- Internet History
- Internet Architecture
- Who owns the Internet

Internetworks and Internet

- Many networks exist in the world
- In order to establish a communication between "different" networks (hardware & software) there are gateways
- A collection of interconnected networks is called internetwork or internet

Internetworks and Internet

- The Internet is the network of networks which
  - either use the TCP/IP protocol or
  - can interact with TCP/IP networks via gateways
- The Internet presents these networks as one, seamless network for its users
- Internet is a particular internetwork

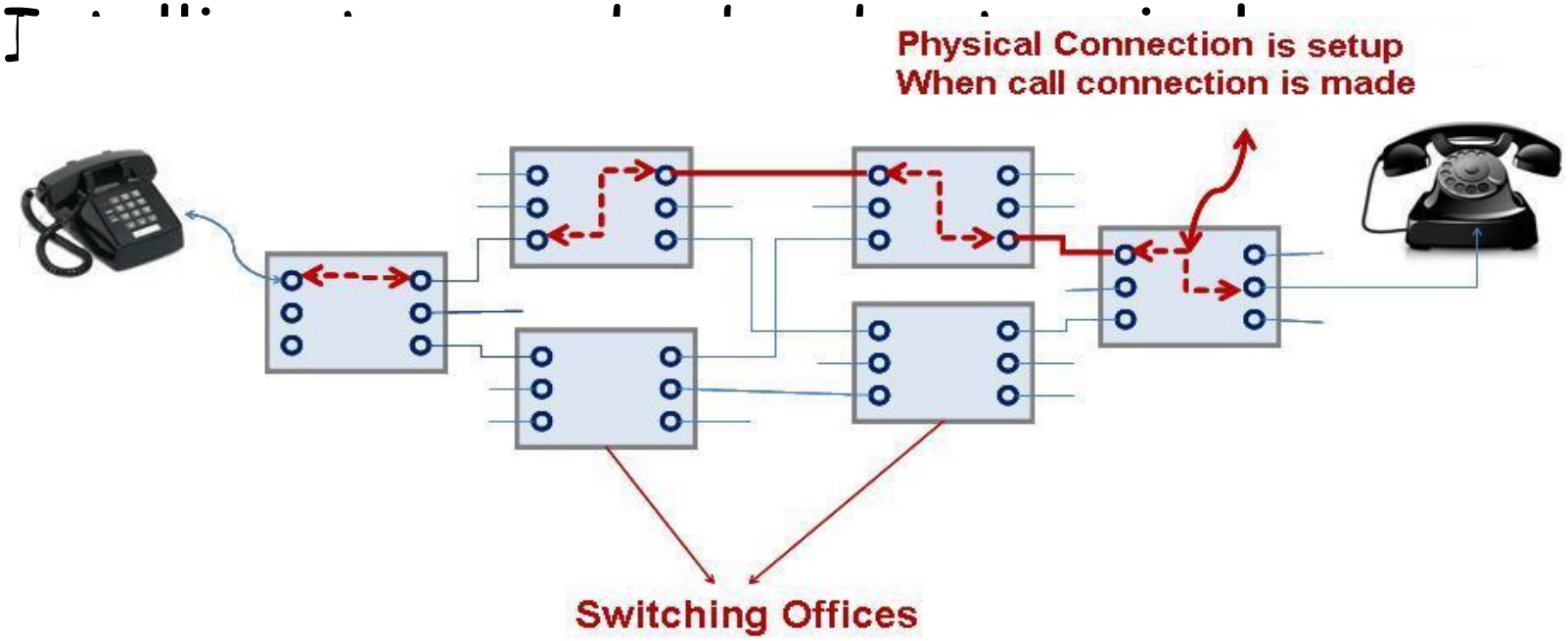
How did the Internet come to be?

- It started as a research project to experiment with connecting computers together with packet switched networks.
- It was developed with funding and leadership of the Defense Department's Advanced Research Projects Agency (ARPA).

Communication Networks…

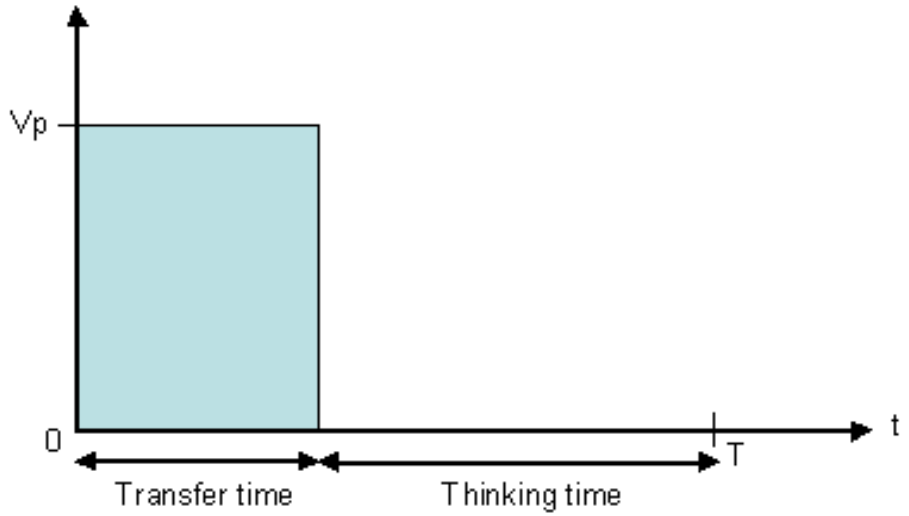
Telecommunication networks are ~100 years old

Circuit-switched, connection oriented



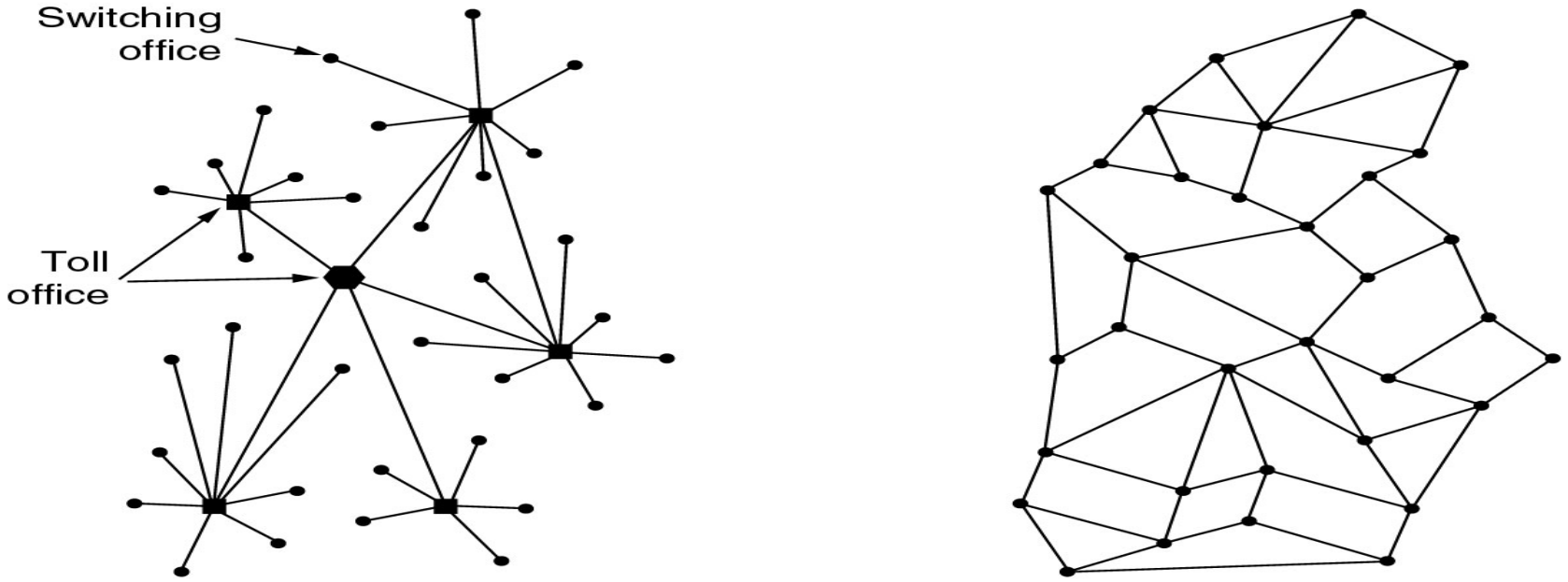
Data traffic is bursty – intervals of activity followed by periods of inactivity.

