The Abdus Salam International Centre for Theoretical Physics

SCHOOL ON RADIO USE FOR DIGITAL AND MULTIMEDIA COMMUNICATIONS
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IP Technology: History, Current State, Prospective

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IP-Technology: History, Current State, Prospective

1. Brief History of the Internet
2. IP Traffic
3. What is IP Technology?
4. What is INTERNET?
5. How Does IP Work?
6. Why use IP?
7. Key Factors of Internet Evolution
8. New Version IP - IPv6
9. Quality of Service (QoS) in INTERNET
10. IP Telephony

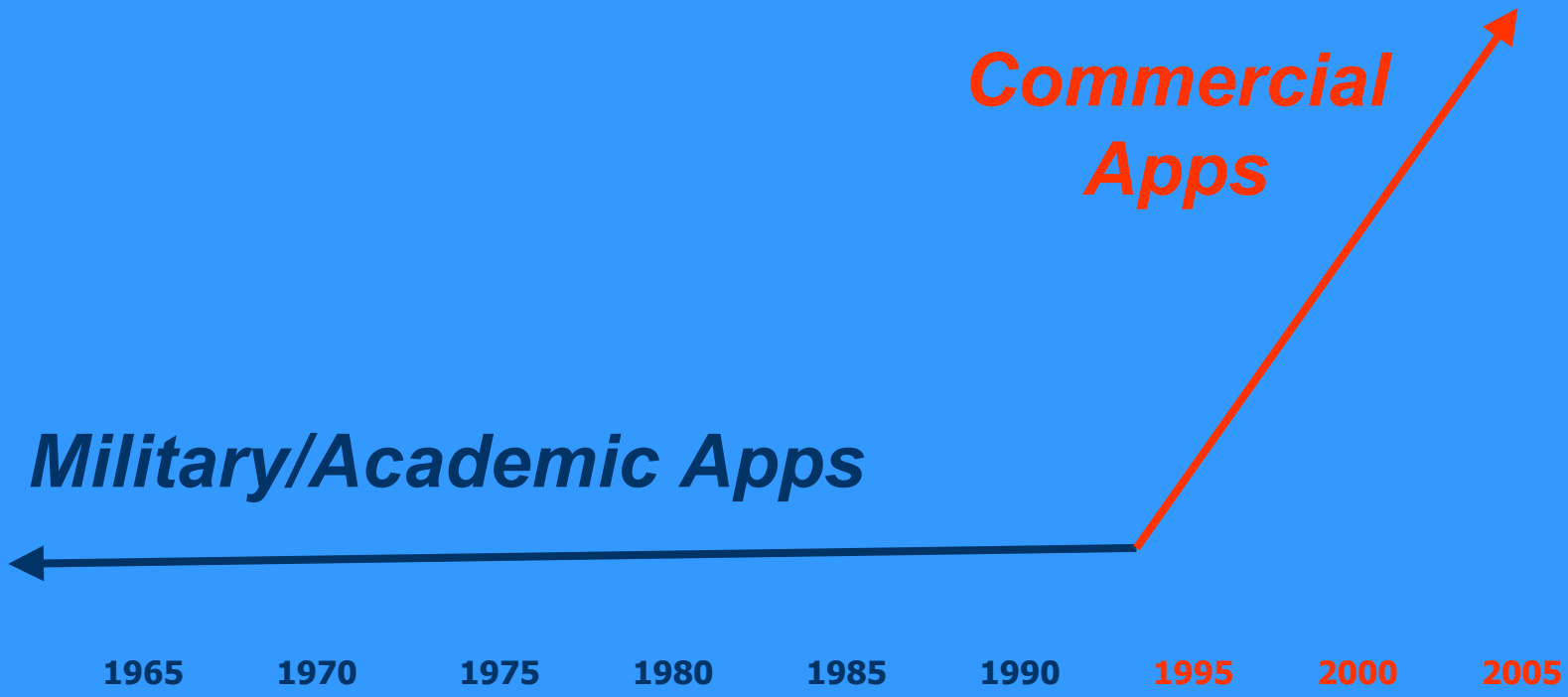
1. Brief History of the Internet

- **1957** – Launch of Sputnic is impetus for U.S. to form ARPA (DoD)
- **1965** – ARPA sponsors a study "Cooperative network for time-sharing"; Innovation of packet switching (*D. Devis*, UK, *P. Baran*, US)
- **1969** – September 2, launch of first computer network ARPANET
- **1972** – Beginning of E-mail (*Tomlinson*, US)
- **1974** – First article about TCP/IP (*Cerf/Kahn*)
- **1979** – Establishing first research computer network (NSF, Univ. Wisc., DARPA)

Continued…

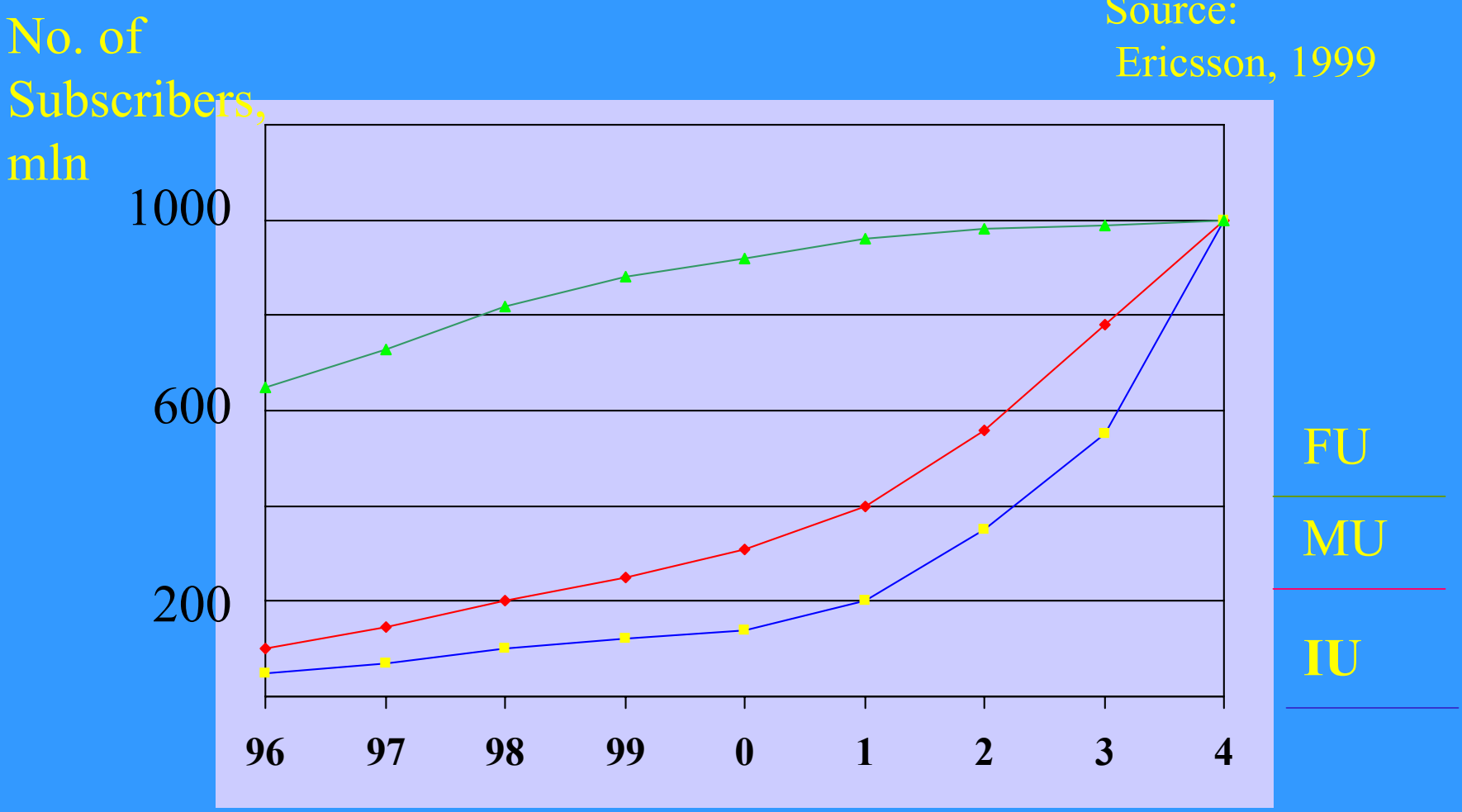
- **1982** – Internet defined as TCP/IP-connected networks
- **1986** – 56 kb/s NSFNET created for 5 supercomputing centers
- **1989** – Number of Internet nodes breaks 100 000; IETF comes into existence
- **1992** – WWW released; Number of nodes breaks 1M
- **1995** – Internet Society was founded VoIP comes to the market
- **2000** – Number of hosts breaks 300M
- **2002** – VoIP has taken away 13% of long-haul telephone traffic

The Internet Timeline



Forecast of Subscribers' Number in Telephone Fixed and Mobile Networks and in Internet

Source:
Ericsson, 1999



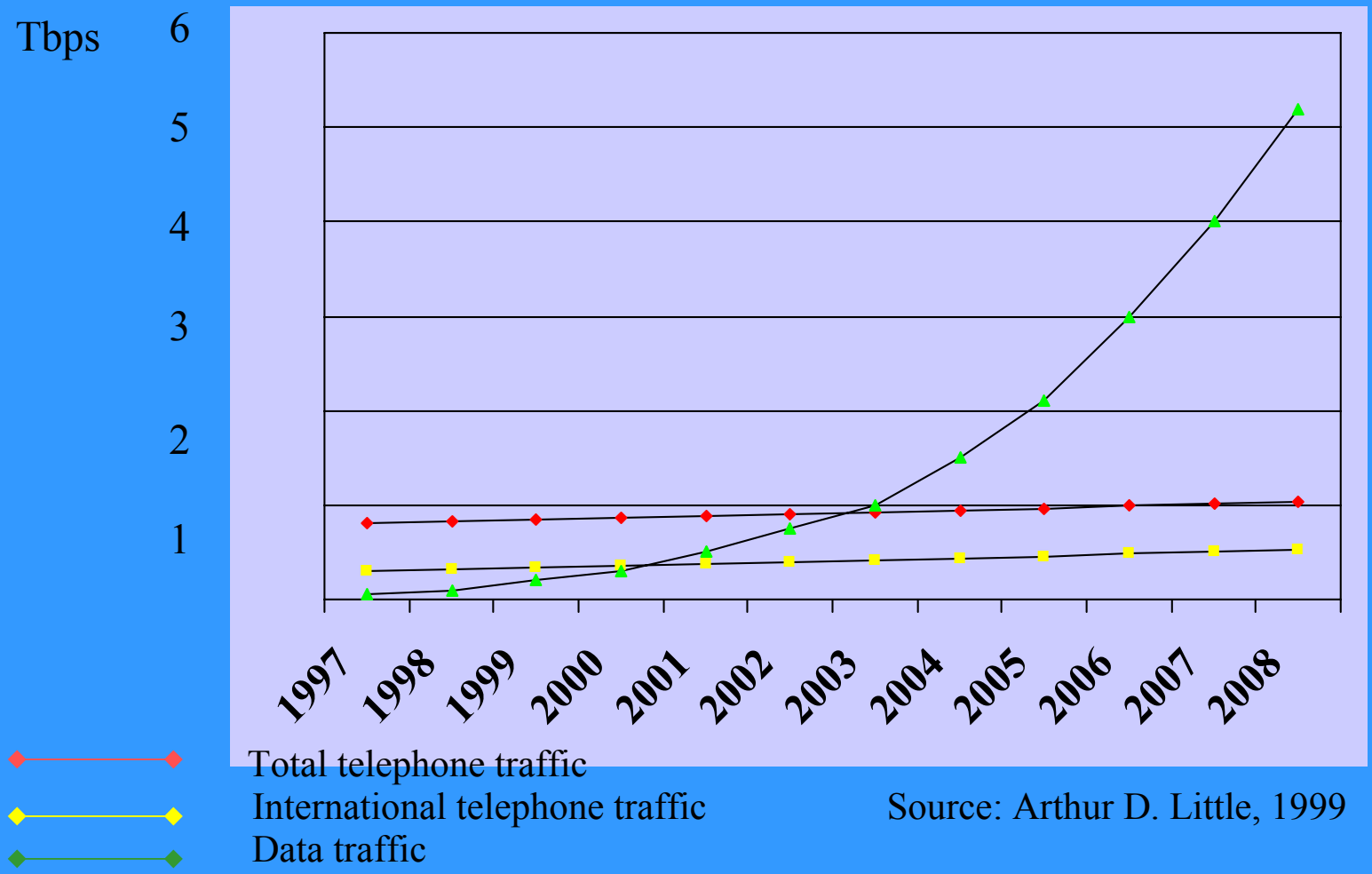
Penetration (in %%) of Different Technologies and Devices

	Internet penetration	PC penetration	Mobile penetration	Broadband Penetration
USA	36	50-60	40	5-10
Europe	20	40	70	<< 5
Asia	17	<5	<30	<<<5

Source: Cisco, 2002

2. IP Traffic

Forecast of the global voice/data traffic's growth



Source: Arthur D. Little, 1999

U.S. Internet IP Traffic Growth

(Based on Report provided by
Lawrence G. Roberts, Chairman & CTO
and ***Cindy Crump***, Director Research,
Caspian Networks)

Following analysis represents the first real measurements of Internet traffic since 1996

Perceived Decline in Internet Growth

- Many analysts, equipment vendors maintain *Internet traffic has been declining*
  - Internet growth has "already begun a relentless process of slowing"
    – JP Morgan H&Q/McKinsey
  - "Internet traffic is down for the first time in history"
    – John Roth, Nortel Networks
  - Has the Net Stopped Growing? [feature article]
    – The Industry Standard

Why This Belief?

