Lecture 1: Introduction to Computer Networks

Timothy A. Gonsalves
Professor and Head
Dept. of CSE, IIT Madras

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Overview of the Syllabus for Computer Networks

- Multiple co-located hosts: addressing, LAN access methods; CSMA/CD, Ethernet, Token passing, Token Ring, wireless LANs; Simple performance models; WAN
  access methods - PPP.

- Remotely located hosts: addressing, interconnection of LANs; repeaters, bridges, routers; ATM cell-switching

Overview of the Syllabus for Computer Networks

- IP: routing protocols (distance vector, link state packet routing); congestion control concepts and mechanisms (choke packets, leaky bucket, token bucket); IPv4, CIDR (Classless Interdomain routing)

- End-to-end reliability: the end-to-end argument; protocols - TCP, UDP,
  RPC; connection establishment, flow control.

Overview of the Syllabus for Computer Networks

- Application protocols for email, ftp, web, DNS.

  Advanced topics:

  Wireless networks and sensor networks; network management systems; security threats and solutions; IPv6; Multimedia applications and its impact on networking.

References

1. Peterson & Davie, "Computer Networks, A Systems Approach", 3rd ed, Harcourt, 2005

2. Andrew S. Tanenbaum, "Computer Networks", 4th ed., Prentice Hall, 2003.

3. Bertsekas and Gallagher “Data Networks, PHI, 2000

4.William Stallings, “Data and Computer Communications,” 5th edition, PHI, 2005

Course Schedule

- Goals of Networking, physical media, RS232 based communication
- Host-to-host communication, packet switching, framing, CRC, stop and wait protocol, sliding window protocol
- Multiple colocated hosts: addressing, ethernet (CSMA/CD), Token Ring (FDDI), MACAW (wireless LANs), bridges
- Internetworking, addressing, ATM cell switching, LANE
- IP routing algorithms, RIP, OSPF, BGP
- end-to-end communication: UDP, TCP, RPC
- Congestion control (Router based, process based)
- Applications: DNS, HTTP
- Advanced Topics: Network Intrusion Detection, SNMP
- Sign Off

Computer Networks

- Heterogeneous systems need to talk to each other:
  - Media to connect
    - wired – twisted pair, coaxial cable, fibre
    - wireless – radio
  - Topology of the Network
  - Protocols and software.

Computer Networks and Distributed Systems

- Distributed systems and Computer Networks:
  - Closely related
  - Distributed system – transparent
  - Computer Network - not transparent

Purpose of a Computer Network

- Primary objective of Computer Networks:
  - Transfer data from machine A to machine B
  - Facilitates access to remote information
  - Facilitates sharing of data
  - Facilitates person to person communication
  - Facilitates Interactive Entertainment
  - Not every machine is connected to every other machine
    - Establish connection between a pair of machines
      - Transfer data
    - Enable machines of different speeds to communicate with each other

Simplest Form of Transfer of Data Across Machines

Eg. : Sharing of Data on DOS machines

- Transfer data from machine A to machine B:
  - DOS machines connected by a serial line
  - No networking support in DOS
  - machine A: copy file to the com1 port
  - machine B: copy com1 to file

Sharing of Data on DOS machines

- Issues:
  - Synchronisation
    - if sender is faster than receiver
  - Error on the line
    - require error checking

Solution (a)

- Solution (a):
  - Synchronisation: interrupt driven
  - Error: checksum, CRC, parity
  - Overrun: flow control
    - sender should send data at the rate at with receiver is ready to accept.

Solution (b)

