Data Communications & Network Management
Data Communications & Networking
Computer Communications

Dr King-Sun Chan

Semester 1 2020

New Combined Unit

- Includes Industry certification with the Cisco Academy
- Topic mainly unchanged but delivery, emphasis and order altered
- Laboratory is VERY demanding - Allow sufficient time

Tuition pattern:

Weekly 2 Hour Lecture

Weekly 2 (3 for B.Tech) hour laboratory

Weekly 1 hour tutorial

Curtin University

Laboratory Info

DCNM, DCN, CC Laboratories

- Labs starts from first week
  - CCNA Introduction to Networks Version 7(All)
- Resources are available on:
- https://www.netacad.com/
- http://netlab.ece.curtin.edu.au/
- Tutorials start WEEK 2

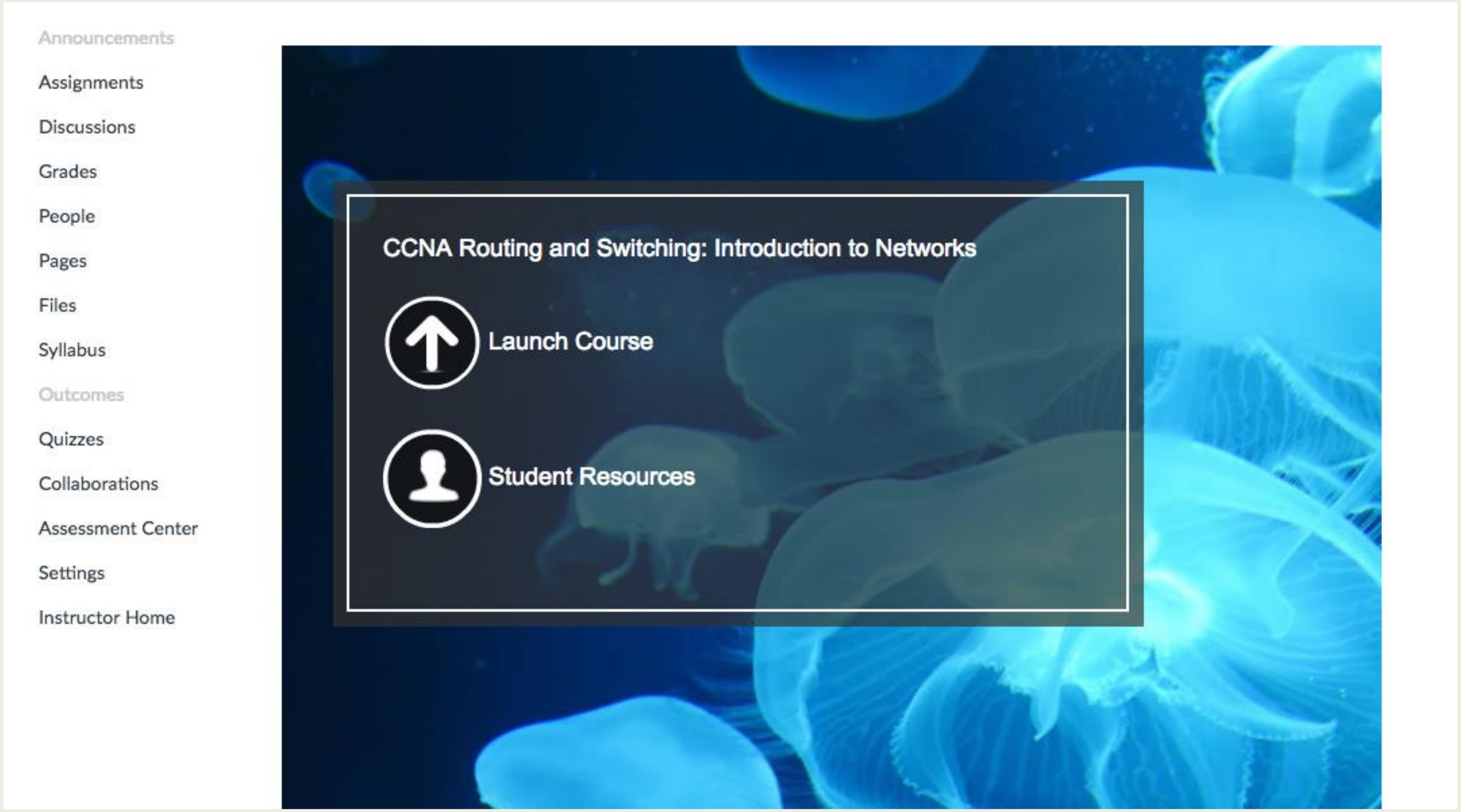
CCNA Intro to Networks

- Include:
  - *Chapter tests*
    - Chapter quizzes are mainly for practice (small contribution)
  - *Lab book*
    - Non assessable item but VERY useful for test preparation
  - *Skill test - week 14*
  - *Final on line test week13*
  - *Pass mark is 75%*
    - *See next slide*

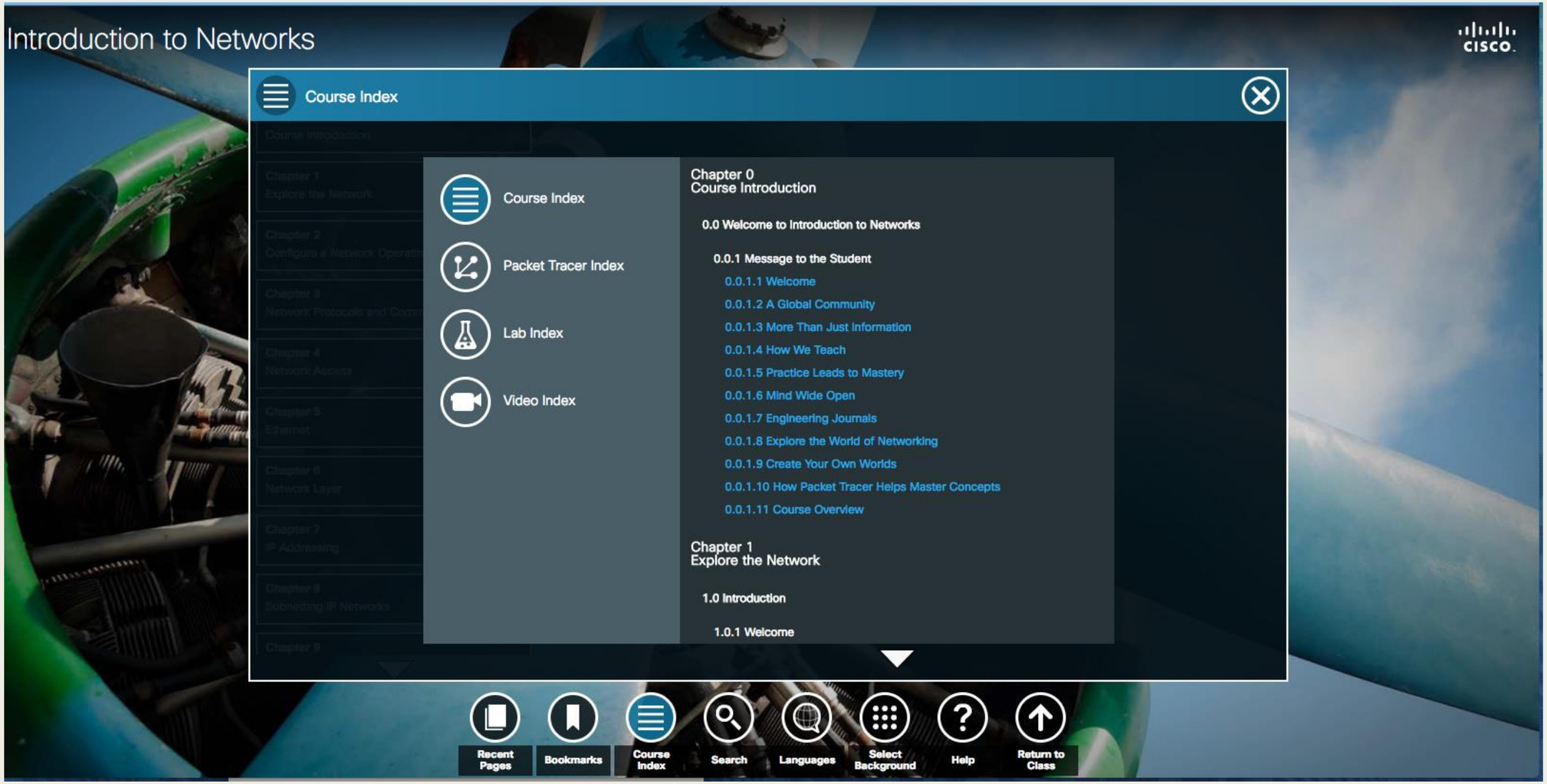
CCNA courses

- *Only one chance on chapter tests*
  - These are formative and only contribute a small amount to the overall grade
- *Two attempts on Final and skill test - second attempt has a maximum score of 75% (ie pass/fail)*
- *Result (R) calculation (to align with Curtin policy of 50% pass grade):*
  - `if R<75`
    - *`Final Result = (50 X Cisco Result)/75`*
  - `else`
    - *`Final Result = (2X(Cisco Result -75))+50`*
- *Chapter and final exams are multiple choice*
- *Chapter tests are open book and final and skill are closed book*
- *Exams are not activated by default*