- IP service providers' capital shortage and margin shortfall
- Vendors report lower sales

Despite these points,

Caspian Networks'
measurements

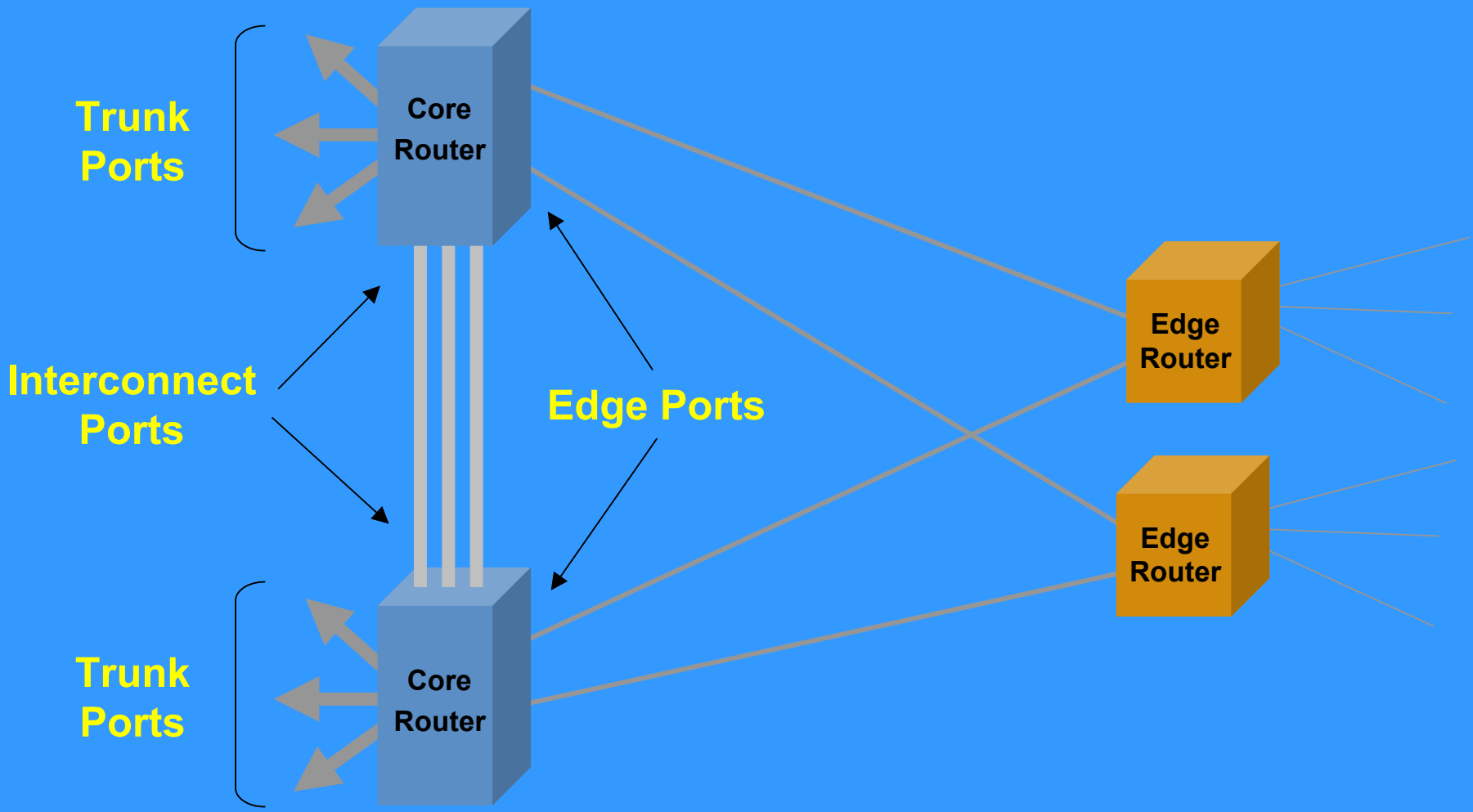
show that IP traffic growth is not slowing

IP Traffic Growing Faster Than Ever

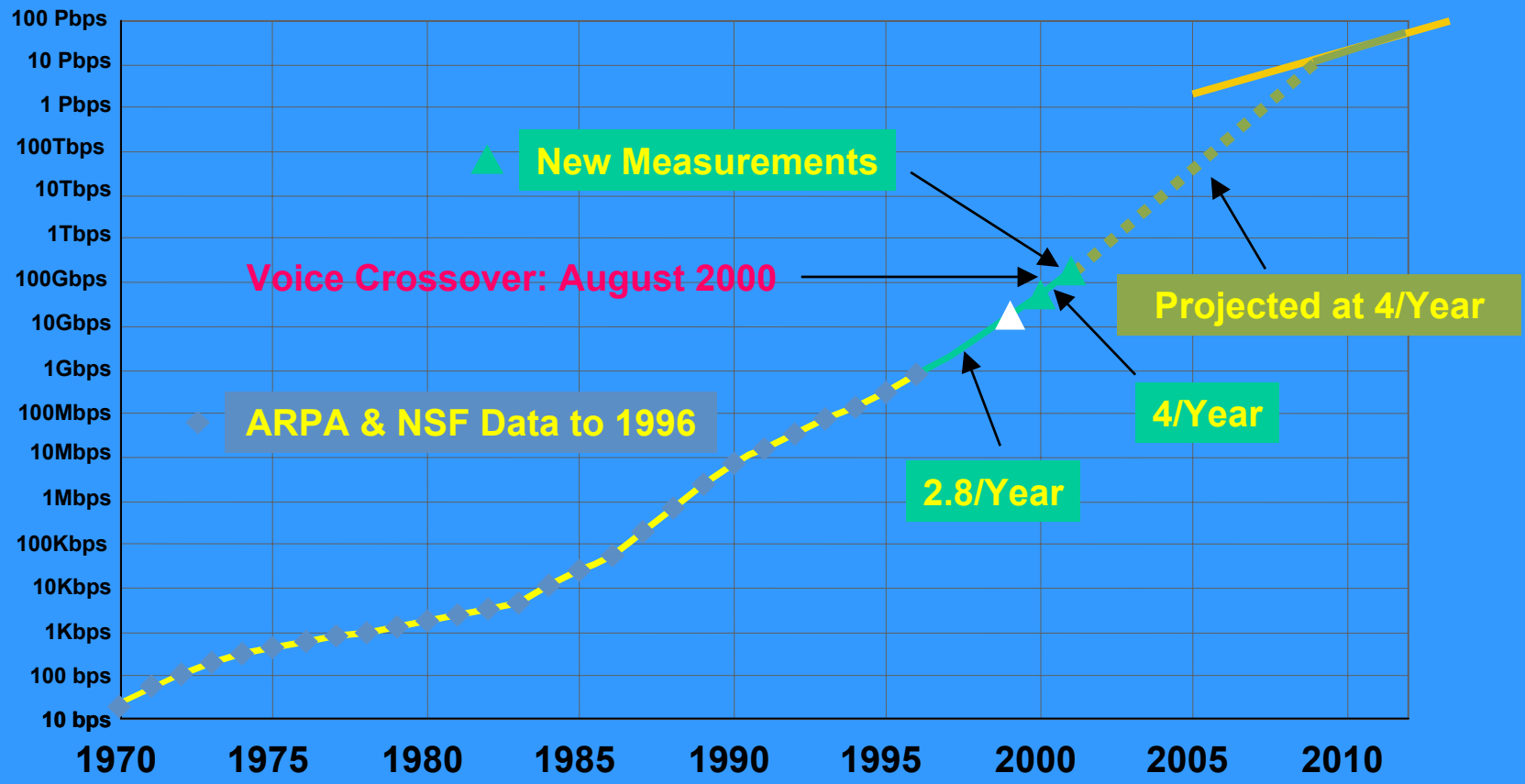
- **IP service providers:**
  - **Bought extra equipment in 2000**
  - **Are improving equipment utilization**
  - **Are fighting for market share**
    - **Will have to start buying again soon**
    - **Will buy equipment to keep up with traffic growth**

The following analysis represents the first real measurements of Internet traffic since 1996

IP Backbone Topology



Total U.S. Internet Traffic



Source: Roberts et al., 2001

Why Has The Growth Rate Increased?

- ***Most traffic is from corporations (80% estimated)***
  - **Main growth is from corporations**
  - **"Last mile" has been improving rapidly (100–1000 Mbps)**
  - **Corporate traffic is anti-recessionary**
    - **Move from private networks to Internet for cost reduction**

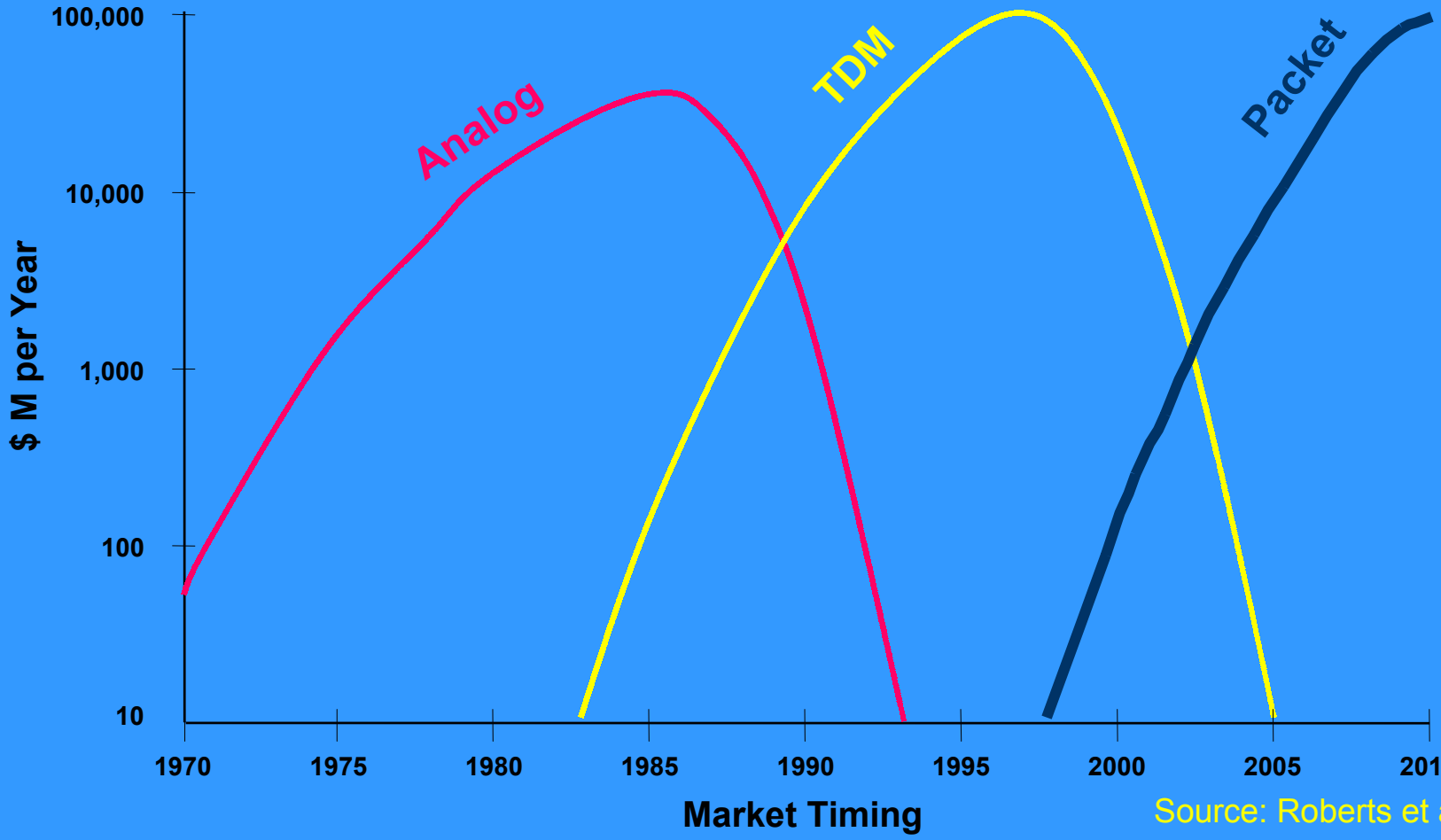
Continued...