Circuit switched networks would be inefficient



How did the Internet come to be?

At that time, there was only the telephone network



(a) Structure of the telephone system – vulnerable!
(b) Baran's proposed distributed Switching system.

Origin of Internet

Paul Baran, a researcher at RAND, offered a solution: design a more robust communications network using "redundancy" and "digital" technology.

- Network of unmanned nodes would act as switches, and route information from one node to another to their final destinations.
- The nodes would use a scheme called"hot-potato routing" or distributed communications.
- Baran proposed to divide information into "message blocks" before sending them out across the network.

Packet Switching

Rapid store-and-forward design.

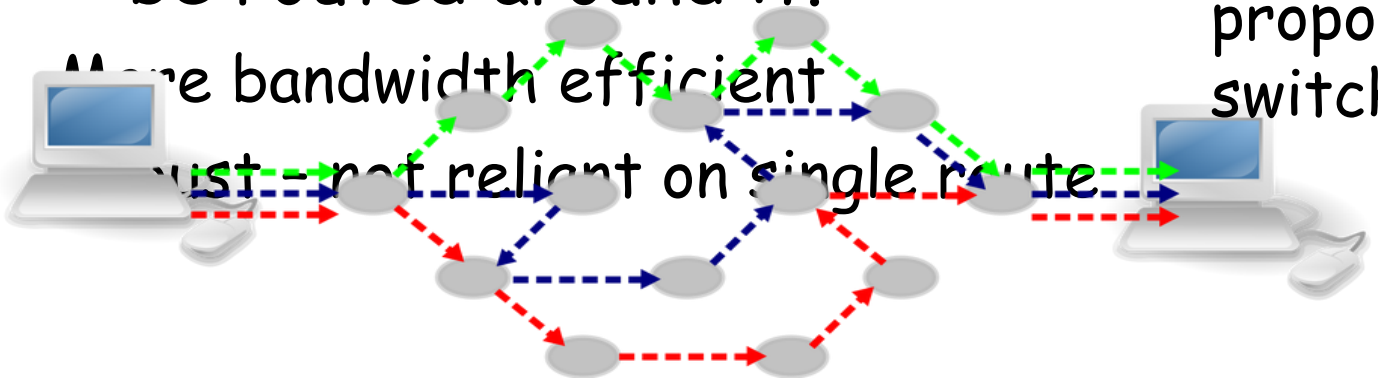
When a node receives a packet it stores it, determines the best route to its destination, and sends it to the next node on that path.

If there was a problem with a node (or if it had been destroyed), packets would simply be routed around it.

More bandwidth efficient

Must not relicnt on single route

1961: Leonard Kleinrock used queuing theory, proposed packet switched networks



1958-1961: Connect Computers?

- 1958-59 – Advanced Research Projects Agency was created within the Department of Defense (DoD)
- 1961 – First published work on packet switching ("Information Flow in Large Communication Nets", Leonard Kleinrock, MIT graduate student)
- 1964 – other independent works in packet switching at RAND Institute and National Physics Laboratory in England

1966 –1968: Connect Computers?

- 1966 – Lawrence Roberts (colleague of Kleinrock from MIT) published overall plan for an ARPAnet, a proposed packet switch network
- 1968 – ARPA awarded contracts for four nodes in ARPANET to
  - UCLA (Network Measurement),
  - Stanford Research Institute (Network Information Center),
  - University of California, Santa Barbara (Interactive Mathematics) and
  - University of Utah (Graphics);

1969: First Connections

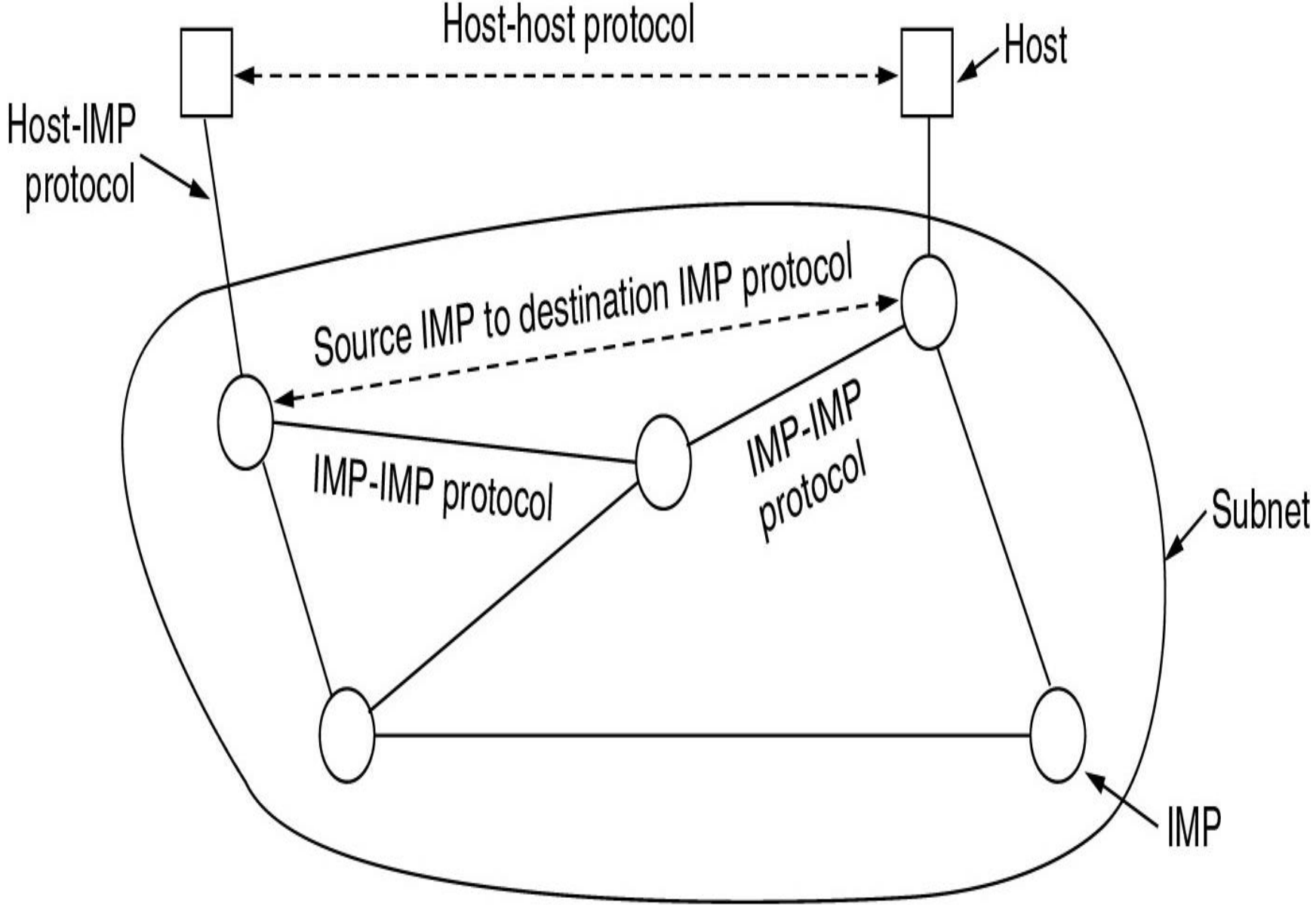
- 7/4/1969 – First RFC ("Host Software" by Steve Crocker)
  - to help record unofficial notes on the development of ARPANET
  - basis for the Network Control Protocol(NCP)
- 2/9/1969 – Leonard Kleinrock's computer at UCLA becomes first node on the ARPANET
- Packet switches were needed - Interface Message Processors (IMP), the contract was awarded to BBN
- Oct 1969: IMPs installed in UCLA, Stanford, UCSB and Utah

