport Signal, level N
OC-N: Syn. Optical Network, level N

STM-1/ OC-3 (+STS-3)	155.52	Mbit/s
STM -4/ OC-12	622.08	Mbit/s
STM-16/ OC-48	2,488.32	Mbit/s
STM-64/ OC-192	9,953.28	Mbit/s
STM-256/ OC-768	39,813.12	Mbit/s
STM-1024/ OC-3072	159,252.48	Mbit/s

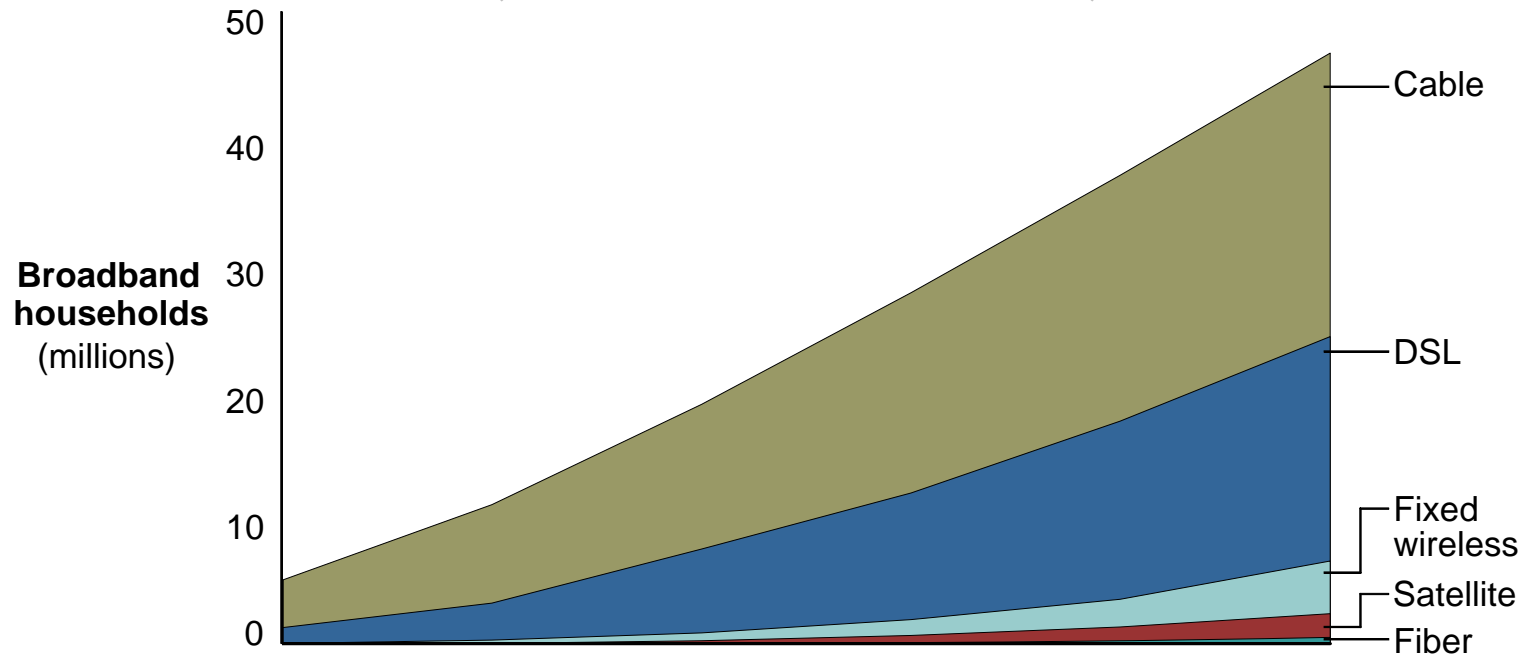
HD-WDM -High Density-Wavelength Division Multiplexing

End 2001:

Commercial: 128 wavelengths @ STM-64

Experimental: 1024 wavelengths @ STM-64

Broadband access, USA (fixed networks)



	2000	2001	2002	2003	2004	2005
Cable	3.74	7.76	11.42	15.81	19.43	22.42
DSL	1.25	2.96	6.61	10.07	14.06	17.75
Fixed wireless	0.02	0.25	0.66	1.25	2.22	4.20
Satellite	0.00	0.00	0.19	0.55	1.11	1.87
Fiber	0.00	0.00	0.01	0.06	0.19	0.47
Total (millions)	5.00	10.97	18.89	27.73	37.01	46.72