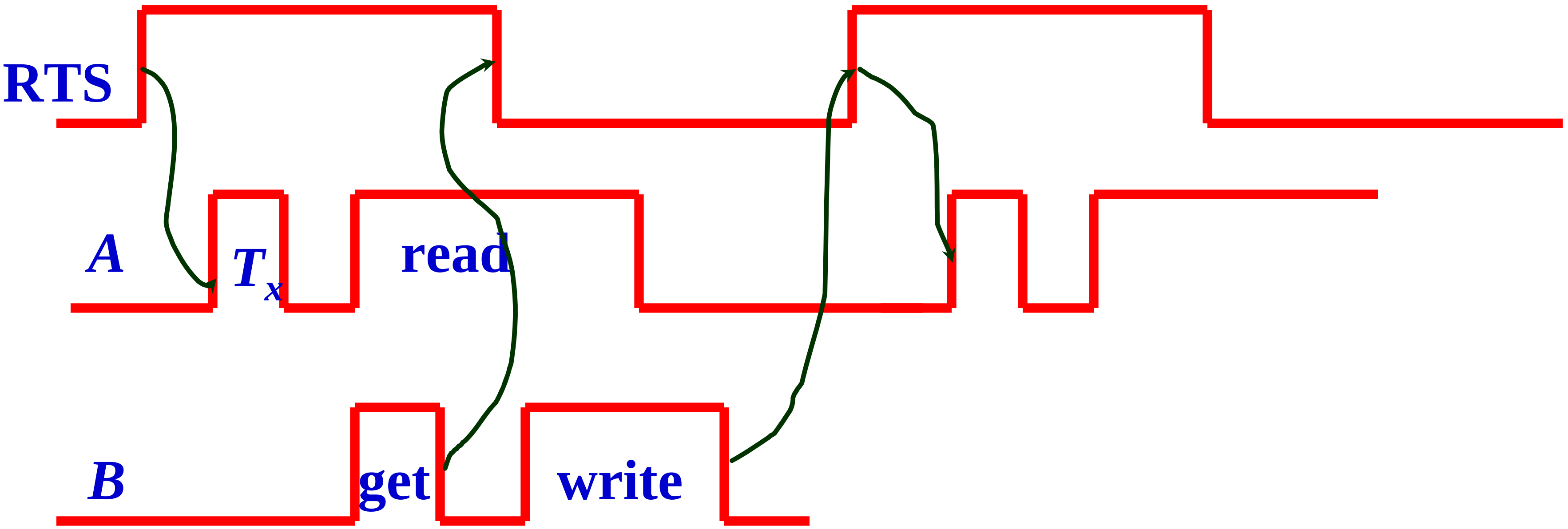
- Use RTS (Request To Send) from B → A
- At A:
  - clear RTS
  - open (file)
  - while not eof(file) do
    - read a byte
    - wait until RTS is high
    - send a byte
  - endwhile
  - send eof
  - close(file)

Solution (b) (contd)

- At B:

```
open(file)
repeat
    set RTS
    get a byte
    clear RTS
    write byte to file
until eof
close(file)
```