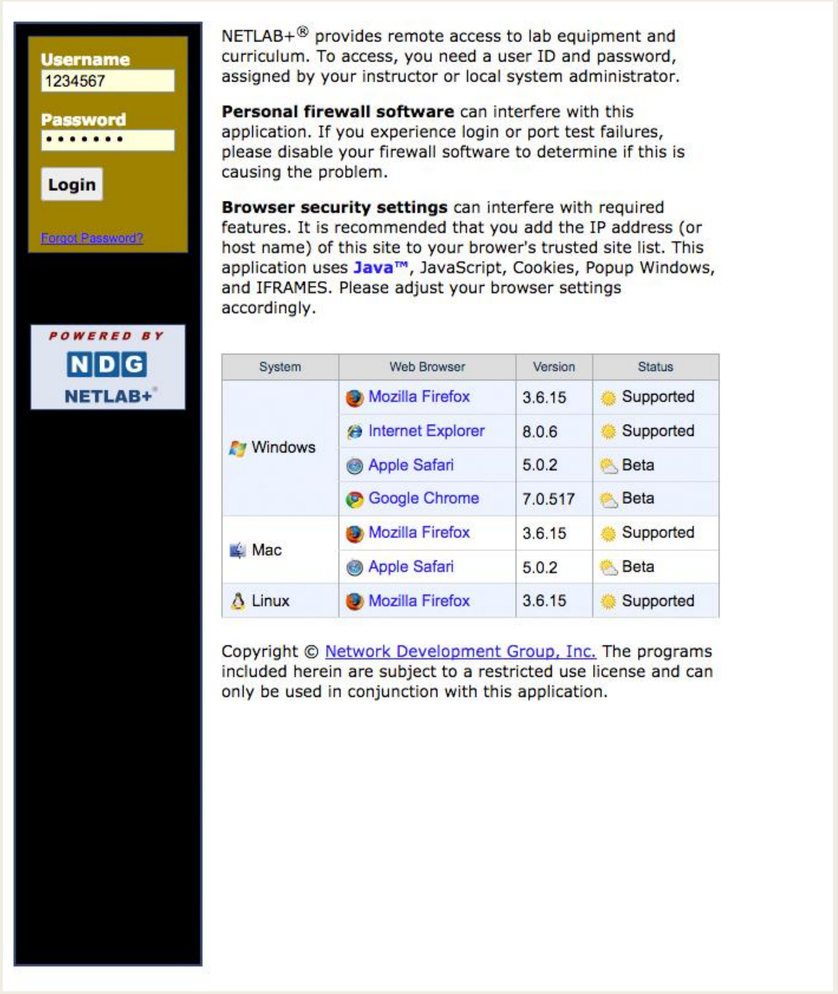
Netacad Home page



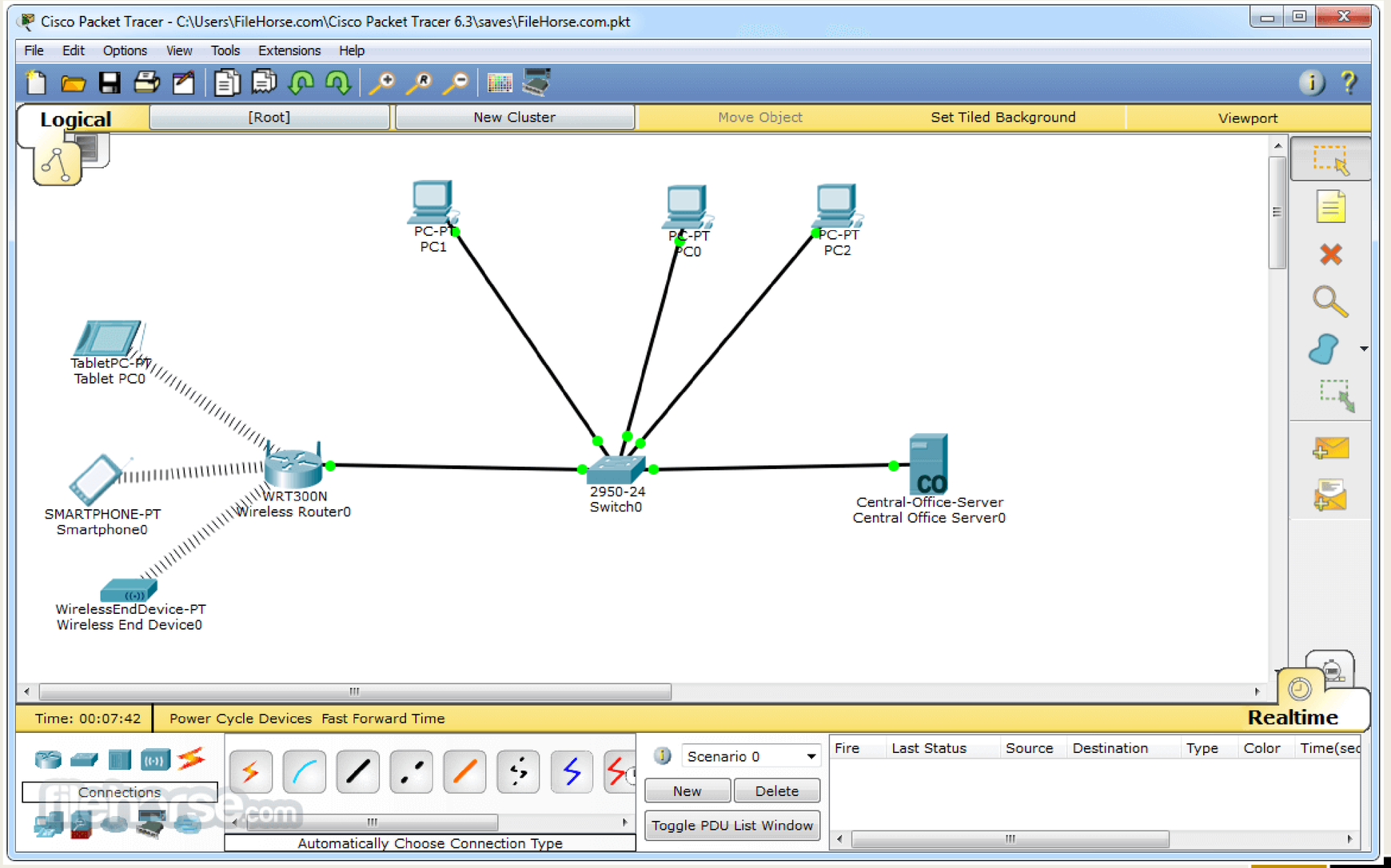
Course Index



NetLab Login page



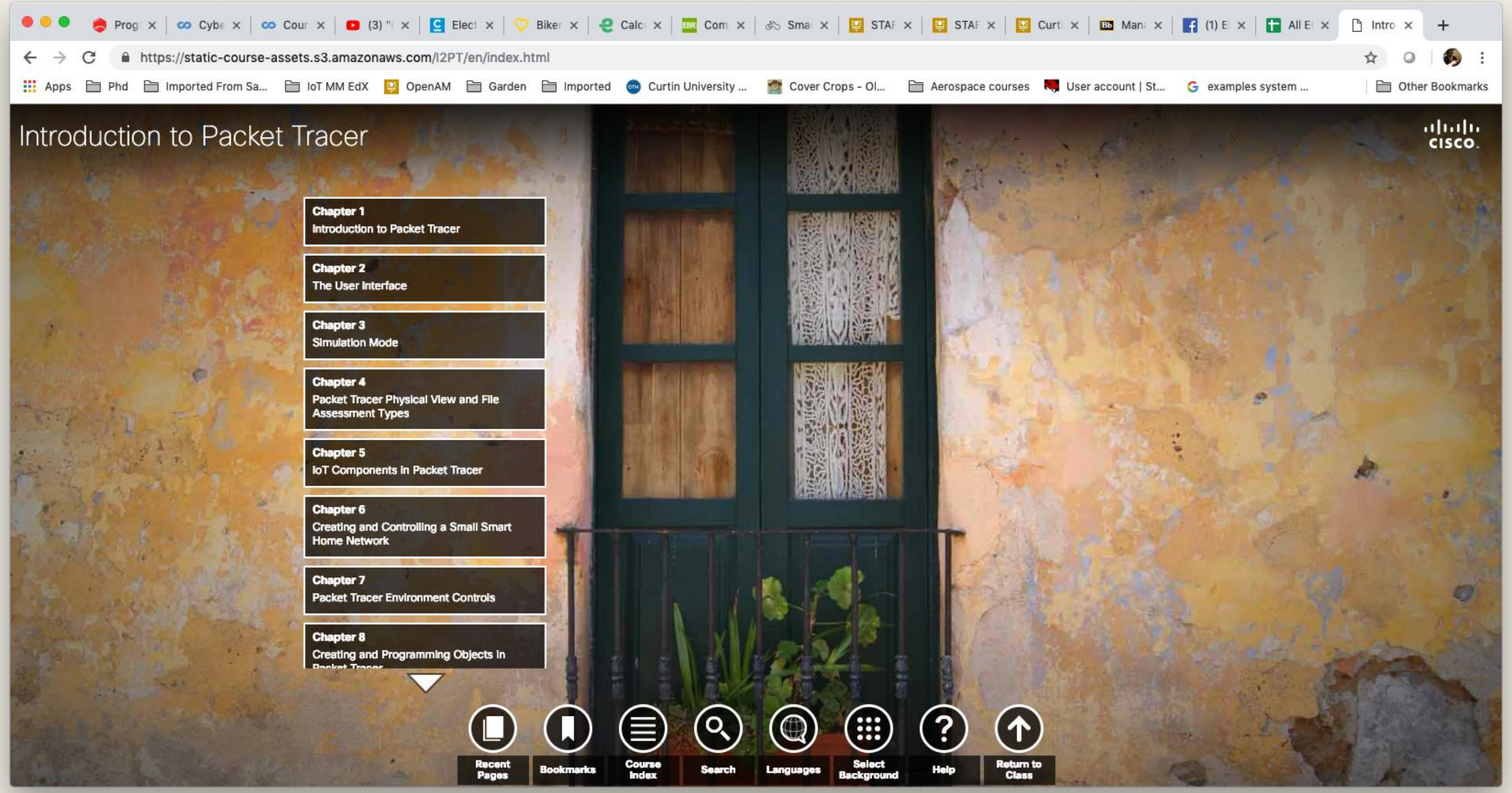
Packet Tracer



Packet Tracer Resources

Intro to PT course

First 2 tutorial sessions

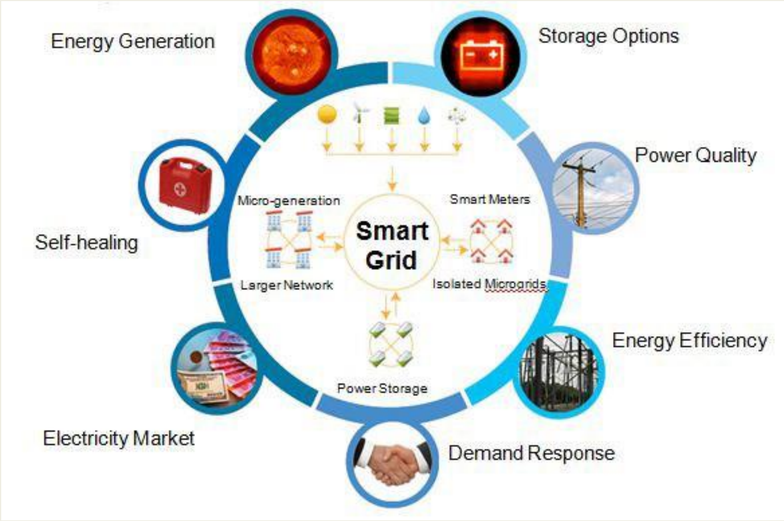


Ch1_Vid1_Introduction to Packet Tracer

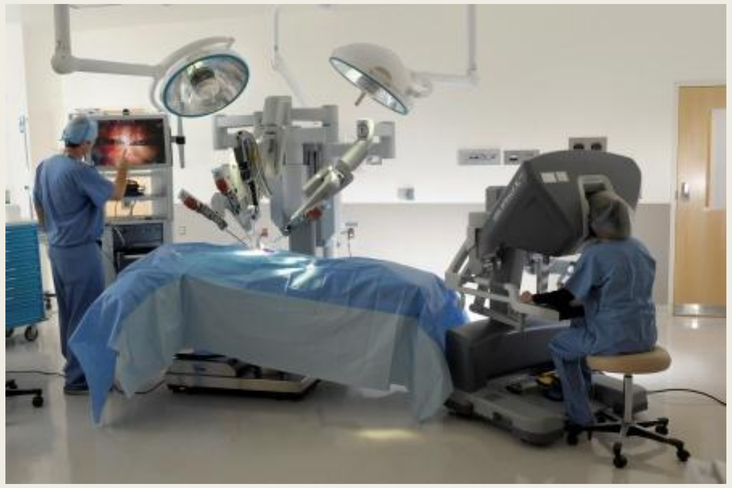
Why?

- This is a core unit for those undertaking the following degree programs
  - *BSc (Computing-Computer Science)*
  - *BSc (Computing-Information Technology)*
  - *BSc (Computing-Software Engineering)*
  - *BSc(Computing-Cyber Security)*
  - *B.Tech(Computer Systems & Networking)*
- Should be obvious why this is in your course!
- Also core to
  - *B.Eng(Computer Systems Engineering)(Hons)*
  - *B.Eng(Electrical Power Engineering)(Hons)*
  - *B.Eng(Electronic & Communications)(Hons)*
  - *B.Eng(Electrical & Electronic Engineering)(Hons)*
- May not be so obvious

Everything is getting connected



- Smart grid
- Internet of Things
- Think of your mobile phone
- Remote operations of mine sites
- Health and surgical monitoring (robotic assisted surgery)



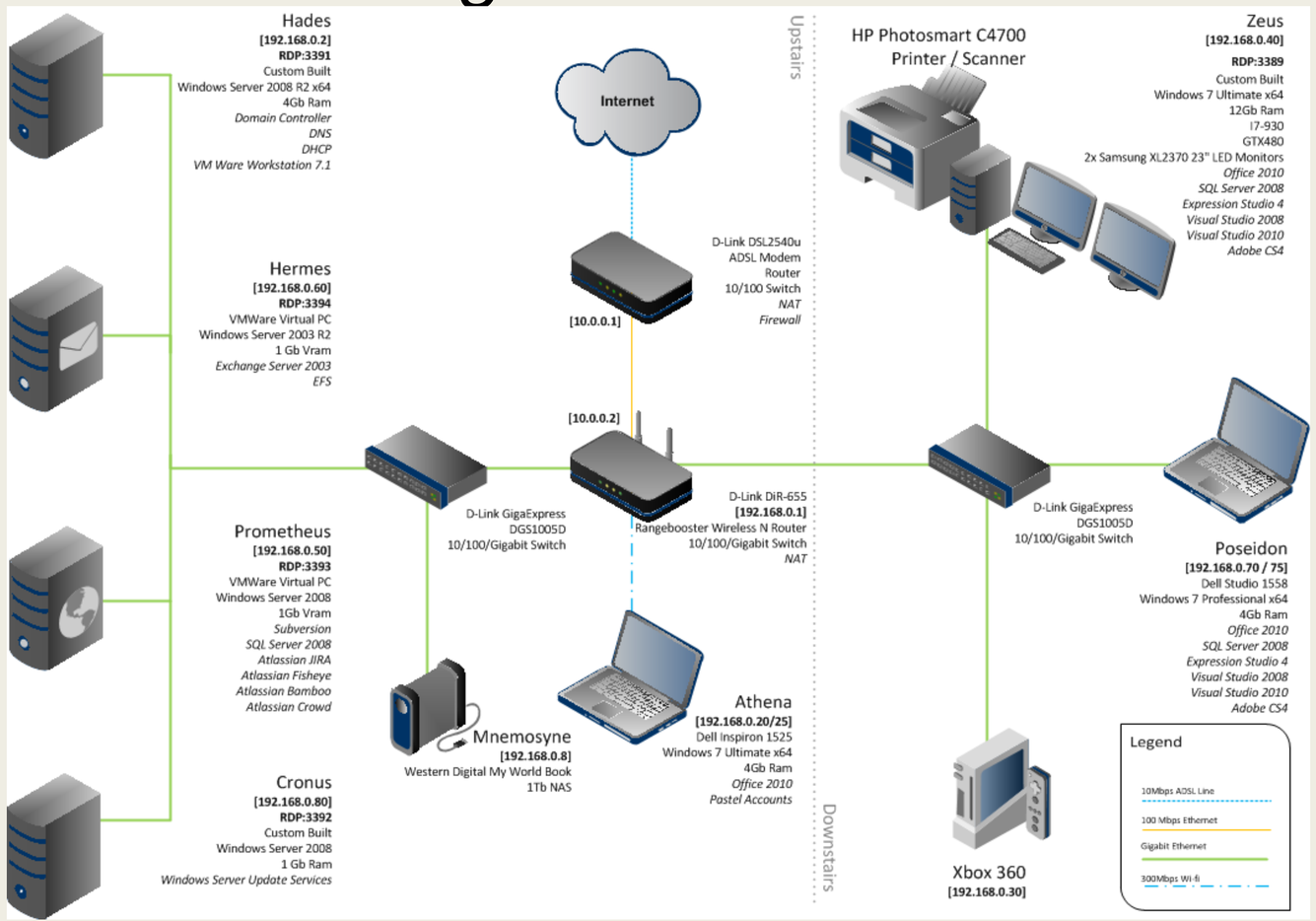
Why network?

- What is a computer network?
- Interconnected collection of autonomous computers.
- Two computers are said to be connected if they are able to exchange information.
- Connection via copper wire, fibre optics, microwaves, infrared and radio frequency etc.
- Information exchange between computers

Computer/Data Communications

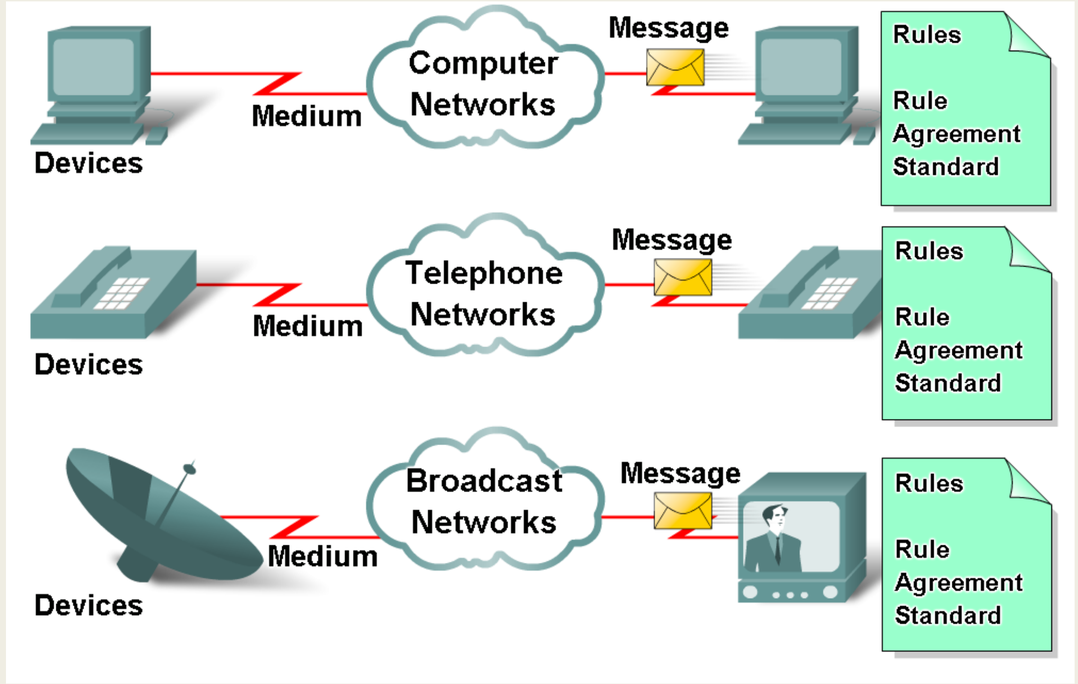
Why Network?

- Business Application/Home Application/Mobile Users
  - *Resource Sharing*



Data Networking Role, Components, and Challenges

- The various elements that make up a network
- Devices
  - *These are used to communicate with one another*
- Medium
  - *This is how the devices are connected together*
- Messages
  - *Information that travels over the medium*
- Rules
  - *Governs how messages flow across network*



The Internet

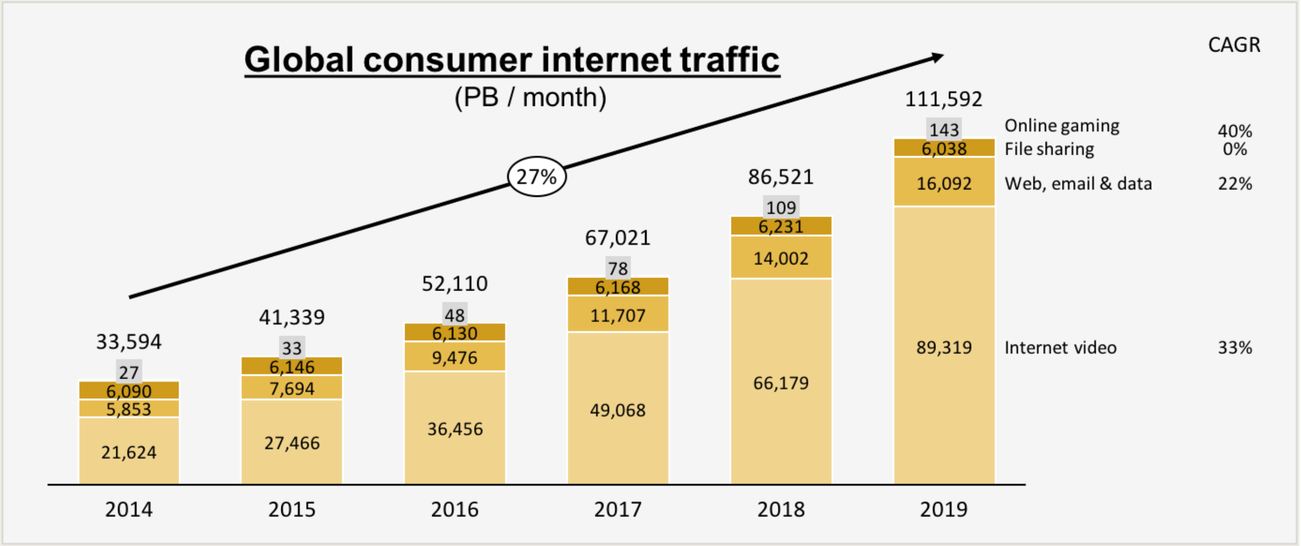
- What lies at the heart of the Internet?
- Two key technical innovations:
  - *packets / Datagrams*
  - *store and forward*
  - BUT:
    - hard to control delay within network
    - switches need memory for buffers
    - convergence of flows can lead to congestion
- Design philosophy: “smart edge dumb core”

Challenges

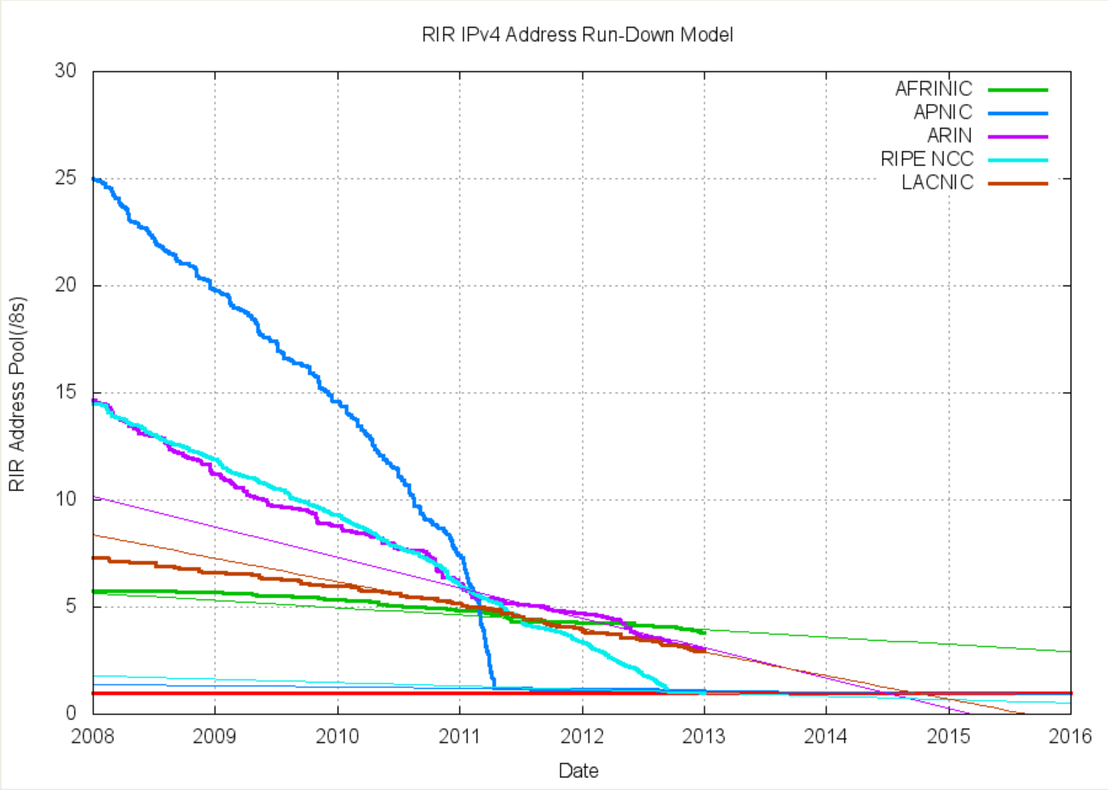
- IP address space shortage
  - *because of free distribution of inefficient Class B addresses*
  - *decentralised control => hard to recover addresses, once handed out*
- Decentralisation
  - *allows scaling, but makes reliability impossible*
  - *cannot guarantee that a route exists, much less bandwidth or buffer resources*
  - *single points of failure can cause a major disaster*
    - and there is no control over who can join!
  - *hard to guarantee security*
    - end-to-end encryption is a partial solution
    - who manages keys?