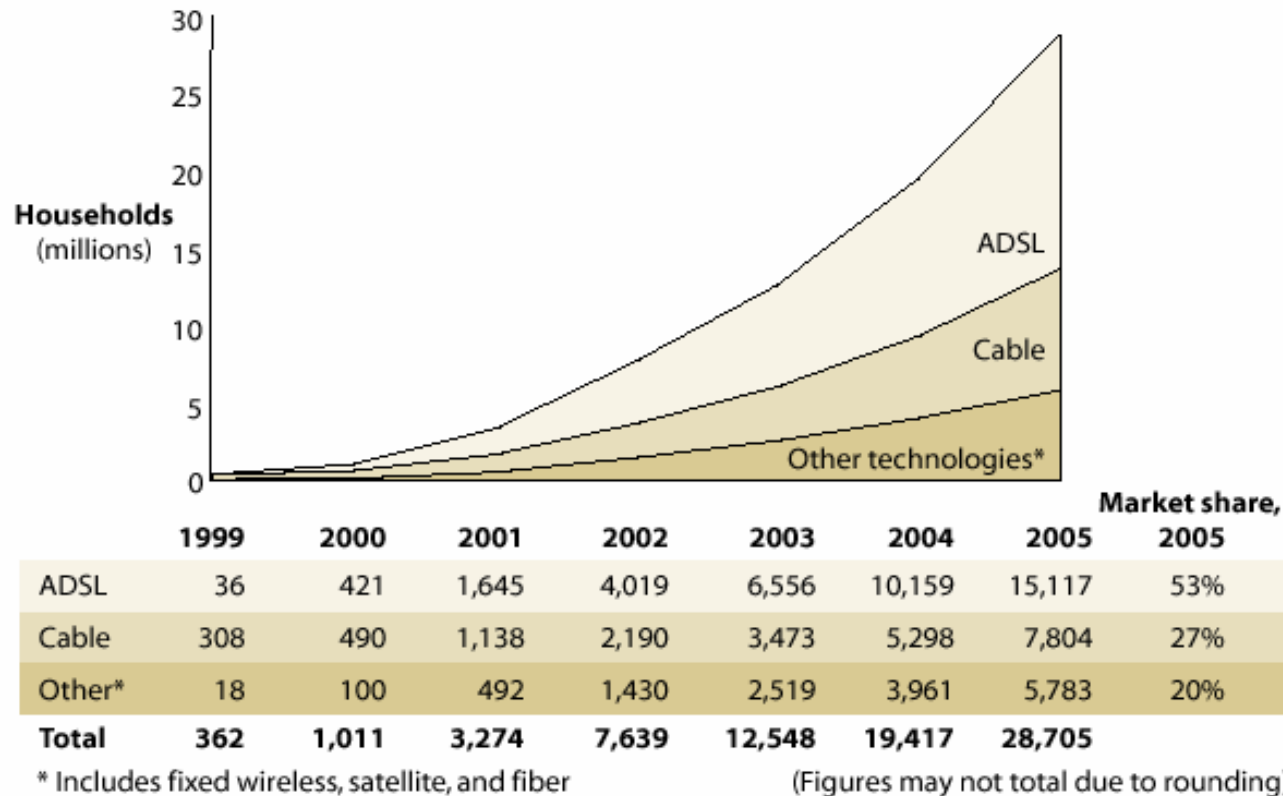
(numbers may not total due to rounding)

Source: Forrester Research, 2000



Broadband access, Europe (fixed networks)

Figure 5 European Residential Broadband Projections By Technology



Source: Forrester Research, Inc.

Source: Forrester Research, 2000

 Università degli Studi di Palermo

Broadband Access in Italy

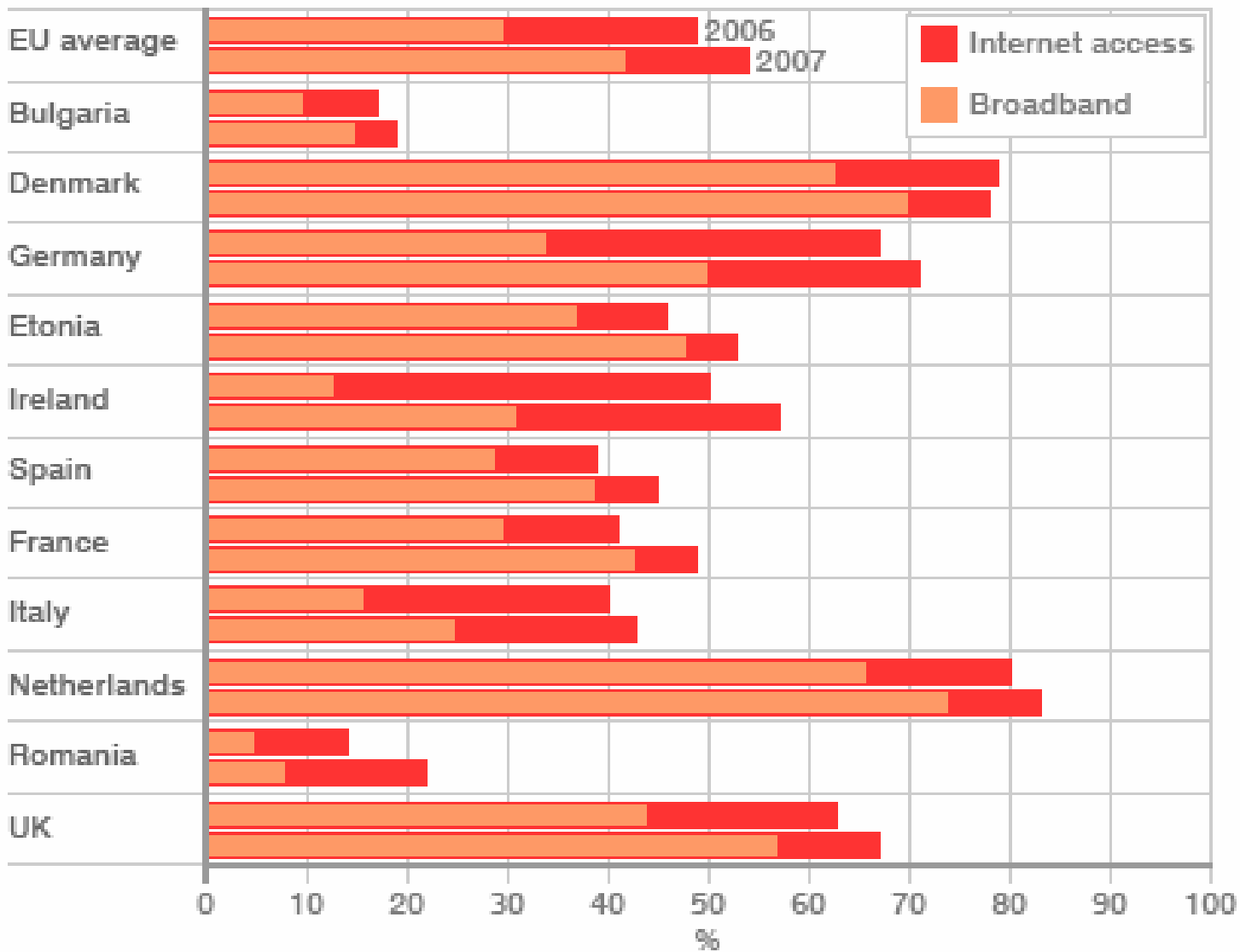
	2000	2001	2002	2003	2004	2005	2006	2007
fibra	0,0	0,1	0,2	0,2	0,4	0,5	0,8	1,0
satellite	0,0	0,1	0,1	0,2	0,4	0,7	1,0	1,2
wireless loops	0,0	0,0	0,2	0,4	0,7	1,0	1,2	1,4
dsl	0,1	0,3	0,8	1,8	2,7	3,8	4,5	5,0
totale fisso lb	0,1	0,5	1,3	2,6	4,2	6,0	7,5	8,6
mobile lb umts	0,0	0,0	0,3	1,5	3,0	6,0	10,0	15,0