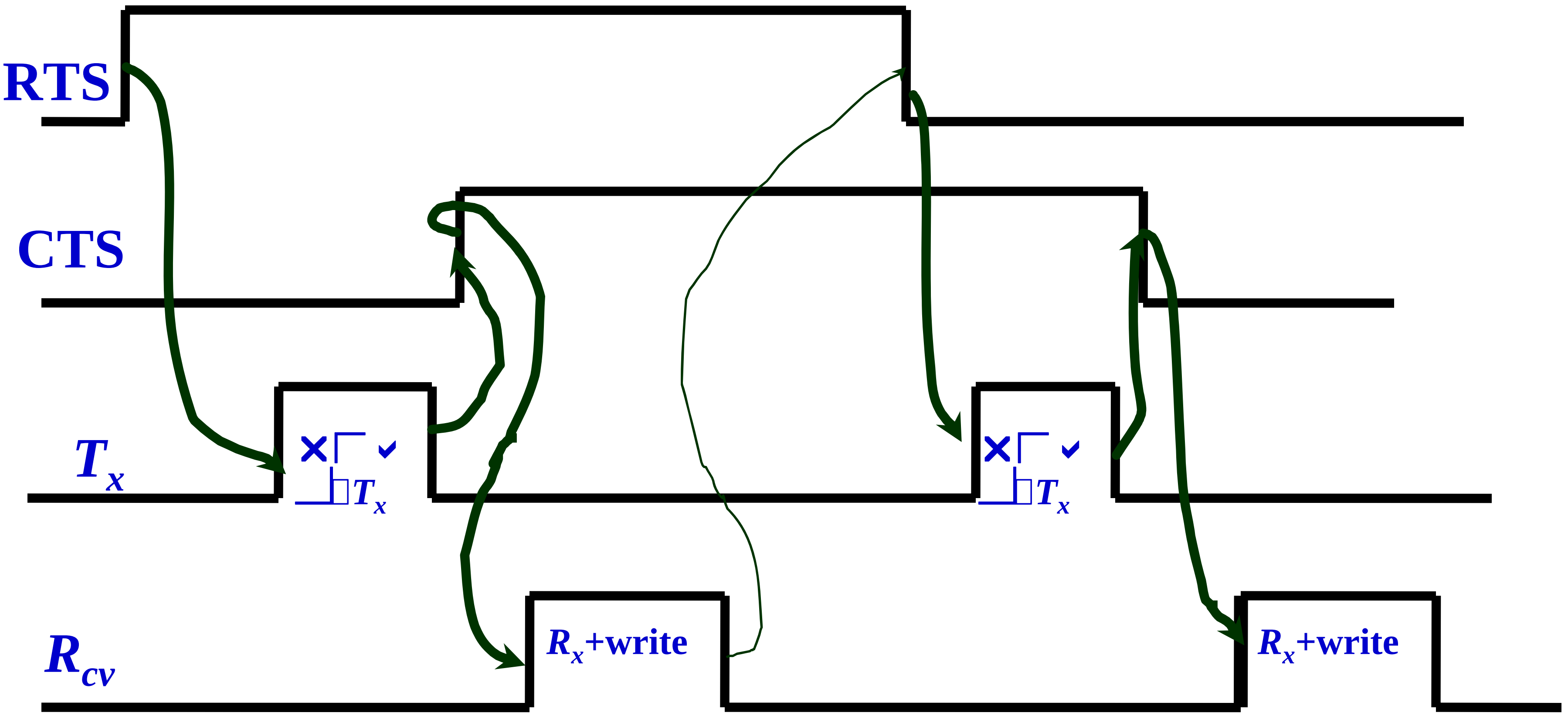
Data Flow Diagram using RTS



Issues

- If read at A is faster than get at B
  - read at A is completed before RTS is reset by B.
  - A will transmit another byte.
  - B will be swamped by A.
- One more signal is required:
  - RTS alone is not sufficient.
  - CTS (Clear To Send) A → B
  - RTS (Request To Send) B → A

Data Flow Diagram using RTS and CTS



The Algorithm

- At A:

```
clear CTS
open(file)
wait for RTS to go High
while not eof(file) do
    read byte
    send byte
    toggle CTS
    wait for RTS toggle
endwhile
wait for RTS toggle
send eof
```

The Algorithm

- At B:

```
open(file)
set RTS
while not eof(file)
    wait for CTS toggle
    read byte
    write to file
    toggle RTS
endwhile
```

Error Control

- At A:
  - Read file
  - compute Checksum
  - repeat
    - send file
    - send Checksum
    - check wires
    - wait for ack
    - get ack
  - until ack
  - send finish

Error Control

- At B:

```
open(file)
while not (finish) do
    get file
    get checksum from A
    compute Checksum from file received
    compare the two
    if same then send send acknowledgement
endwhile
```

Issues

- What if file is very large?
  - Heavy retransmissions
  - Very inefficient
- Requires splitting the file.
  - Split file into what units?
    - packets?

Packetised File Transmission

- At A:
  - Packetise file
  - Transmit each packet separately with its own error control
  - If erroneous retransmit

- At B:
  - Receive packet by packet
  - Check for errors
  - Acknowledge reception of packet
  - Assemble packets and save to a file

Packet based transmission: Issues

- A Protocol is required for:
  - Start/end of a byte
  - Start/end of a packet
  - Start/end of a file
  - Error control mechanism required
  - Out of order arrival of packets:
    - Sequence number for each packet

A Layered Approach to Error Control

- ***files:*** checksum
- ***messages:*** checksum or CRC
- ***packets:*** CRC
- ***bytes:*** parity
- ***bits:*** voltage levels
- Different error control mechanisms at different layers

LAN: Multiple co-located PCs

- Connect by a shared bus
  - Broadcast: every PC receives every packet
- Issues:
  - Addresses to distinguish receiver
  - Medium access control

