ELG 5369
IP-Based Internetworking Technologies

Chap1
Networking Technology Standards and Services
An Overview

FALL 2017

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Chapter Outline

- Introduction and Overview
- Internetworking Concept and Architectural Model
- OSI and Internet
- Internetworking, Services, Next Generation Networks (NGN)
- Internet and Networks
- Internet Standards

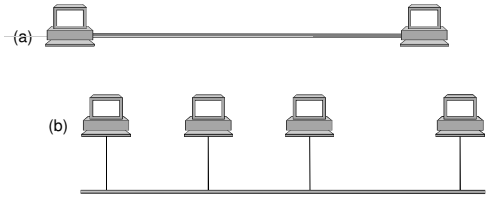
Networking

- A **network** is a hierarchical system of communication devices such as router, switches, and others, and wires organized by geographical proximity:

  Building blocks:
  – Nodes: hosts, switched, routers,
  – Links: special cables connecting the above:

  •Point-to-point

  •Multiple access

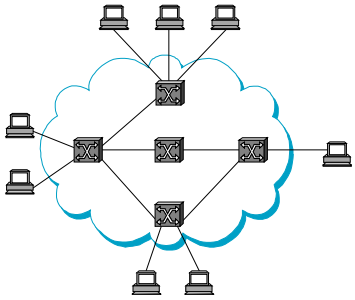


Networking

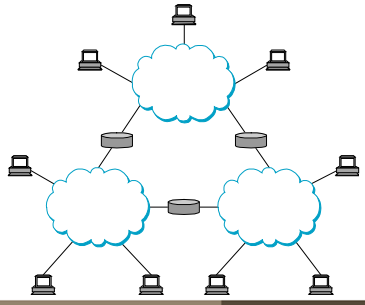
- Organization by geographical proximity:
  - LAN (local area network) spans building or campus
    - Ethernet is most prominent example
    - 802.11 (wireless) becoming more important
  - MAN (Metro Area Network) spans over a city:
    - Typically high-speed ISDN, Ethernet, or SONET over fiber lines
  - WAN (Wide-Area Network) spans country or world
    - Typically high-speed point-to-point copper or fiber lines
    - Also microwave and satellite links in some situations

Networking

- Network:
  - Two or more nodes connected by a link



- Or:
  - Two or more networks Connected together by one or more nodes



Networking Issues

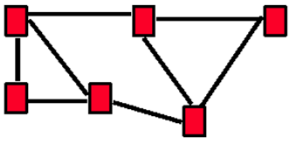
- Performance:
  - *Latency* (time between send and start to receive)
  - *Data transfer rate* (bits per second) [max]
  - Transmission time = latency + length / transfer rate
  - System bandwidth, throughput [actual]: total volume of traffic in a given amount of time
  - Using different channels concurrently can make bandwidth > data transfer rate
  - traffic load can make bandwidth < data transfer rate
  - network speed < memory speed (about 1000 times)
  - Access to local disk is usually faster than remote disk
  - Fast (expensive) remote disk + fast network
    - can beat slow (cheap) local disks

Networking Issues

- scalability
- reliability
  - corruption is rare
  - mechanisms in higher-layers to recover errors
  - errors are usually timing failures, the receiver doesn't have resources to handle the messages
- security
  - firewall on gateways (entry point to org's intranet)
  - encryption is usually in higher-layers
- mobility--communication is more challenging: locating, routing,...
- quality of service--real-time services
- multicasting--one-to-many communication

Types of Networks

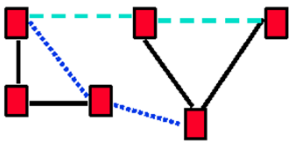
WAN



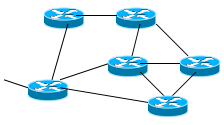
NOTE: acronyms:WAN = Wide Area Networks →50+ km

Point to point

Circuit switched



packet switched



Types of Networks

- Local Area Networks (LAN)
  - floor/building-wide
  - single communication medium
  - no routing, broadcast
  - segments connected by switches or hubs
  - high bandwidth, low latency
  - Ethernet - 10Mbps, 100Mbps, 1Gbps
  - no latency guarantees (what could be the consequences?)
  - Personal area networks (PAN) [ad-hoc networks]: blue tooth, infra-red for PDAs, cell phones,

Types of Networks

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- Metropolitan Area Networks (MAN)
  - city-wide, up to 50 km
  - Digital Subscriber Line (DSL): .25 - 8 Mbps, 5.5km from switch
    - Bell: .8 to 6 Mbps
  - SONET
- Cable modem: 1.5 Mbps, longer range than DSL
- More recently: 10GE, 40GE, vlan in vlan, or a combination of SONET and 10GE Ethernet

Types of Networks

- Wide Area Networks (WAN)
  - world-wide
  - Different organizations
  - Large distances
  - routed, latency .1 - .5 seconds
  - 10-40 GE (100 GE in the making)
- SONET carrier with country size SONET circles
- 10GEPON

Types of Networks

- Wireless local area networks (WLAN)
  - IEEE 802.11 (WiFi)
  - 10-100 Mbps, 1.5km
    - 802.11 (1997): upto 2 Mbps, 2.4 GHz
    - 802.11a (1999): upto 54 Mbps, 5 GHz, ~75 feet outdoor
    - 802.11b (1999): upto 11 Mbps, 2.4 GHz, ~150 feet [most popular]
    - 802.11g (2003): upto 54 Mbps, 2.4 GHz, ~150 feet [backward compatible with 802.11b, becoming more popular]
- Wireless metropolitan area networks (WMAN)
    - IEEE 802.16 (WiMax)
    - 1.5-20 Mbps, 5-50km

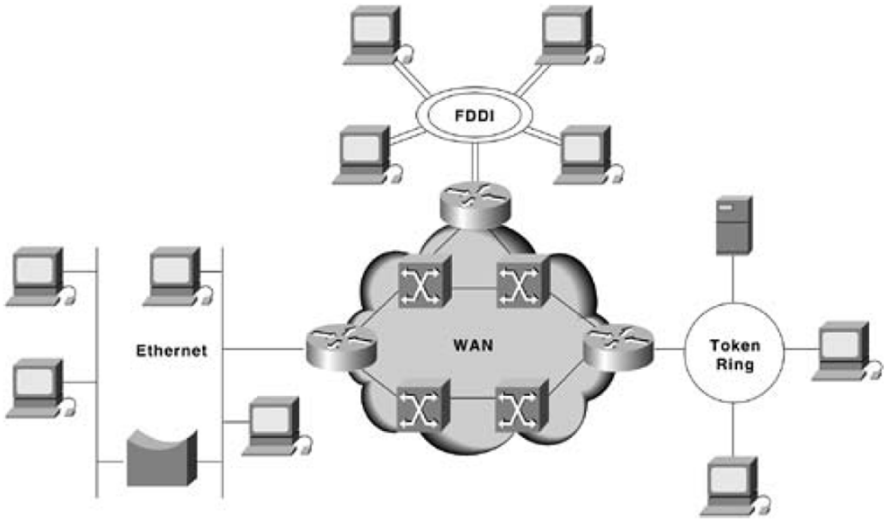
Types of Networks

- Wireless wide area networks (WWAN)
  - Worldwide
  - GSM (Global System for Mobile communications)
- 9.6 – 33 kbps
- 3G ("third generation"): 128-384 kbps to 2Mbps
- 4G: WiMAX (lost the completion) and LTE
  - 100 megabits per second (Mbit/s) for high mobility communication (such as from trains and cars) and
  - 1 gigabit per second (Gbit/s) for low mobility communication (such as pedestrians and stationary users).