Challenges

- Decentralisation (contd.)
  - *no uniform solution for accounting and billing*
    - can’t even reliably identify individual users
  - *no equivalent of white or yellow pages*
    - hard to reliably discover a user’s email address
  - *Non-optimal routing*
    - each admin unit makes a locally optimal decision
- Multimedia
  - *requires network to support quality of service of some sort*
    - hard to integrate into current architecture
    - store-and-forward => hard to provide service quality



Source: Cisco VNI, 2015



- Since 1997, total volume of Worldwide Data traffic has surpassed that of PSTN Voice traffic
  - But the revenue generated from data traffic is much less than that from voice
  - IANA's exhaustion on 31 January 2011 the exhaustion of the RIRs APNIC on 15 April 2011 and RIPE NCC on 14 September 2012

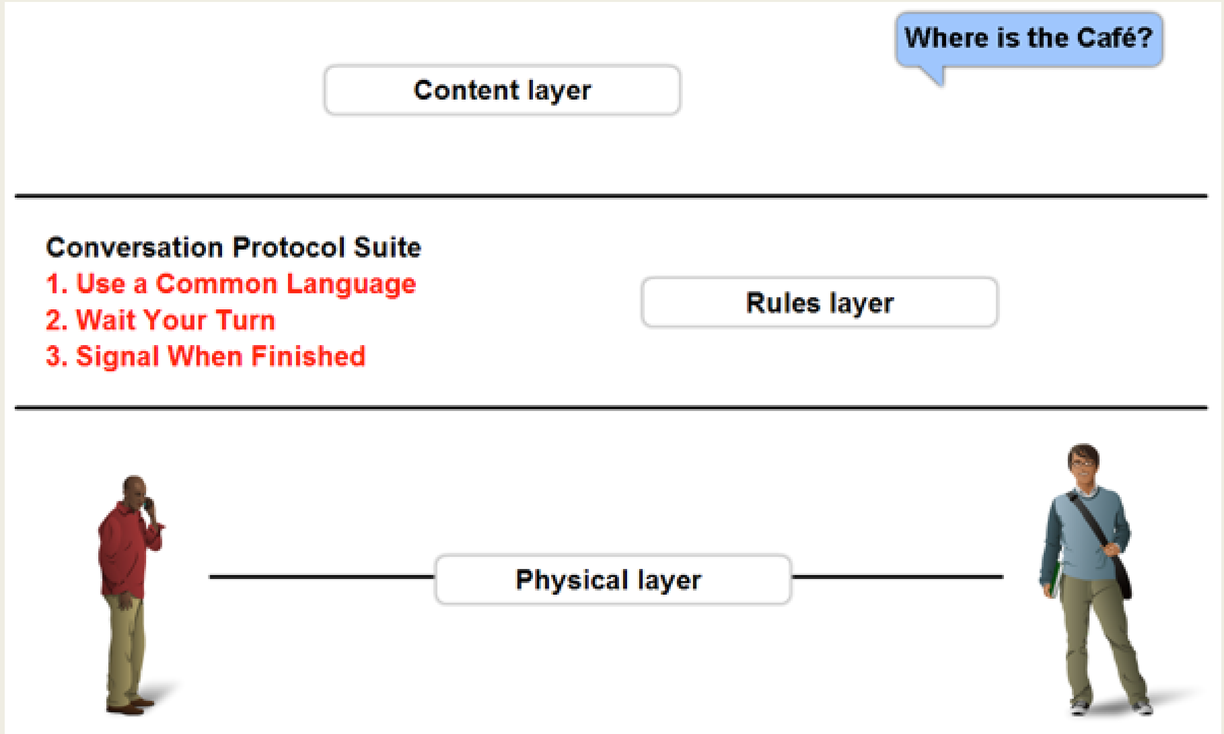
Layers, Services & Protocols

- The overall communications process between two or more machines connected across one or more networks is very complex

- Layering partitions related communications functions into groups that are manageable
- Each layer provides a service to the layer above
- Each layer operates according to a protocol

Protocols

- A protocol is a set of rules that governs how two or more communicating entities in a layer are to interact
- Messages that can be sent and received
- Actions that are to be taken when a certain event occurs, e.g. sending or receiving messages, expiry of timers
- The purpose of a protocol is to provide a service to the layer above



Why Layering?

- Layering simplifies design, implementation, and testing by partitioning overall communications process into parts
- Protocols in each layer can be designed separately from those in other layers
- Protocol makes “calls” for services from layer below
- Layering provides flexibility for modifying and evolving protocols and services without having to change layers below
- Monolithic non-layered architectures are costly, inflexible, and soon obsolete

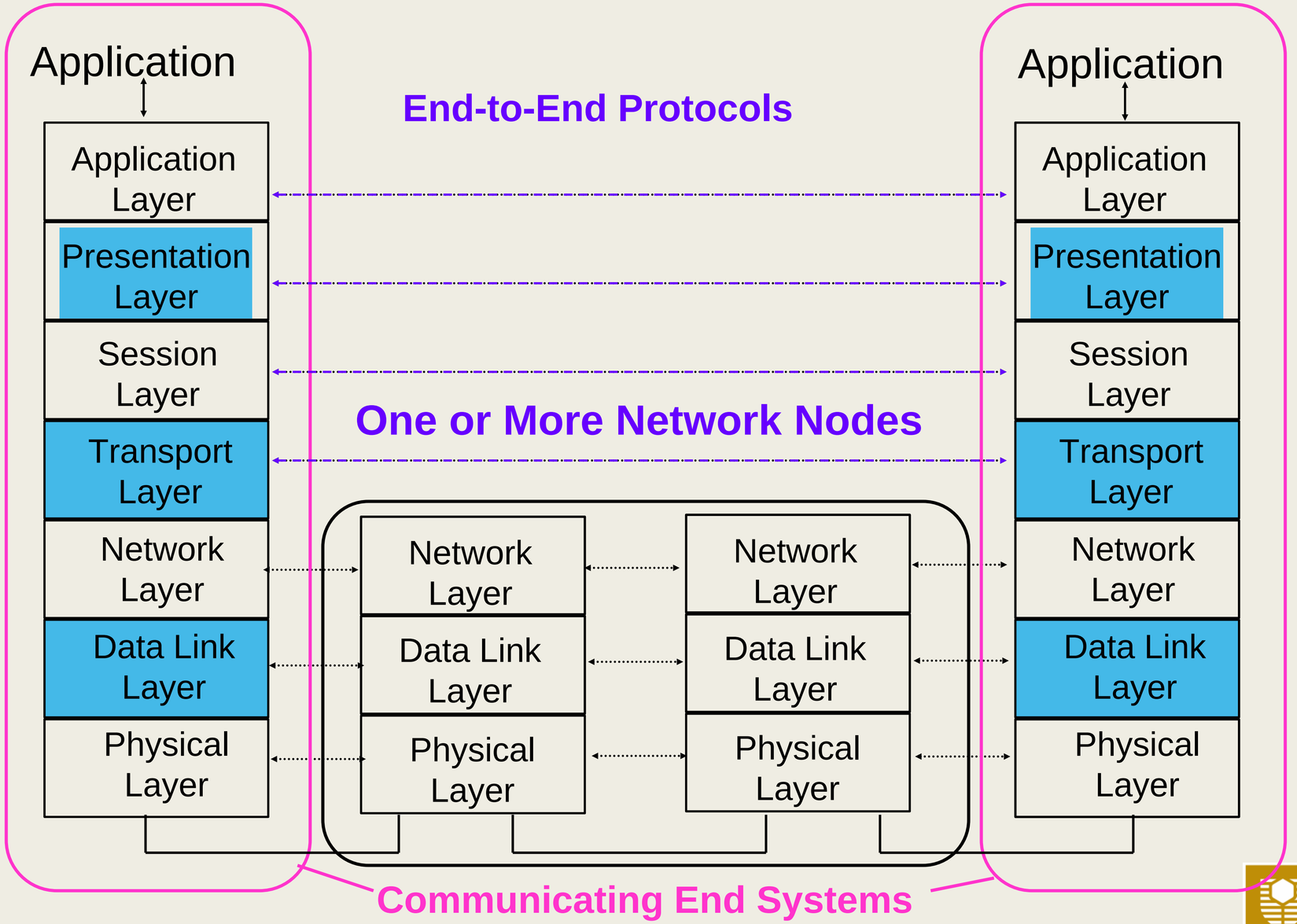
Open Systems Interconnection

- Network architecture:
  - *Definition of all the layers*
  - *Design of protocols for every layer*
- By the 1970s every computer vendor had developed its own proprietary layered network architecture
  - *Problem: computers from different vendors could not be networked together*
- Open Systems Interconnection (OSI) was an international effort by the International Organisation for Standardisation (ISO) to enable multivendor computer interconnection

OSI Reference Model

- Describes a seven-layer abstract reference model for a network architecture
- Purpose of the reference model was to provide a framework for the development of protocols
- OSI also provided a unified view of layers, protocols, and services which is still in use in the development of new protocols
- Detailed standards were developed for each layer, but most of these are not in use
- TCP/IP protocols preempted deployment of OSI protocols

7-Layer OSI Reference Model



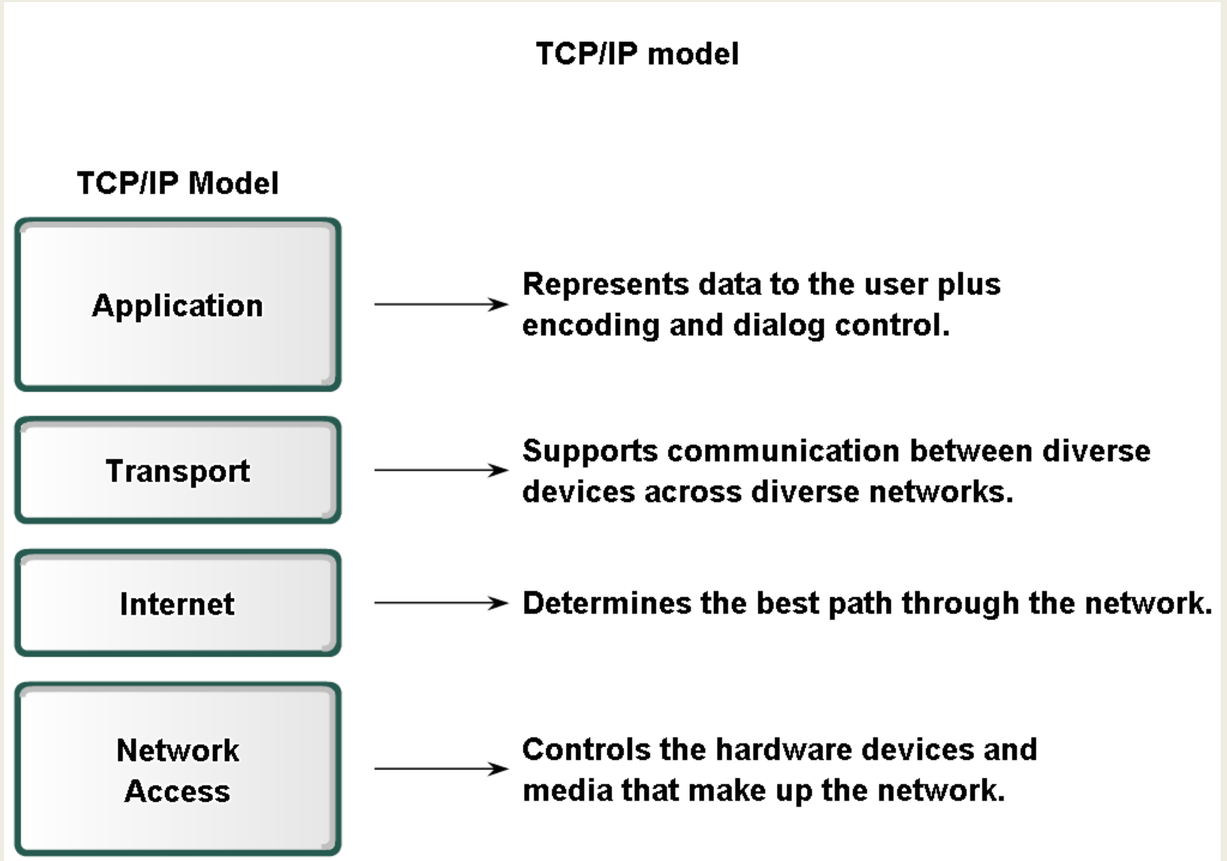
Layers

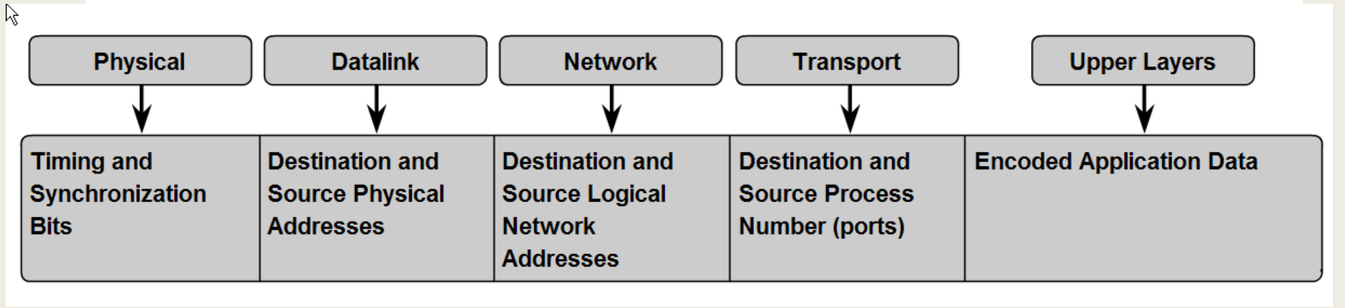
- A set of related communication functions that can be managed and grouped together
  - Application Layer: communications functions that are used by application programs
    - *HTTP, DNS, SMTP (email)*
  - Transport Layer: end-to-end communications between two processes in two machines
    - *TCP, User Datagram Protocol (UDP)*
  - Network Layer: node-to-node communications between two machines
    - *Internet Protocol (IP) v4 & v6*

Layers

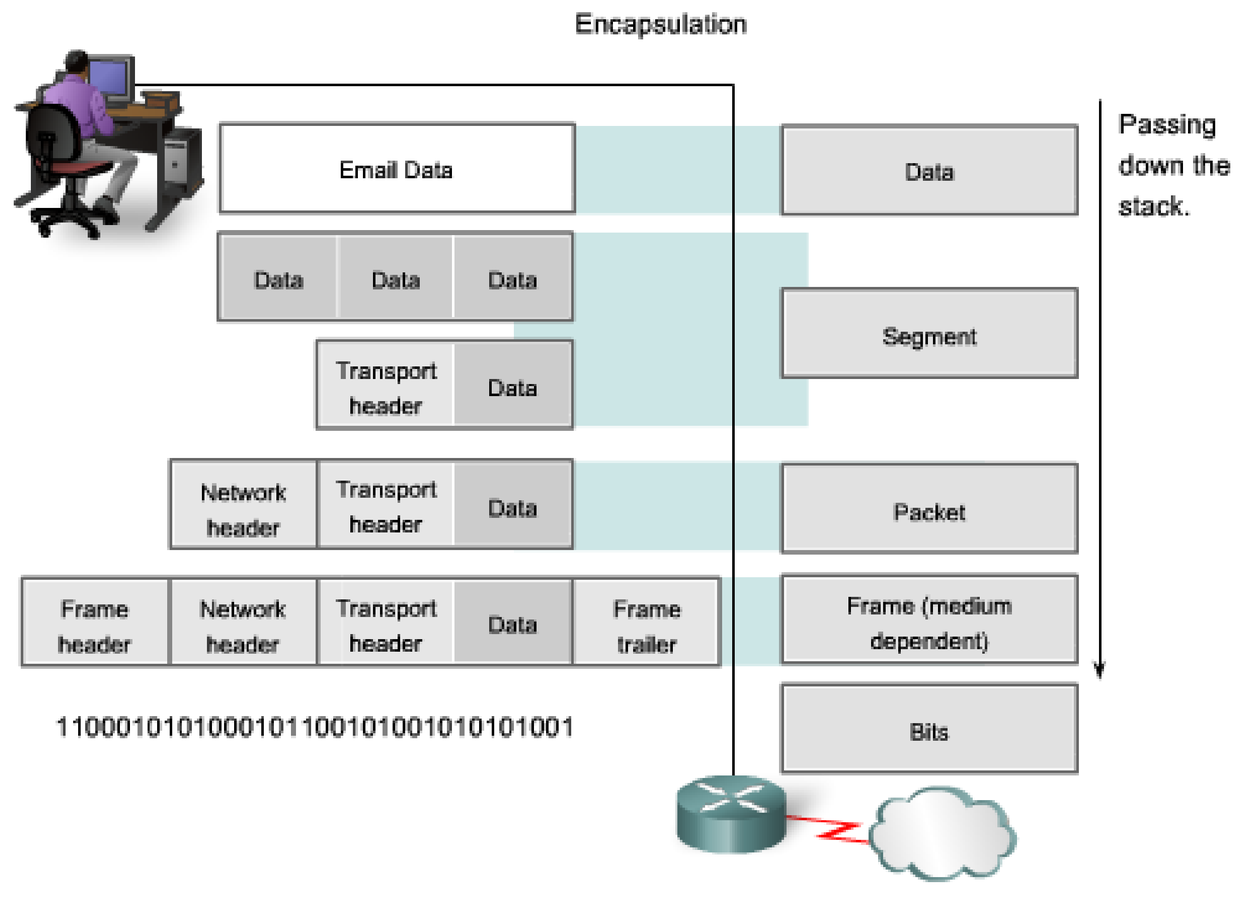
- Data Link Layer
  - Local communication
  - Physical addresses
  - Media Access
  - Eg Ethernet
- Physical Layer
  - Electrical properties
  - Connectors
  - Media types
  - Eg Ethernet (again) - but more specialised - 1000Base T