The original ARPANET

IMPs (Interface Message Processors) are minicomputers connected by 56-Kbps transmission lines (*the grandfathers of the routers*)

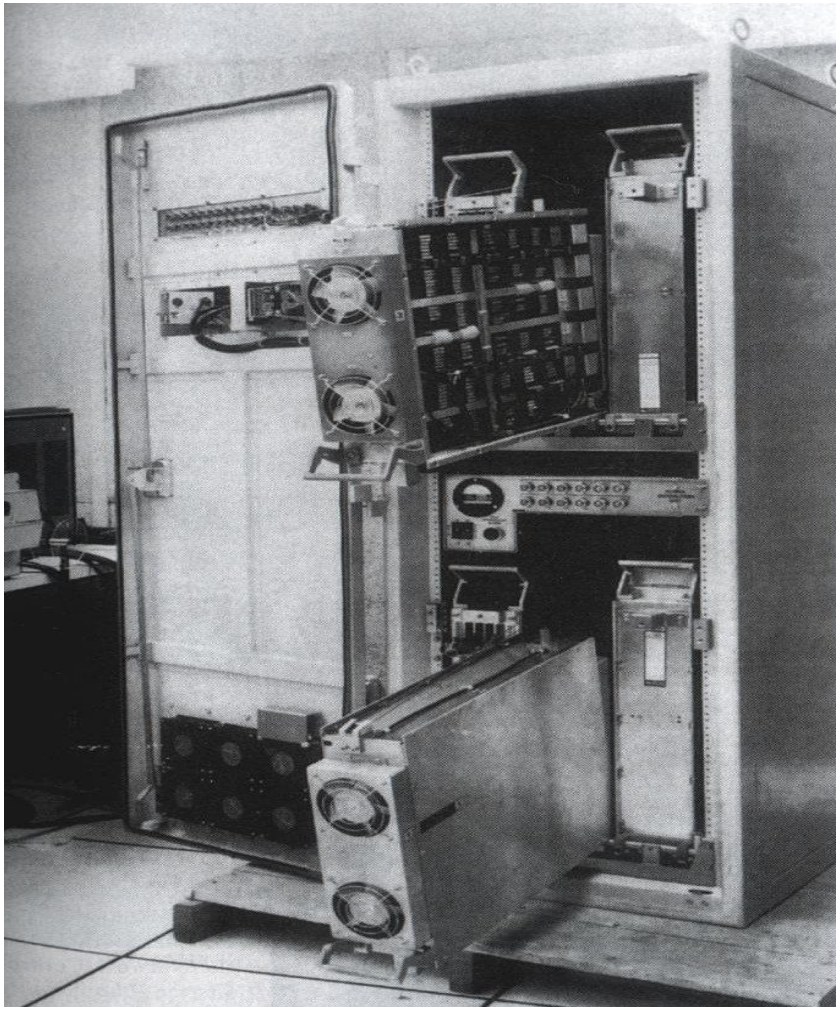
Each IMP is **connected** with (at least) **2** IMPs

A host is connected to an IMP – it sends to it a message that is split into packets (1008 bits) forwarded independently to destination

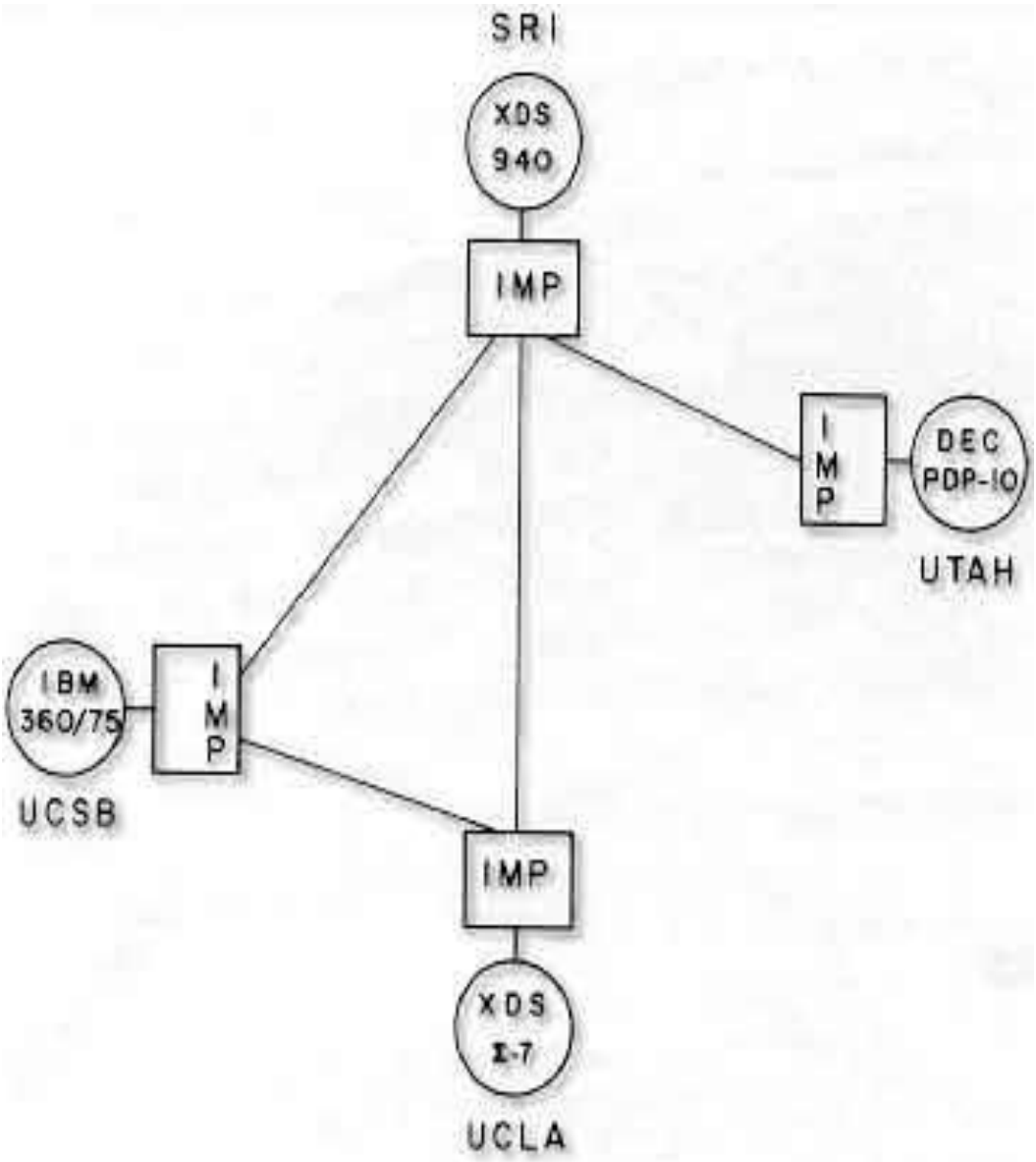

Host-host protocol
Host
Host-IMP
protocol
Source IMP to destination IMP protocol
IMP-IMP protocol
IMP-IMP
protocol
Subnet
IMP

1969: First Connections

- 29/10/1969 – First packets sent; Charlie Kline attempted use of remote login from UCLA to SRI



ARPANET



1969: At UCLA Kleinrock attempted the first ever remote login at Stanford:

"We set up a telephone connection between us and the guys at SRI...," Kleinrock said in an interview: "We typed the L and we asked on the phone,

"Do you see the L?"