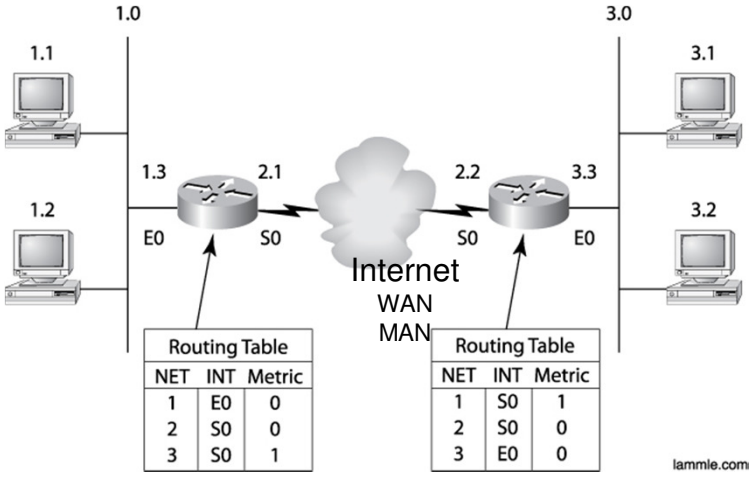
Internetworking

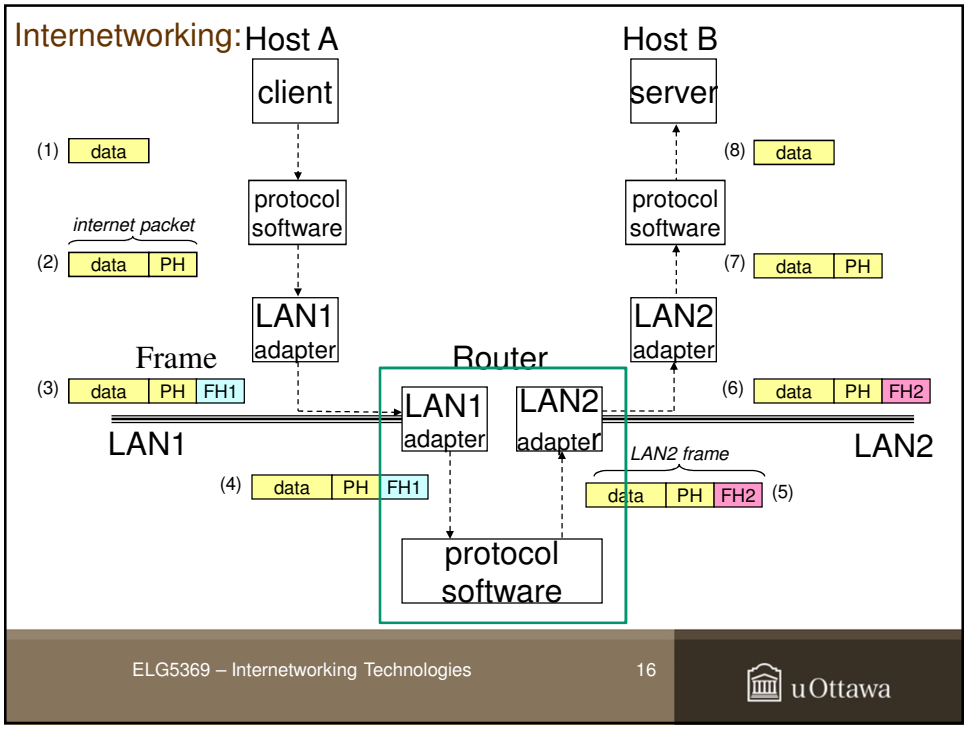
- An *internetwork* is a collection of individual networks, connected by intermediate networking devices, that functions as a single large network.
- It relates to the technologies needed to link in a compatible way a series of network devices with cables or radio frequencies such that those devices send and receive meaningful data coded in such a way that the peer device can receive it and can read it properly.
- These devices can be switches, routers, Asynchronous Transfer Mode machines (ATM switches), Synchronous Optical Networking (**SONET**) and Synchronous Digital Hierarchy **(SDH)**, and Optical Switches, Optical Amplifier, Optical Add-Drop Multiplexers, and Wireless Base Stations, Controllers, and others.

Internetworking: Example



Internetworking: more details





Internet: History

- U.S. Department of Defense had multiple networks.
- Advanced Research Projects Agency (ARPA) funded research on packet-switched networking.
- Late 60's - ARPANET went on-line with point-to-point leased line interconnection.
- The goal was to interconnect all machines at different sites so that researchers could share data and their findings across the ARPANET.
- ARPA researchers designed networking software called TCP/IP Internet Protocol Suite or TCP/IP in the mid 70's.

Internet: History

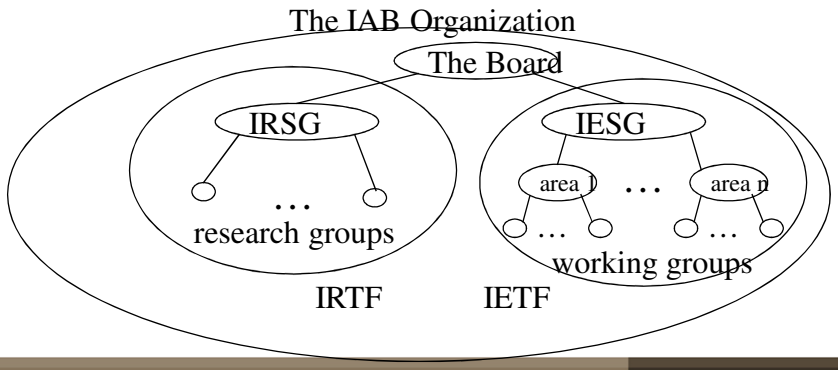
- 1983 - Defense Communications Agency (DCA) mandates all computers connected to backbone Internet use TCP/IP.
- 1983 - commercial implementation of TCP/IP begins.
- ARPA reached over 90% of university computer science department by funding UC Berkeley to integrate TCP/IP into UNIX.
- 1983-1993: Internet changed from a small experimental research project into the world's largest computer network.
- By late 1987, estimated the growth rate had reached 15% per month. By 2000, the global Internet reached over 50 million computers in 209 countries. Both the size and the use of the Internet continued to grow much faster than anticipated.
- Today maybe 10 B

Internet, Internetworking and Standards

- All activities on the Internet are governed by the Internet standards.
- Who makes up these standards?
- How they are organized?
- Where to find these standards?
- What is RFC?

The Internet Architecture Board (IAB)

- IAB decides which protocols are a required standard of the TCP/IP suite, sets official policies, and guides the evolution of the Internet.
  - Internet Research Task Force (IRTF) – coordinates research activities
  - Internet Engineering Task Force (IETF) – short-term and medium-term engineering problems



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RFC

- RFCs – Request For Comments
  - Most protocols of the TCP/IP are specified by RFCs
  - Internet Engineering Steering Group (IESG) edits and approves the RFCs.
- RFCs publications are for the Internet community.
- RFCs are published by the IAB and are freely available online.
- Internet drafts are preliminary versions of RFC documents.