- **Corporate Internet use hit critical mass in 2000**
  - **Now *need* to use the Internet for all business**
  - **Inter-corporate traffic is now mainly over the Internet**
  - **Intra-corporate traffic is growing in size (E-mail documents)**

- **Personal traffic is growing but *broadband deployment is slow***
- **Internationally, traffic is still at the pre-2000 growth rate of *2.8/year***

Communications Switching Equipment Market

Switching equipment sales must grow with IP traffic



Source: Roberts et al., 2001

Equipment price decreased 37%/year

Traffic measurements: Concluding remarks

- Internet traffic growth rate increased from 2.8 to 4 per year in 2000
  - Traffic over measured period doubled every 6 months
- Internet traffic continued to grow at 4 per year through Q1 2001
- The main traffic source, corporate traffic, is anti-recessionary

Continued…

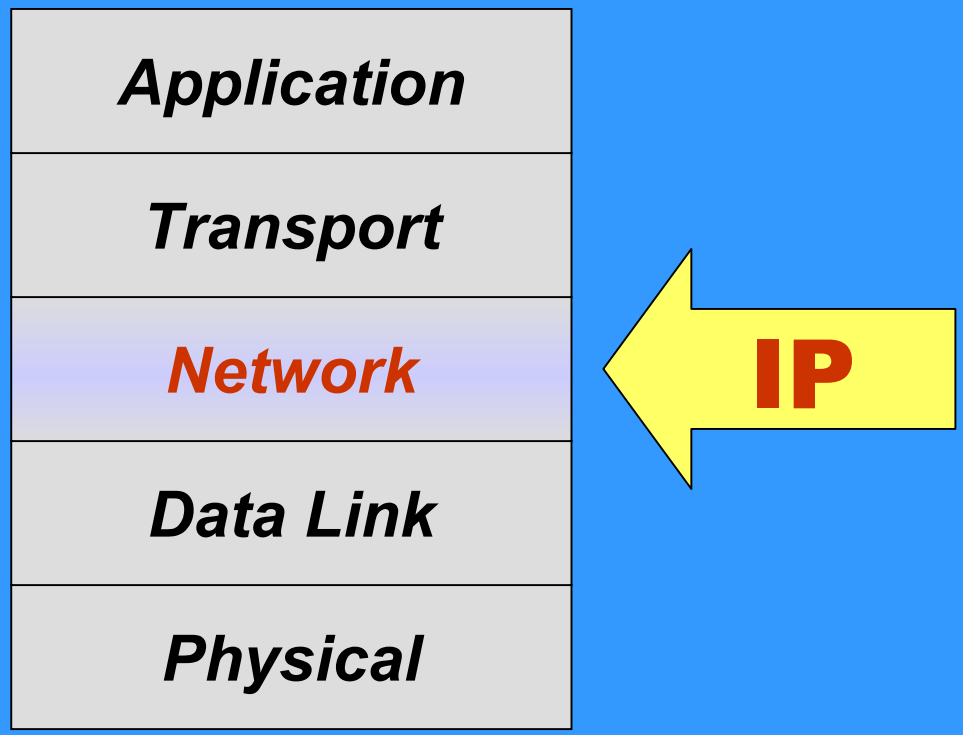
Traffic measurements: Concluding remarks

- Service providers have serious problems
  - They can only avoid equipment purchases for a short period
  - They must buy equipment soon to hold market share
- Assuming traffic keeps doubling every 6 months:
  - Optical and IP switching equipment purchases must also grow at 4x
  - If IP service prices continue to fall at 2x, service provider's IP revenue will grow at 2x and IP service revenue will then exceed voice revenue in about 2–3 years

3. What is IP Technology?

(Position of IP Among Other Forwarding Techniques)

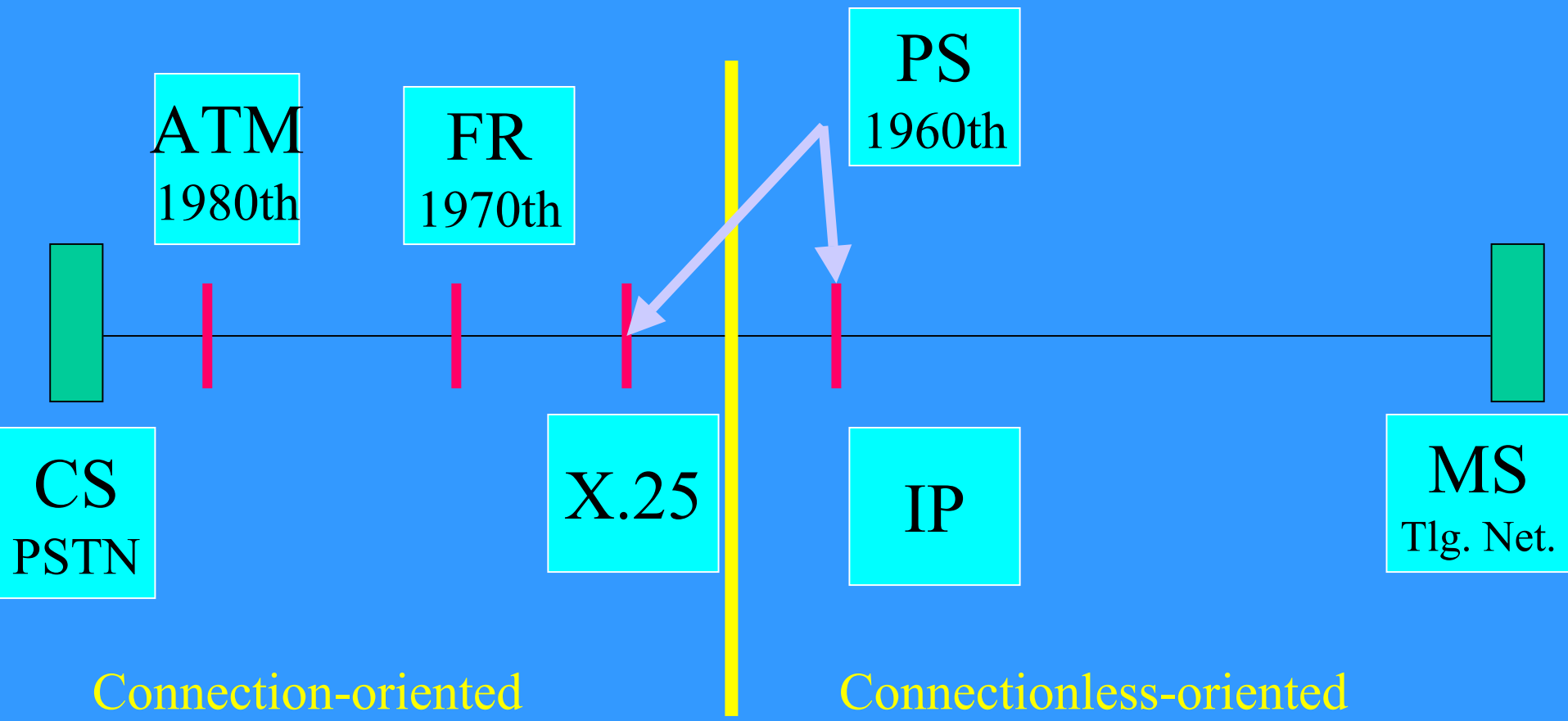
3.1. IP - Internet Protocol and the IETF Model



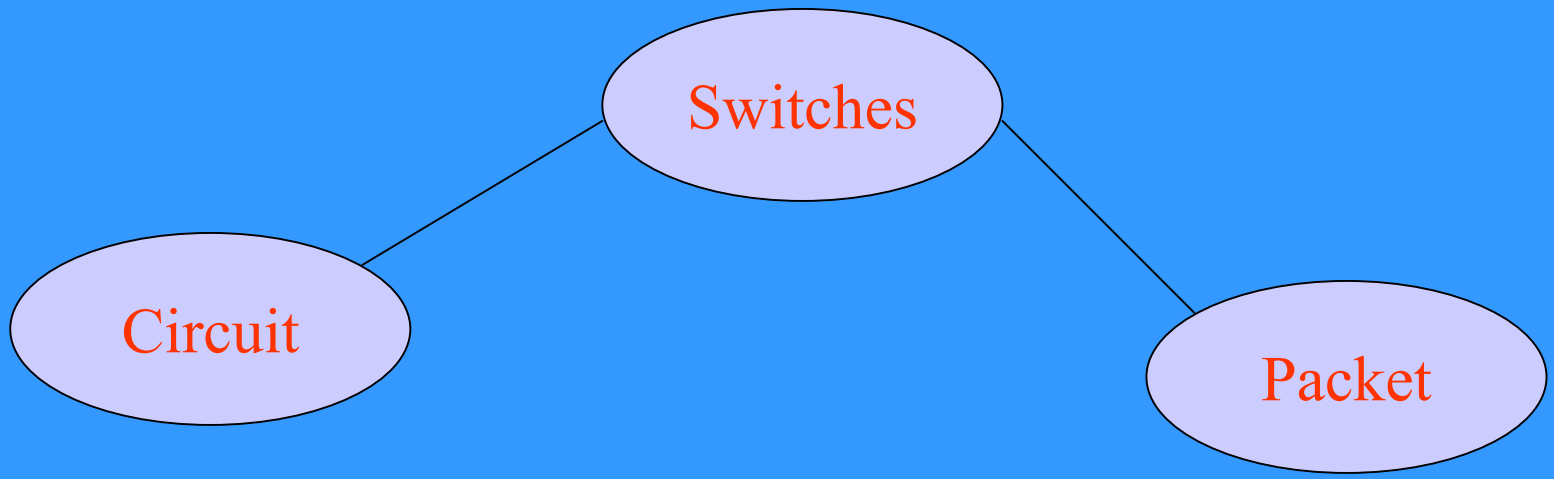
Definition of Internet Protocol

- *Network Layer Protocol (Layer 3)*
- *Protocol Data Unit (PDU) is Packet*
- *End-to-End Addressing (Source and Destination)*
- *Connectionless-oriented Protocol*
- *"Best Effort" Service – Provides unreliable packet delivery services*

Switching Technologies



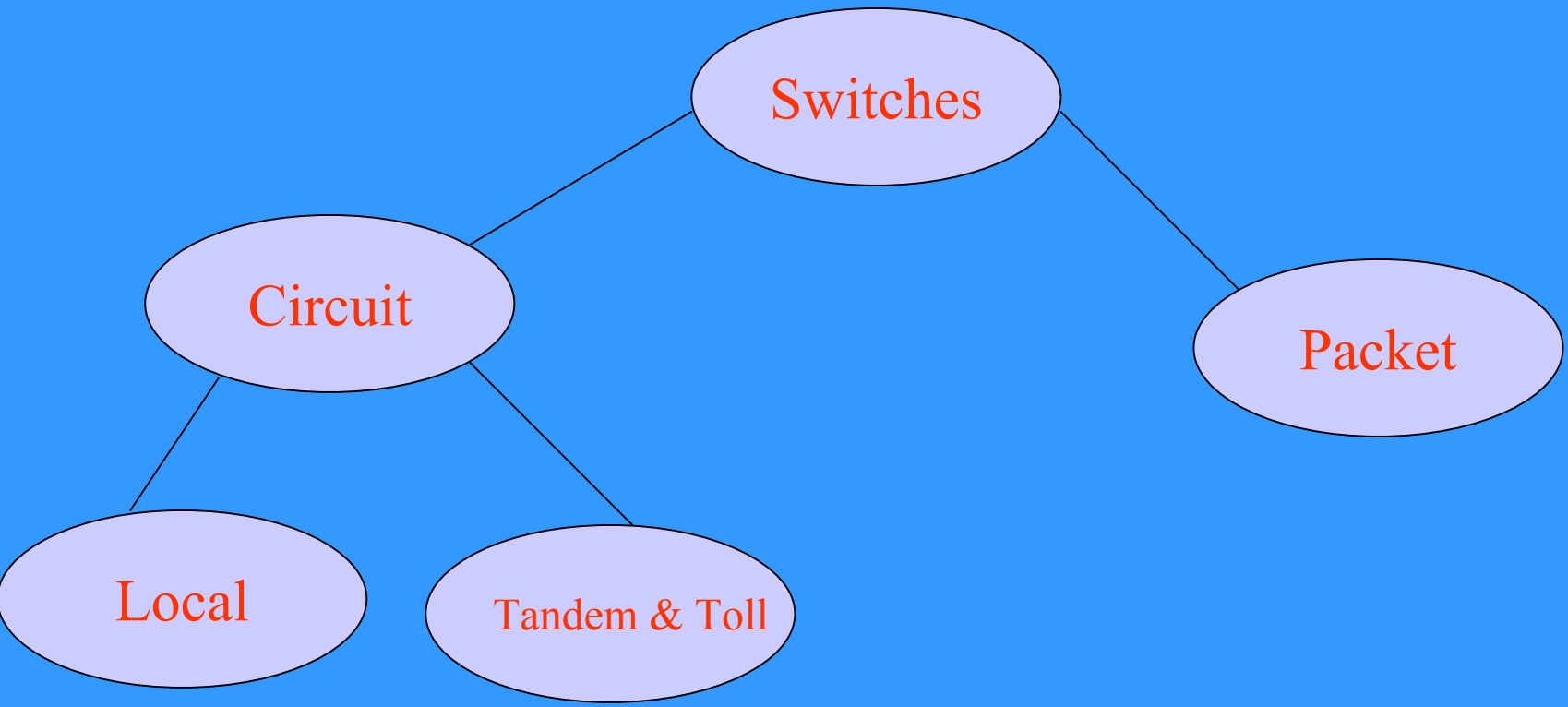
What is the "Switch"