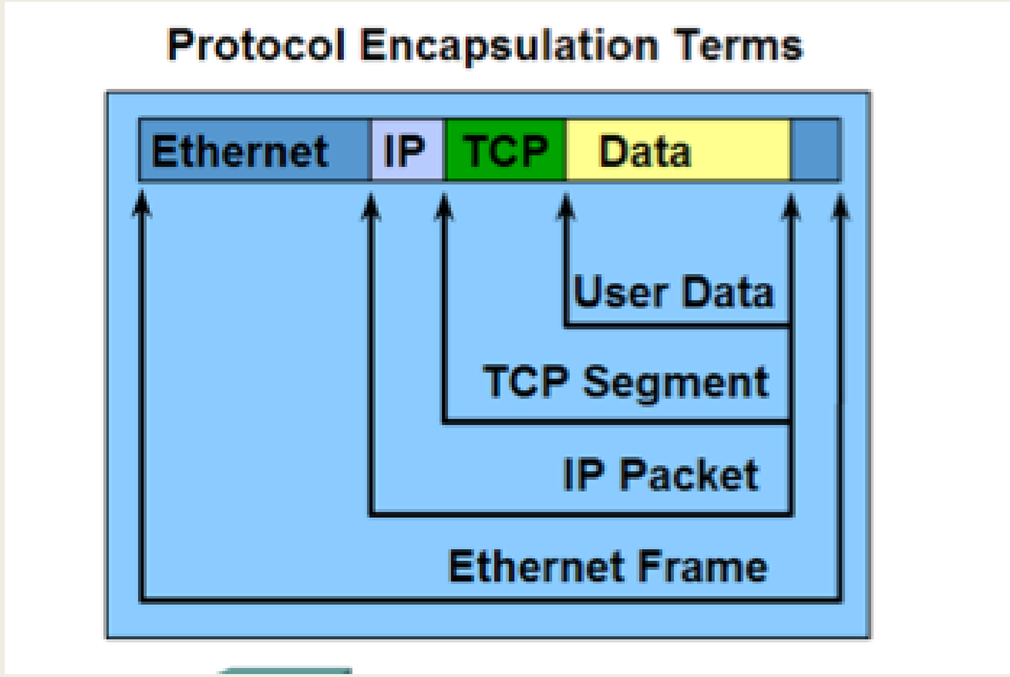
Layers with TCP/IP and OSI Model





Encapsulation



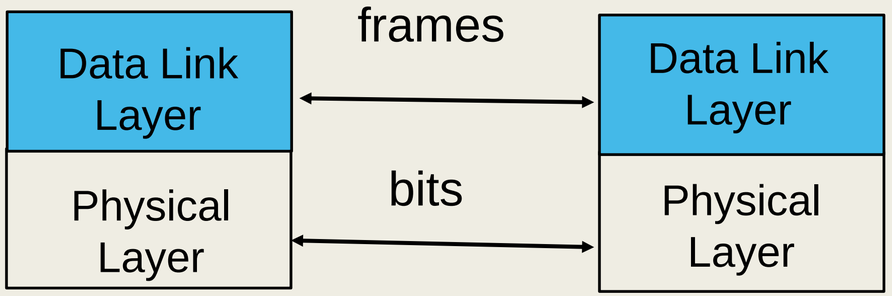


Physical Layer

- Transfers bits across link
- Definition & specification of the physical aspects of a communications link
  - *Mechanical: cable, plugs, pins...*
  - *Electrical/optical: modulation, signal strength, voltage levels, bit times, …*
  - *functional/procedural: how to activate, maintain, and deactivate physical links…*
- Ethernet, DSL, cable modem, telephone modems…
- Twisted-pair cable, coaxial cable optical fiber, radio, infrared, …

Data Link Layer

- Transfers frames across direct connections
- Groups bits into frames
- Detection of bit errors; Retransmission of frames
- Activation, maintenance, & deactivation of data link connections
- Medium access control for local area networks
- Flow control

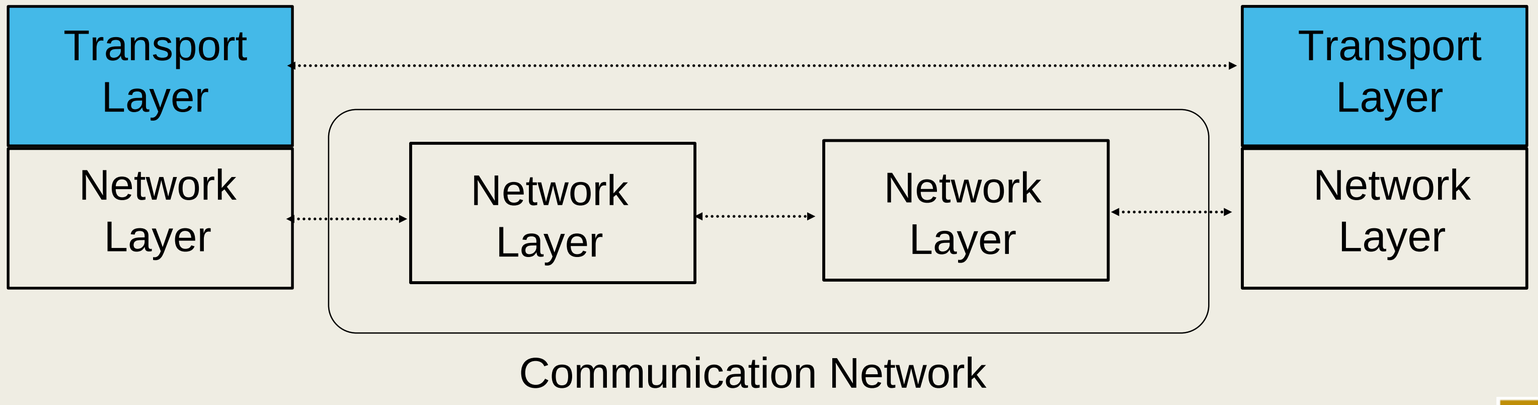


Network Layer

- Transfers packets across multiple links and/or multiple networks
- Addressing must scale to large networks
- Nodes jointly execute routing algorithm to determine paths across the network
- Forwarding transfers packet across a node
- Congestion control to deal with traffic surges
- Connection setup, maintenance, and teardown when connection-based

Transport Layer

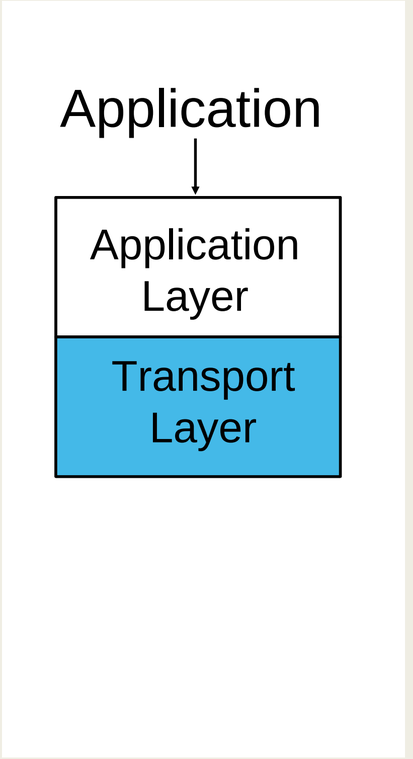
- Transfers data end-to-end from process in a machine to process in another machine
- Reliable stream transfer or quick-and-simple single-block transfer
- Port numbers enable multiplexing
- Message segmentation and reassembly
- Connection setup, maintenance, and release



Application & Upper Layers

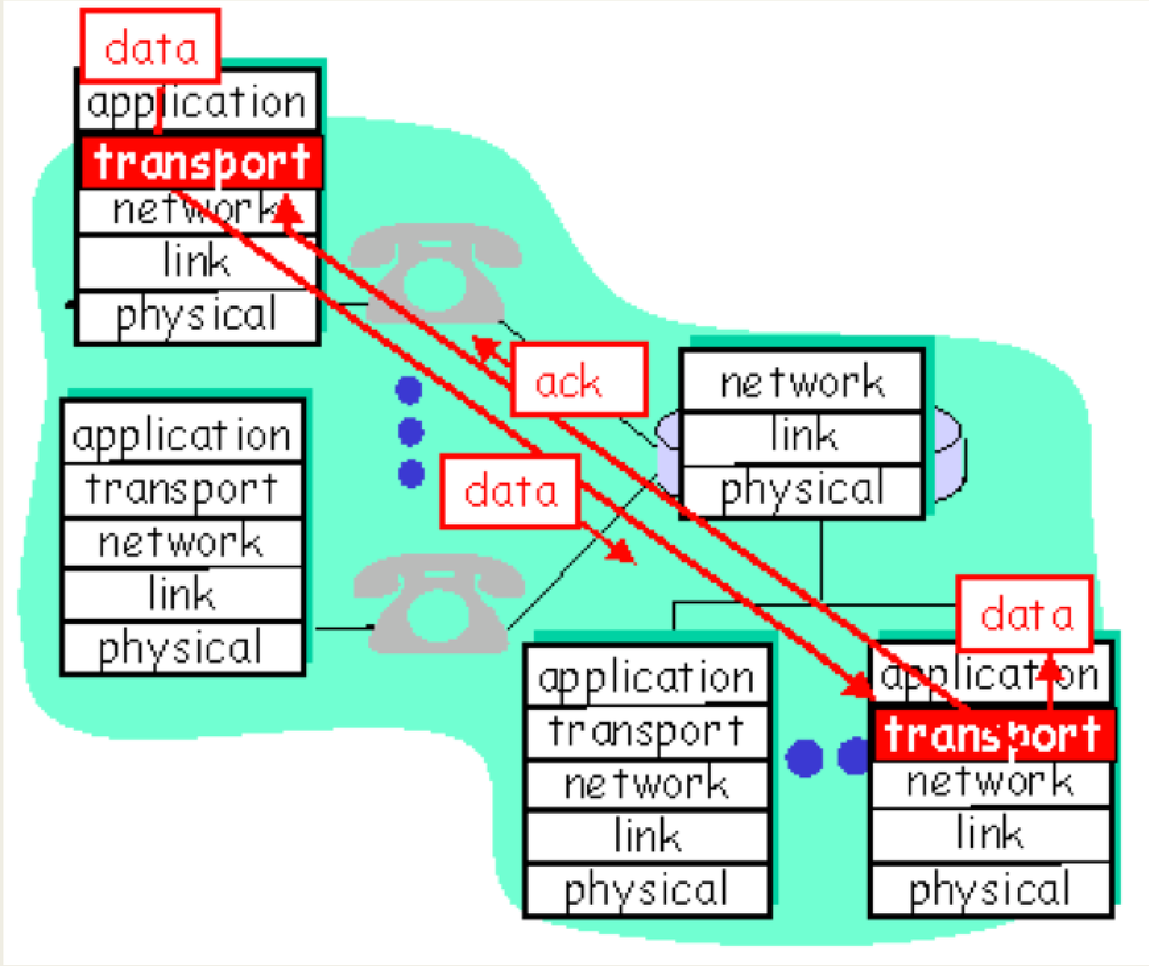
- Application Layer: Provides services that are frequently required by applications: DNS, web access, file transfer, email…
- ~~Presentation Layer: machine-independent representation of data…~~
- ~~Session Layer: dialog management, recovery from errors, …~~

Incorporated into Application Layer

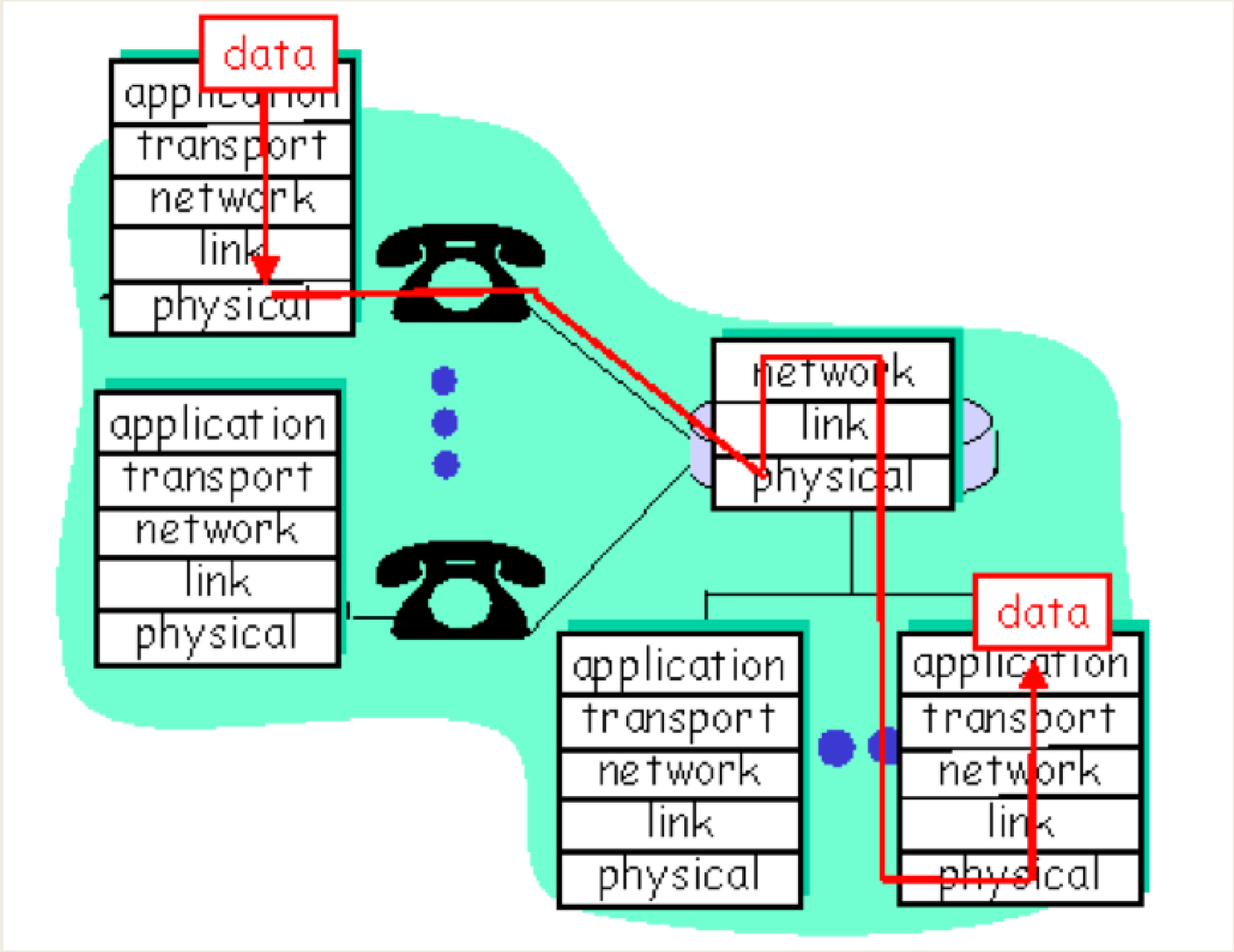


Layering: logical communication

- Each layer:
  - *Distributed "entities" implement layer functions at each node*
  - *entities perform actions, exchange messages with peers*
- E.g.: transport
  - *take data from app*
  - *add addressing, reliability check info to form "datagram"*
  - *send datagram to peer*
  - *wait for peer to ack receipt*
- analogy: post office