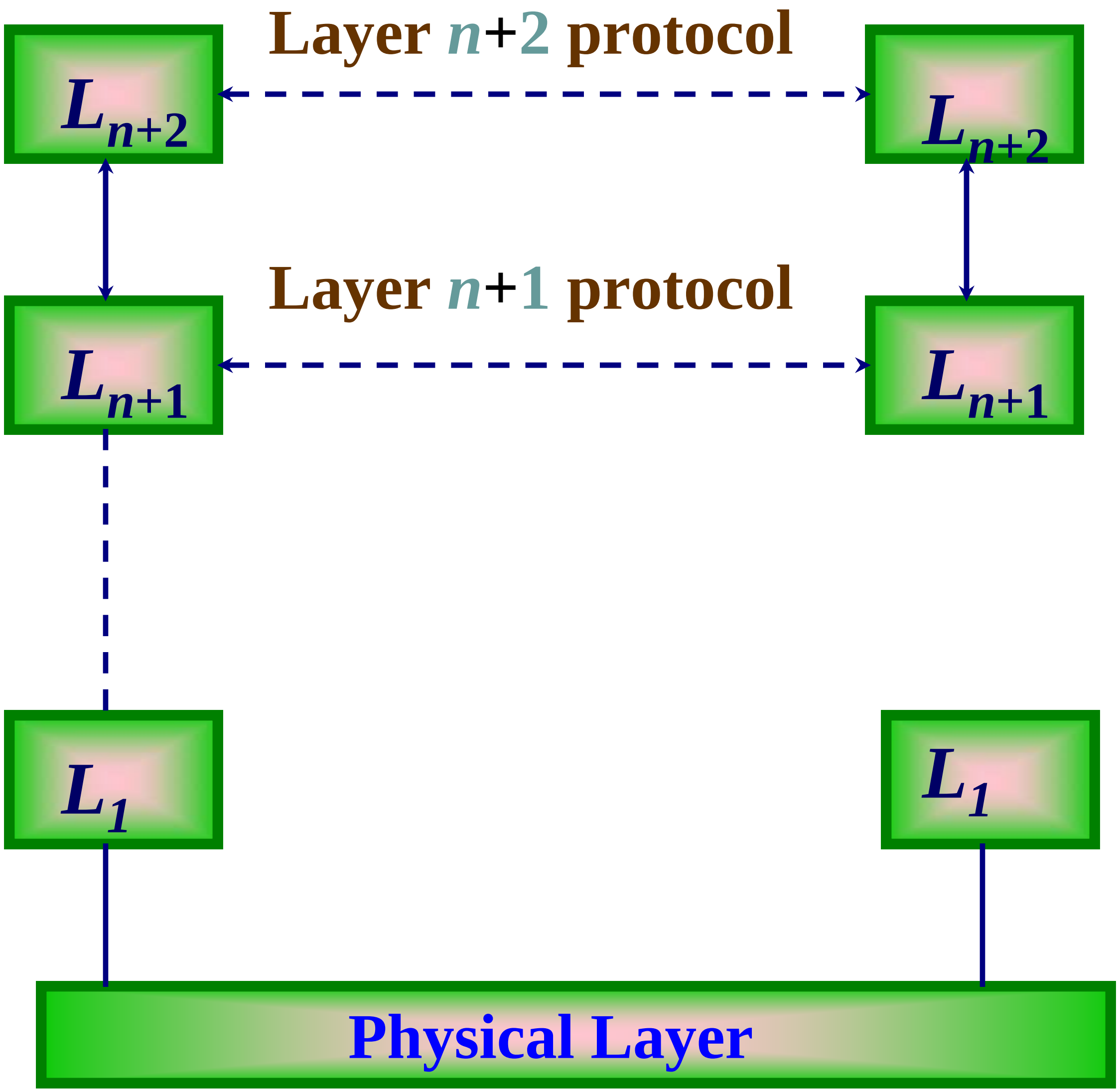
Internet: Multiple LANs

- Mesh topology, not broadcast
- Issues:
  - Globally-unique addresses
  - Routing
  - Subnets may provide different levels of service
    - End hosts need to ensure desired service

A Layered Approach to Computer Networks

- Physical Layer
- Data Link Layer
- Network Layer
- Transport Layer
- Session Layer
- Presentation Layer
- Application Layer

- Different layers of abstraction
- Different error control mechanisms at different layers