Two Main Classes

Source: Telecommunications Research Association, TRA, 2000

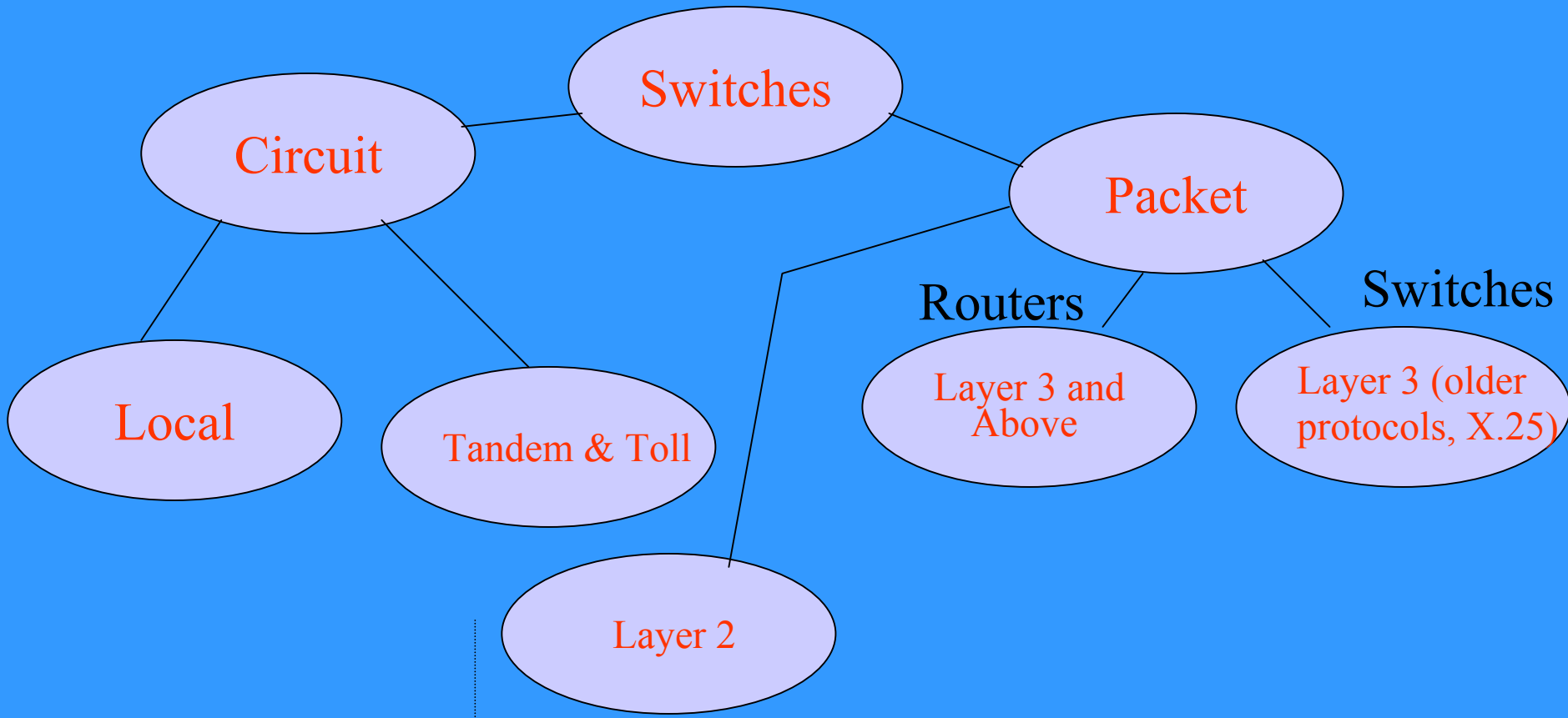
What is the "Switch"



Samples of Circuit Switches

Source: TRA, 2000

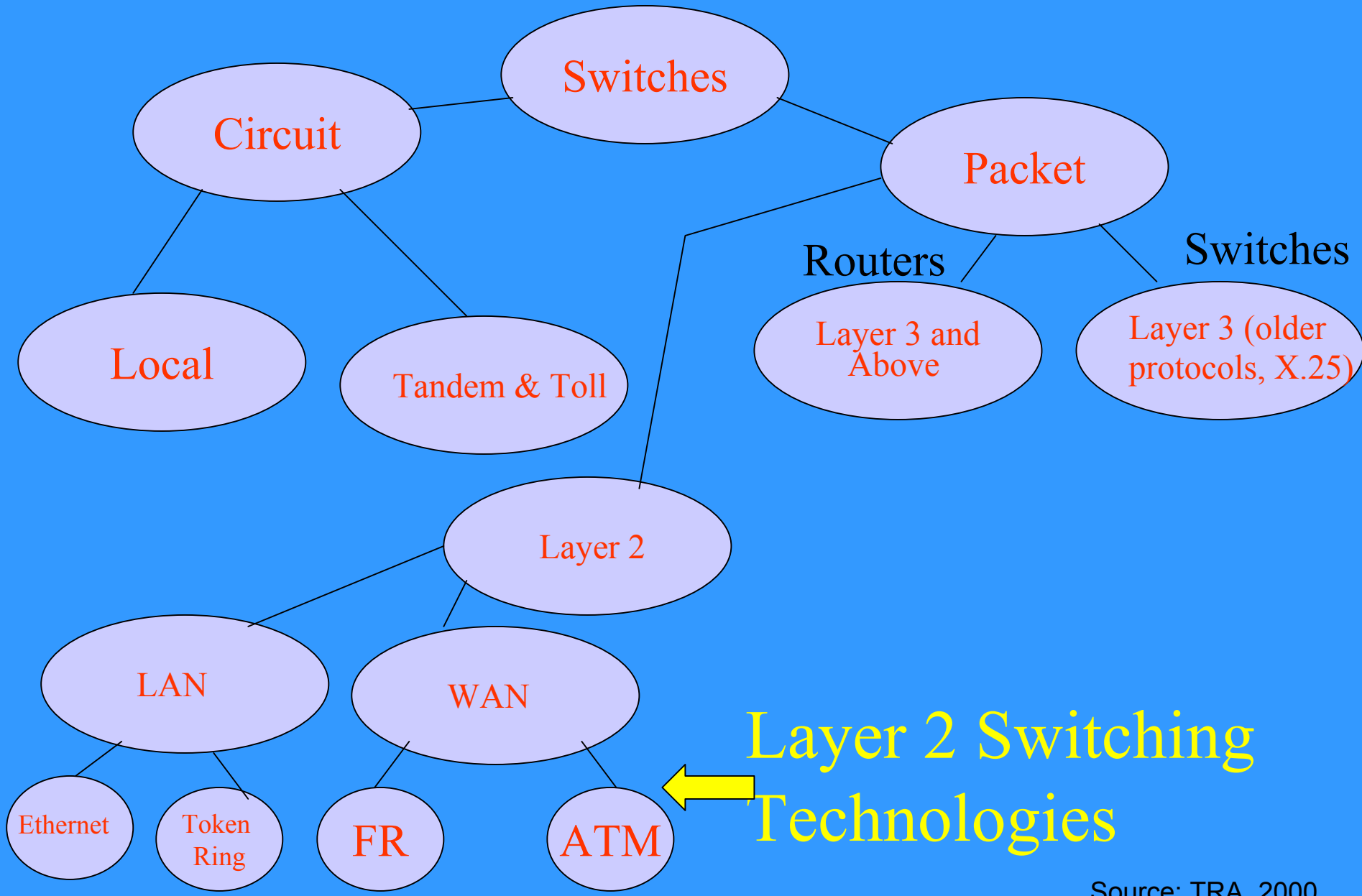
What is the "Switch"



Taxonomy of Packet Switching

Source: TRA, 2000

What is the "Switch"



Source: TRA, 2000

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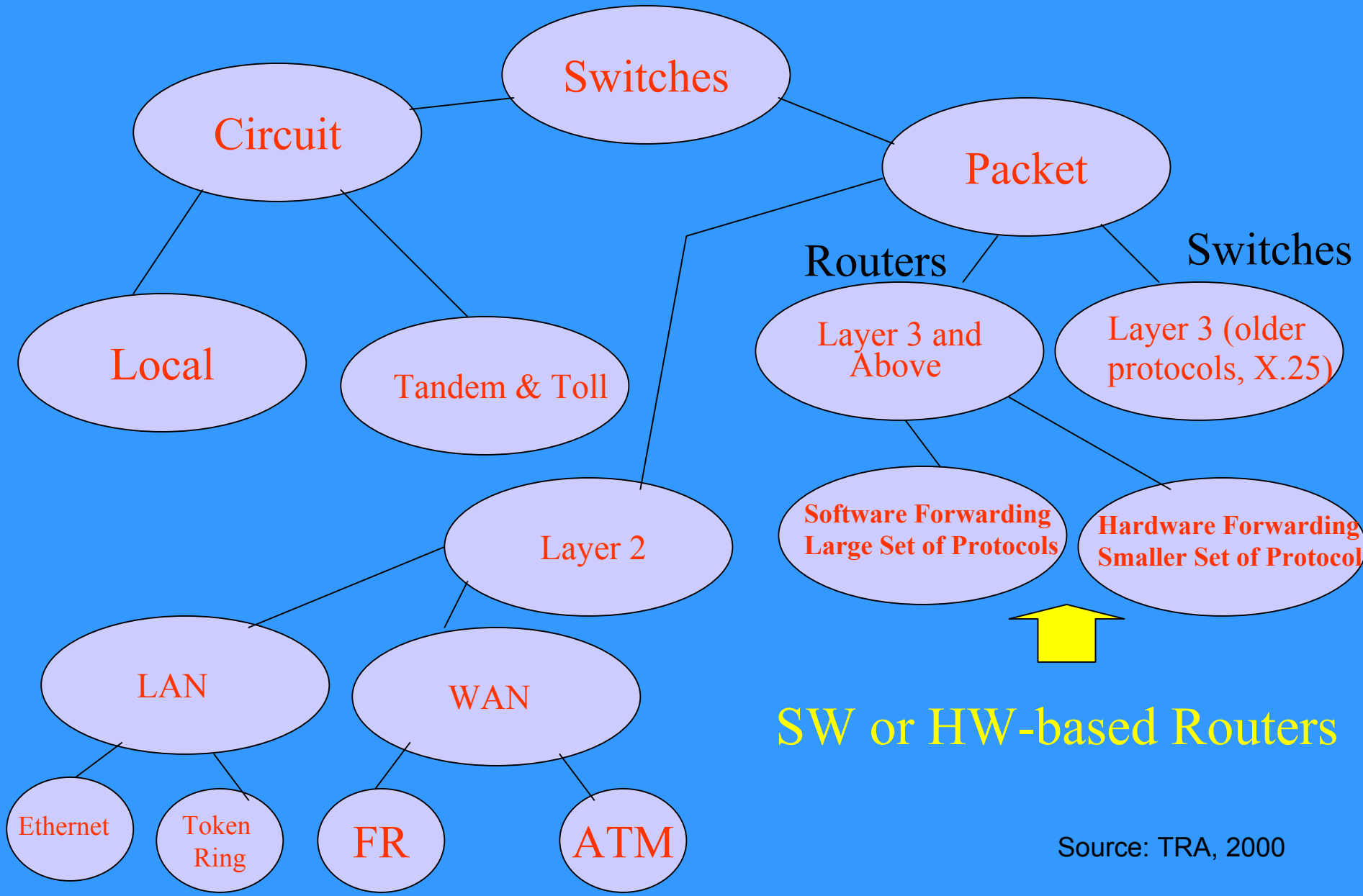

Source: TRA, 2000

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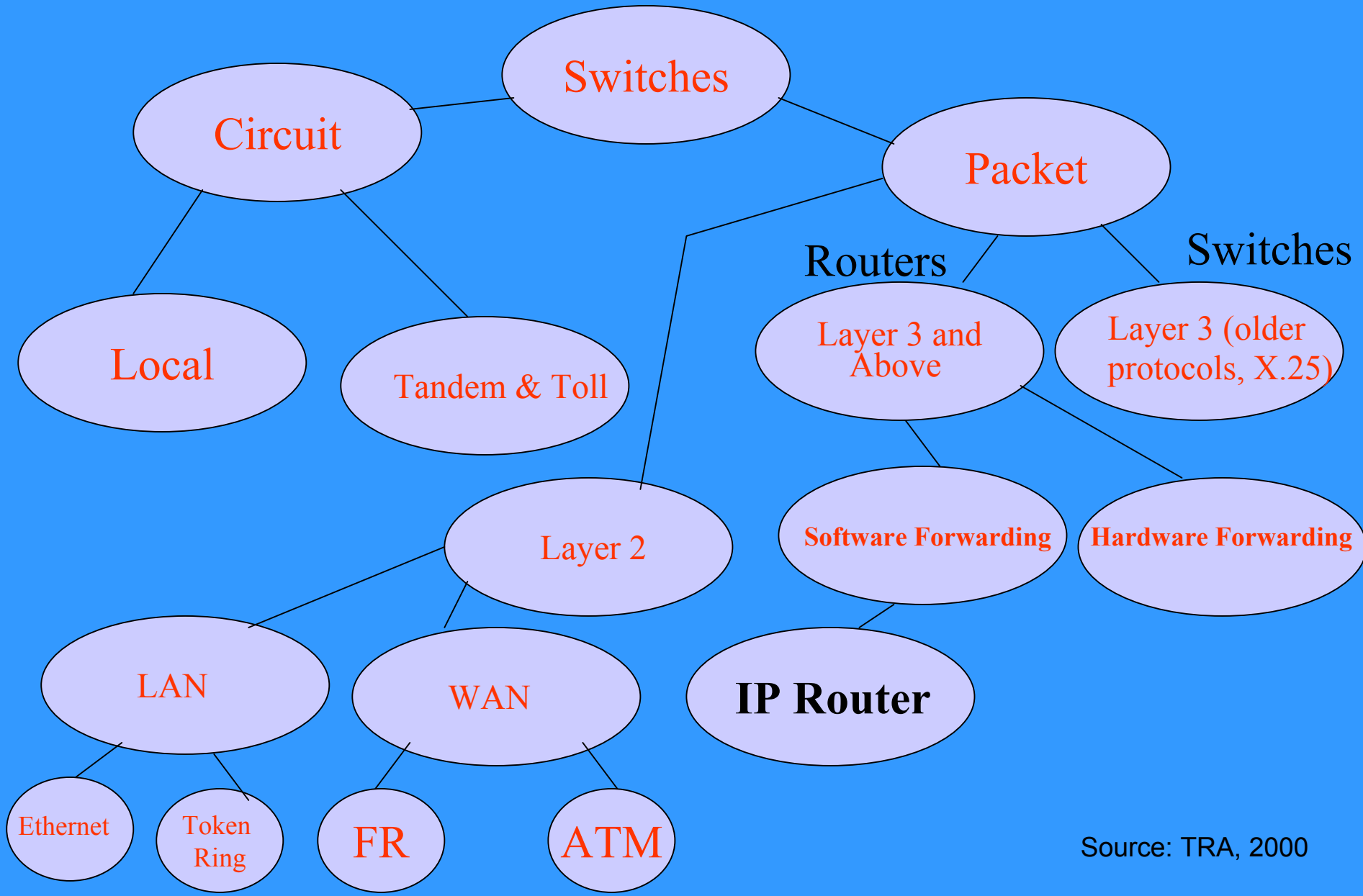