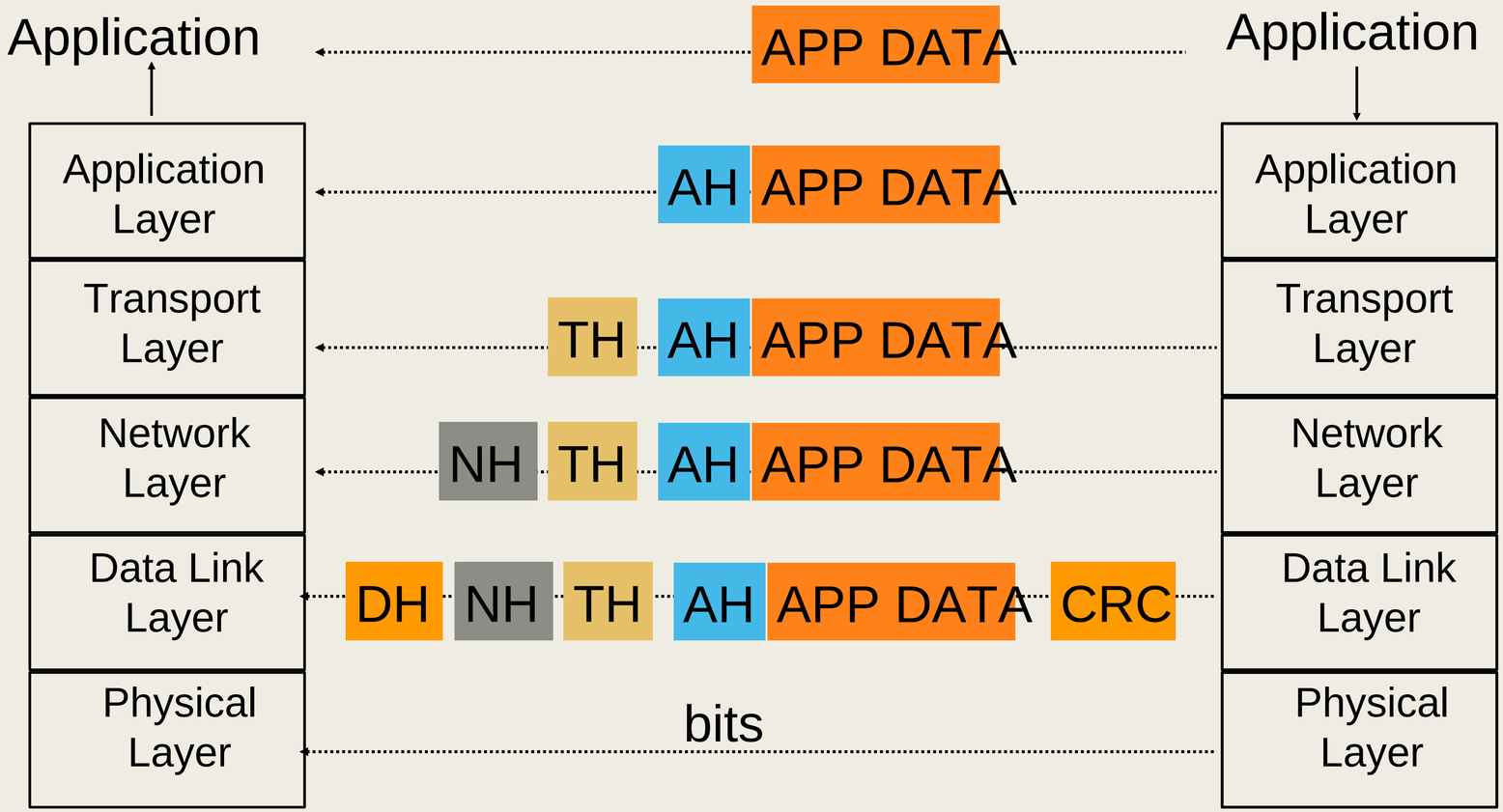


Layering: physical communication



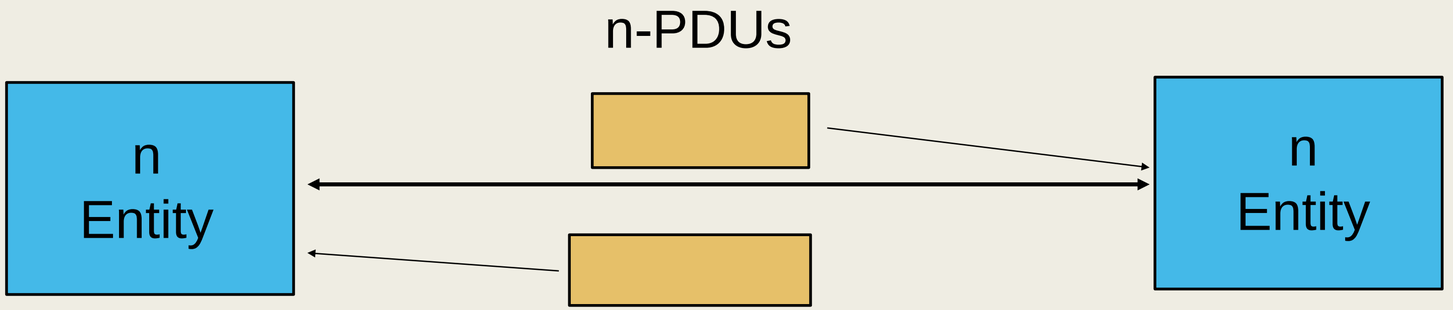
Headers and Trailers

- Each protocol uses a header that carries addresses, sequence numbers, flag bits, length indicators, etc…
- CRC check bits may be appended for error detection



OSI Unified View: Protocols

- Layer n in one machine interacts with layer n in another machine to provide a service to layer n +1
- The entities comprising the corresponding layers on different machines are called peer processes.
- The machines use a set of rules and conventions called the layer-n protocol.
- Layer-n peer processes communicate by exchanging Protocol Data Units (PDUs)

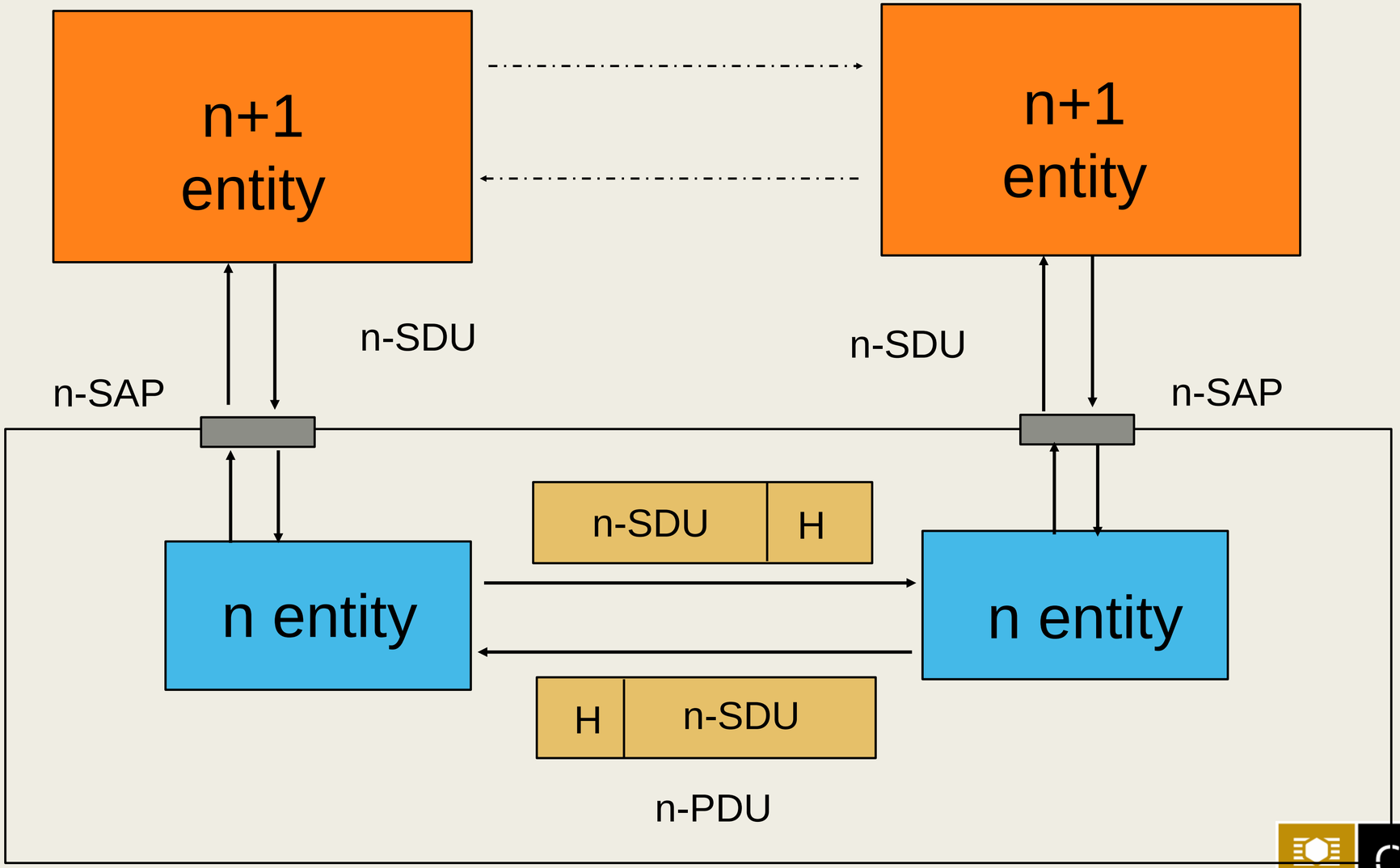


Layer n peer protocol

OSI Unified View: Services

- Communication between peer processes is virtual and actually indirect
- Layer n+1 transfers information by invoking the services provided by layer n
- Services are available at Service Access Points (SAP's)
- Each layer passes data & control information to the layer below it until the physical layer is reached and transfer occurs
- The data passed to the layer below is called a Service Data Unit (SDU)
- SDU's are encapsulated in PDU's

Layers, Services & Protocols

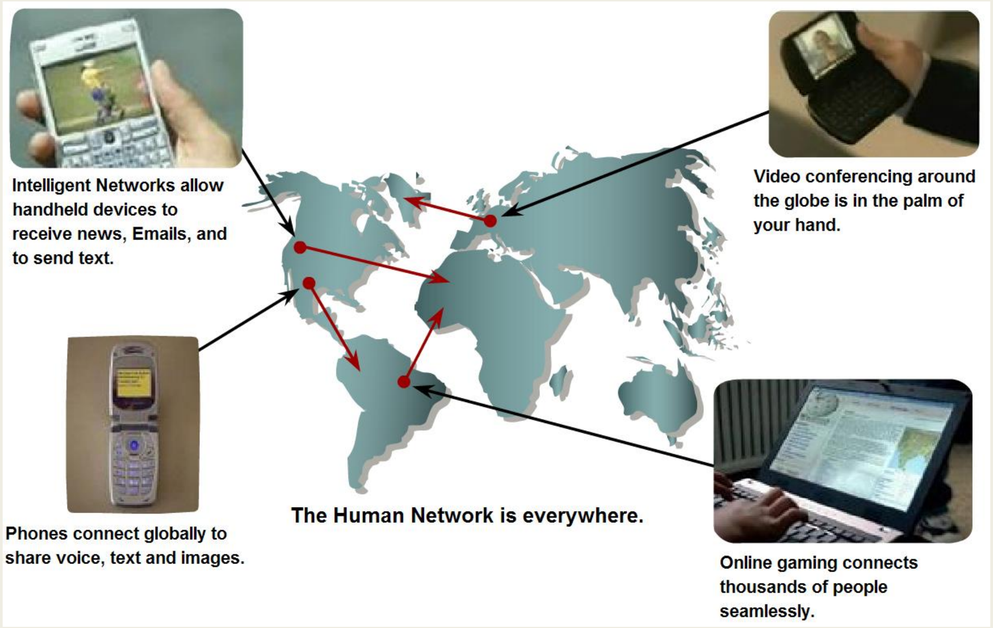


Protocol Stack Summary

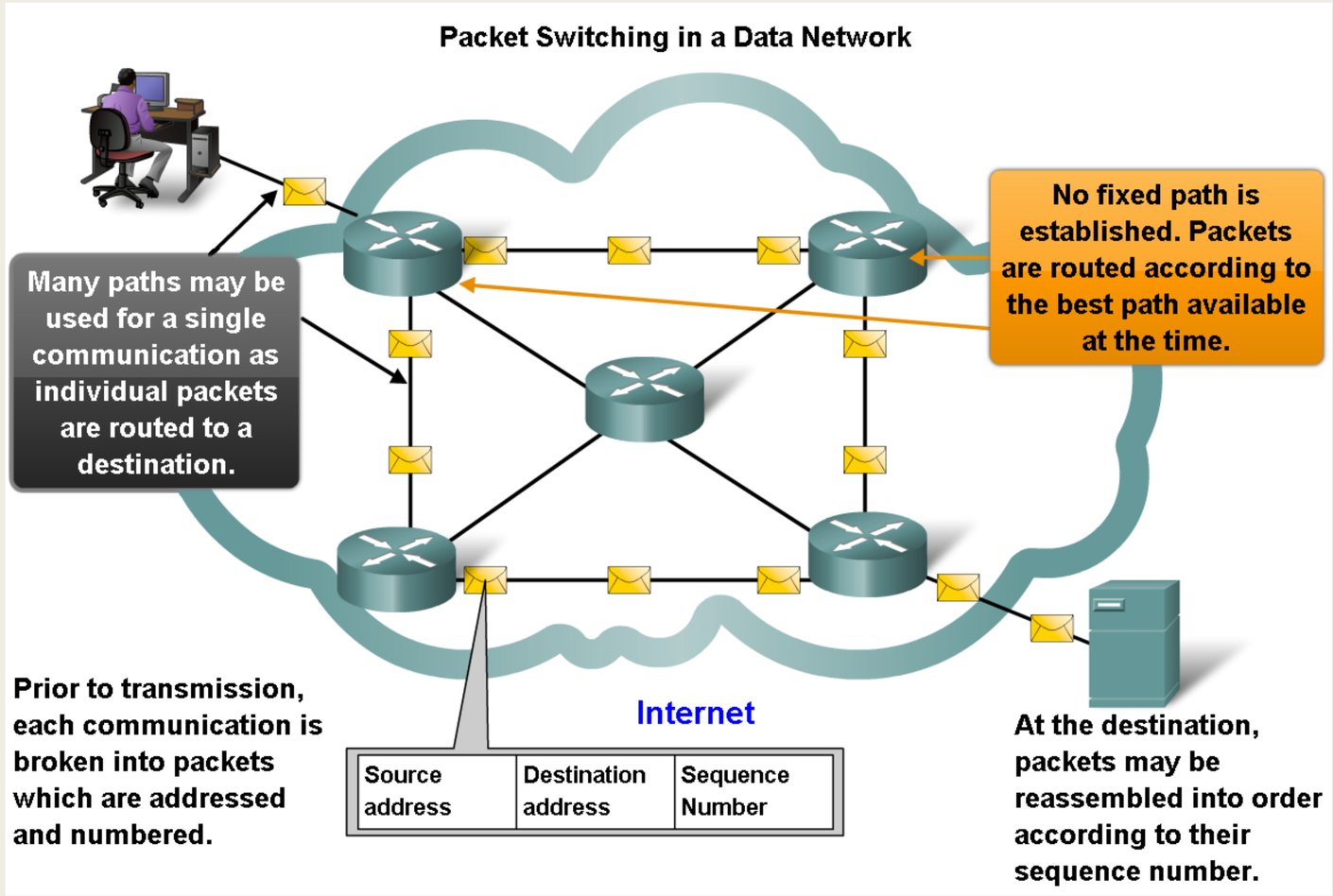
- Layers: related communications functions
  - *Application Layer: HTTP, DNS*
  - *Transport Layer: TCP, UDP*
  - *Network Layer: IP*
  - *Data Link Layer: Ethernet, Frame relay, HDLC*
- Services: a protocol provides a communications service to the layer above
  - *TCP provides connection-oriented reliable byte transfer service*
  - *UDP provides best-effort datagram service*
- Each layer builds on services of lower layers
  - *HTTP builds on top of TCP*
  - *DNS builds on top of UDP*
  - *TCP and UDP build on top of IP*

Data Networking Role, Components, and Challenges

- Network Convergence is a broad term used to describe emerging technologies, and network architecture designs used to migrate voice and data networks into a single network. Specifically, Network Convergence describes the transition from separate circuit-switched voice network and packet-switched data networks, to a single packet-switched network supporting both voice and data protocols.