Layer n+2 protocol

L_{n+2} L_{n+2}

Layer n+1 protocol

L_{n+1} L_{n+1}

L_1 L_1

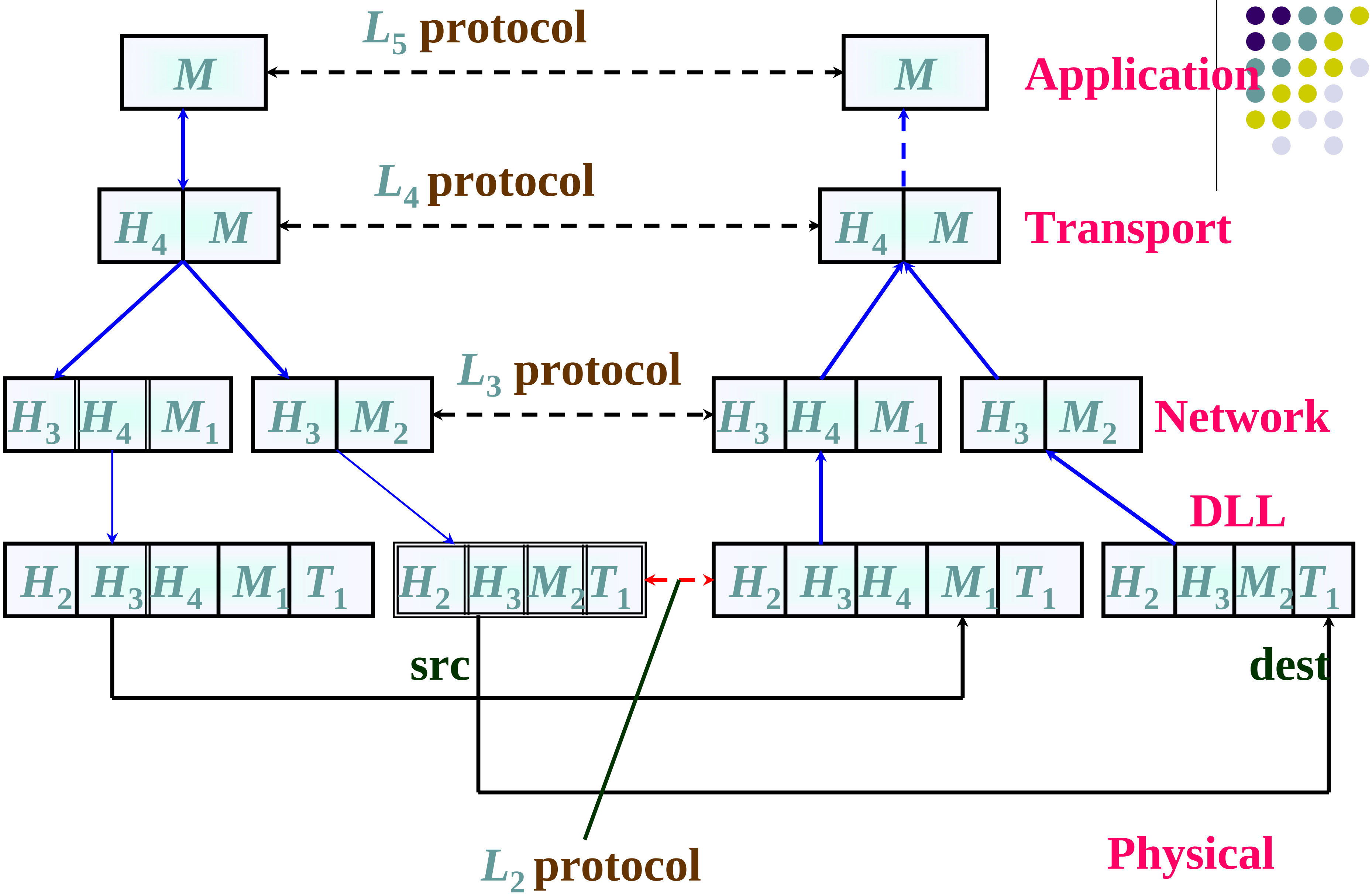
Physical Layer

Layer to Layer Communication

- Layer n on ‘A’ talks to Layer n on ‘B’.
  - No data transferred directly between layers at the same level.
  - Data and control flow from one layer to the layer below it until it reaches Physical Layer.
  - All transmission only at the Physical Layer.

Design of a Network

- Layer to Layer interface must be well understood.
- A set of layers and protocols constitute a network architecture.
- A set of protocols, one per layer is called a protocol stack.