(Millions of units)

UPDATED: march 2001

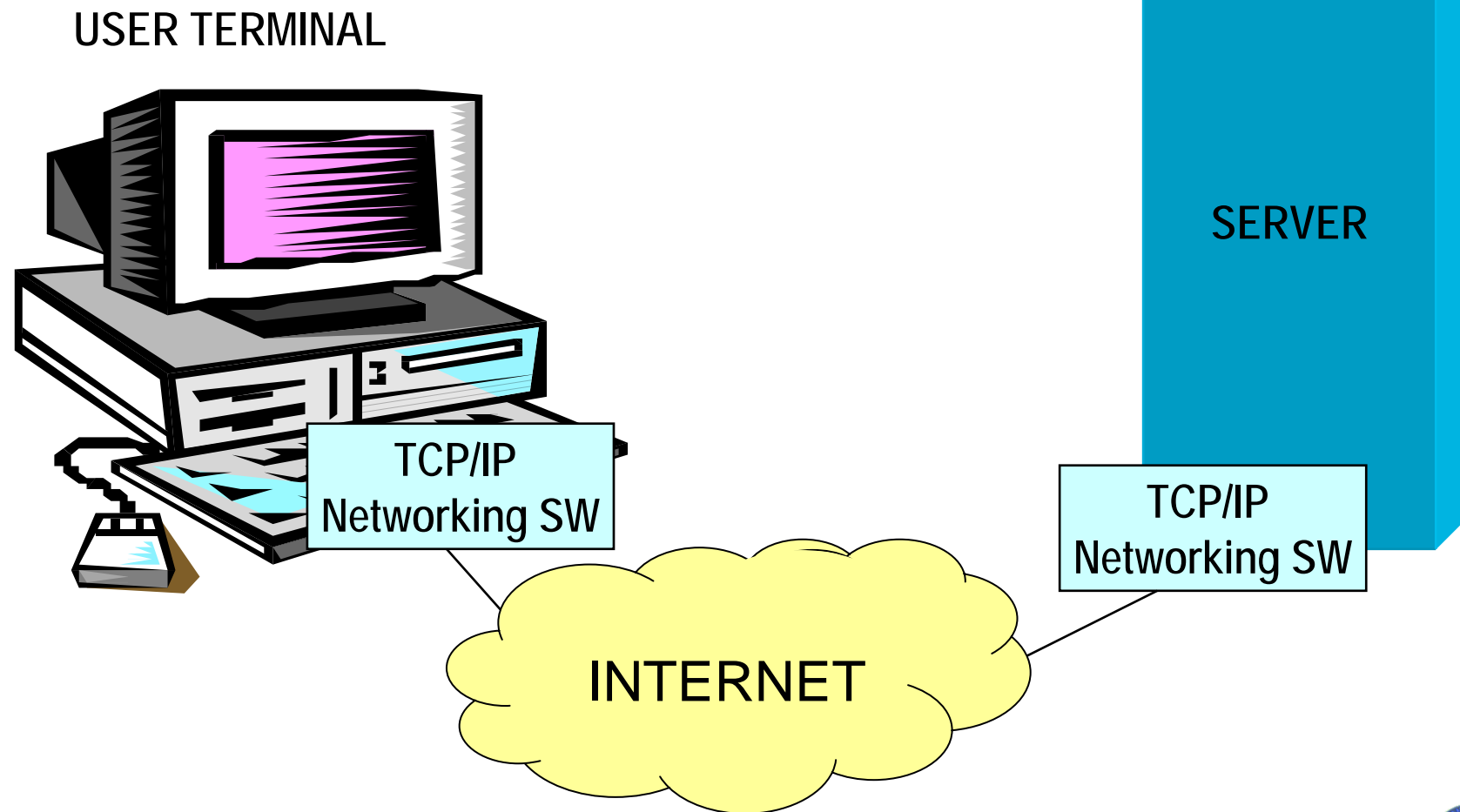
INTERNET ACCESS BY EU HOUSEHOLDS, 2007 (%)