"Yes, we see the L," came the response.

"We typed the O, and we asked, "Do you see the O."

"Yes, we see the O."

"Then we typed the G, and the system crashed"...

1967-1971: So what do we do with it?

1967-1972 – Vint Cerf, graduate student in Kleinrock's lab, worked on application level protocols for the ARPANET (file transfer and Telnet protocols)

1971 - Ray Tomlinson of BBN wrote email application; derived from two existing: an intra-machine email program (SENDMSG) and an experimental file transfer program (CPYNET)

Networks Growing

1970 - First cross-country link installed by AT&T between UCLA and BBN at 56kbps

1972-1974 – Robert Kahn and Vint Cerf developed protocols to connect networks without any knowledge of the topology or specific characteristics of the underlying nets

NCP, first host-to-host protocol, enables network applications

1972 – Robert Kahn gave first public demonstration of ARPAnet (now 15 nodes) at International Conference on Computer Communication

Networks Growing

First computer to computer chat took place between Stanford and BBN

1972: Telnet protocol RFC published

1973: FTP protocol RFC published

1973-75 – Ethernet was designed in 1973 by Bob Metcalfe at Xerox Palo Alto Research Center (PARC)

Bob Metcalfe's doctoral dissertation led to the Ethernet protocol

Dissertation initially rejected by Harvard for not being analytical enough, but won acceptance when a few more equations were added!

Proprietary Networks

ARPANET was a standalone network.

Other proprietary, standalone networks were created in the 70s:

ALOHANET: Linking Hawaiian universities, using microwave as transmission medium

Telenet: by BBN, commercial

Cyclades: French packet switching network

Number of networks was growing!

At DARPA, Vinton Cerf and Robert Kahn were working on an architecture to create a "*network of networks*" - *internetting!*

"Internetting" principles

Decentralized control

Stateless routers

Autonomy - networks should be independent, require no modification to participate in the Internet

Best Effort Service Model - Packets would be routed through the fastest available route

- In a best effort network , packets are treated in the same fashion.
- The network undertakes its "best effort" to deliver every packet as quickly as it can.

1974-1978: Development of TCP/IP

- 1974 – First full draft of TCP produced
- November 1977 - First three-network TCP/IP based interconnection demonstrated linking SATNET, PRNET and ARPANET in a path leading from
  - Menlo Park, CA to
  - Univ. College London and back to
  - USC/ISI (Marina del Ray, CA)
- 1978 – TCP split into TCP and IP

1981 -1984: Base Protocols In Place

- 1981 – Term "Internet" coined to mean collection of interconnected networks
- 1982 – ISO releases OSI seven layer model; actual protocols die but model is influential
- 1/1/1983 – Original ARPANET NCP was banned from the ARPANET and TCP/IP was required

TCP and UDP

Early versions had in sequence delivery (transport layer) combined with forwarding (network layer)

It was soon apparent that unreliable, non-flow controlled service was important, e.g. packetized voice

This led to separation of TCP and IP and creation of the UDP protocol.

1983-1986: Not Just a Research Project Anymore

- 1983 – ARPANET split into ARPANET and MILNET;
  - MILNET to carry defense related traffic
- 1984 – Domain Name System introduced;
  - 1000+ hosts (200 hosts by end of 1970s; over 100,000 by end of 1980s)
- 1986 – NSFNET was created to provide access to 5 super computer centers including Theory Center at Cornell (NSFNET backbone speeds 56 Kbps)

1988-1989: Growing Pains?

- 1988 - Nodes on Internet began to double every year
- November 1988 – Internet worm affecting about 10% of the 60,000 computers on the Internet (Robert Morris, Cornell)
- 1988 - Internet Assigned Numbers Authority (IANA) established in December

1990-1993: WWW Explosion

1990 – ARPANET ceased to exist

1990 – Tim Berners-Lee developed hypertext system with initial versions of HTML and HTTP and first GUI web browser called "WorldWideWeb"

1993 – Mosaic, a GUI web browser, written by Marc Andreessen and Eric Bina at NCSA took world by storm (showed in-line images and was easy to install);