Source: TRA, 2000

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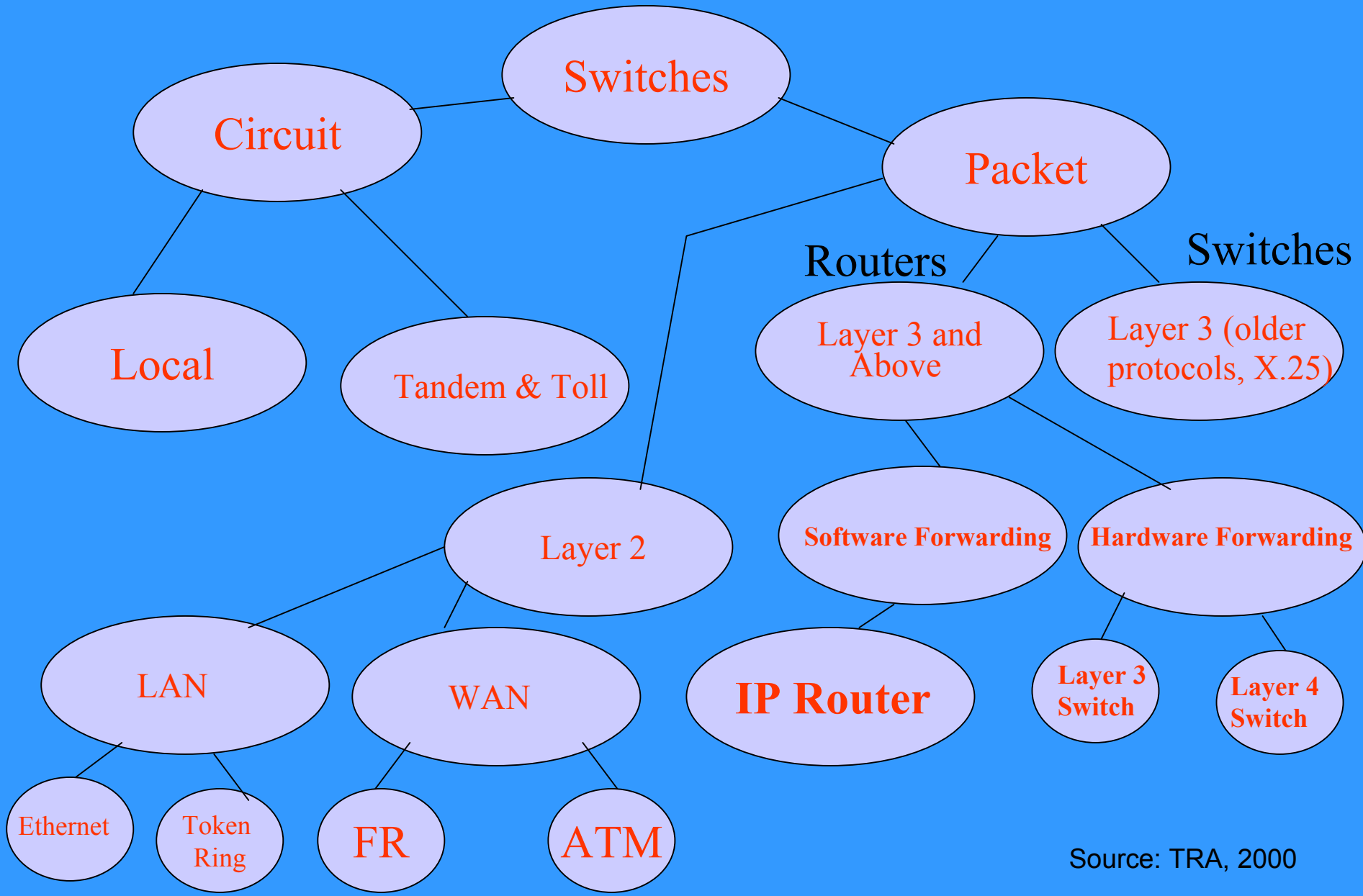

Source: TRA, 2000

What is the "Switch"

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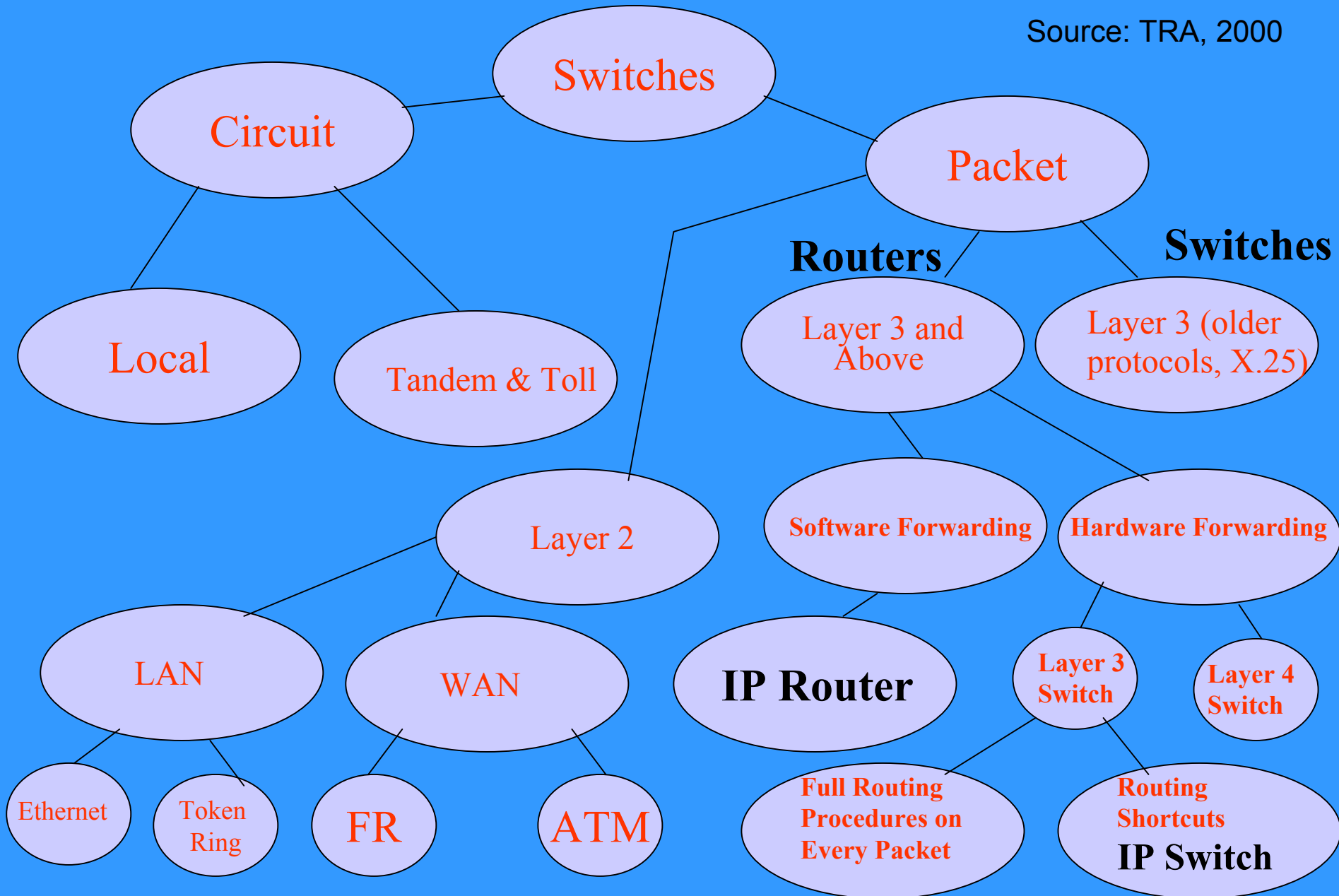
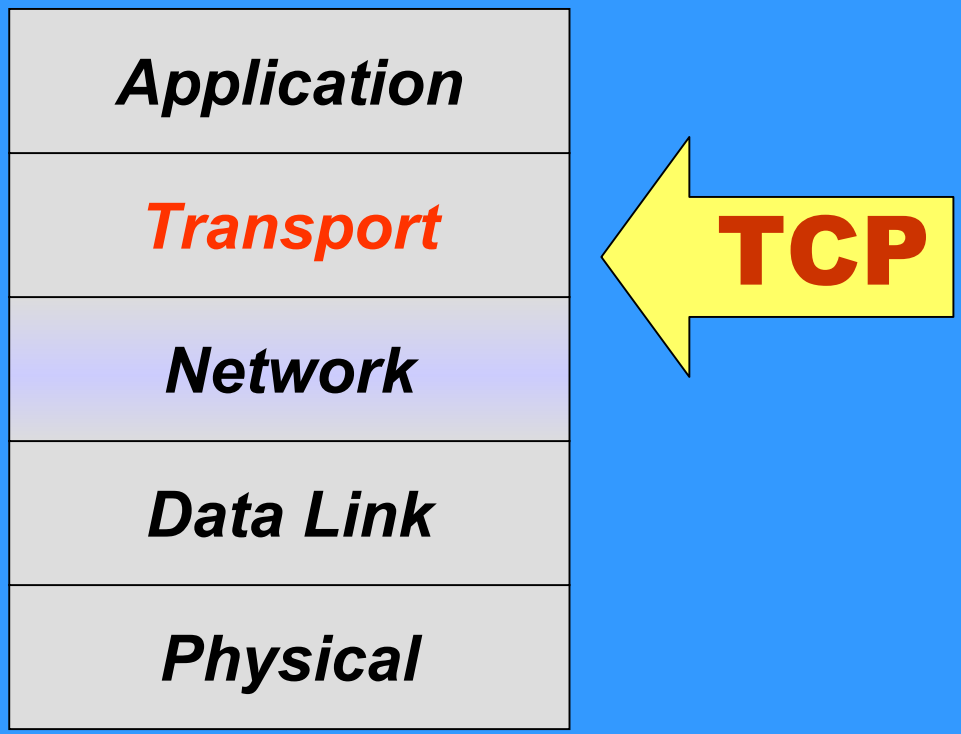


Summary of Switches' Taxonomy

- *Switch – Layer 2 (LAN, FR, ATM)*
- *Router – Traditional Layer 3, SW-based IP router*
- *Layer 3 Switch – HW-based Router*
- *IP Switch – HW-based Router with Shorted Routing*
- *Layer 4 Switch – HW-based Router with some Elements of Layer 4 for QoS*

3.2. TCP – Transmission Control Protocol and the IETF Model



TCP – Transmission Control Protocol

- *Transport Layer (Layer 4)*
- *Is processed in endpoints*
- *Connection-oriented protocol*
- *Provides flow control and adapts to a network congestion*

4. What is INTERNET?

(Draft definition)

(Generally) A collection of thousands of networks

- Based on the TCP/IP suite
- With no central policy-making/regulatory body
- Based on technical specs developed by ***Internet Engineering Task Force (IETF)*** and called ***Request for Comments (RFCs)***
- Using single address space
- Provides for users on any one of the networks to communicate or use the services located on any of the other networks