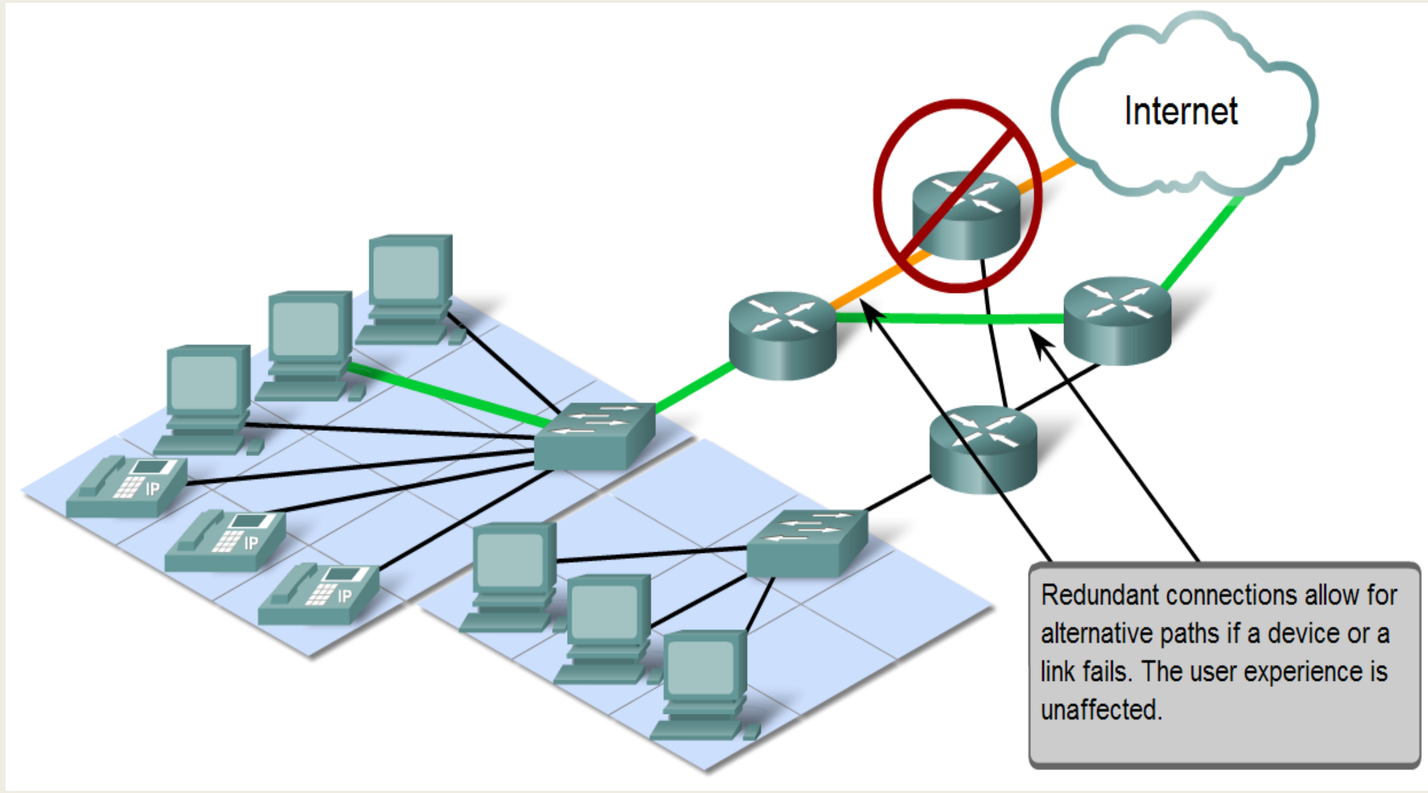


Network Architecture Characteristics



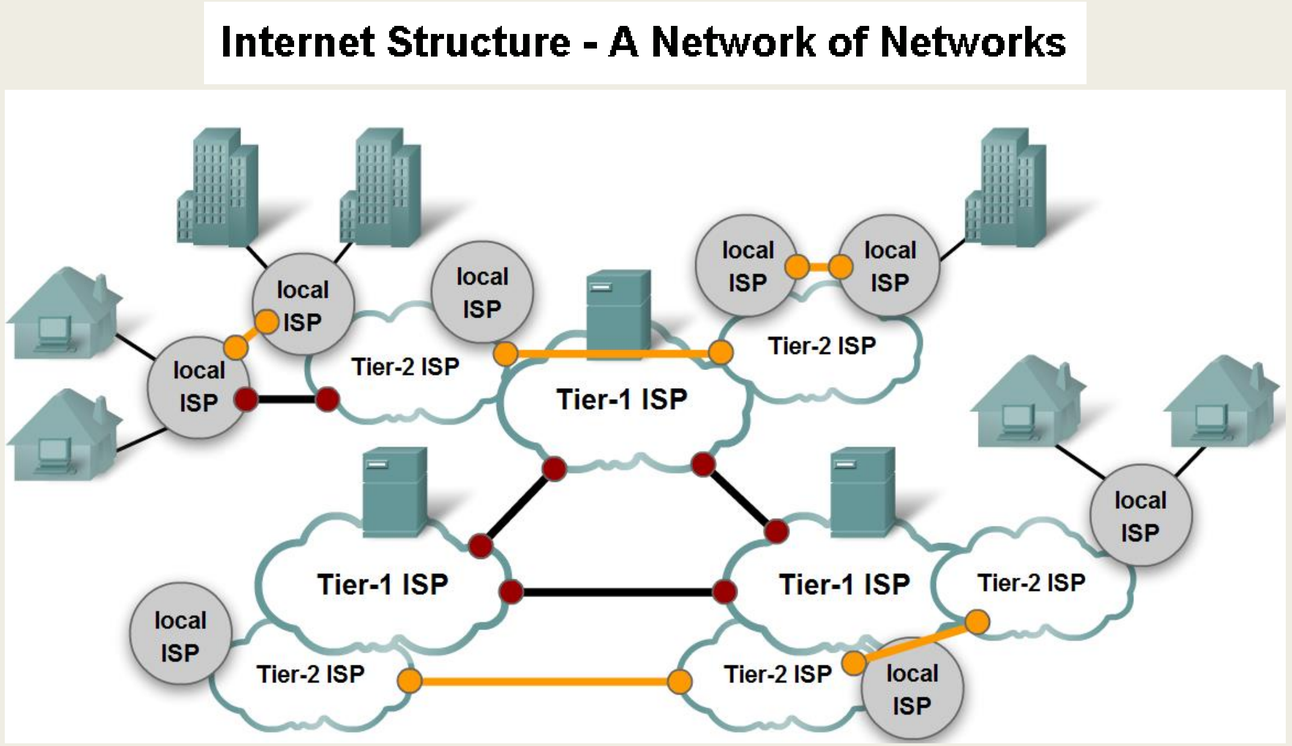
Network Architecture Characteristics

- Design requirements include:
  - *Fault tolerance*
  - *Scalability*
  - *Quality of service*
  - *Security*



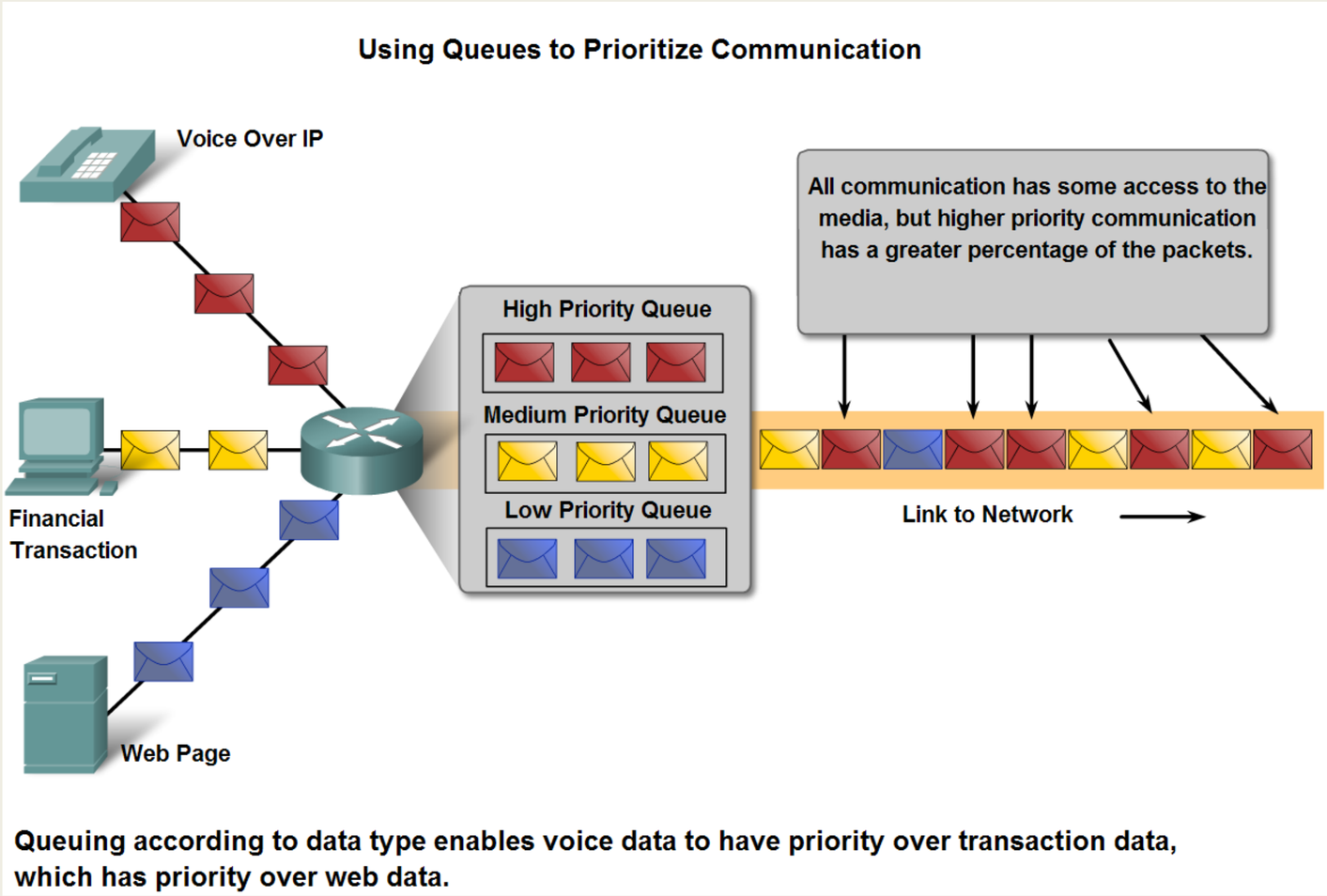
Network Architecture Characteristics

- Characteristics of the Internet that help it scale to meet user demand
  - *Hierarchical*
  - *Common standards*
  - *Common protocols*



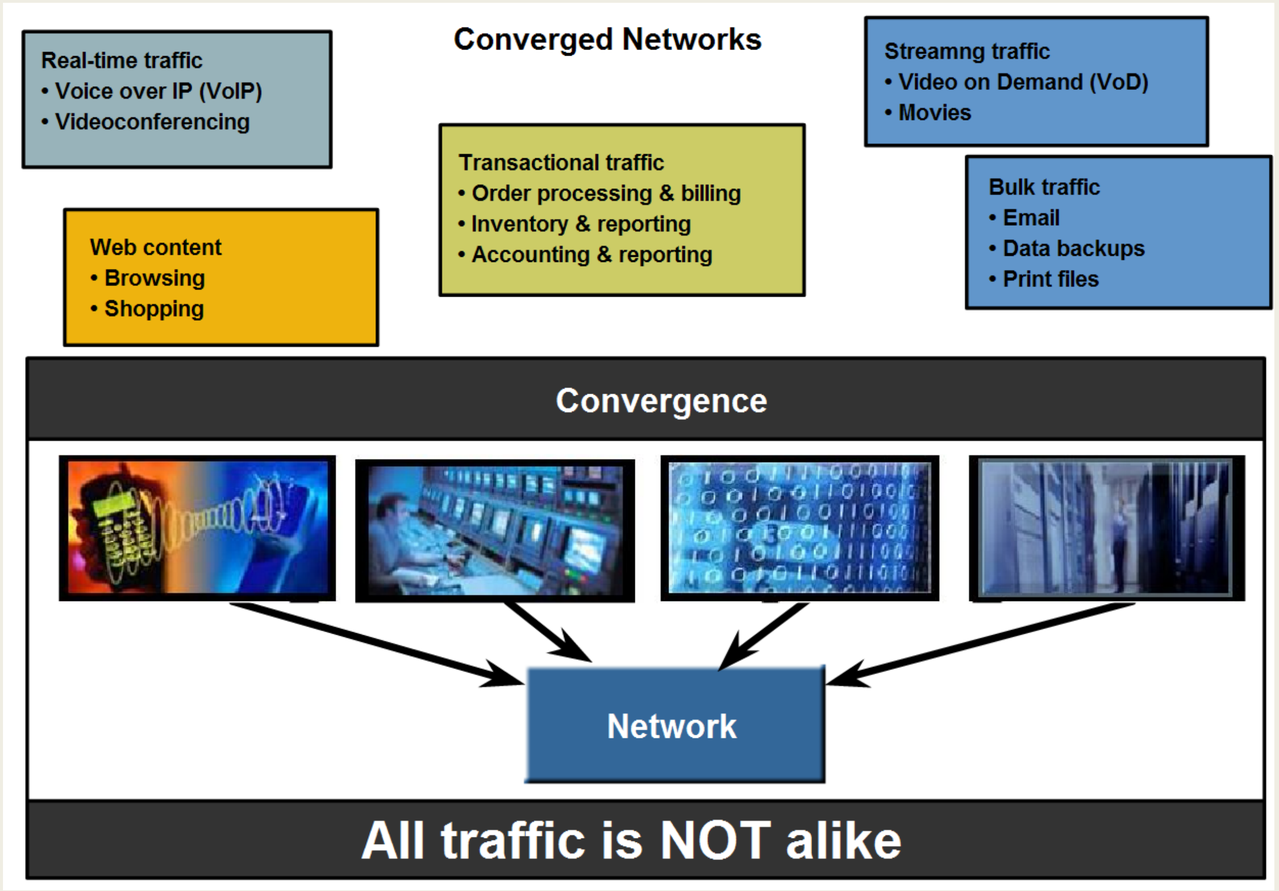
Network Architecture Characteristics

- Quality of Service - QoS



Network Architecture Characteristics

- Convergence
  - *All Traffic is NOT alike!*



Classification of Networks

- Communication networks can be classified based on the way in which the nodes exchange information
- Communication Network
  - *Broadcast Networks*
  - *Switched Networks*
    - Circuit-Switched Networks
    - Packet-Switched Networks
      - *Datagram Networks*
      - *Virtual Circuit Networks*

Note: Different networks provide different services (or quality of services), due to their own characteristics.

Broadcast Networks

- Transmission from any station is received by all other stations => Multiple Access Problem
- Goal:
  - *maximise message throughput*
  - *minimise mean waiting time*
- Simple solutions:
  - *Use a moderator*
    - a speaker must wait for moderator to call on him or her, even if no one else wants to speak => polling
    - what if the moderator's connection breaks?
  - *Distributed solution*
    - speak if no one else is speaking
    - but if two speakers are waiting for a third to finish, guarantee collision
  - *Designing good schemes is surprisingly hard!*

Connection Oriented & Connectionless Services

Connection oriented

- Three-phases:
  - *Connection setup between two SAPs to initialise state information*
  - *SDU transfer*
  - *Connection release*
- E.g. TCP, ATM

Connectionless

- *Immediate SDU transfer*
- *No connection setup*
- *E.g. UDP, IP*
- Layered services need not be of same type
  - *TCP operates over IP*
  - *IP operates over ATM*