WWW proliferated at a 341,634% annual growth rate of service traffic

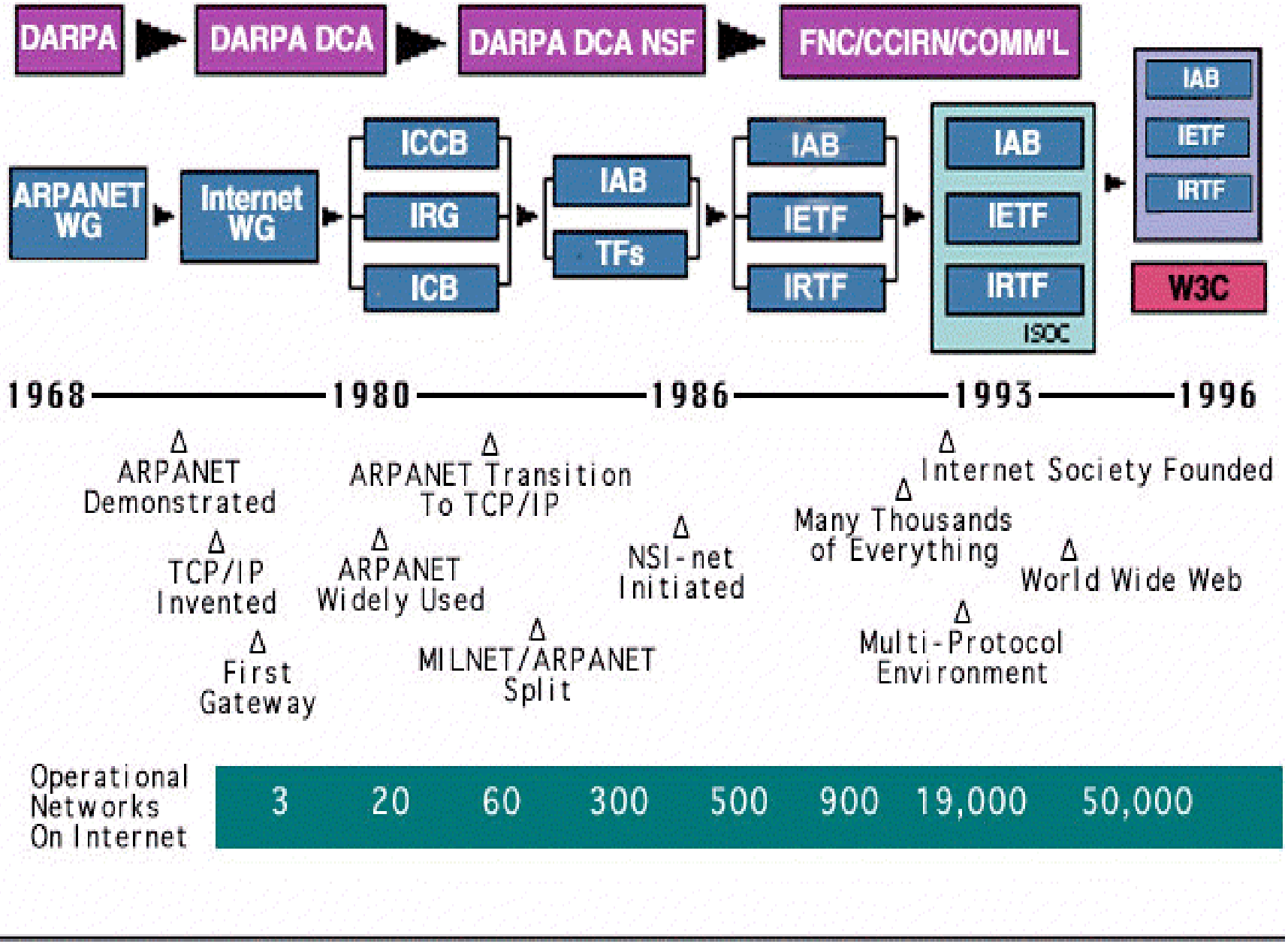
1990-1993: WWW Explosion

1990 – First ISP world.std.com

1991 – NSFNET lifted restrictions on use of NSFNET for commercial purposes

1992 – Internet Society founded

- NSFNET began to serve as backbone, linking regional networks in US and networks abroad
- NSFNET was decommissioned in 1995, most Internet backbone traffic carried by commercial ISPs
- Increased commercialization, advent of WWW, all lead to explosion of growth


DARPA
DARPA DCA
DARPA DCA NSF
FNC/CCIRN/COMM'L
ARPANET WG
Internet WG
ICCB
IRG
ICB
IAB
TFs
IAB
IETF
IRTF
IAB
IETF
IRTF
ISOC
IAB
IETF
IRTF
W3C
1968
1980
1986
1993
1996
ARPANET Demonstrated
TCP/IP Invented
First Gateway
ARPANET Transition To TCP/IP
ARPANET Widely Used
MILNET/ARPANET Split
NSI-net Initiated
Internet Society Founded
Many Thousands of Everything
World Wide Web
Multi-Protocol Environment
Operational Networks On Internet
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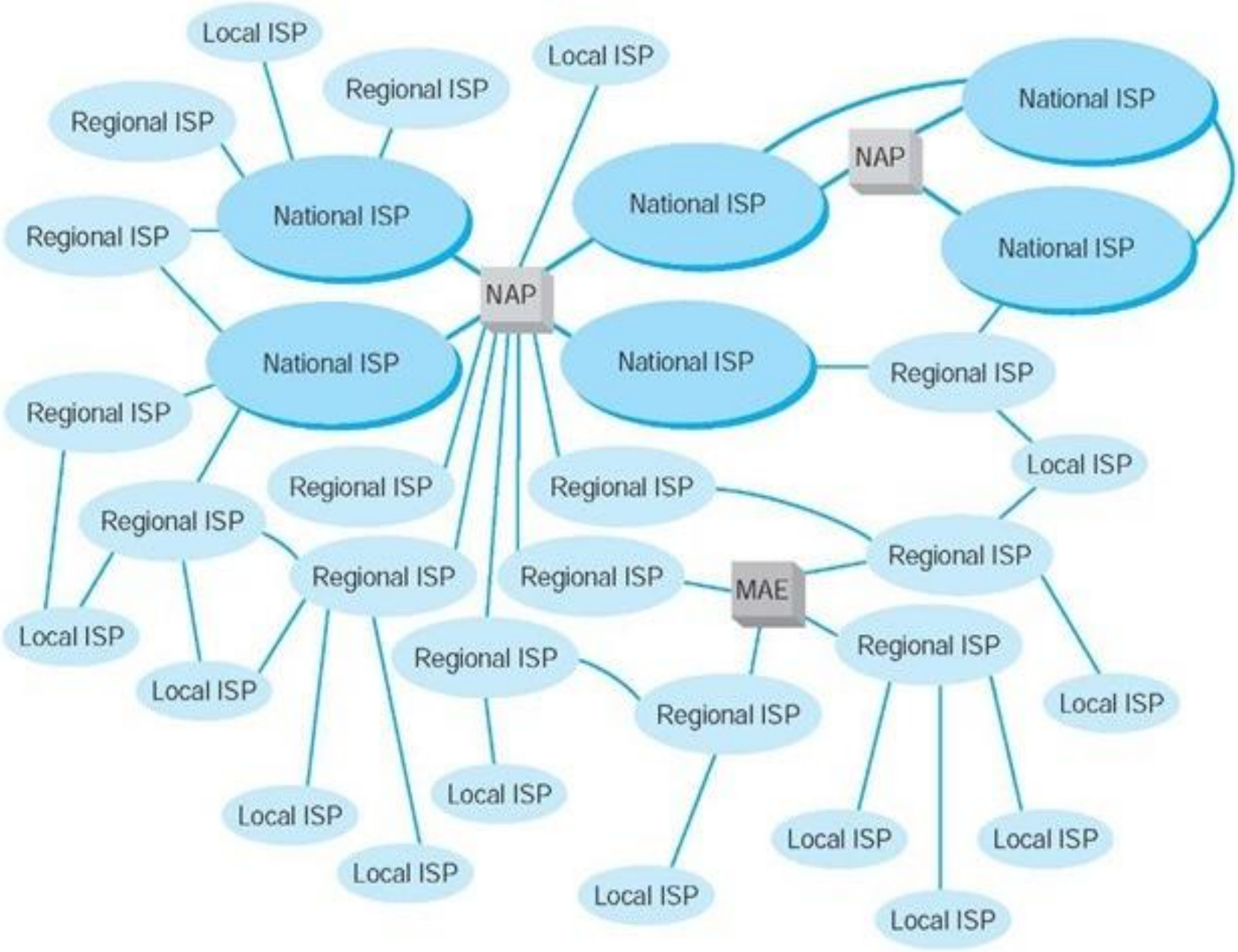
20
60
300
500
900
19,000
50,000