5. How Does IP Work?

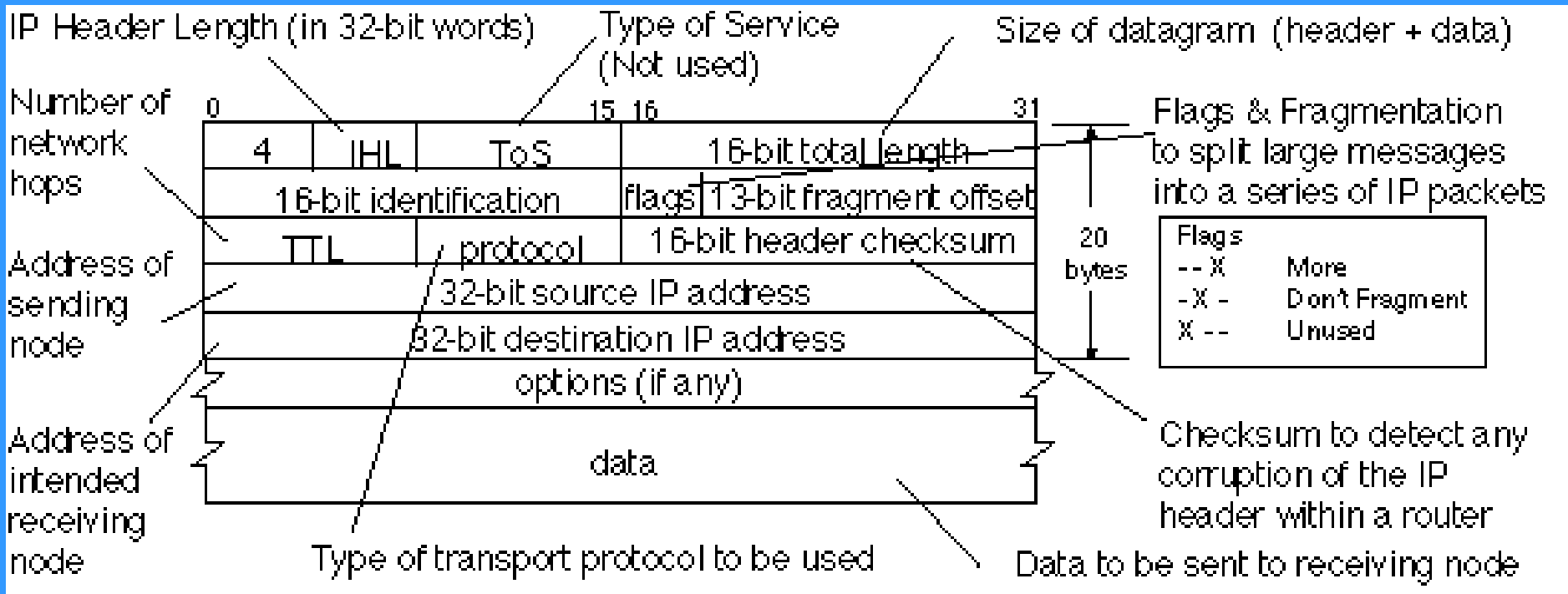
IP - Internet Protocol

Packet Structure

- *Header & Data*
- *Variable Length - Not predictable*

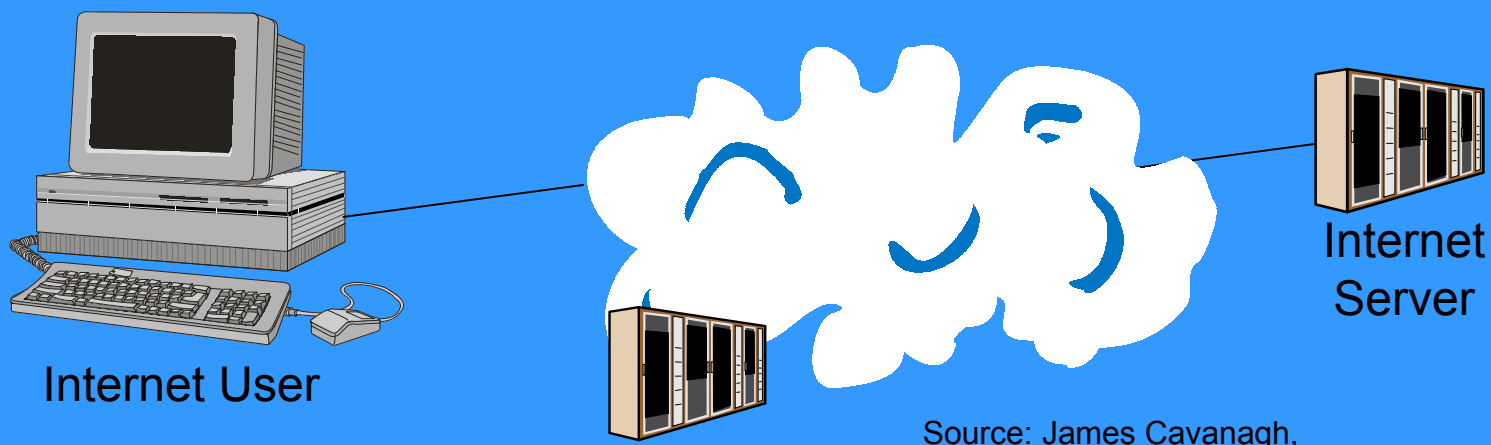
IP Addressing

IP Header


IP Header Length (in 32-bit words)
Type of Service
(Not used)
Size of datagram (header + data)
Number of
network
hops
Address of
sending
node
Address of
intended
receiving
node
0
15
16
31
4
IHL
ToS
16-bit total length
16-bit identification
flags
13-bit fragment offset
TTL
protocol
16-bit header checksum
32-bit source IP address
32-bit destination IP address
options (if any)
data
20
bytes
Flags & Fragmentation
to split large messages
into a series of IP packets
Flags
-- X More
-X - Don't Fragment
X -- Unused
Checksum to detect any
corruption of the IP
header within a router
Type of transport protocol to be used
Data to be sent to receiving node

IP Addressing

- **Numeric Addressing**
- **Symbolic Addressing**
- **Domain Name** and **Domain Name Service (DNS)**
- **URL**



Source: James Cavanagh,
Global telecommunications Consultant, GTC,
Lecture Notes, 2000

IP Addressing

- **IP Numeric Addressing**

  Dotted Decimal Notation

  IP Classfull Addressing - Classes A,B,C,D & E

IP Numeric Addressing

Two-level addressing – networks/devices

Number of possible addresses - 4 294 967 296

Devices

- PC
- Servers
- Routers

- **Class A – big networks (BNs)**

  Address – 8 bits

  Number of BNs –126

  17 mln devices per network

  Total amount of devices ~2 bln

IP Numeric Addressing

- **Class B – medium networks (MNs)**
  Address – 8 bits
  Number of MNs –16,382
  65 thousands devices per network
  Total amount of devices ~1bln
- **Class C – small networks (SNs)**
  Address – 24 bits
  Number of SNs –1,097,152
  254 devices per network
  Total amount of devices ~500 mln
- **Class D – for multicast communications**
- **Class E – for different kind of testing**

Class Addresses

A - 1.xxx.xxx.xxx - 126.xxx.xxx.xxx

B - 128.0.xxx.xxx - 191.255.xxx.xxx

C - 192.0.0.xxx -223.255.255.xxx

D - 224.0.0.0 - 239.255.255.255

Note: xxx from 0 to 255

Symbolic Addressing (Domain Form)

ictp.trieste.it

com – commercial (for-profit enterprise)

edu – educational (educational facility)

mil – military (military body)

net – network (network facility or service provider)

gov – government (body or agency of a government entity

org – organization (entity, which does not fall clearly into any mentioned categories)

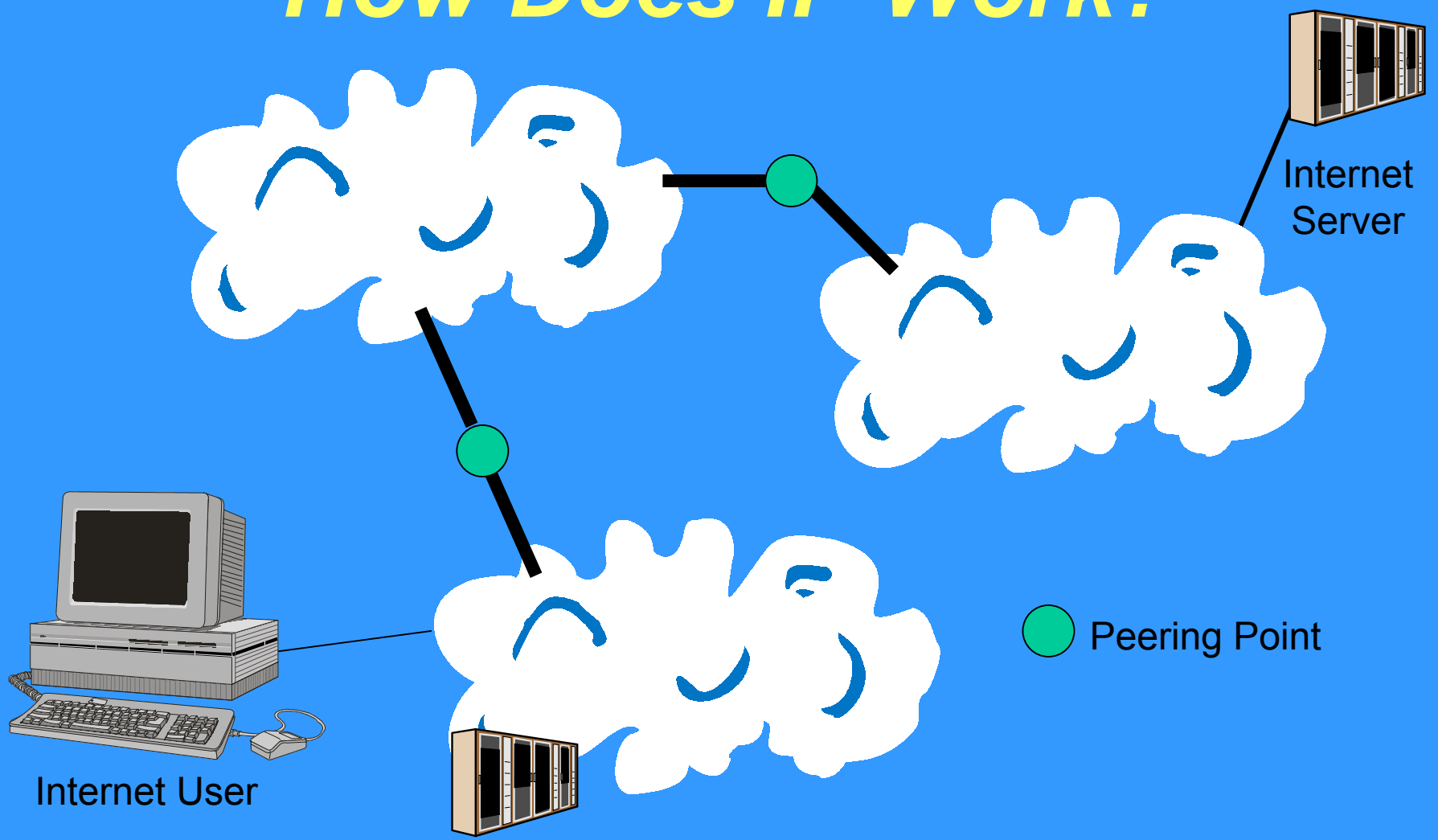
Domain Name and Domain Name Service

Domain Name locates an organization or other entity on the Internet.
DNS is a way that Internet *domain name* are translated addresses into numeric Internet protocol address.
DNS is based on the number DNS servers.

Universal Resource Locator

URL is the address of a file (resource) accessible on the Internet. URL contains a *name of a protocol* required to access the resource, *domain name* that identifies a specific computer on the Internet, and hierarchical description of the file location on the computer

How Does IP Work?



Source: James Cavanagh, GTC, Lecture Notes, 2000

Some Definitions

(www. isoc.org)

•***Internet Society*** is an **international non-profit organization** that acts as a guide and conscience for working of the Internet. It was founded in 1992 and based in Reston, Virginia

- 150 organizations, 6000 individuals in over 170 countries

- standards, public policy, training and education, membership activities

- ***IETF - Internet Engineering Task Force,*** is the body that **defines standard Internet operating protocols** such as TCP/IP. IETF is supervised by Internet Society **IAB.** Standards are expressed in the form of **RFCs.** IETF is large open international community of network designers, vendors, operators and researchers

- ***IAB - Internet Architecture Board,*** is a **technical advisory group of Internet society**. IAB is an overseer of the technical evolution of the Internet and IAB supervises IETF

•***ICANN - Internet Corporation for Assigned Names and Numbers*** *(former IANA)* is a private (non-government) corporation with responsibility for
- **IP address space allocation**
- **protocol parameters assignment**
- **domain name system management**
- **rout server system management**

RFC - Request for Comments is a **formal document** from IETF that is result of committee drafting and subsequent review by interested parties.
The final version of RFC becomes the standard and no further comments or changes are permitted.

6.Why use IP?

Key Features of IP Technology

A. Universality

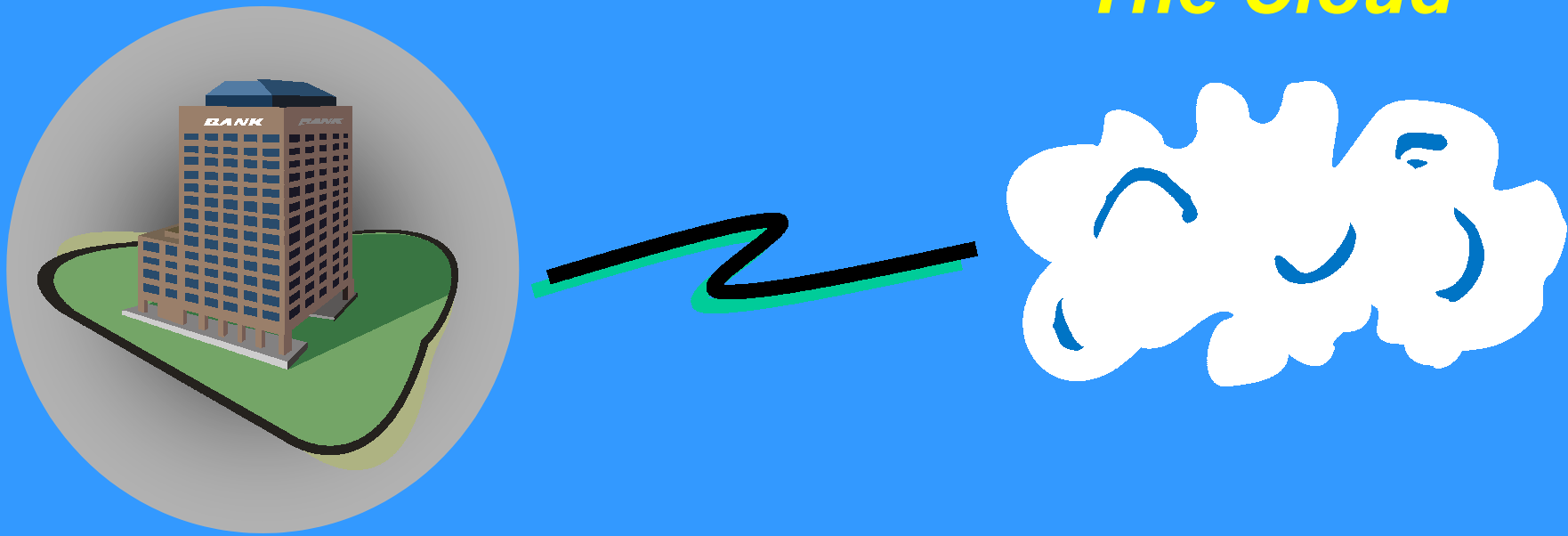
Used:

- In all network segments
- For transport data, voice, video
- In fixed/mobile networks
- In public and corporate networks

Continued…

The "Generic" Network Model

"The Cloud"



Premise (PCE)