EU state



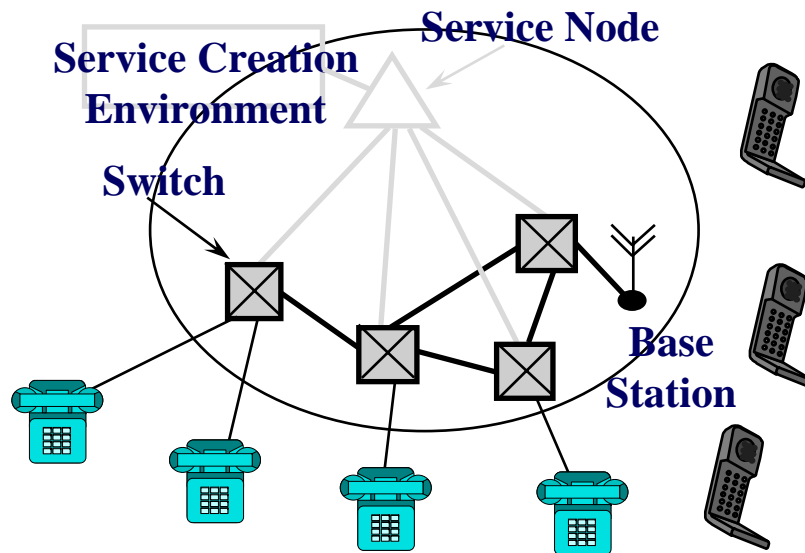
SOURCE: Eurostat

Where the networking software stays



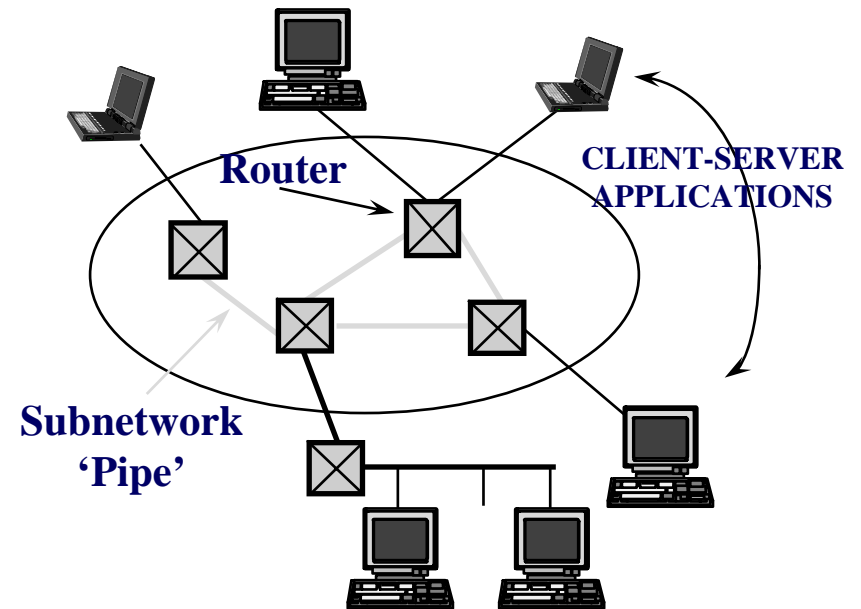
Telecom vs Internet Intelligence

A major motivation for Internet success



Telephony Service Control Architecture

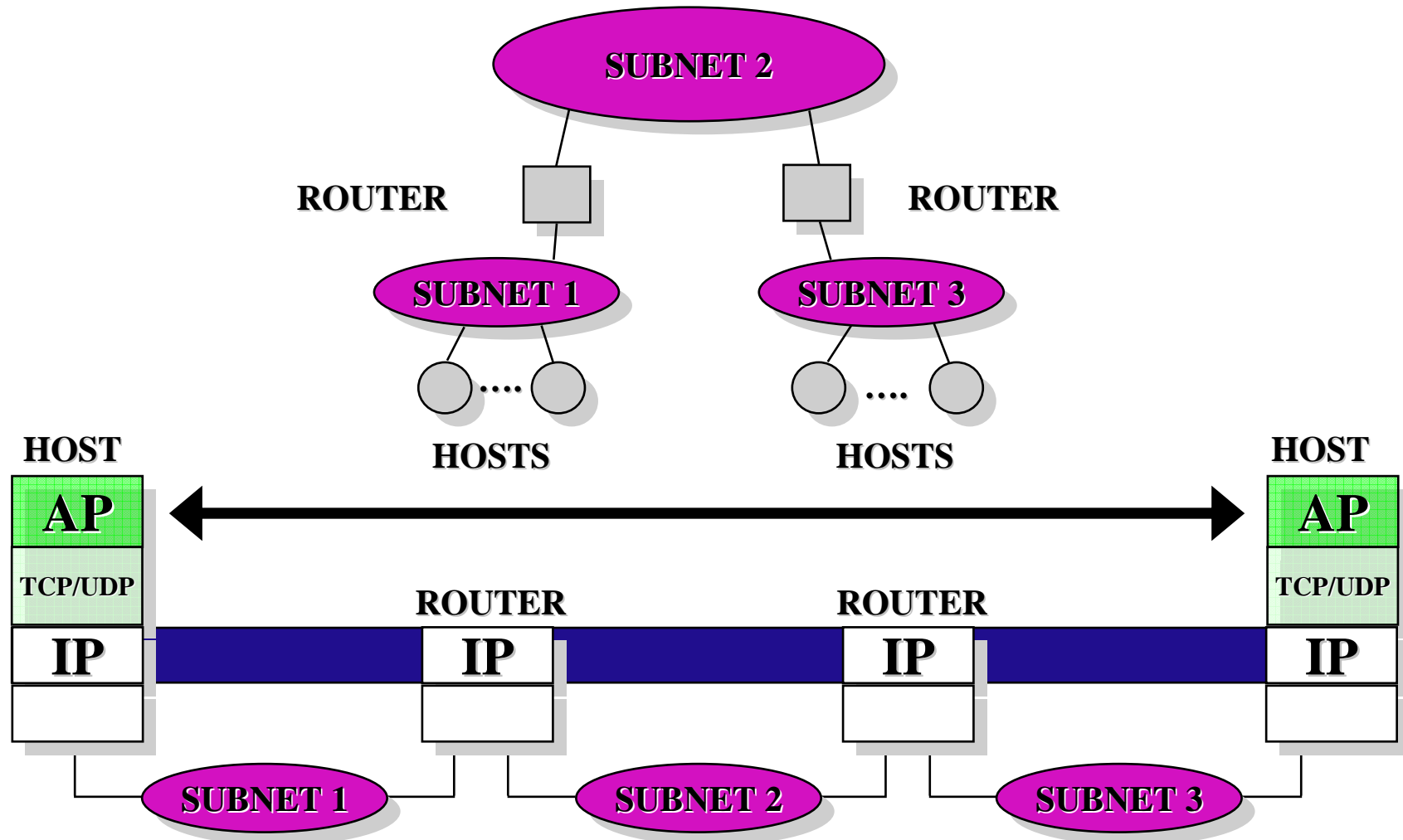
Network provides Intelligence
Proprietary API