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Internetworking

- Internetworking Challenges:
  - An Internetwork has to assure:
    - Connectivity
    - Reliability
    - Network management
    - Flexibility
    - Interoperability
    - Security.

Internetworking Definitions

- A **network** is a collection of *hosts* and *nodes* (*routers, switches,* or *gateways*) interconnected by communication links.
- **Protocols** are standards which specify the procedures for passing messages, the details of message formats and describe how to handle error conditions.
- A **gateway** interconnects two disparate networks, translates protocols, and forwards packets from one to the other.

Layers

- A technique to organize a network system into a
  - succession of logically distinct entities, such that :
    - the service provided by one entity is solely based on the service provided by the previous (lower level) entity

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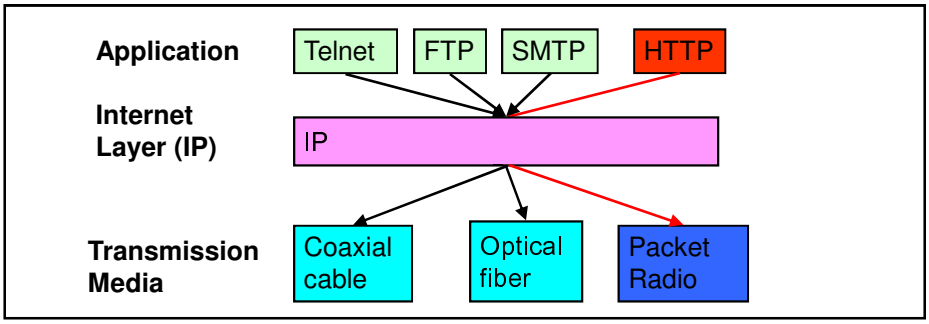
Network-Level Interconnection



- Advantages
  - **Efficient**: mapping packets directly onto network media
  - **Flexible**: adding or modifying network software without the need for changing the application software.
  - **Hides low-level details** from the user.

Networks and Layers

Different types of networks

→different types of physical signals conveyed through

→ different types of mechanism to send the signals and interpret their meaning:

Protocol Layers

Problem: different layers "speak" different languages.

Unification needed → standards and protocols for each layer

Layering

Protocols of each layer have to perform a set of functions

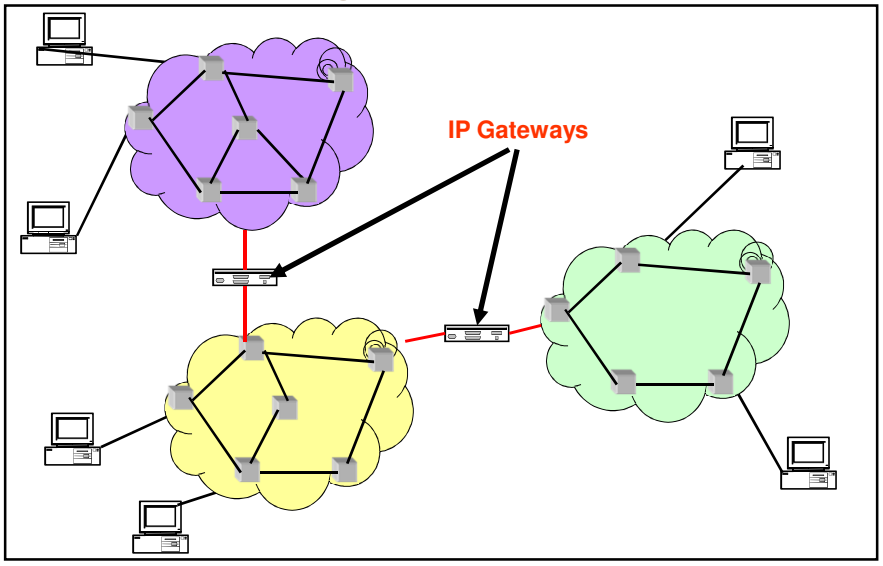
All alternatives for a row have the same interfaces

Choice of protocols at each layer is independent of those of at

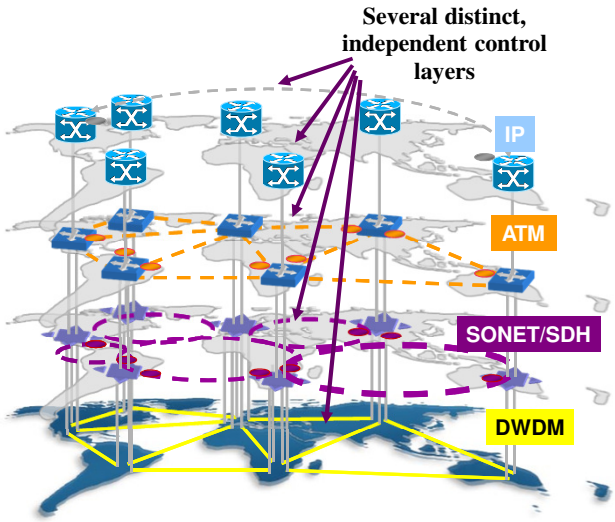
other layers. E.g., IP works over Ethernet or token ring

N-th layer control info is passed as N-1th layer data.

Internetworking Solution



Present Network Architectures

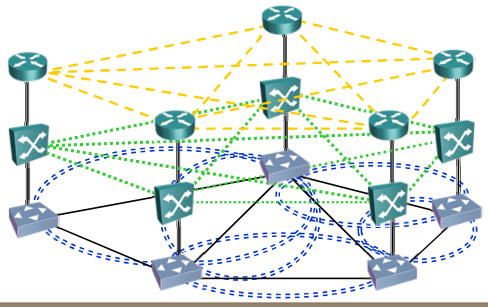


Network Technologies

Standards concerning protocols, algorithms and technologies for transmitting analog and/or digital information over:

- terrestrial
- wireless
- or satellite networks

Digital info transmitted over terrestrial networks



Motivation: From Network to Services

- Networks have evolved from simple wires connecting telephones (via switch boards of course), to wires connecting computers, telephones and lately, via radio frequencies, wireless devices
- Services have been added by allowing point-to-point, then point-to-multipoint, and lately multipoint-to-multipoint dynamic connectivity
- Web has been a big engine of this evolution: web 2.0 a revolution
- VoIP and IPTV is already available
- Web 2.0 expected to push it even further
- Social Networking pushed the communication via digital networks to extreme

- **The need to communicate is the engine of the network evolution**

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ISO OSI Reference Model

- ISO – International Standard Organization
- OSI – Open System Interconnection
- Started to 1978; first standard 1979
  - ARPANET started in 1969; TCP/IP protocols ready by 1974
- Goal: a general open standard
  - Allow vendors to enter the market by using their own implementation and protocols

OSI Model Concepts

- Service – says what a layer does
- Interface – says how to access the service
- Protocol – says how is the service implemented
  - A set of rules and formats that govern the communication between two peers

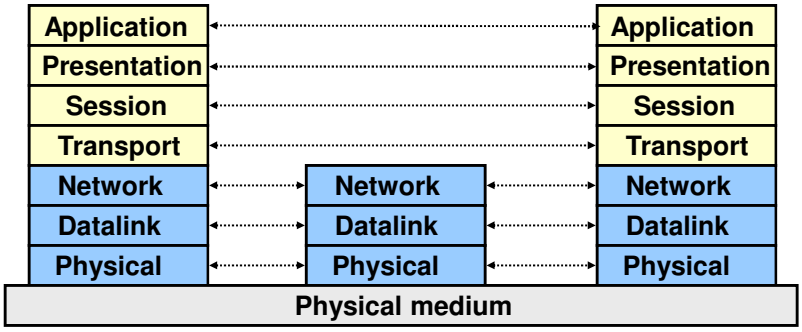
ISO/OSI Reference Model: a seven layer model for telecoms