L_5 protocol

M | M Application

L_4 protocol

H_4 M | H_4 M Transport

L_3 protocol

H_3 H_4 M_1 | H_3 M_2 | H_3 H_4 M_1 | H_3 M_2 Network

DLL

H_2 H_3 H_4 M_1 T_1 | H_2 H_3 M_2 T_1 | H_2 H_3 H_4 M_1 T_1 | H_2 H_3 M_2 T_1

src

dest

L_2 protocol

Physical

H = Header M = Message

Design of a Network

- Addresses for source and destination
  - multiple machines with multiple processes
  - a process on one machine must know the identity of process on the other machine that it wants to talk to
    - Machine Address
    - Process Address

Design of a Network

- Virtual communication between peers except Physical Layer.
- Each layer thinks that there is a horizontal communication.
- Procedures at each layer:
  - Send To Other Side
  - Get From Other Side
- each layer communicates with lower layers
- each layer needs a mechanism to identify senders and receivers

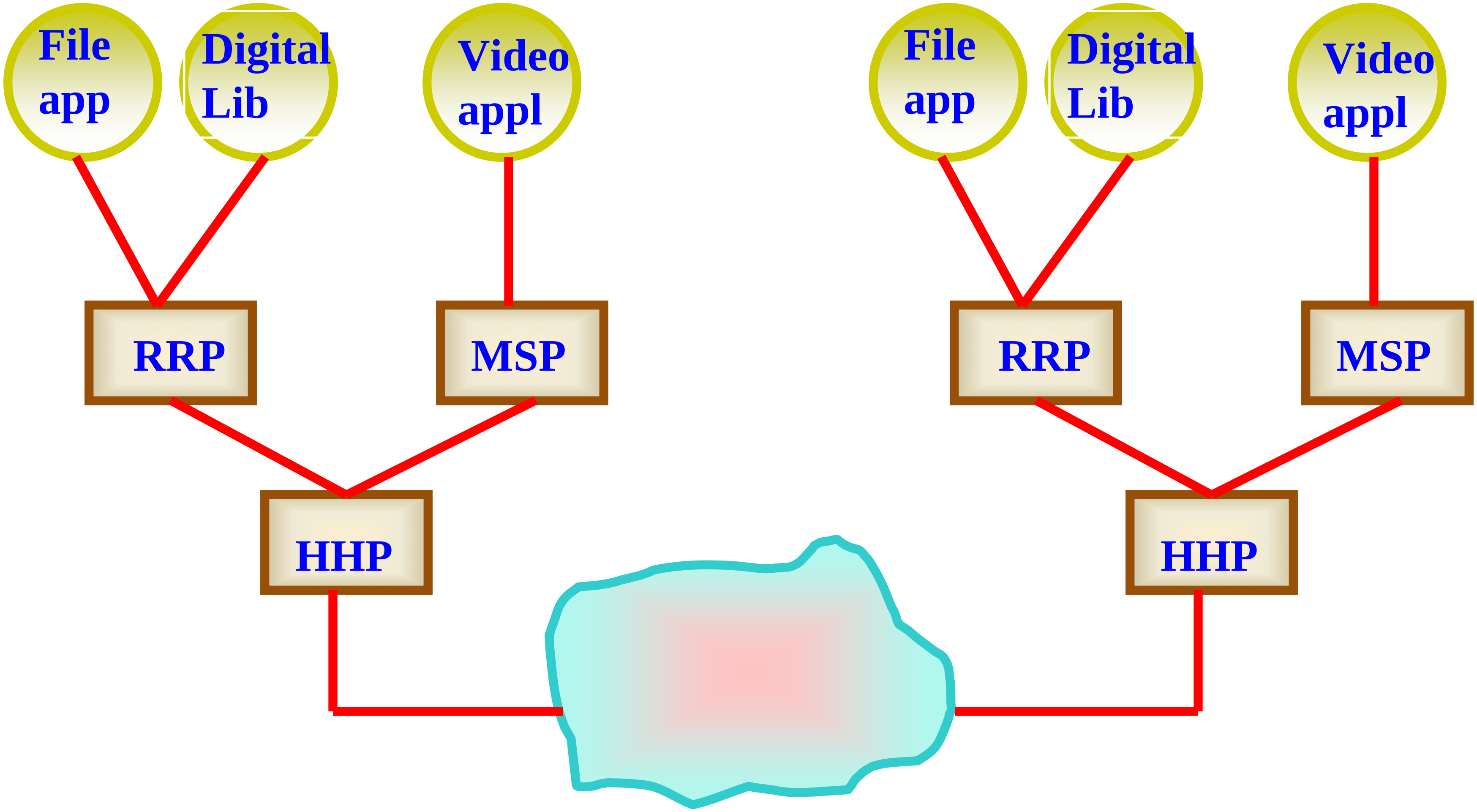
Design of a Network (Continued)

- Modes of data transfer
  - Simplex, duplex, half-duplex
- Number of logical channels
  - Minimum two
    - One for data, one for control