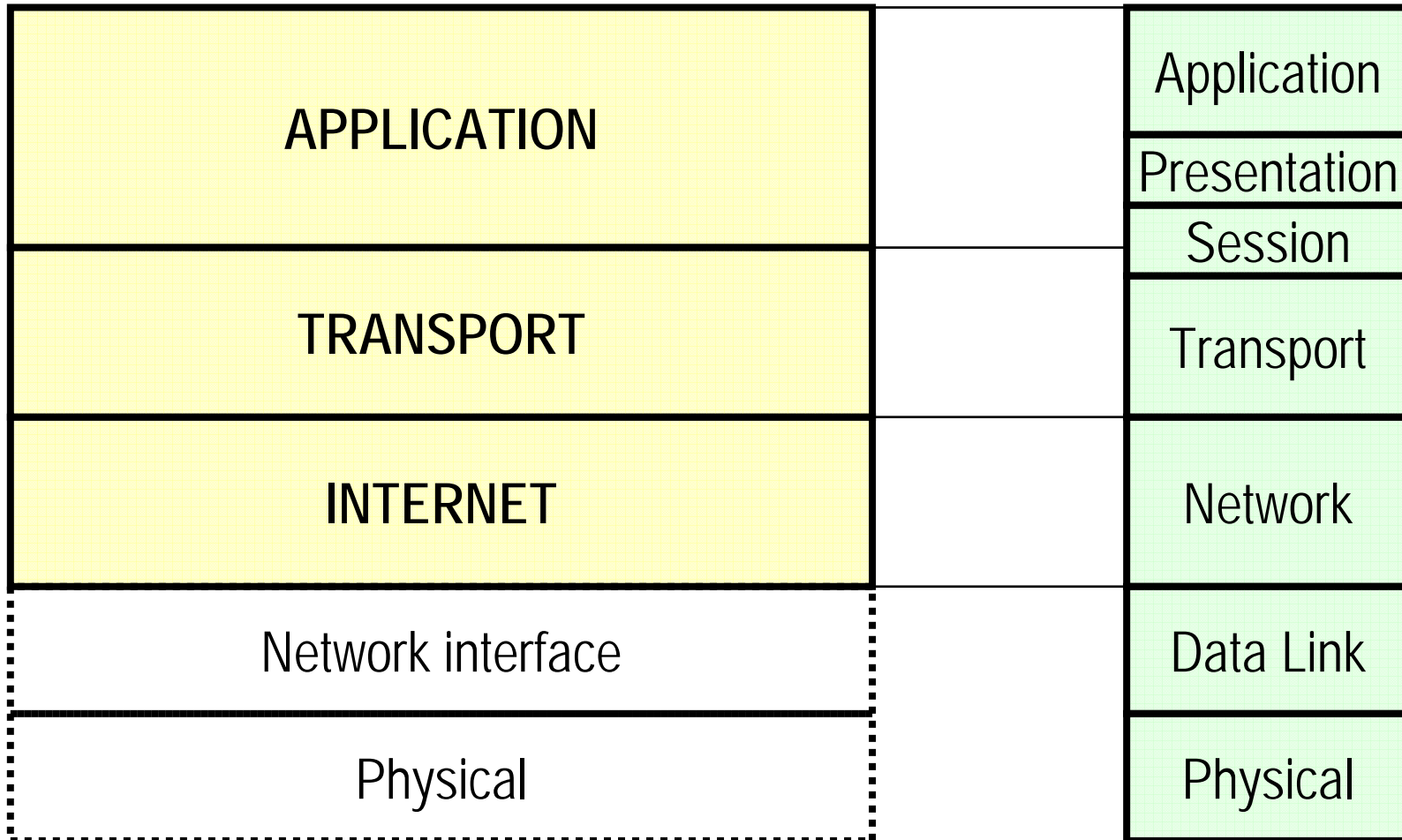
Internet Network Architecture

Intelligence at the Edge:
Network only provides "bearer services"
Open API

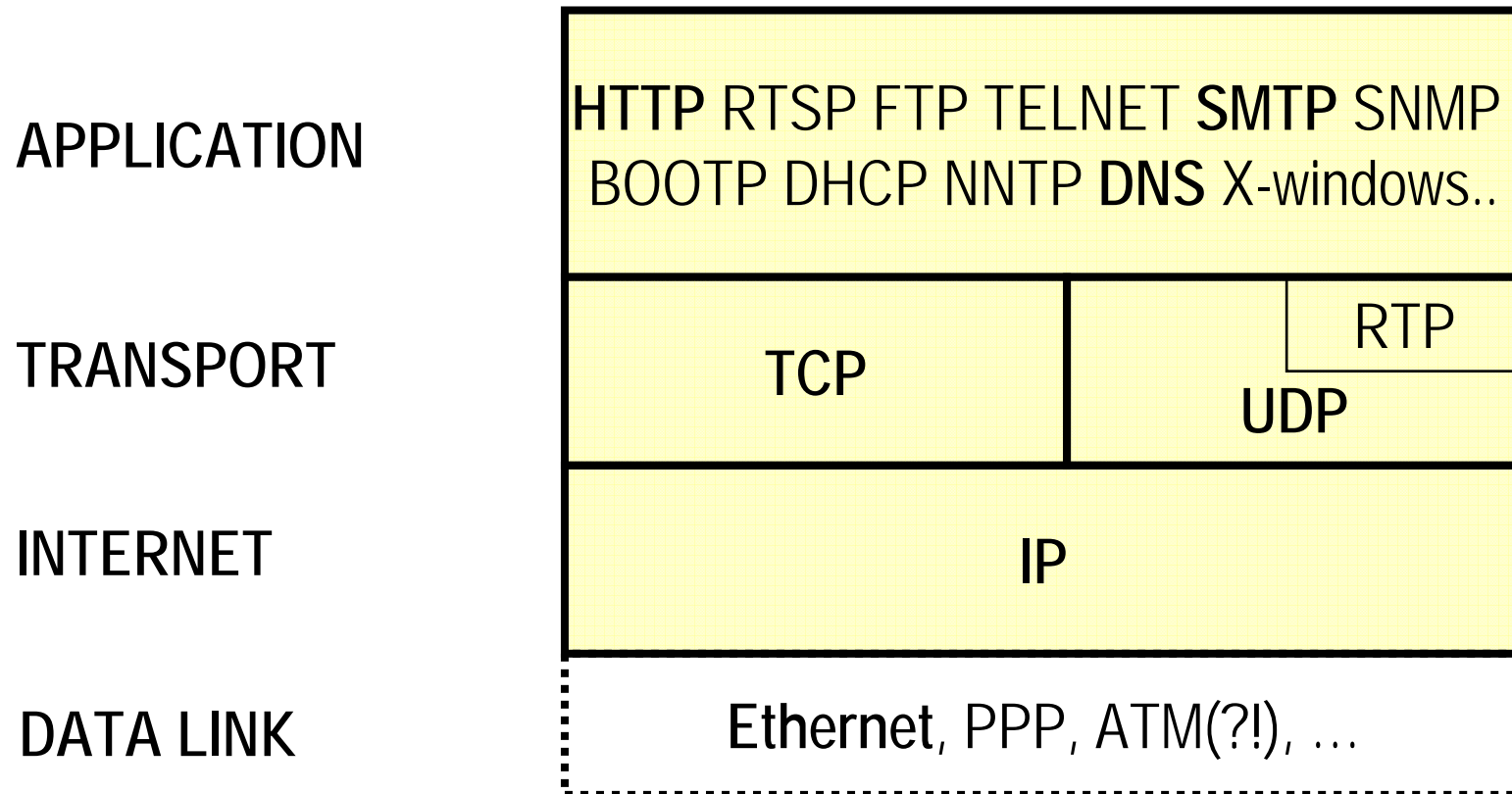
Architecture and layers



TCP/IP protocol layers and relationship with OSI



TCP/IP basic protocol stack



Internet early history

(before Internet)

- ❑ 1957: Cold War, USA establishes ARPA
- ❑ Early 1960: concept of packet switching
 - (Paul Baran? Leonard Kleinrock?)
- ❑ 1967: ARPA presents ARPANET concepts
 - Computers connected through “Interface Message Processors”
- ❑ 1969: ARPANET becomes real
 - 4 nodes (UCLA Los Angeles, UCSB Santa Barbara, Stanford Research Institute, University Utah)
 - 50 kbps lines
 - Network Control Protocol (NCP)
- ❑ 1971: 15 nodes

Internet history

(The Birth of Internet)

- ❑ 1972: Vint Cerf, Bob Karn join ARPANET
 - Launch the “Internetting Project”
- ❑ 1973: Cerf, Karn: TCP/IP design (monolithic protocol)
- ❑ 1973: first satellite link (California-Hawaii)
- ❑ 1973: Ethernet (PhD dissertation, Bob Metcalfe)
- ❑ 1977: first true inter-network
 - ARPANET + Packet Radio Network + Satellite network
- ❑ 1977/79: TCP and IP become two distinct protocols
- ❑ 1979: 100 nodes ARPANET
- ❑ 1981: CSNET (early network from NSF)
- ❑ 1983: old ARPANET protocols dismissed
 - TCP/IP as official and UNIQUE protocol
- ❑ 1983: 4.2 BSD Unix (from UCB) with TCP/IP: first widely available TCP/IP implementation!