Local ISP
Regional ISP
Local ISP
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National ISP
NAP
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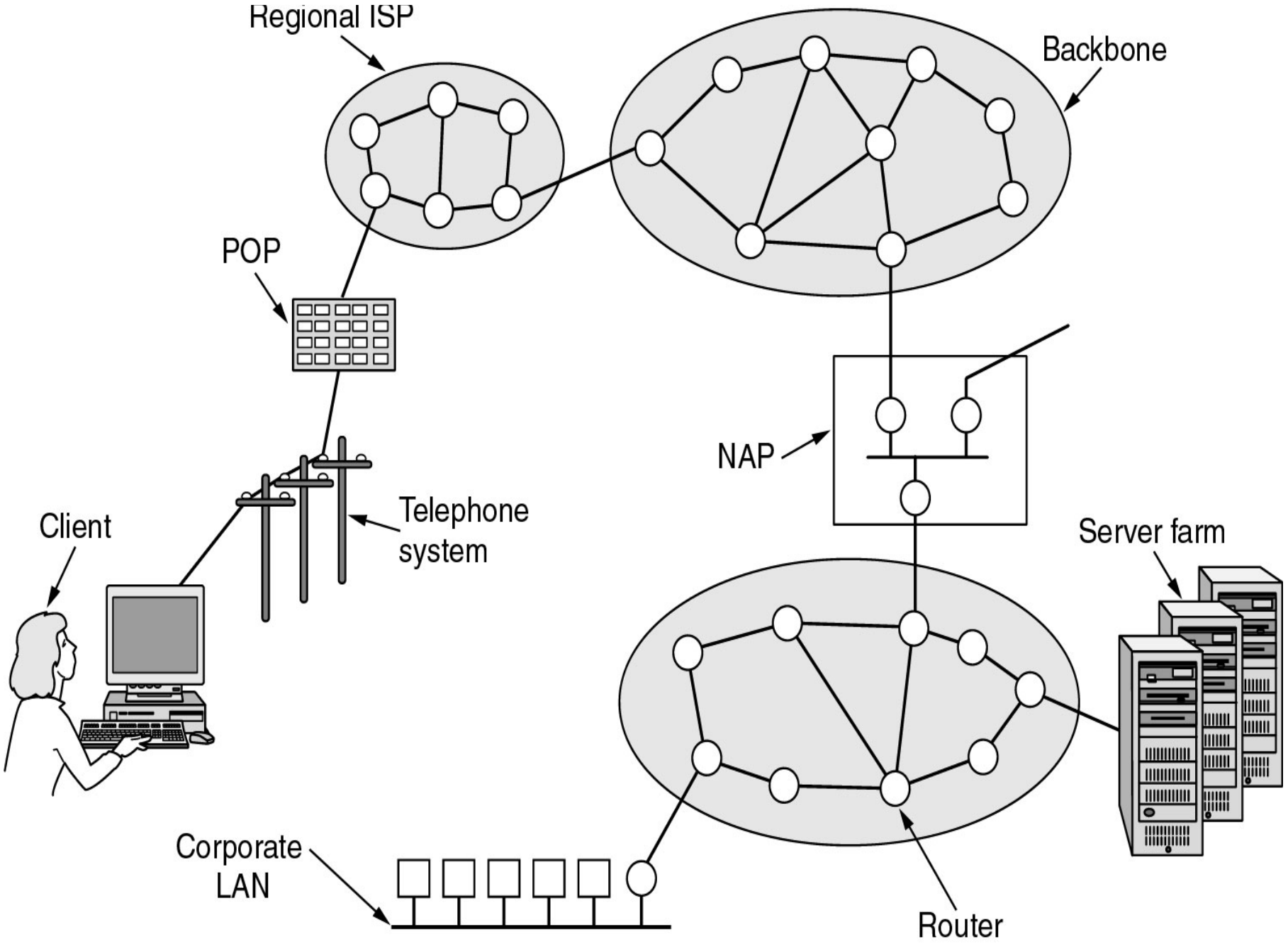

Regional ISP
Backbone
POP
NAP
Client
Telephone system
Server farm
Corporate LAN
Router

Important Terms

ISP (Internet Service Provider): business or organization that provides consumers or businesses access to the Internet and related services

NAP (Network Access Point): Historically, 4 Network access points where a packet switches from one backbone to another.

Now replaced with **Internet Exchange Points** or **IXPs**

(physical infrastructures through which Internet service providers (ISPs) exchange Internet traffic between their networks)

MAEs (metropolitan area exchange) are

Important Terms

POP (Point of Presence): an access point to the Internet. It is a physical location that houses servers, routers, ATM switches and digital/analog call aggregators

Backbone: a large collection of interconnected commercial, government, academic and other high capacity data; routes and core routers that carry data across the countries, continents and oceans of the world

Internet service providers (ISPs)

Local ISPs- Tier 3 (cablevision)

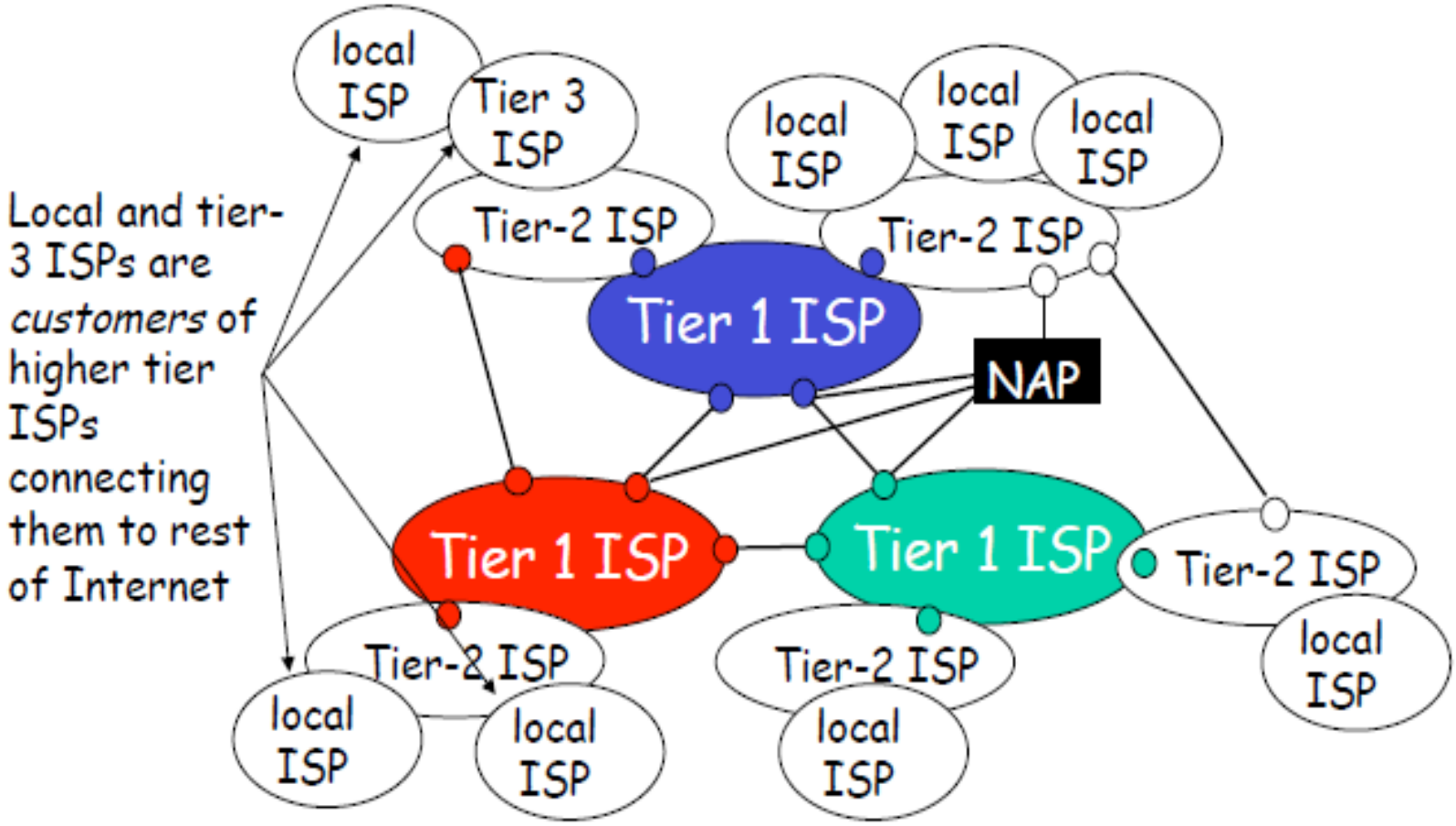
Regional ISPs – Tier2 (Bharti Airtel, Reliance Globalcom)

Global ISPs (verizon, Sprint, ATT, Tata Communications, Deutsche Telekom) provide access to entire internet; connect ISP to other ISPs – Tier 1

Peering ISPs – Have a mutual relationship about forwarding traffic of each other's customers (no $ involved)