Application	**A**pplications: File transfer, Email, Remote Login
Presentation	**P**resentation: ASCII Text, Sound
Session	**S**ession: Establish/manage connection
Transport	**T**ransport: End-to-end communication: TCP
Network	**N**etwork: Routing, Addressing: IP
Datalink	**D**ata: Two party communication: Ethernet
Physical	**P**hysical: How to transmit signal: Coding

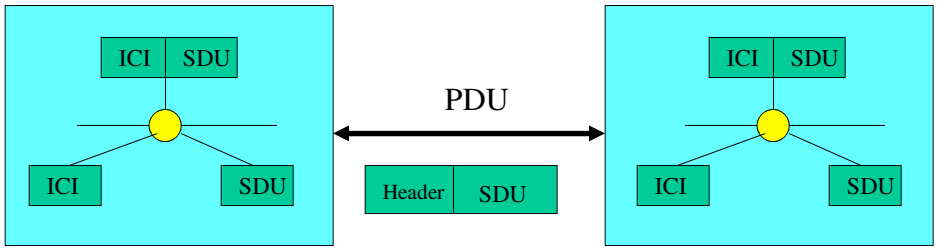
- OSI introduced concept of services, interface, protocols
- **Mnemonic: A**ll **p**eople **s**eem **t**o **n**eed **d**ata **p**rocessing

ISO OSI Reference Model

- Seven layers
  - Lower three layers are peer-to-peer
  - Next four layers are end-to-end



Interfacing using Layers



IDU = Interface Data Unit = ICI + SDU

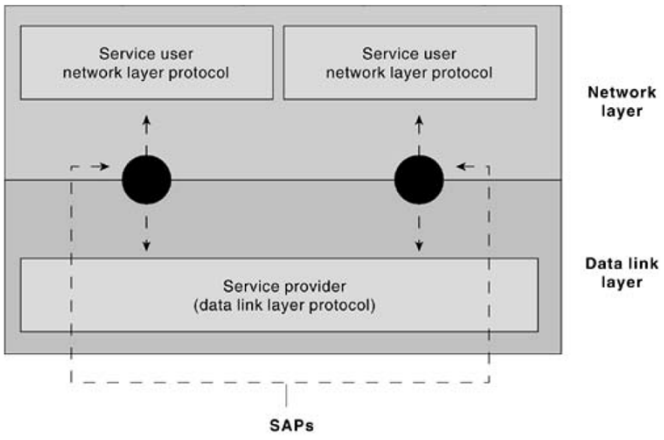
ICI = Interface Control Information

SDU = Service Data Unit

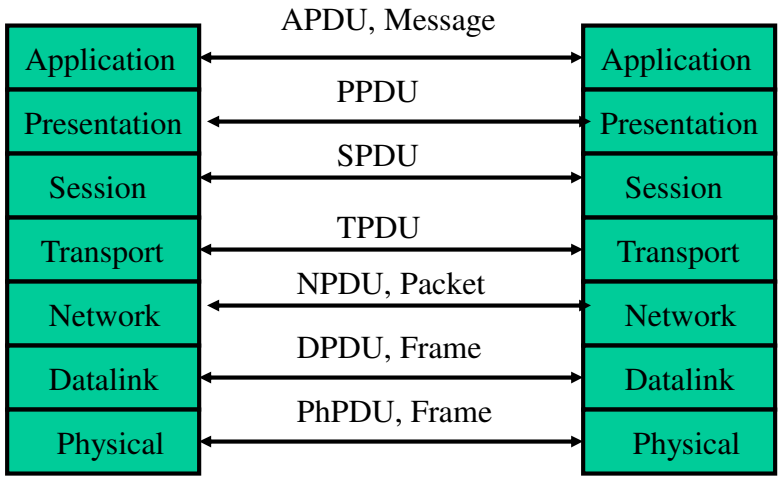
PDU = Protocol Data Unit = Fragments of SDU + Header --- blocks sometimes

SAP = Service Access Point

Service Providers, and SAPs Interact at the Network and Data Link Layers

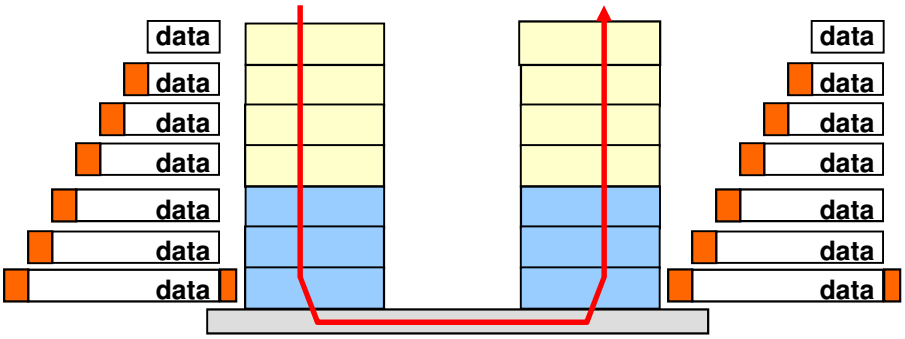


Protocol Data Unit (PDU)