Internet history

(the growth)

- ❑ 1983: split ARPANET (research) - MILNET (military)
- ❑ 1984: 1000 nodes
- ❑ 1984: DNS (Internet names)
- ❑ 1986: NSFNET backbone
 - T1 speed (1.544 Mbps)
- ❑ 1986: Internet meltdown
 - Jacobson foresees Internet collapse (congestion)
- ❑ 1988: 4.3 BSD Tahoe: TCP serious improvements (slow start, congestion avoidance, fast retransmit)
- ❑ 1989: 100.000 nodes; Berners Lee: intuition on WWW concepts
- ❑ 1990: ARPANET fully replaced by NSFNET
- ❑ 1990: 4.3 BSD, TCP Reno
- ❑ 1992: MBONE (multicasting)
- ❑ 1992: 1M nodes

Internet recent history

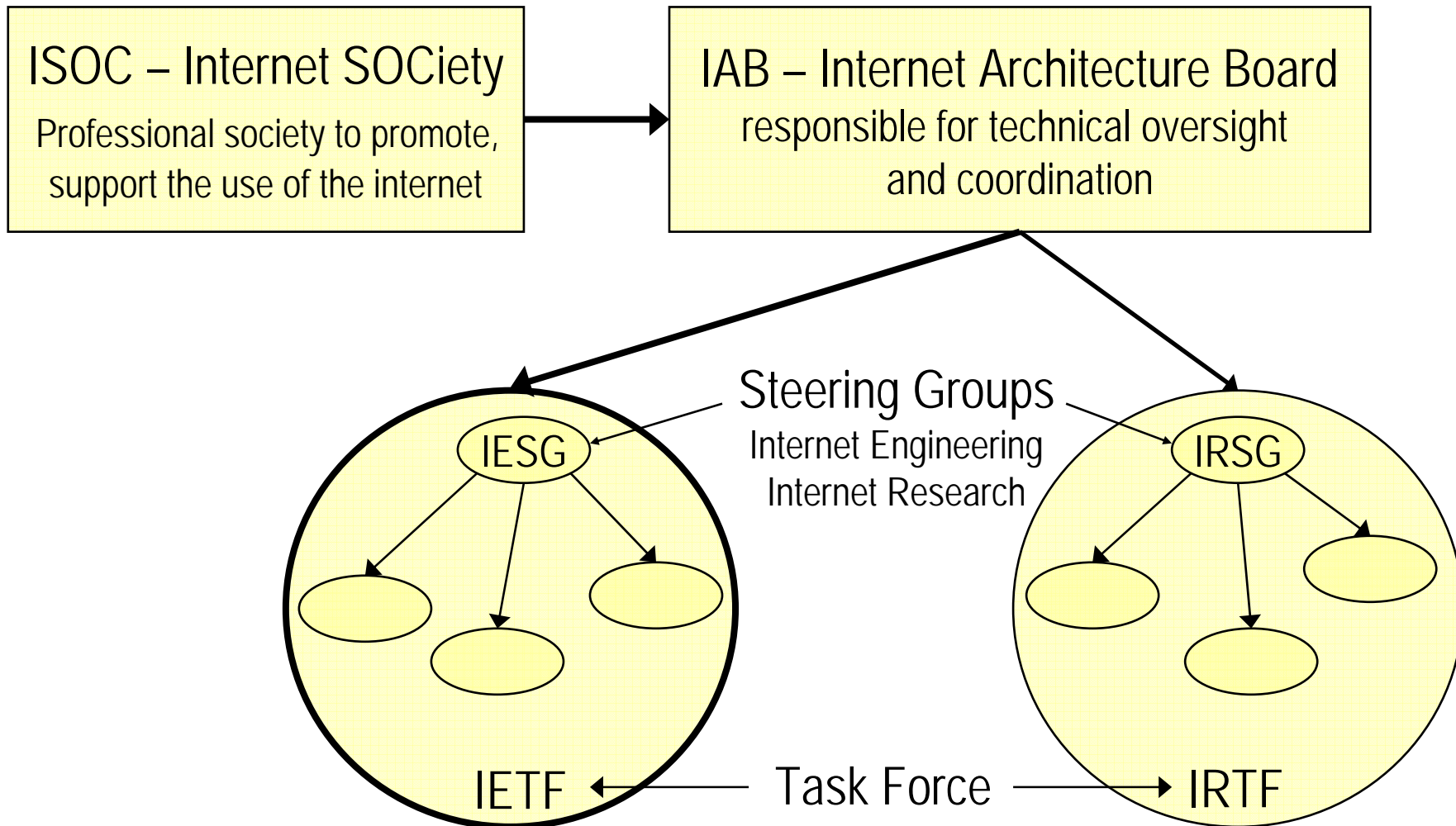
(mass-market)

- ❑ 1993: WWW deployment (mosaic)
- ❑ Starting from early 1990: security attacks
- ❑ 1995: Sun Java
- ❑ 1996: 10M nodes
- ❑ 1996: Microsoft enters Web business
- ❑ 1999: 2M web servers
- ❑ 1999: Commercial Wireless Internet on 2G cellular
- ❑ 2000: widespread emergence of peer to peer
- ❑ 2000: 100M nodes
- ❑ 2002: Wireless Internet Hotspots on wi-fi
- ❑ 2006: >400M hosts (registered IP addresses), >100M webservers
- ❑ 2008: 1.3B users

A short digression:
where is Internet standardized?
Who controls the Internet?