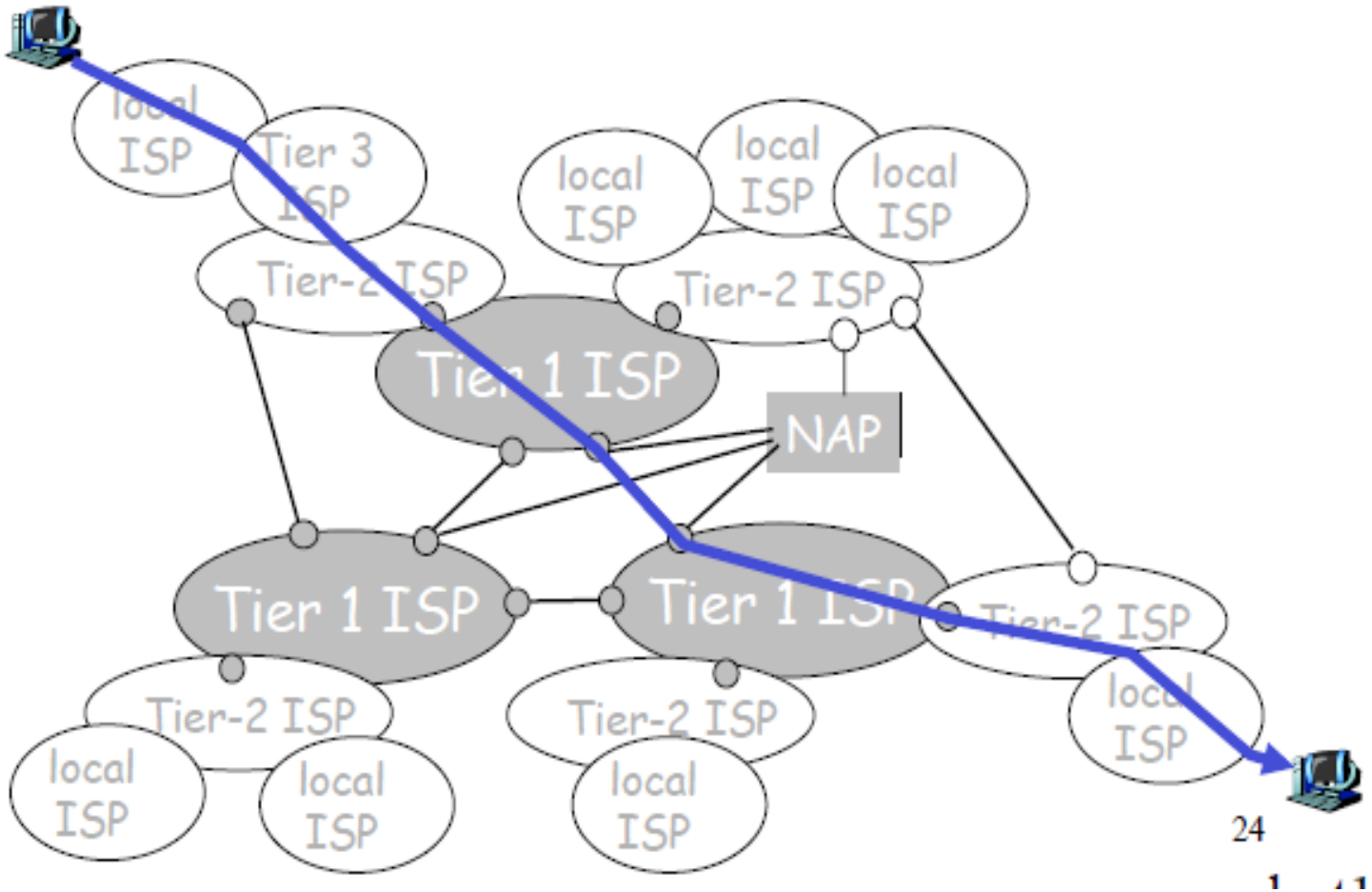
Transit ISPs – Provides access to all reachable customers ($$ involved)

Core Networks: ISP Tiers



Core Networks: ISP Tiers

- a packet passes through many networks!



Who owns the Internet?

Nobody

The Internet has global reach and integrity, and is not constrained in terms of supported services and applications

The Internet is for everyone there is no central authority that designates or permits different classes of Internet activities

The Internet requires some basic agreements and social behavior between technologies and between human

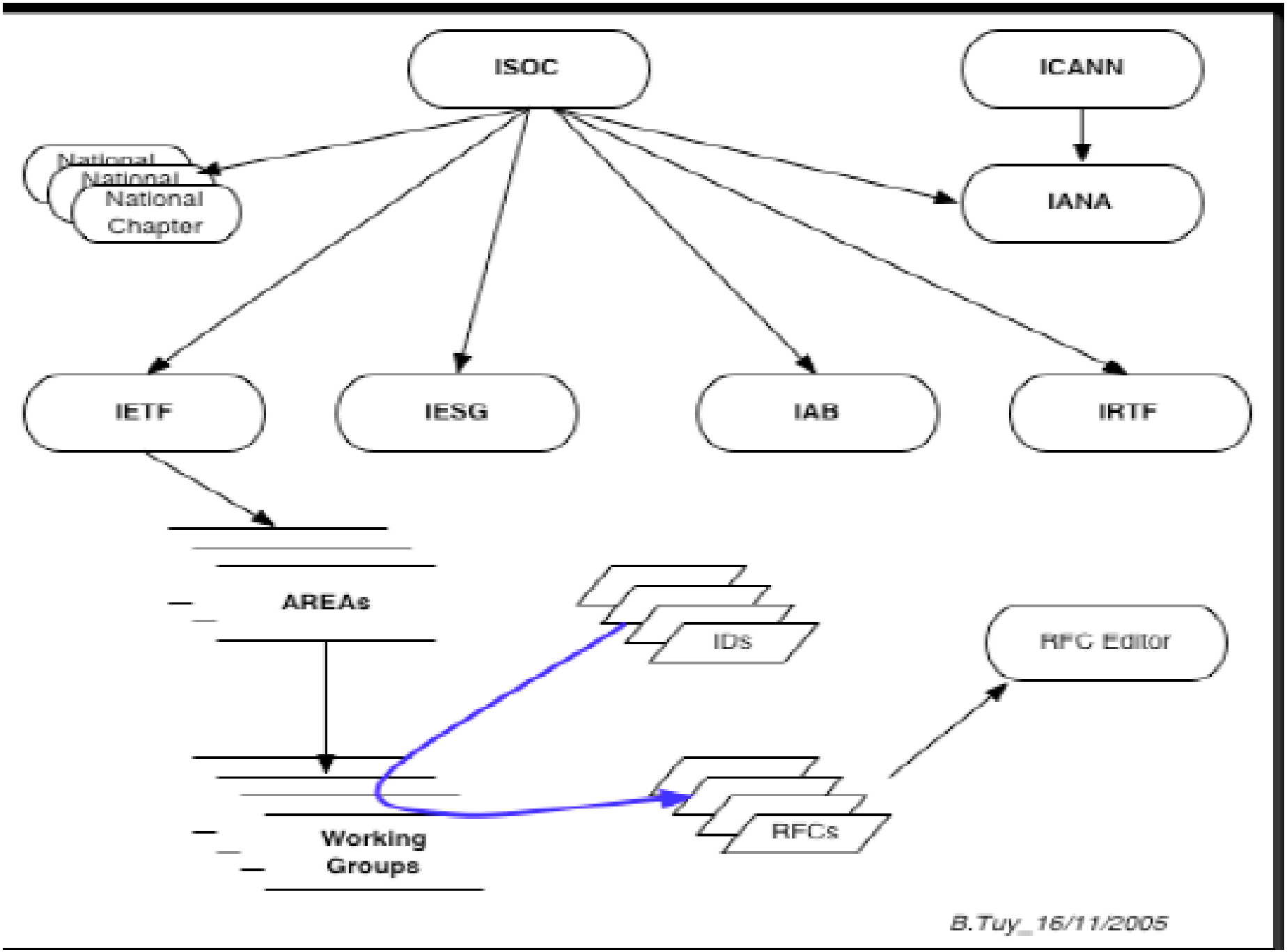
Although no specific technology defines the Internet, there are some basic characteristics that describe what works

And, finally, the more the Internet stays the same, the more it changes

Who owns the Internet?