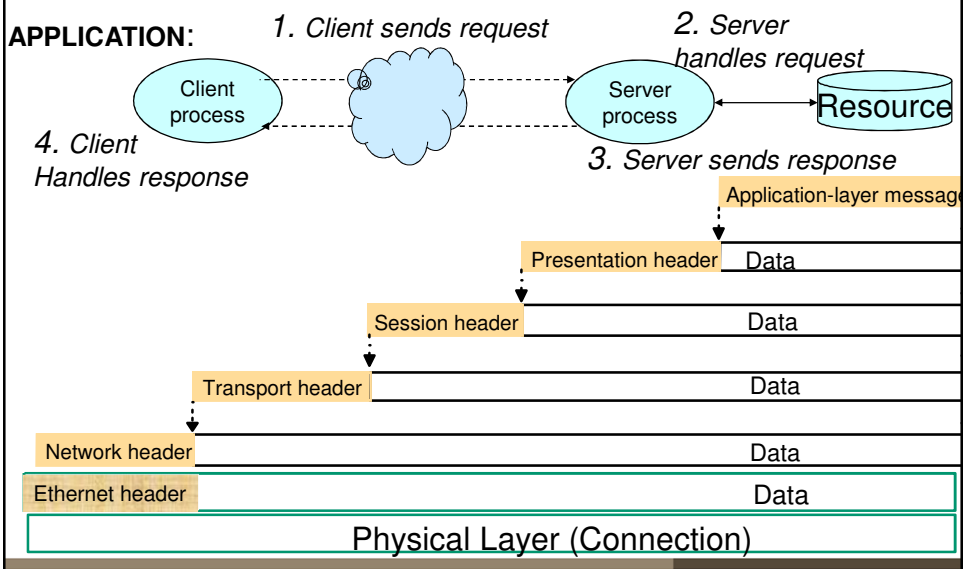


Data Transmission

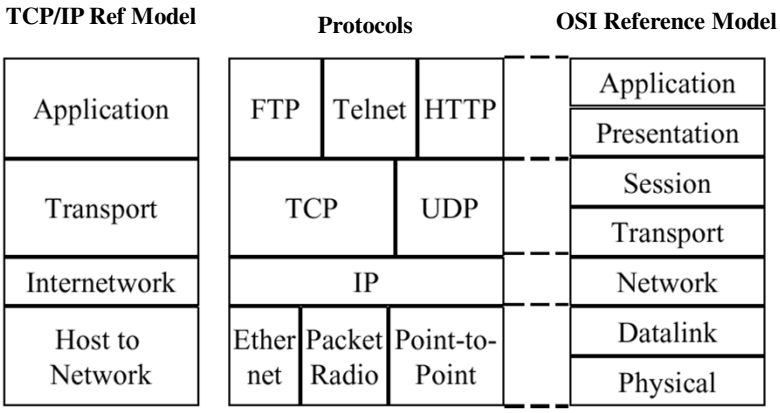
- A layer can use only the service provided by the layer immediately below it
- Each layer may change and add a header to data packet



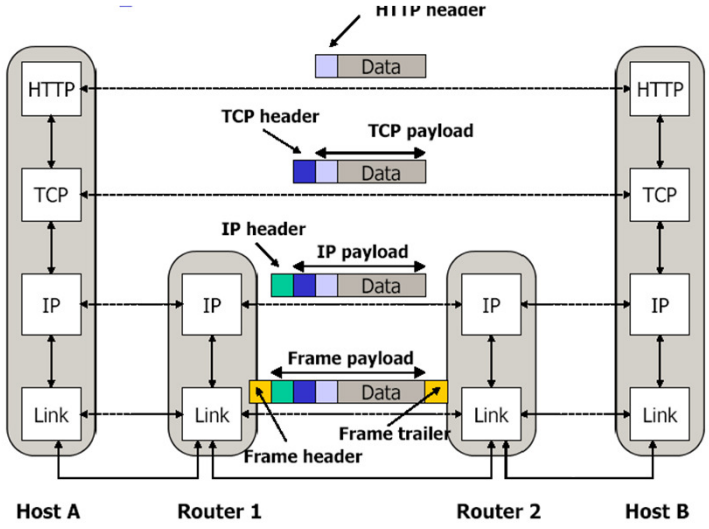
Internetworking Principle: Encapsulation



Applying Layering in IP Networking



Ip Layering



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Internet Services

- Internet is a set of applications that use the underlying network to carry out communication tasks.

Popular Internet **application services** are:

- World Wide Web or **Web** allows users to view multimedia documents and to follow hyper links from one computer to another.
- Electronic Mail or **E-mail** allows a user to compose and send messages to other individuals or groups on the Internet.
- **File Transfer** application allows users to send or receive a coy of a data file.

Internet Services

- Internet provides a connectionless or connection-oriented packet delivery service for transporting data across network.
- Data is divided (fragmented) into smaller pieces called *packets*. Packets may take different routes from a given source to a given destination.

- **Connectionless**
  - No guaranteed delivery of packets. Packets may arrive out-of-order.
- **Connection-oriented**
  - Reliable transmission of packets delivery. Will retransmit packet if errors (transmission error, lost packets, hardware failure).

Types of Services

- Voice Services
  - Terestrial
  - Wireless
  - Satellite
- Data Services
  - Voice over IP (VoIP)
  - Access services
  - Virtual Private Network Services
  - Video on Demand (VonD)
  - Video Teleconferences

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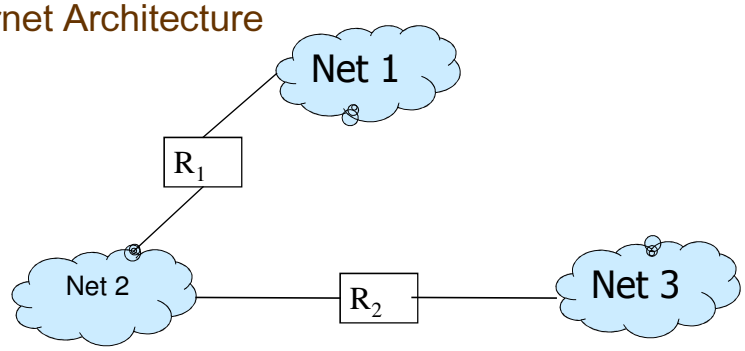
Properties of the Internet

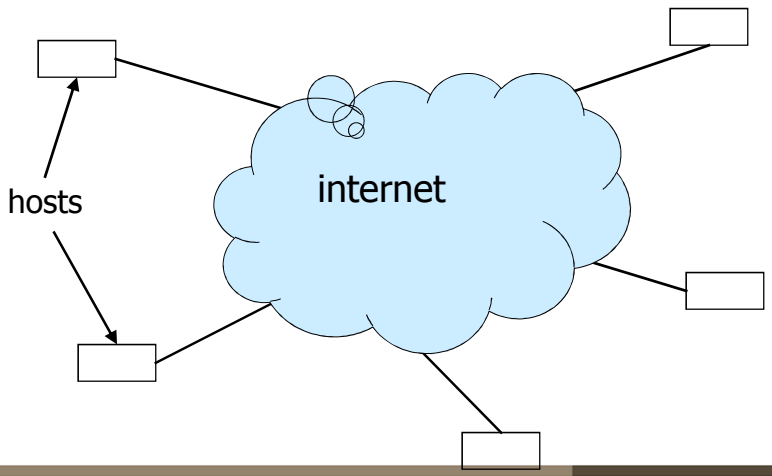
- Interconnects all computers by assigning a universal **unique IP address**.
- **Universal interconnection** - allows any two nodes to communicate irrespective of their network architectures, network topologies, and distance.

Internet Architecture

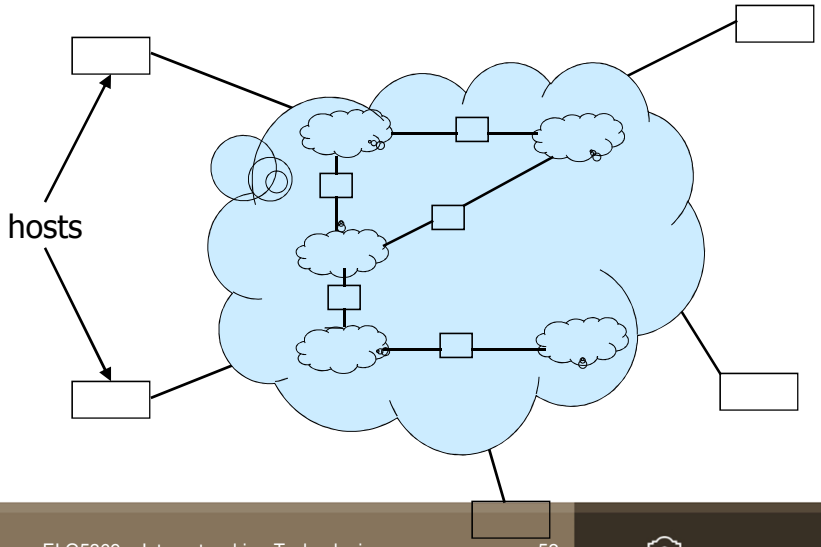


- A collection of cooperative, interconnected networks by IP gateways or routers (R_i).
  - IP routers provide interconnections among physical networks.
  - Routers use the destination network, not the destination computer, when forwarding a packet.
- All networks are equal. A network can be a local area network (LAN), a wide area network (WAN), or a point-to-point link between two computers.