Switched Networks

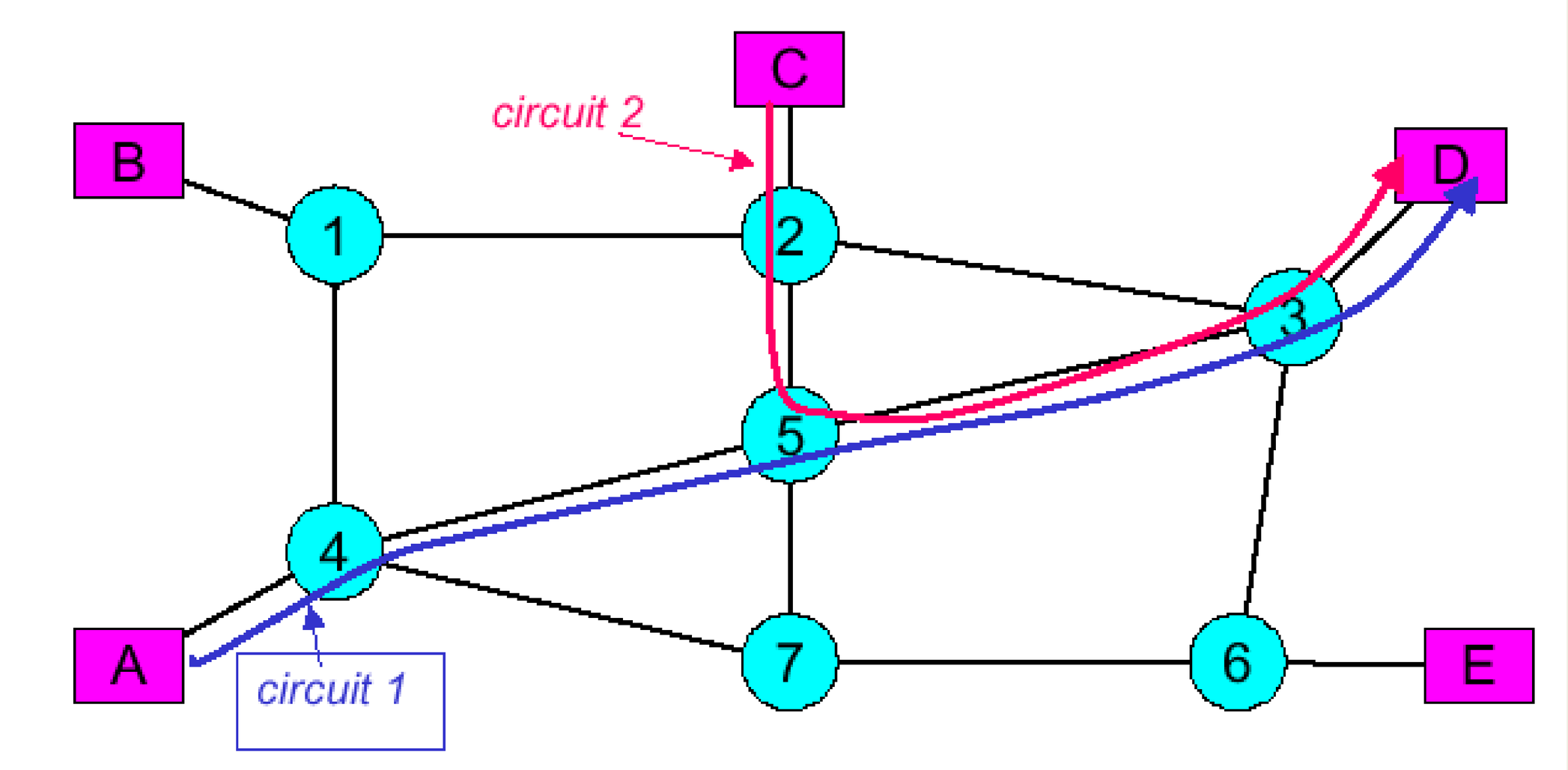
- A switched communication network consists of an interconnected collection of nodes. Data are transmitted from source to destination by being routed through the nodes
- The switching method describes how data are processed and routed in the network
- The basic switching methods are:
  - *Circuit Switching*
  - *Packet Switching*
    - Datagram Packet Switching
    - Virtual-Circuit Packet Switching

Circuit Switching

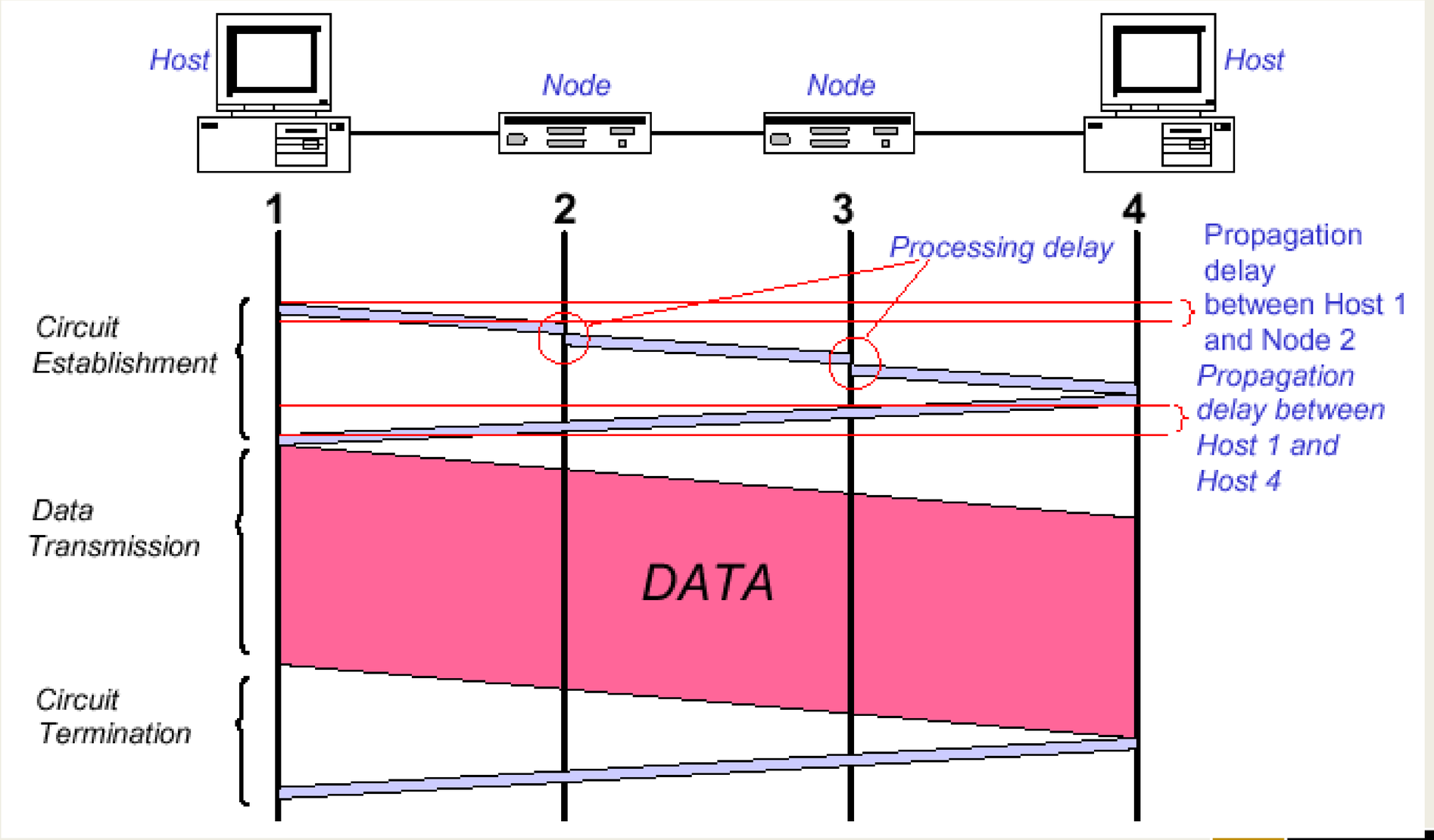
- In a circuit-switched network, a dedicated communication path is established between two stations through the nodes of the network
- The dedicated path is called a circuit-switched connection or circuit
- A circuit occupies a fixed capacity of each link (e.g. a time slot, or a frequency channel) for the entire lifetime of the connection.
- Capacity unused by the circuit can’t be used by other circuits

- Data is not delayed at the switches in Circuit Switching
- Circuit-switched communication involves three phases:
    1. *Circuit Establishment*
    2. *Data Transfer*
    3. *Circuit Termination*
- Busy Signal if capacity for a circuit is not available.
- Most important circuit-switching networks:
- Telephone networks
- ALL-optical networks

E.g.



Timing in Circuit Switching



Packet Switching

- Data are sent as formatted bit-sequences, so-called packets.
- Packets have the following structure:

- Each p m node to node along some path (Routing)
- At each node the entire packet is received, stored briefly, and then forwarded to the next node (Store-and-Forward Networks)
- No physical capacity is allocated for packets

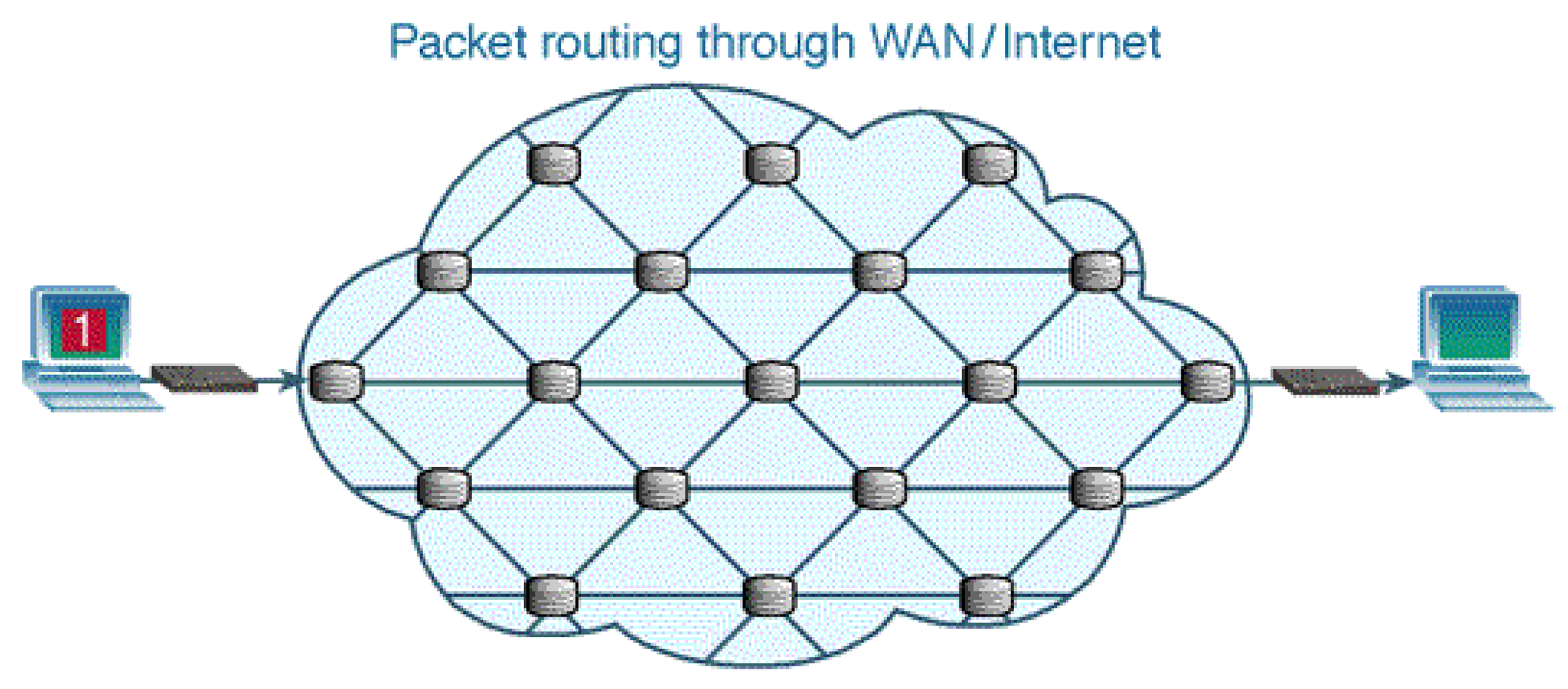
Datagram Packet Switching

- Packets are called datagrams
- The network nodes process each packet independently:
  - *If Host A sends two packets back-to-back to Host B over a datagram packet network, the network cannot tell that the packets belong together. In fact, the two packets can take different routes.*

Datagram Packet Switching

- Implications of processing packets independently:
  - *A sequence of packets can be received in a different order than they were sent (packet out-of-sequence problem, or packet integrity is not preserved)*
  - *Each packet header must contain the full address of the destination*
  - *Less state information to be stored*

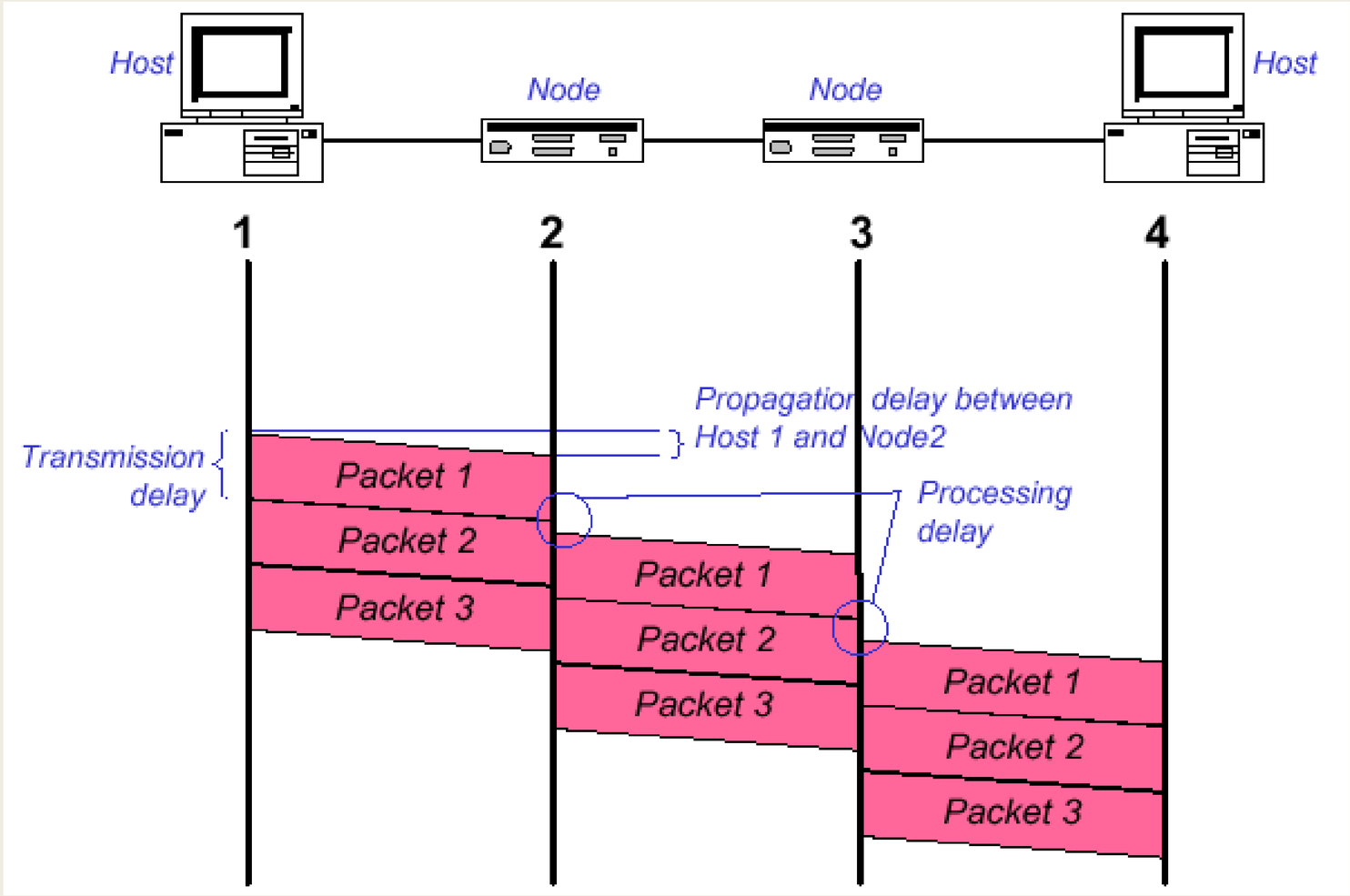
E.g.



http://www.ocrcomputing.org.uk/f451/networks/circuit_packed_switching.html

Timing of Datagram Packet Switching

How would the packet size affect the transmission overhead, node complexity, and end-to-end transmission delay?