- ❑ **No single administrative organization**
- ❑ **IETF - Internet Engineering Task Force**
 - Development of current protocols and specifications for standardization.
 - International community, open to everyone
 - Most of the work via mailing lists
 - Meets three times/year
 - organized in areas and working groups
 - Dynamically activated & deactivated on need
 - group coordination: IESG (Internet Engineering Steering Group)
- ❑ **Industry also preemptively determine standards**

Technical Bodies Structure

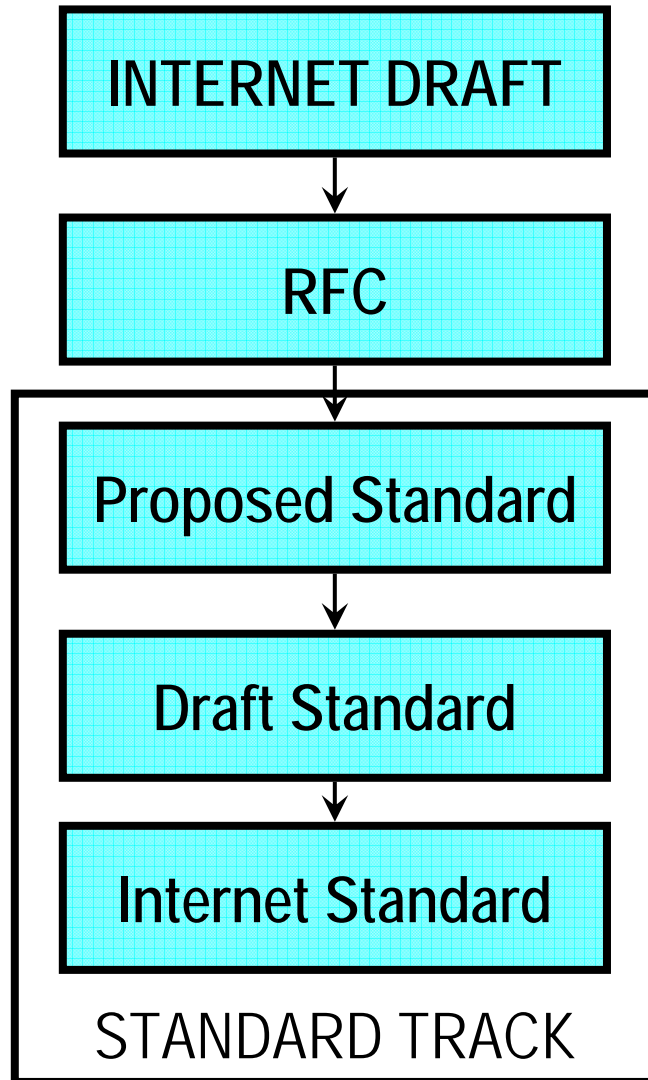


IETF credo

***We reject kings, presidents and voting.
We believe in rough consensus
and running code***

David Clark (MIT), 1992

Internet Standard Process



Draft version for information review and comments. 6 months lifetime

Official Internet publication: never expires

Entry level - protocol specification should be stable technically

At least 2 independent & interoperable implementations testing all spec. fcts

Have had significant field use and clear community interest in production use

Non-Standard Track

(the most common track!!)

- ❑ Specifications may not be intended to be an Internet standard**
- ❑ Three labels**
 - Informational
 - Experimental
 - Historic
- ❑ Informational status: entry status for any proposal...**

Internet Documents

□ RFC - Request For Comments

- RFC3000 in Nov 2000, RFC3901 in Sept 2004
- 295 RFCs in 2004
- Updated RFCs published with new numbers
- Not all describe protocols
- Not all used!

□ BCP - Best Current Practice

□ FYI - For Your Information

- RFC subseries: FYI = no protocol specs (es. RFC1718: the Tao of the Internet)

□ STD - STanDard

- official Internet Standard

Important Documents

all RFCs from <ftp://ds.internic.net/rfc>
RFCs + IDs + WG: <http://www.ietf.org>

- RFC2300 (STD0001): Internet Official Protocol Standards
- RFC1340 (STD0002): Assigned Numbers
- RFC1122 + RFC1123 (STD0003)
Requirement for Internet hosts -
communication layer (1122), Application and
support (1123)

Internet Administration

- ❑ **IAB (Internet Architecture Board)**
 - general operation trends
 - coordination
 - standard approval
- ❑ **ICANN (Internet Corporation For Assigned Names and Numbers)**
 - Internet Protocol (IP) address space allocation
 - protocol identifier assignment
 - generic (gTLD) and country code (ccTLD), Top-Level Domain name system management, and root server system management functions.
 - These services were originally performed under U.S. Government contract by the IANA (Internet Assigned Numbers Authority) and other entities.