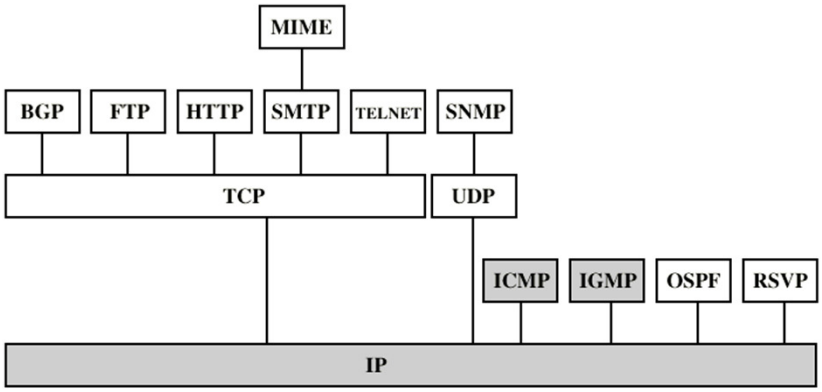
Internet Architecture – User's View



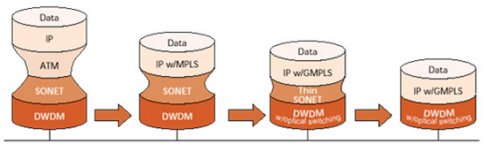
Internet Architecture

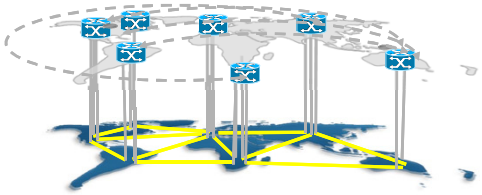


Internetworking Protocols



Next Generation Networks

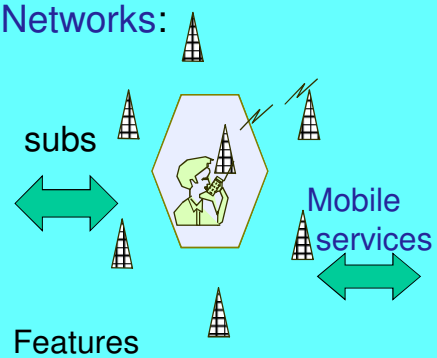




- **Simplified network architectures:**
  - **IP over Optical**
  - **Optical Ethernet**
- **Migration of Ethernet to MAN and WAN**

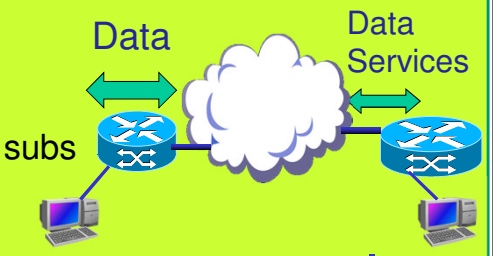
NGN Services: Convergence PSTN

PSTN and Mobile Networks:



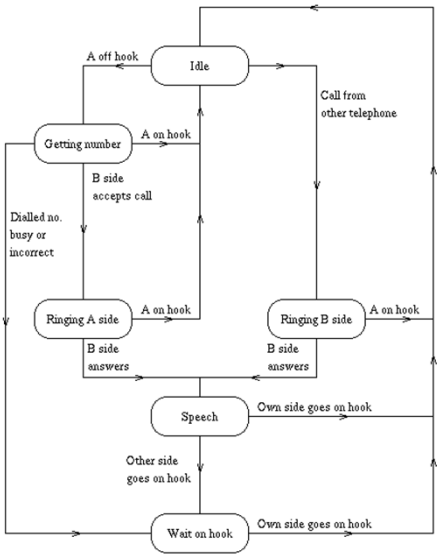
Features
- Connection oriented
- FSM based

Data Network



Features
- Connectionless
- No States and no FSM

NGN Services: Convergence: PSTN and Mobile Phone FSM

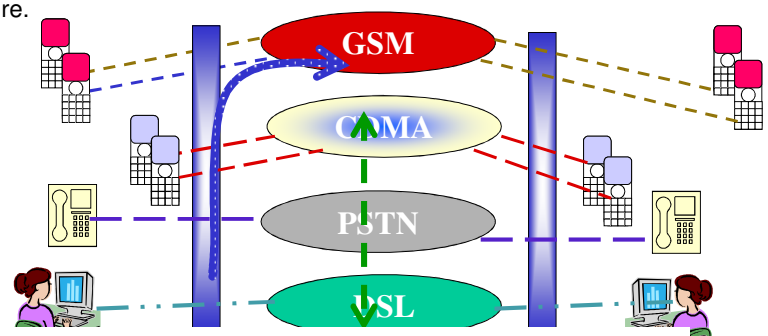


NGN Services: Convergence

We have a separate network (access / aggregation / core, AAA, Provisioning) for each service vertical.

Opex is very high.

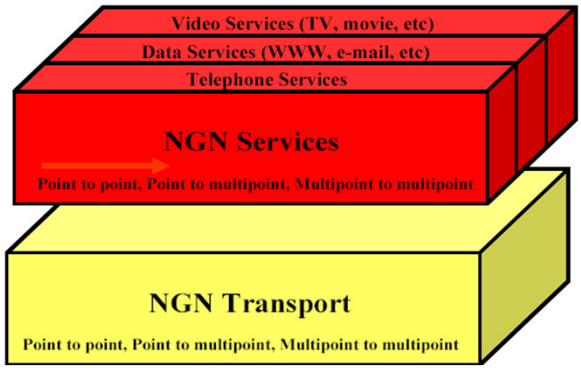
The network has to track user for his *Presence/ Location* and preference for terminals. Doing this through vertical *silos* does not make the business case anymore.



USER WANTS SEAMLESS CONNECTIVITY ON THE MOVE.

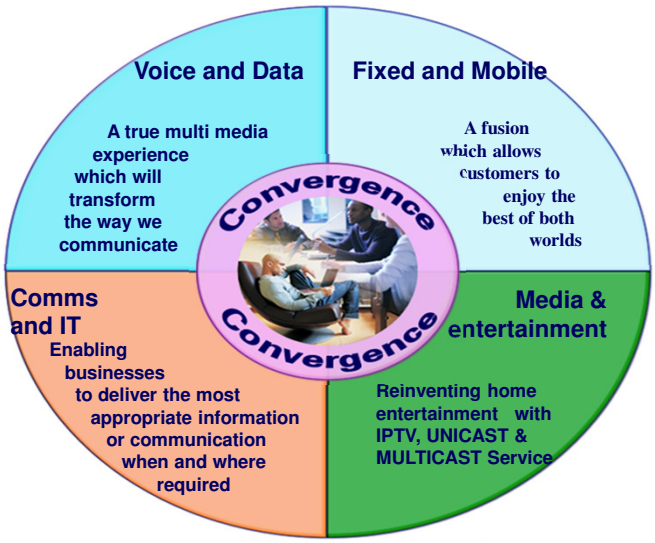
NGN: Horizontally Integrated Networks

Single Packet Bearer Network for all services



VERTICALS BROKEN INTO HORIZONTALS AND INTEGRATED TOGETHER IN HORIZONTAL STRATA. ONE COMMON IP BASED IMPLEMENTATION !!!