Design of a Network (Continued)

- Layers of abstraction
- PDU formats at each layer
- Mechanisms for error control at each layer
- Mechanisms for flow control
- Sequencing of PDUs at each layer
- Support multiple protocols at each layer

Example of Multiple protocols in the same layer



Different requirements for different Applications

- protocol stack for:
  - file application:
    - RRP / HHP
  - Digital Library
    - RRP / HHP
  - Video Application:
    - MSP / HHP - enable QoS, jitter, delay

      video on demand / video conferencing

Must ensure reliable transmission

Layering in a Network

- Abstracting details away from physical layer:
  - keeps switches in the middle of the Network as simple as possible
    - Compare with telephone network: put intelligence in switch
      - telephone handsets as simple as possible
  - A single physical connection to multiplex different conversations

Layering in a Network

- flow control:
  - prevents sender from swamping receiver
- message formats:
  - different sizes at different levels
  - assemble / disassemble messages

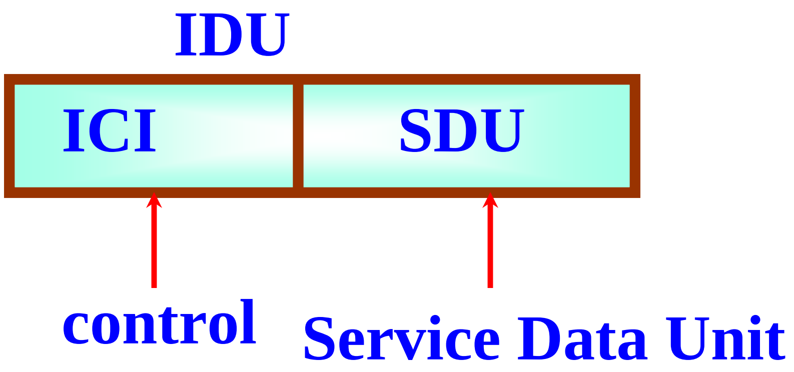
Layer to Layer Communication

- Each layer provides service to the layer above it
  - Layer n provides services for Layer n+1
  - Layer n service provider
  - Layer n+1 service user

Interfaces between Layers

- Service access point (SAP)
  - place where Layer n+1 accesses Layer n services
- unique address
  - SAP in telephone NW
    - telephone jack or socket
  - SAP address:
    - telephone number

Exchange of information between two layers. (IDU)



IDU

ICI

SDU

control

Service Data Unit

(Interface Data Unit)

Interfaces and Services

- **SDU** transmitted across Network
- **Control** useful for lower layer to do their job
- **e.g.** number of bytes
- **Layer *n*** fragments data into **PDUs (Protocol Data Unit – packets)**
  - each **PDU** has a header.
- **PDUs** are used by peers

Services and Protocols

- Services:
  - set of primitives or operations that a layer provides to the layer above it.
- Protocols:
  - set of rules governing the format and meaning of frames, packets, messages exchanged between peers.

Types of Services

- connection oriented service
  - Telephone system
- connection less
  - E.g. Postal system
    - Two letters posted at the same time to same address
    - (second message come before first – no acknowledgement)
- reply paid telegram
    - Acknowledgement received for message

Layers and their functions

- Physical layer:
  - Transmits bits 0 & 1
    - what voltage to use
    - width of a bit
  - connection establishment
  - tearing down of connection
  - number of pins on Network connector and use of each pin on the connector

Layers and their functions

- Data Link Layer:
  - convert it to a line that appears free of undetected transmission errors to the layer above it.
    - data frames, ack frames
  - handshaking between transmitter, receiver
  - control access to the shared channel

Layers and their functions

- Network Layer:
  - operation of the subnet
  - routing of packets src to destination
  - static / dynamic routing;
  - congestion control