Why organizations / bodies are needed?

- Define protocol specifications
- Agree on a process for standards
- Specify the rules of the IP resources allocation


ISOC
ICANN
National
National
National
Chapter
IANA
IETF
IESG
IAB
IRTF
AREAs
IDs
RFC Editor
RFCs
Working
Groups
B.Tuy_16/11/2005

Who controls the Internet

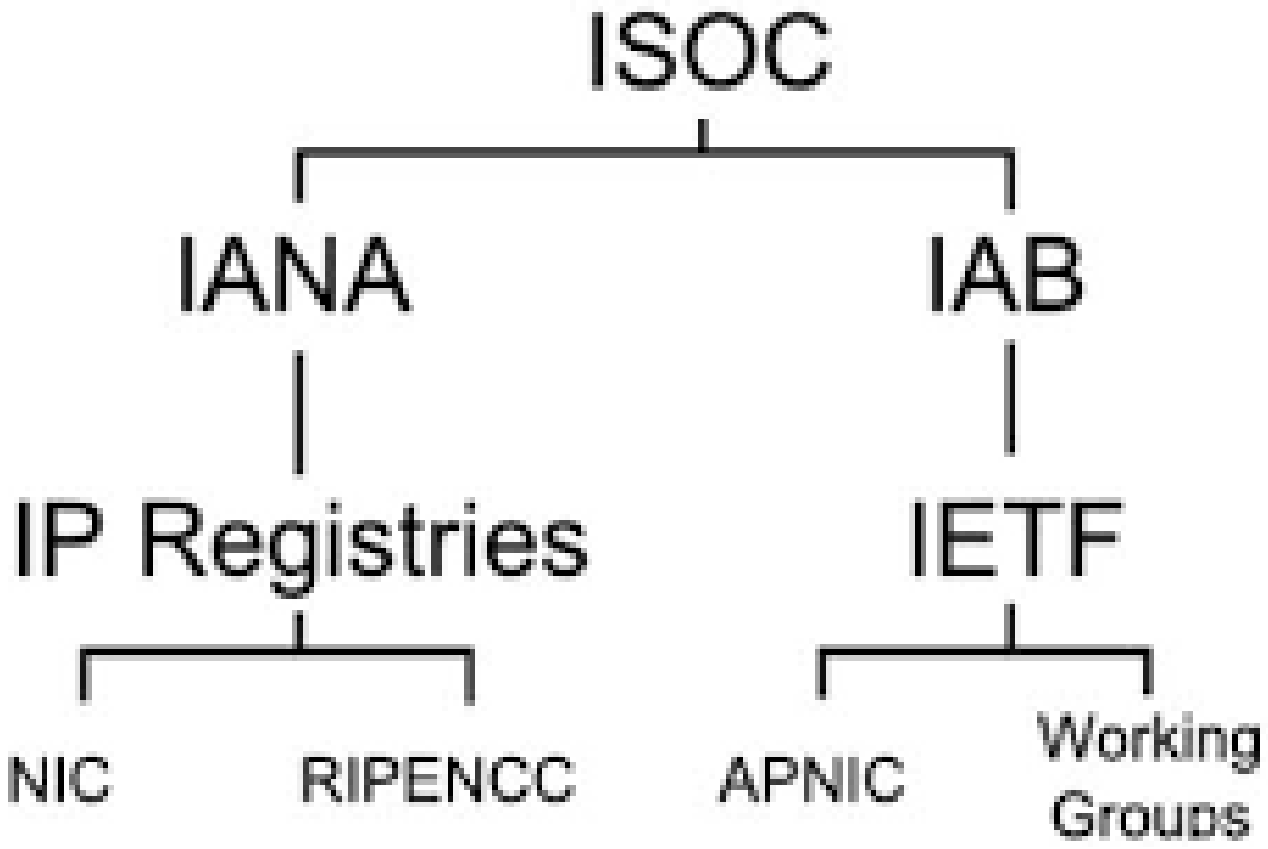
Internet Corporation for Assigned Names and Numbers (ICANN), based in Marina Del Rey, California

- regulates online addresses (domain names), and their suffixes, such as ".com" and ".org"
- reports to the US government's Department of Commerce
- Any changes carried out at the "top" level – (e.g. adding new country-level suffixes) have to be checked by the US Department of Commerce
- the actual implementation of the change is carried out by Verisign, a US-based private company that manages the root name database, which contains the full official list of recognised suffixes.

Who controls the Internet

The Internet Society (ISoc) is an international, non-profit organization founded in 1992 to provide leadership in Internet related standards, education, and policy

- Headquarters in Reston, Virginia, United States and offices in Geneva, Switzerland.
- membership base of more than 130 organizations and more than 55,000 individual members.


ISOC
IANA
IAB
IP Registries
IETF
NIC
RIPENCC
APNIC
Working Groups

Who controls the Internet

The Internet Society is the parent corporation of the Internet Engineering Task Force (IETF)

- IETF develops and promotes voluntary Internet standards, in particular the standards that comprise the Internet protocol suite (TCP/IP)
- It is an open standards organization
- All IETF Request for Comments documents, including those RFCs which describe "Internet Standards", are copyrighted by the Internet Society

Who controls the Internet

The Internet Engineering Steering Group (IESG) is a body composed of the IETF chair and area directors

It provides the final technical review of Internet standards and is responsible for day-to-day management of the IETF

Members of the IESG include directors of the following areas:

Applications Area (app)

Internet Area (int)

Operations & Network Management Area (ops)

Routing Area (rtg)

Real-time Applications and Infrastructure Area (rai)

Security Area (sec)

Transport and Services Area (tsv) - frequently also referred to as the "Transport Area"

Who controls the Internet

The Internet Architecture Board (IAB) is the committee charged with oversight of the technical and engineering development of the Internet by the Internet Society (Isoc)

Responsibilities of IAB

Architectural Oversight: aspects of the architecture for the network protocols and procedures used by the Internet.

Who controls the Internet

Responsibilities of IAB

Standards Process Oversight and Appeal: the process used to create Internet Standards. The IAB serves as an appeal board for complaints of improper execution of the standards process

Request for Comments series: The IAB is responsible for editorial management and publication of the Request for Comments (RFC) document series.

Who controls the Internet

Responsibilities of IAB

Internet Assigned Numbers Authority: In conjunction with the Internet Corporation for Assigned Names and Numbers (ICANN), the IAB is responsible for administration of the assignment of IETF protocol parameter values by the Internet Assigned Numbers Authority (IANA).

Who controls the Internet

Responsibilities of IAB

Advice to the Internet Society: The IAB acts as a source of advice and guidance to the Board of Trustees and Officers of ISOC concerning technical, architectural, procedural, and (where appropriate) policy matters pertaining to the Internet and its enabling technologies.

Who controls the Internet

Responsibilities of IAB

Internet Engineering Steering Group Confirmation: The IAB confirms the IETF Chair and IESG Area Directors

Internet Research Task Force Chair: The IAB selects a chair of the IRTF for a renewable two year term..

How to Make the Internet a Lot Faster

Feb. 2010 - Google announced its plans to build an experimental fiber network that would offer **gigabit-per-second** broadband speeds to U.S. homes

This will make possible: transfer of very large files, streaming high-definition (and possibly 3-D) video, video conferencing, and gaming

BUT the transmission control protocol (TCP), the 20-year-old algorithm that governs most of the traffic flow over the Internet, doesn't work well at gigabitper-second speeds

In order to make sure that it does not lose data, it uses too little of the bandwidth available (Steven Low, Caltech).