Convergence –Core of future business



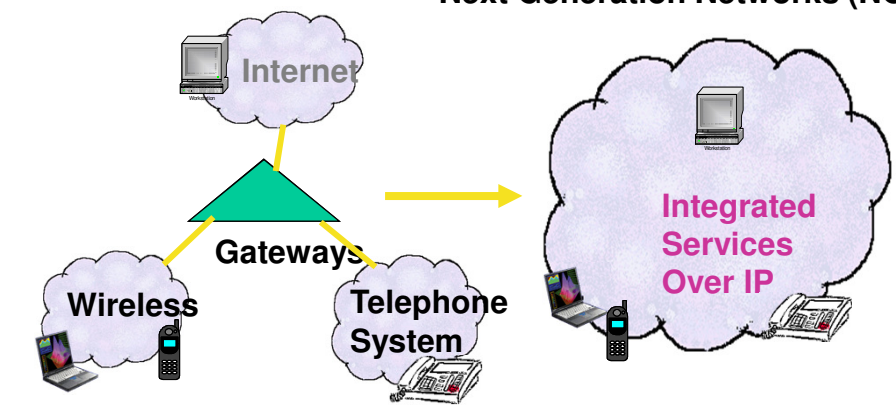
Next Generation Networks

- Key Characteristics of NGN
  - ✓ Packet-based network (generally IP).
  - ✓ Interworking with legacy networks via open interfaces.
  - ✓ Generalized mobility (User/Terminal/Access)
  - ✓ Independence of service-related functions from underlying transport technologies i.e. no separate vertical for each service
  - ✓ Multiple parallel sessions from same user for various services

Next Generation Networks

- Next Generation Services – Converged (quad-play, voice, data, video, mobile)
- Next Generation Access – High speed (Broadband) IP based connectivity (ADSL,VDSL, Wi-Max, Cable TV, FTTH, Entertainment.
- Next Generation Transport – Ethernet, IP-MPLS
- Next Generation Architecture – Service oriented, layered (transport, control, application)
- Next Generation Mobile – 3G+, 4G, 5G
- Next Generation Internet – IPv6
- Next Generation Interconnect – Capacity and Quality based
- Next Generation Licensing – Unified

NGN



Evolving towards IP Communications

Mobility and Convergence anywhere, anytime, anyplace

CONVERGENCE IS ABOUT SERVING A CUSTOMER SEAMLESSLY THROUGH DIFFERENT ACCESS NETWORKS

Converged Services and NGN

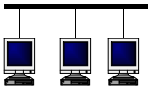
- One infrastructure is required.
- One backbone for voice and data services instead of two parallel ones.
- No maintenance of proprietary switching systems.
- Fewer call controlling entities in the network so less capital and operating cost.
- Easier configuration of equipment.
- Fast advanced and new services deployment is possible.

Outline

- Introduction and Overview
- Internetworking Concept and Architectural Model
- OSI and Internet
- Internetworking, Services, Next Generation Networks (NGN)
- Internet and Networks
- Internet Standards

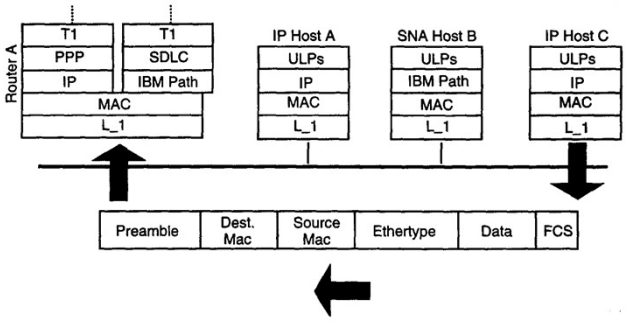
Types of Networks

LAN on a BUS



LAN = Local Area Networks → 0-2 km modern Ethernet devices can push Ethernet traffic to long distances (140 km)

LAN on a Ring



where:

FCS	Frame check sequence
IP	Internet Protocol
MAC	Media access control
PPP	Point-to-Point Protocol
SDLC	Synchronous Data Link Control
ULPs	Upper layer protocols

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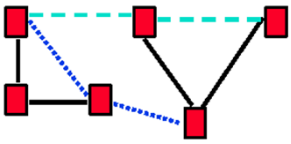
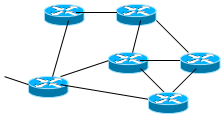
Types of Networks

MAN = Metropolitan Area Networks→ 2-50 km,

Circuit switched

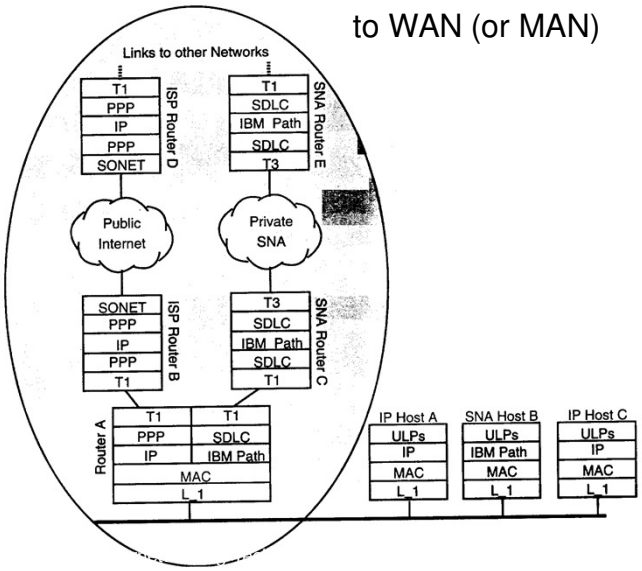


packet switched



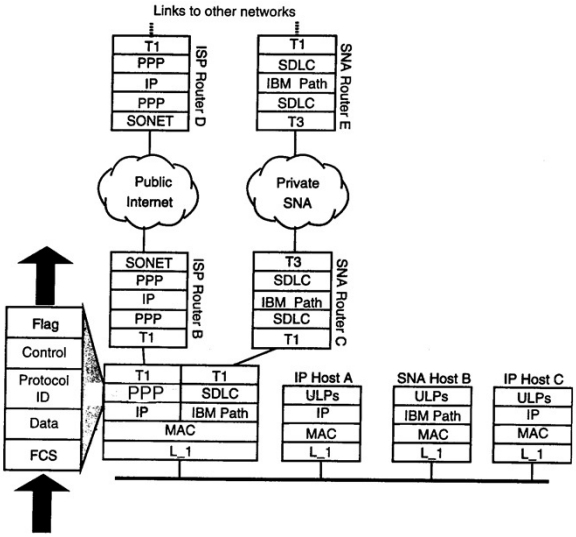
Types of Networks

How Internet works from LAN to WAN (or MAN)