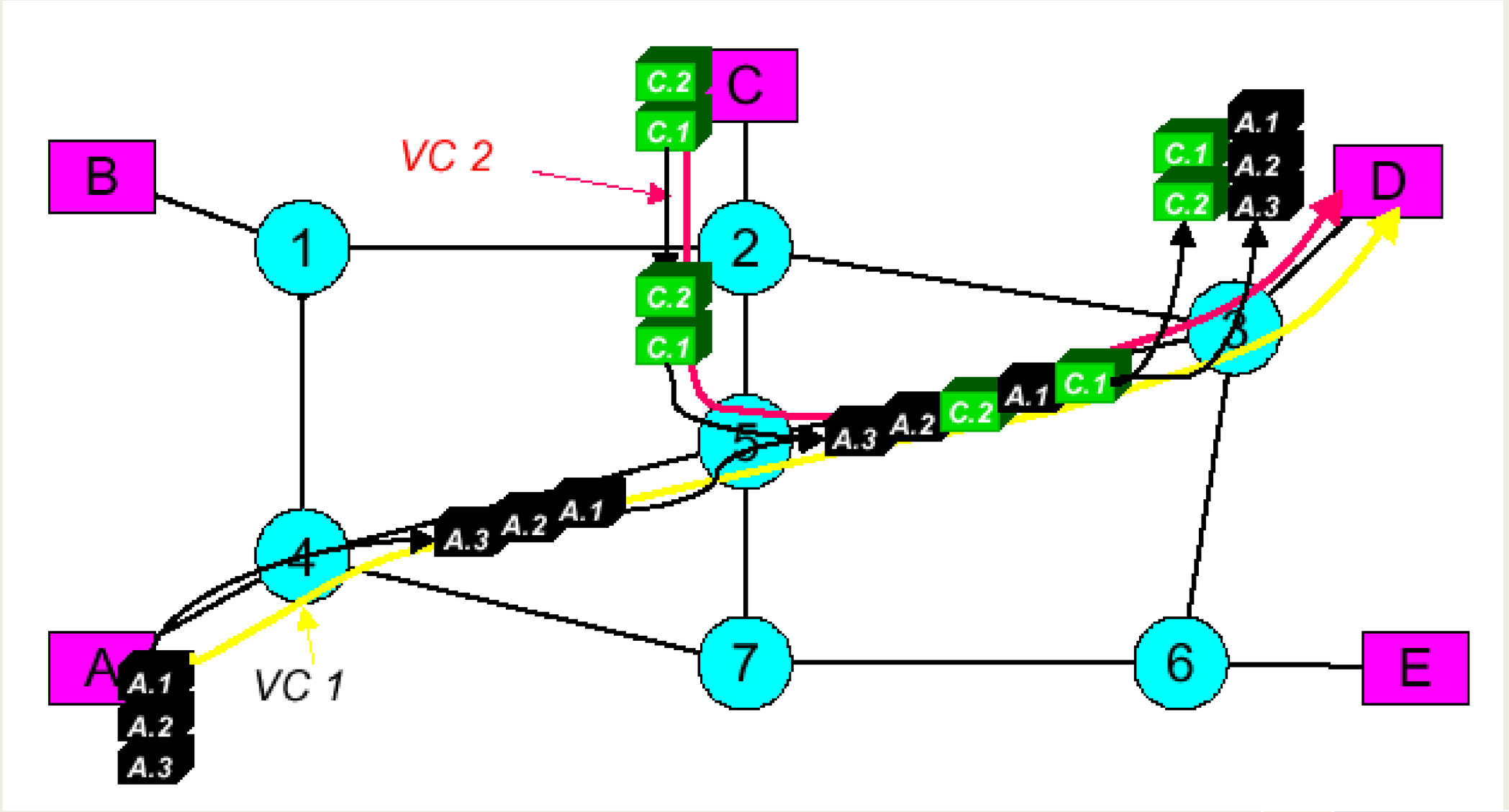


Virtual Circuit Packet Switching

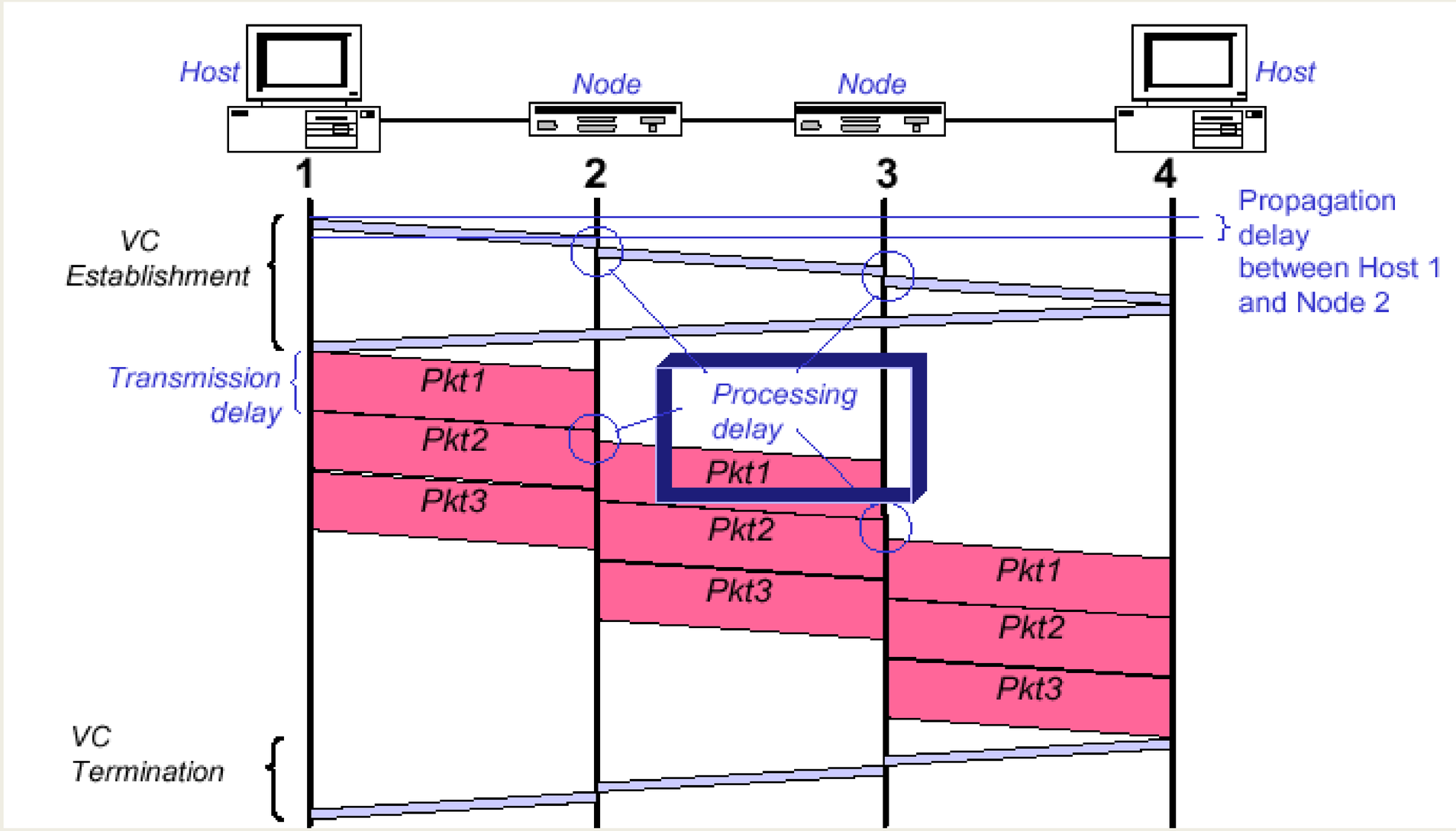
- Virtual-circuit packet switching is a hybrid of circuit switching and packet switching
- All data is transmitted as packets
- All packets from one packet stream are sent along a pre-established path (= virtual circuit)
- Guarantees in-sequence delivery of packets belonging to the same virtual circuit
- But packets from different virtual circuits may interleave

- Communication with virtual circuits (VC) takes place in three phases:
- 1. VC Establishment
- 2. Data Transfer
- 3. VC Disconnect
- Note: Packet headers don't need to contain the full destination address of the packet (why?)
- But more state information to be maintained by network nodes

E.g.


B
C
C.2
C.1
VC 2
1
2
C.2
C.1
C.1
A.1
A.2
C.2
A.3
D
3
5
A.3
A.2
C.2
A.1
C.1
4
A.3
A.2
A.1
A
A.1
A.2
A.3
VC 1
7
6
E

Timing of VC Packet Switching



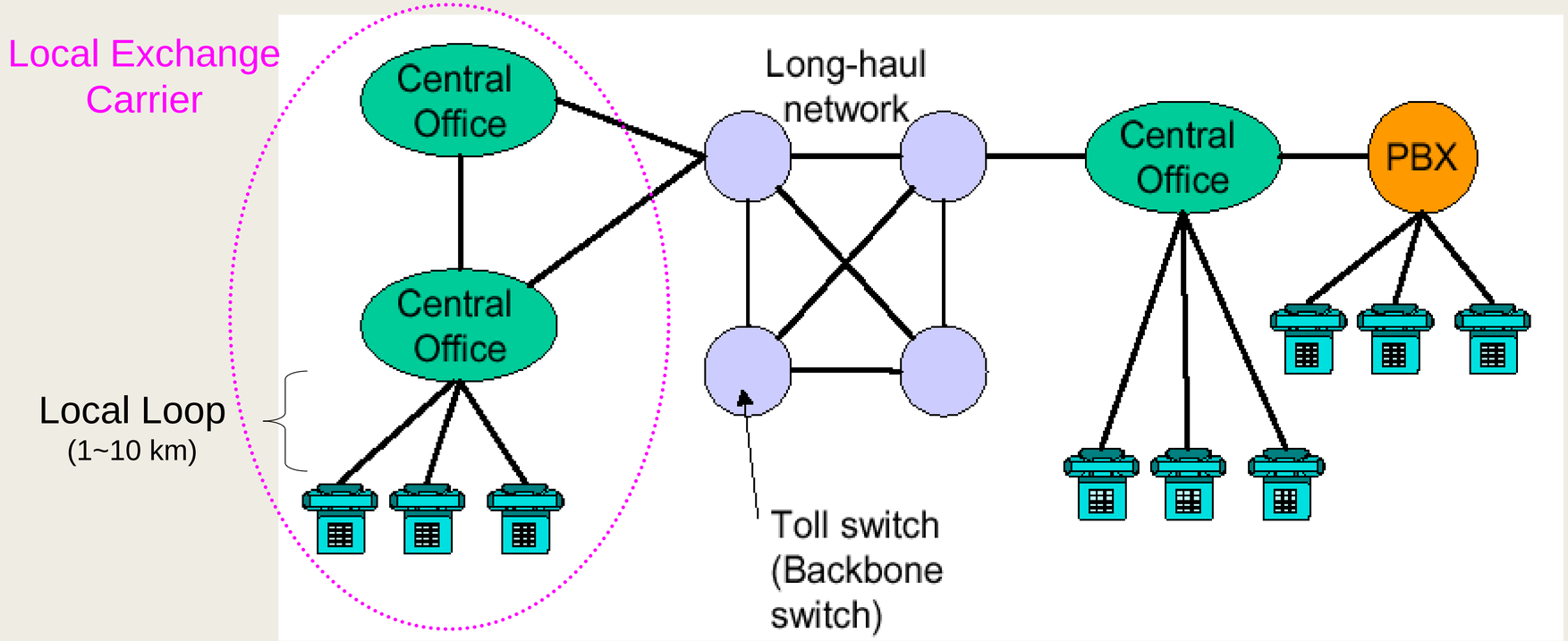
Comparison

Circuit Switching	Datagram Packet Switching	VC Packet Switching
Dedicated transmission path	No dedicated transmission path	No dedicated transmission path
Continuous transmission	Transmission of packets	Transmission of packets
Path stays fixed for entire connection	Route of each packet is independent	Path stays fixed for entire connection
Call setup delay	No setup delay	Call setup delay
No queuing delay	Queuing delay at switches	Queuing delay at switches
Busy signal overloaded network	Delay increases in overloaded networks	Delay increases in overloaded networks
Fixed bandwidth for each circuit	Bandwidth shared by all packets	Bandwidth shared by all packets
No overhead after call setup	Overhead in each packet	Overhead in each packet

Common Networking Technologies

- Telephone Networks
  - *The largest worldwide computer network, specialized for voice*
  - *Switching technique: Circuit-switching*
- The Internet
  - *A newer global and public information infrastructure*
  - *Switching technique: Datagram packet switching (Mostly)*
- ATM
  - *Goal: A network that has the flexibility and low-cost of the Internet, yet offers the end-to-end quality of service guarantees of the telephone network, i.e. to replace telephone networks and data networks.*
  - *Switching technique: VC packet switching*
  - *But lost momentum due the success of the Internet*
  - *Nevertheless, ideas from ATM have influenced thinking on "next-generation" Internet*

Telephone Networks

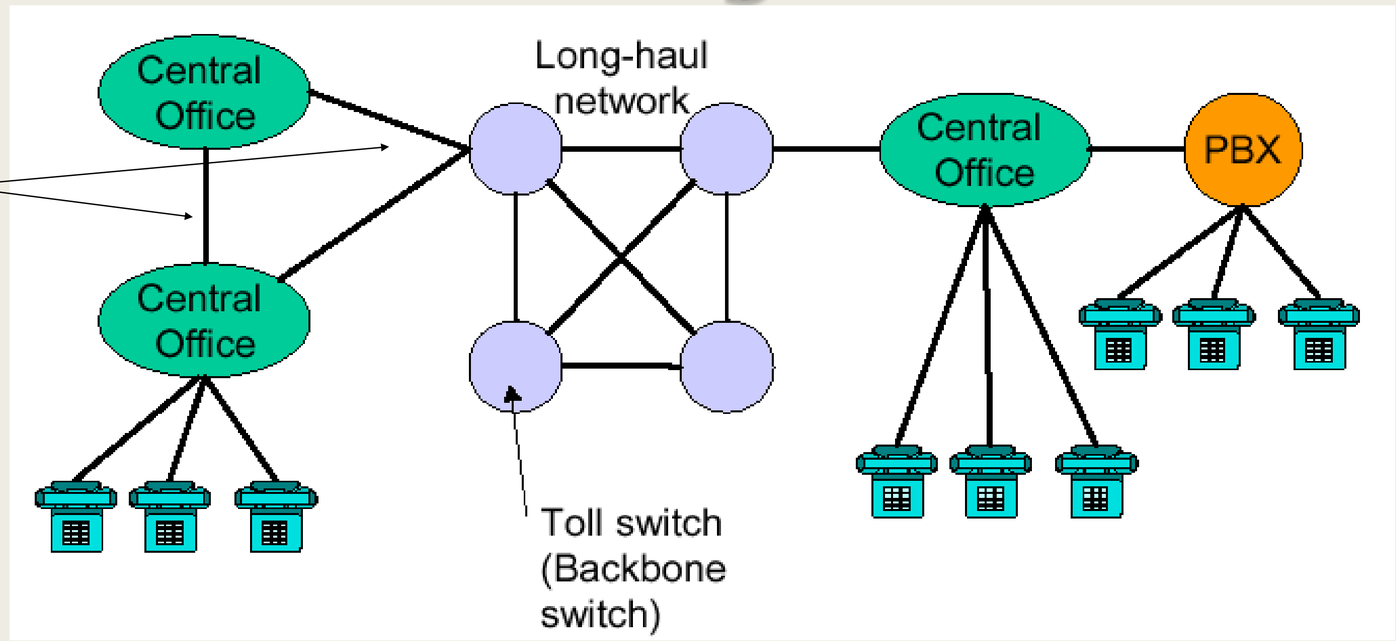


- Starting in 1876, the public switched telephone network (PSTN) has become a global infrastructure for voice communications
- Design philosophy: "Smart core dumb edge"

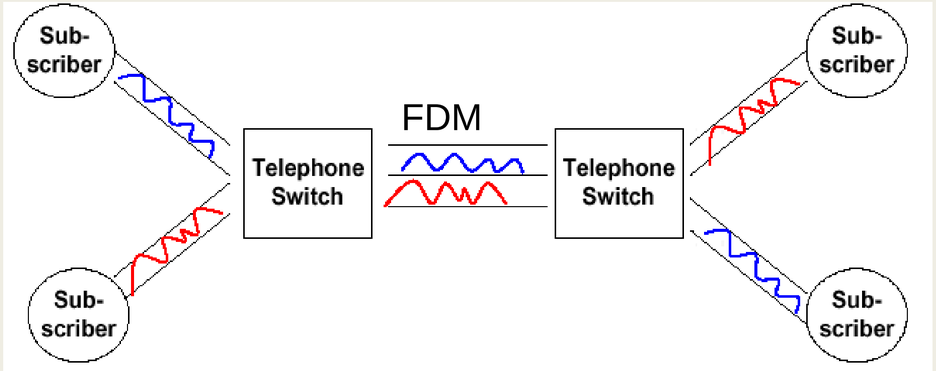
Transmission & Switching

High-bandwidth link to carry multiple calls

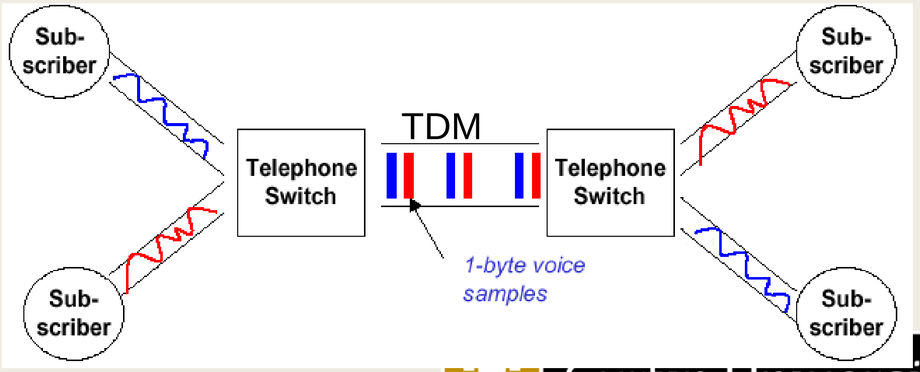
Dedicated link to carry a single call



Analog (space/frequency-division) switching



Digital (time-division) switch



Challenges

- Multimedia
  - *existing network can't handle it*
    - bandwidth requirements
    - burstiness in traffic (waste of resource when source is idle)
    - change in statistical behaviour
- Backward compatibility of new services
  - *huge existing (inefficient) infrastructure*
- Regulation
  - *sometimes stifles innovation*
- Competition
  - *future telephone networks will no longer be monopolies*

Summary

- Layered standardised protocols allow for
  - Interconnectivity of different vendors
  - Rapid modification (eg 802.11 & 802.3)
  - Each layer provides a service to the layer above
- Networks may be classified as:
  - Broadcast (WiFi & 10base2, more on this later)
  - Switched
    - Circuit Switched (POTS - plain old telephone system)
    - Packet Switched (Ethernet & IP)
      - Virtual Circuit (ATM and Frame Relay)

Labs and Tutorials

- Labs start this week
  - 207:117
  - Create your accounts on netacad.com
  - Lab machines do not use Oasis login
  - Do at least one lab on the real equipment
- Tutorials start week 2
  - Weekly
  - These will cover the material in the final exam!
  - Tutorials are every week