Access Segment

Backbone or Core Network

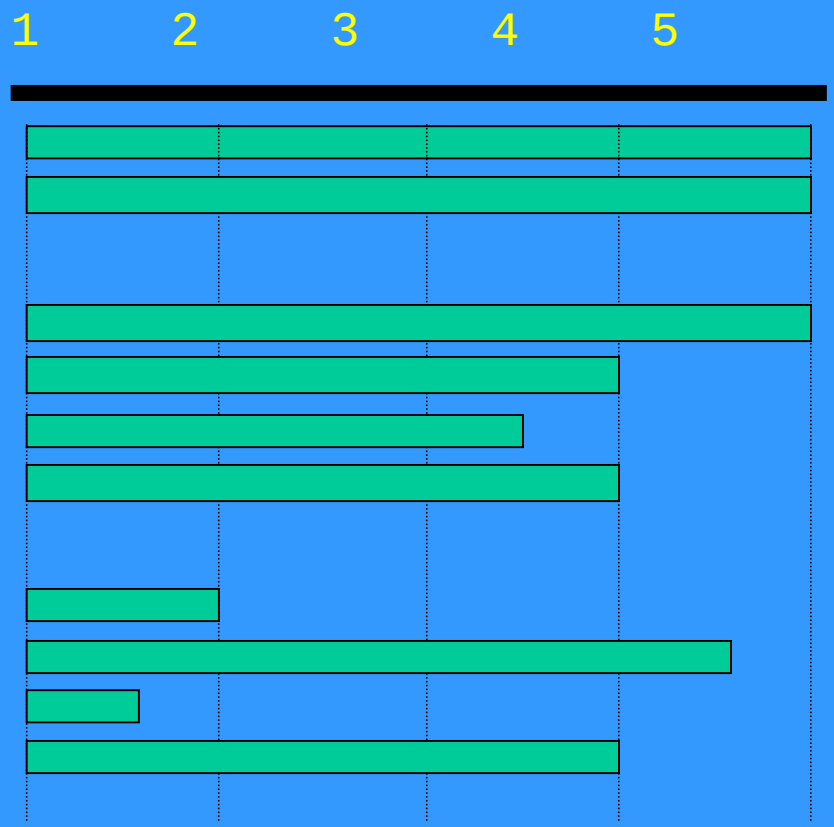
Source: James Cavanagh, GTC, Lecture Notes, 2000

IP's Role in the Network

Premise
- LAN/Desktop
- Campus Backbone

Access
- Low Speed (56/64)
- Medium Speed (E1)
- High Speed (>E1 to SDH)
- Integrated Access

Backbone
- Voice
- Data
- Video
- Multimedia



Source: James Cavanagh, GTC, Lecture Notes, 2000

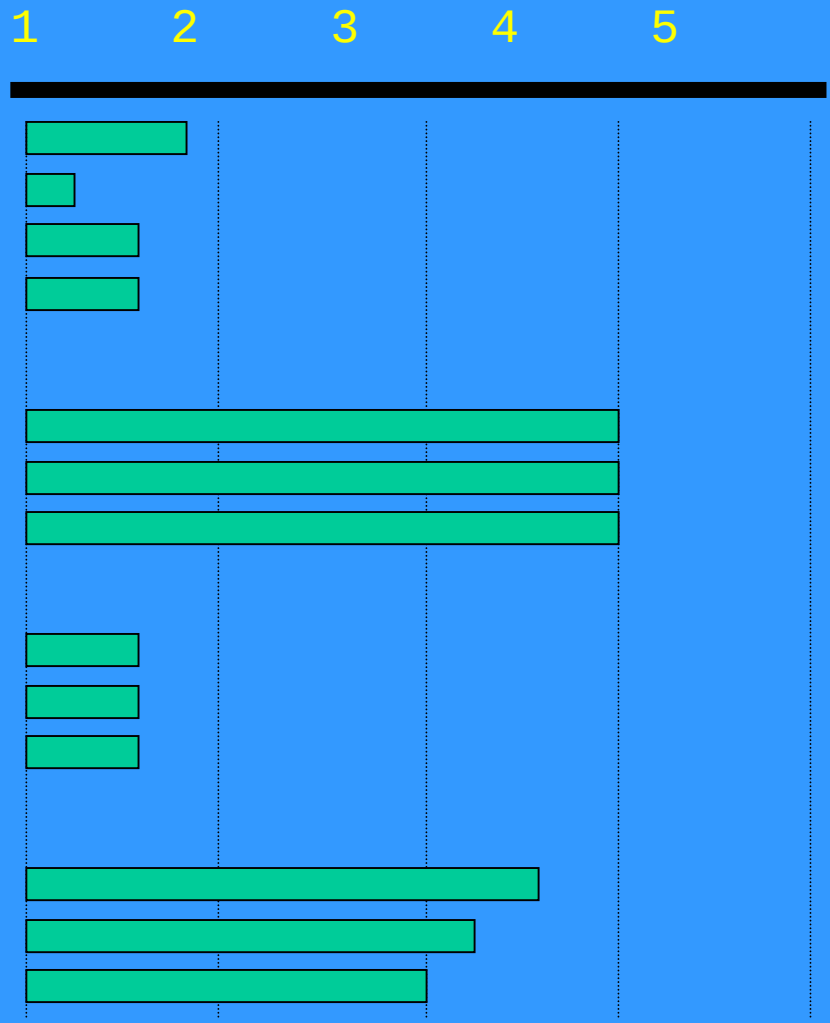
Putting IP to Work

Voice
- Delay
- Delay Variation
- Loss
- VBD /FAX

Data
- Delay
- Delay Variation
- Loss

Video
- Delay
- Delay Variation
- Loss

Multimedia
- Delay
- Delay Variation
- Loss



Source: James Cavanagh, GTC, Lecture Notes, 2000

Key Features of IP Technology

Continued…

B. Scalability

- Allows to combine a great number of networks (number of nodes, hosts and users)

C. Openness

- Open protocol platform
- Networks' interoperability
- Simple protocol stack (TCP/IP)
- Availability of specifications

http://www.rfc-editor.org

IP Characteristics

"Best Effort" Protocol

Reliability via Higher Layers

Used with TCP and UDP

Why use IP?

- *Wide Acceptance*
  - Internet Popularity
  - Global Reach
- *IP Standards*
  - Mature Standards
  - Interoperability
- *IP Protocol Characteristics*
  - Simple Protocol
  - Good General Purpose Protocol

IP's Perfect Applications

Internet

Intranet

Extranet

Intranet is a **private network** that is contained within an enterprise. It may consist of many interlinked LANs and also use WANs. Typically, *Intranet* includes connections through one ore more gateway computers to the outside *Internet.*

The ***main purpose*** *of an Intranet* is to share company's information and computing resources among employees.

An *Intranet* uses ***TCP/IP, HTML*** and other Internet protocols and in general looks like a private version of the *Internet.* One of the main problem in communications via public network is to provide the ***required level of security***

Extranet is a **private network** that uses the Internet protocols and the public telecom system to securely share a part of a business information with suppliers, vendors, partners and customers.

Extranet can be considered as a ***part of company's Intranet*** *that is extended to users outside the company.* interlinked LANs and also use WANs.

An *Extranet* requires security and privacy and it uses the same tools as *Intranet - firewall servers, users authentication, encryption and also VPNs*

7. Key Factors of Internet Evolution

- **New regulations in telecommunications**
  - Open markets, grows of competition, globalization
  - Alternative operators
  - New service providers
- **New technologies**
  - Grows of network's capacity (CNs - FOT, SDH, DWDM; ANs – Gigabit Ethernet, xDSL)
  - Progress in microprocessors' productivity (Moore Law)
  - New mechanisms and protocols
- **Market requirements**
  - Grows of users
  - Commercialization of Internet
  - Development of customized applications

Model of Service Waves
(Development of IP Networks)

FW – Dial-up access

SW – VoIP

TW – New services (FoIP, Call Centers, CTI)

FW – Multiservice IP-based networks

Challenges of IP Using as a Base for Multiservice Network Solution

- Capacity
  - Access networks
  - Core networks
- Quality of service (QoS)
  - Best Effort Principle (is suitable for E-mail, FTP, Web services)
- Information security's problems in commercial networks (Heterogeneous WANs)
- Lack of addresses

8. New Version IP - IPv6

Total length – 320 bits
Source address – 128 bits
Destination address – 128 bits
New mechanisms of security – IPsec
New mechanisms of QoS
Support of RT services

9. Quality of Service (QoS) in INTERNET

Definition of QoS

1. The performance specification of a communications channel or system
2. A subjective rating of telephone communications quality in which listeners judge transmissions by qualifiers, such as excellent, good, fair, poor or unsatisfactory

The Glossary of the Telecommunications Term, U.S. Federal Standard 10377

New mechanisms for guaranteed QoS

- IntServ (hard mechanisms)
  - RSVP (Resource reSerVation Protocol) - 1997
- DiffServ (soft mechanisms) – 1998

Resource Reservation Protocol

A signaling protocol between IP hosts and routers

- Host request QoS
- Router either accept or deny the request
- Routers give priority to traffic with higher QoS

  - PASS (TSpec)
  - RESV (RSpec)
  - Admission control
  - Policy control

Differentiated Services

Based on DS field (delay, losses, capacity):

- Type of Service field (IPv4) or
- Traffic Class field (IPv6)
- SLA - Service Level Agreement - a service contract between customer and service provider

Main Mechanisms of DiffServ

- Traffic profile (rate and bust size)
- Classification (sorting packets on the content of headers
- Policing (handling out-of profile traffic, e.g. discarding some packets)
- Shaping (delaying packets for confirming to defined traffic profile)
- Scheduling (buffer mechanisms)
- Admission control - a decision process regarding request for possible network resources

10. IP Telephony

1995 – SW VocalTec

- Independent from distance – low cost
- Low quality

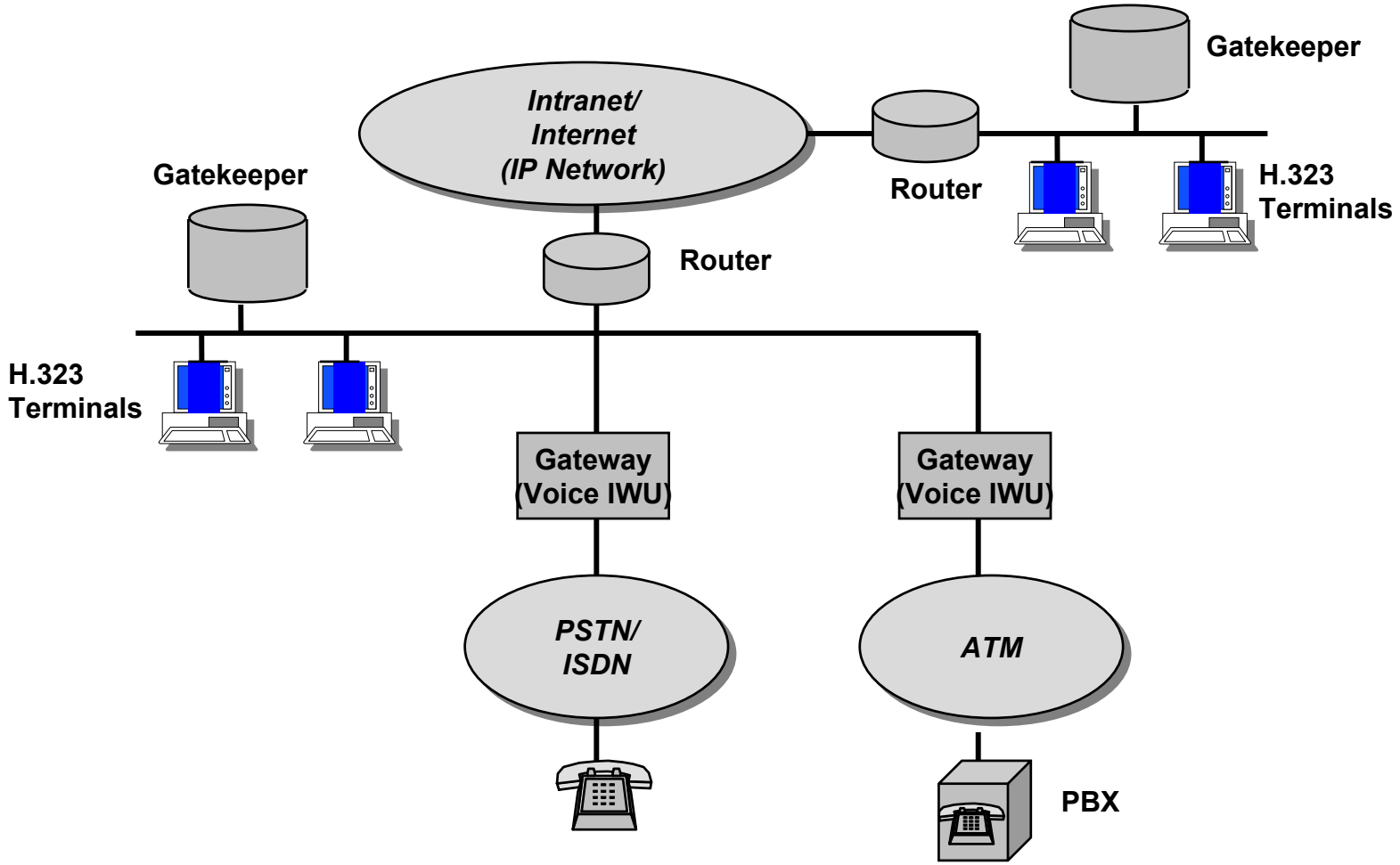
Current state

- Effective voice coding
- New services (FoIP, Videoconferences, Universal Messaging, Call Centers)
- New mechanisms of QoS
- Standardization

H.323 – Standards for Multimedia Communications Over IP Networks

- "Umbrella" standard, references other standards and ITU recommendations
- Intended for data, voice and video communications
- H.323 Components:
  - Terminal
  - Gateway
  - Gatekeeper
  - Multipoint Control Unit (MCU)

H.323 components



Source: R. Koch, G.Yanovsky, Evolution and Convergence in Telecommunications, book, published in 2001

H.323 Terminal

- Client endpoins on the network
- Must support audio 64 kb/s, 8, 6.2, 5.3 kb/s
- Video, data support is optional