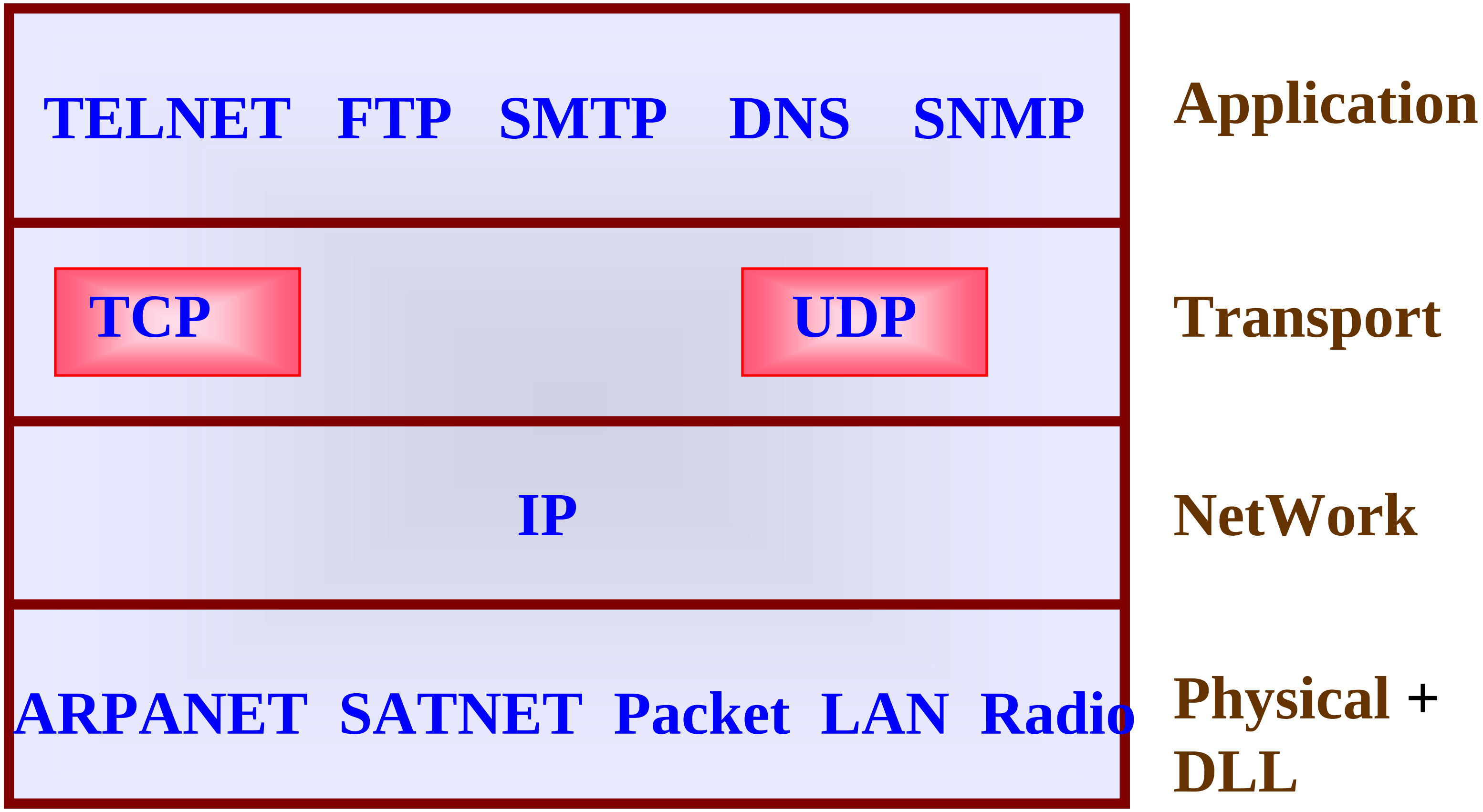
Layers and their functions

- Transport Layer:
  - Lowest end-to-end layer
  - split data from session passes to Network Layer, pieces arrive correctly at the other end.
  - flow control
- Session Layer (not used in Internet):
  - allows uses on different machines to establish a session between them.
  - synchronisation, check parity

Layers and their functions

- Presentation Layer (not used in Internet):
  - coding standards machine to Network and back
    - Example: ASCII to Unicode and vice versa
- Application Layer:
  - variety of protocols required
    - File transfer protocol, Simple Mail Transfer Protocol, Directory Server, Simple Network Management Protocol

The TCP/IP Protocol Stack



TELNET FTP SMTP DNS SNMP	Application
TCP UDP	Transport
IP	NetWork
ARPANET SATNET Packet LAN Radio	Physical + DLL

A Simple Network

- Connecting two machines directly to physical medium
  - Encoding
  - Framing and error detection
  - Link should appear reliable
  - shared link
    - medium access

Summary

- Handshaking for flow control
- Redundancy for error control
- Protocol: set of conventions for communication
- End-to-end protocol for robustness
- Layered architecture simplifies a complex problem