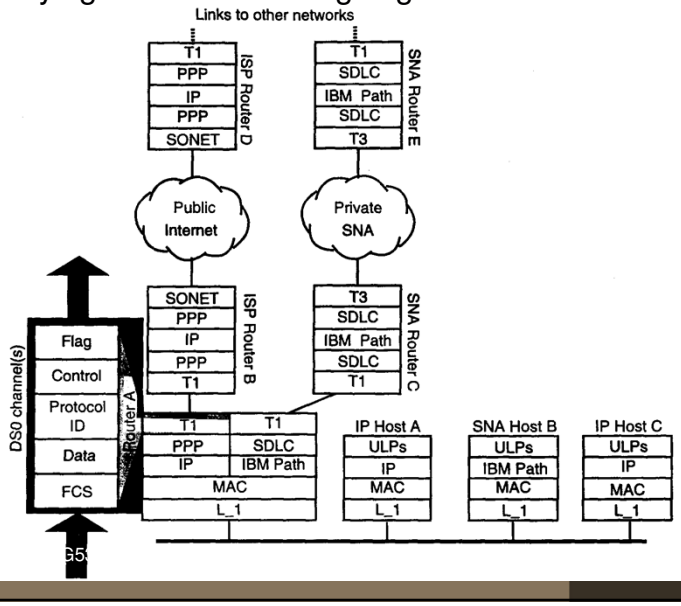
Types of Networks

Presenting traffic to the WAN



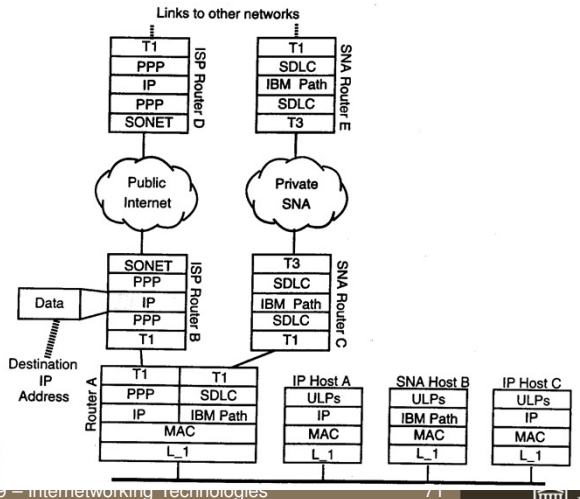
Types of Networks

Relaying traffic to the outgoing link



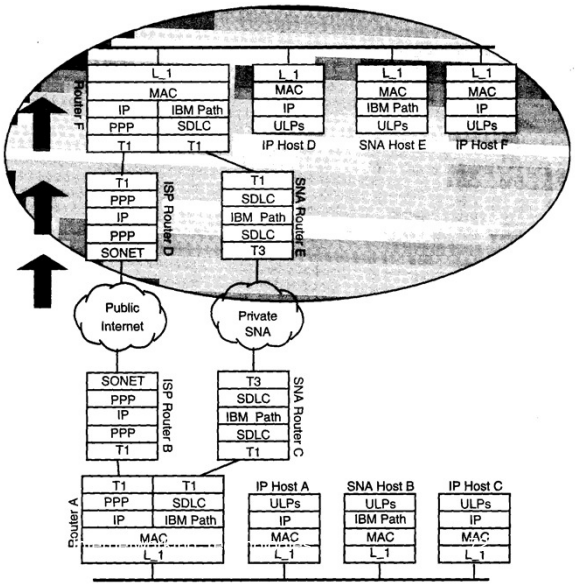
Types of Networks

Traffic at an intermediate router



Types of Networks

Delivering Traffic to the receiving network



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Outline

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Ethernet Standards

IEEE No.	*Name*	*Title*	*Reference*
802.3	Ethernet	CSMA/CD Networks (Ethernet)	[IEEE 1985a]
802.4		Token Bus Networks	[IEEE 1985b]
802.5		Token Ring Networks	[IEEE 1985c]
802.6		Metropolitan Area Networks	[IEEE 1994]
802.11	WiFi	Wireless Local Area Networks	[IEEE 1999]
802.15.1	Bluetooth	Wireless Personal Area Networks	[IEEE 2002]
802.15.4	ZigBee	Wireless Sensor Networks	[IEEE 2003]
802.16	WiMAX	Wireless Metropolitan Area Networks	[IEEE 2004a]

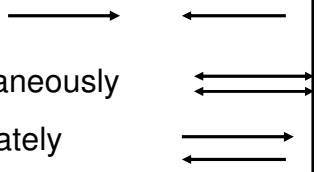
Ethernet

- Ethernet, CSMA/CD, IEEE 802.3
  - Xerox Palo Alto Research Center (PARC), 1973, 3Mbps
  - 10,100,1000 Mbps
  - extending a segment: hubs and repeaters
  - connecting segments: switches and bridges
  - Contention bus
  - Packet/frame format
    - preamble (7 bytes): hardware timing
    - start frame delimiter (1)
    - dest addr (6)
    - src addr (6)
    - length (2)
    - data (46 - 1500): min total becomes 64 bytes, max total is 1518
    - checksum (4): dropped if incorrect

Layers; Issues

Transmission mode:

- Simplex: Transmit or receive
- Full Duplex: Transmit and receive simultaneously
- Half-Duplex: Transmit and receive alternately



Error Control: Error detection and recovery

Flow Control: Fast sender

Networking and Internetworking Standards

Request **f**or **C**omments (RFC):

- Memos in the **Requests for Comments (RFC)** document series contain technical and organizational notes about the Internet.
- They are general specifications of all aspects of the Internet which are compulsory to adhere onto.
- They cover many aspects of computer networking, including protocols, procedures, programs, and concepts, as well as meeting notes, opinions etc.
- RFCs are associated with an active IETF Working Group
- **IETF Repository Retrieval**
- **RFC Editor Repository Retrieval**

OSI Questions

1. What are the layers of the OSI model?
2. Which layer determines path selection in an internetwork?
3. What types of things are defined at the physical layer?
4. What is one method of mapping network addresses to MAC addresses?
5. Which includes more overhead, connection-oriented or connectionless services?
6. Discuss in detail, the reasons why a layered Network Architecture Model is used to construct a communications network.
7. What are the Internetworking parameters that a network architect is taking into account when designing a network?

OSI Questions

7. **Which of the following are benefits of using a layered network model? (circle one single choice)**
   A . it specifies how changes to one layer must be propagated through the other layers
   B . it facilitates troubleshooting
   C . it focuses on details rather than general functions of networking
   D . it breaks the complex process of networking into more manageable chunks
   E . it allows layers developed by different vendors to interoperate.

a. A and B only
b. B, D, and E
c. A and C only
d. none of the above
e. all of the above

OSI Questions

8. Which of the following operate at the presentation layer?

- **A** . MIDI
  B . FTP
  C . SMTP
  D . TFTP
  E . JPEG

a. A and B
b. A, C, and E
c. C and E
d. A and E
e. none of the above

OSI Questions

9. Bit synchronization is handled at which layer?
   a. data link
   b. Session
   c. Transport
   d. Presentation
   e. physical
10. Which layer is responsible for packet sequencing, acknowledgments, and requests for retransmission?

a. The MAC sublayer of the data link layer
b. transport
c. physical
d. application
e. network

OSI Questions

10. Which layer is responsible for packet sequencing, acknowledgments, and requests for retransmission?

a. The MAC sublayer of the data link layer
b. transport
c. physical
d. application
e. network

Internetworking Questions

11. Which layer 1 devices can be used to enlarge the area covered by a single LAN segment?

a. Switch
b. NIC
b. Hub
c. Repeater
d. RJ45 transceiver

12. Why does the data communication industry use the layered OSI reference model?