H.323 Gateway

- Support interoperability with other terminal types
- Provides translation functions between H.323 and circuit-switched networks (PSTN):
  - Transmission formats
  - Signaling procedures
  - Audio/video transcoding

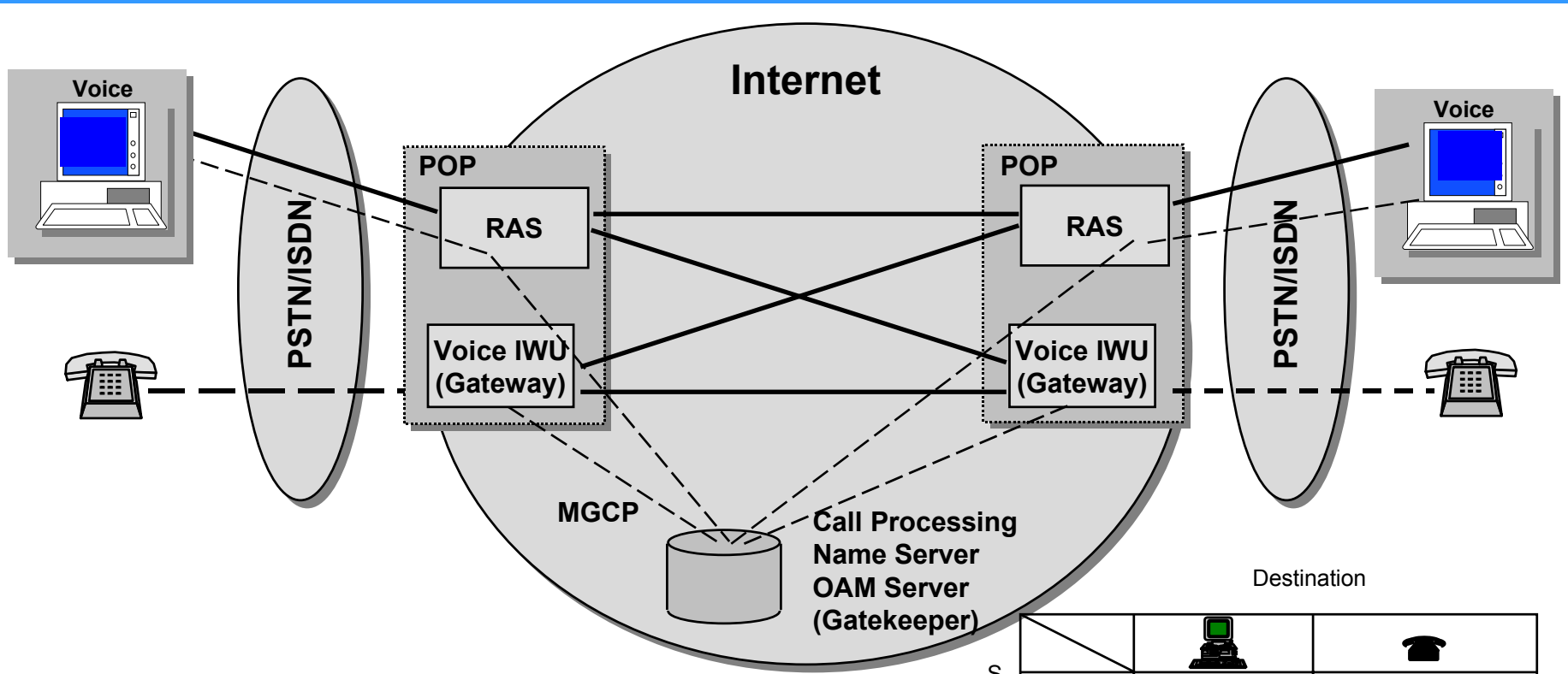
H.323 Gatekeeper

- Admission coding for the network
- Bandwidth control and management
- Address translation (PSTN Address ⟷ IP Address)
- Manages all terminals, Gatewways, MCUs in H.323 area

H.323 MCU

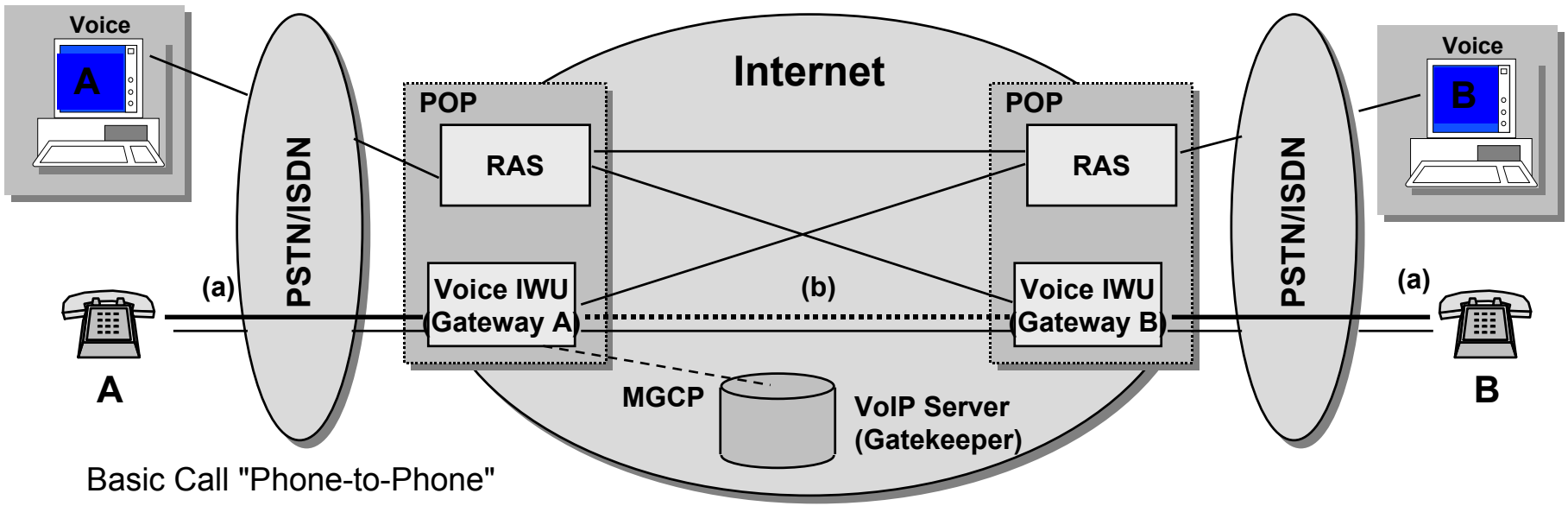
- Support conference between 3 or more endpoints
- Mixes, switches and processes media streams
- May be located in Terminal, Gateway or Gatekeeper

Network scenarios for Voice-over-IP (VoIP)



Source: R. Koch, G.Yanovsky, Evolution and Convergence in Telecommunications, book, published in 2001

Voice-over-IP - Phone-to-Phone

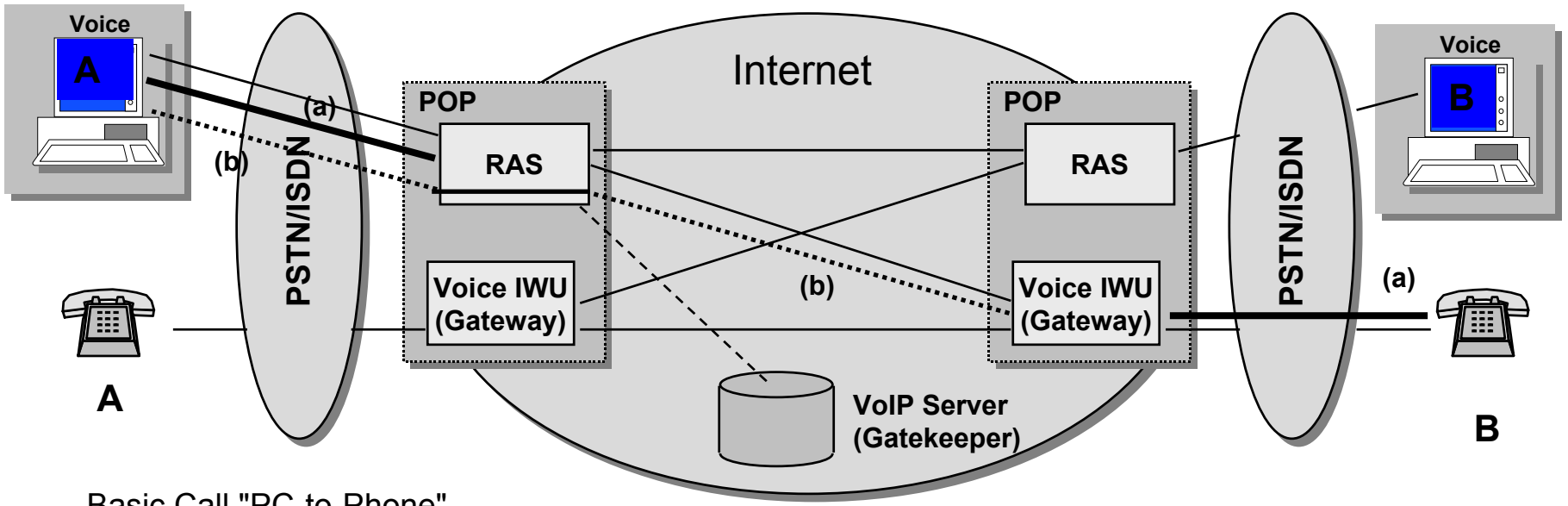


Basic Call "Phone-to-Phone"

- A-Subscriber dials IWU E.164 number
- *Normal Call Setup* **(a)** between A-Subscriber and A-IWU
- Announcement from A-IWU to user
- Input of A-Subscriber E.164 Number, PIN and B-Subscriber E.164 Number (via multi-frequency code)
- *H.323 call setup* **(b)** within the Internet between A-IWU and B-IWU (routing function in gatekeeper)
- *Normal Call Setup* **(a)** between B-IWU and B-Subscriber.

Source: R. Koch, G.Yanovsky, Evolution and Convergence in Telecommunications, book, published in 2001

Voice-over-IP - PC-to-Phone

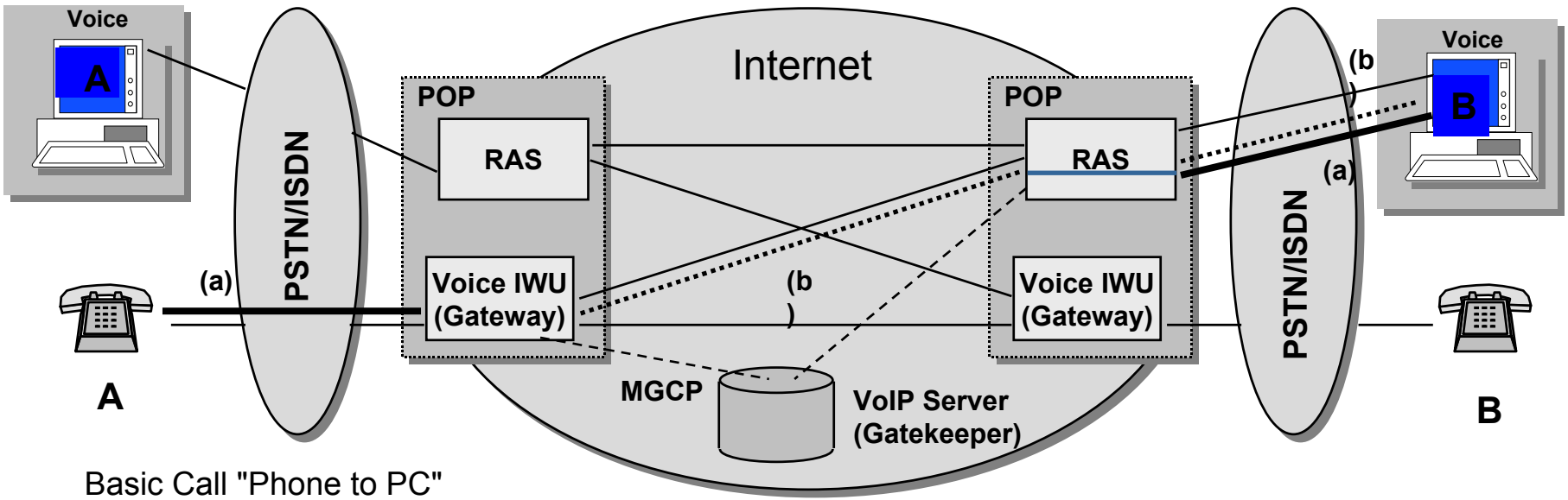


Basic Call "PC-to-Phone"

- ⇨ PC needs VoIP software (e.g. H.323)
- ⇨ *Normal Internet login* **(a)** of A-Subscriber
- ⇨ Access to VoIP Server
- ⇨ Input PIN and B-Subscriber E.164 Number
- ⇨ *H.323 call setup* **(b)** within the Internet between A-subscriber and B-IWU (routing function in gatekeeper)
- ⇨ *Normal Call Setup* **(a)** between B-IWU and B-Subscriber.

Source: R. Koch, G.Yanovsky, Evolution and Convergence in Telecommunications, book, published in 2001

Voice-over-IP - Phone-to-PC



Basic Call "Phone to PC"

- PC needs VoIP software (e.g. H.323)
- *Normal Internet login* **(a)** of B-Subscriber and registration at gatekeeper (E.164 to IP address mapping)
- A-Subscriber dials IWU E.164 number
- *Normal Call Setup* **(a)** between A-Subscriber and A-IWU
- Input of A-Subscriber E.164 Number, PIN and B-Subscriber E.164 Number
- *H.323 call setup* **(b)** within the Internet between A-IWU and B-subscriber PC (routing function and address mapping in gatekeeper)

Source: R. Koch, G.Yanovsky, Evolution and Convergence in Telecommunications, book, published in 2001

Concluding Remarks

Questions

Thank you!