# Data Link Technology (2)

Suguru Yamaguchi
Nara Institute of Science and Technology
Department of Information Science

# Flow Control

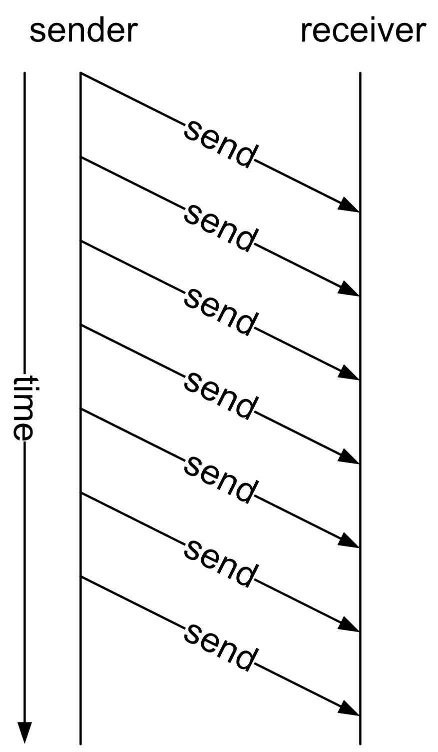
# Flow Control

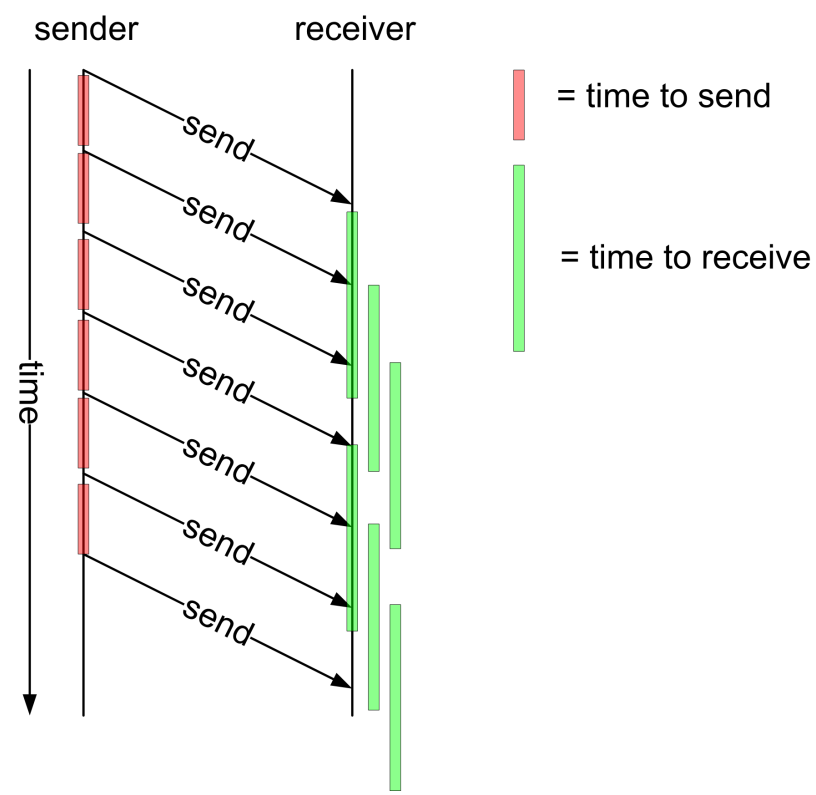
- Flow Control Protocols deal with how to send sequences of DLL frames
- They have two jobs:
  - Recover from lost frames
  - Prevent buffer overflows
- Network Layer must receive same set of frames in the same order they were sent
- Automatic Repeat Request (ARQ)
  - Stop-and-wait
  - Go-back-N
  - Selective-repeat

# Unrestricted Case

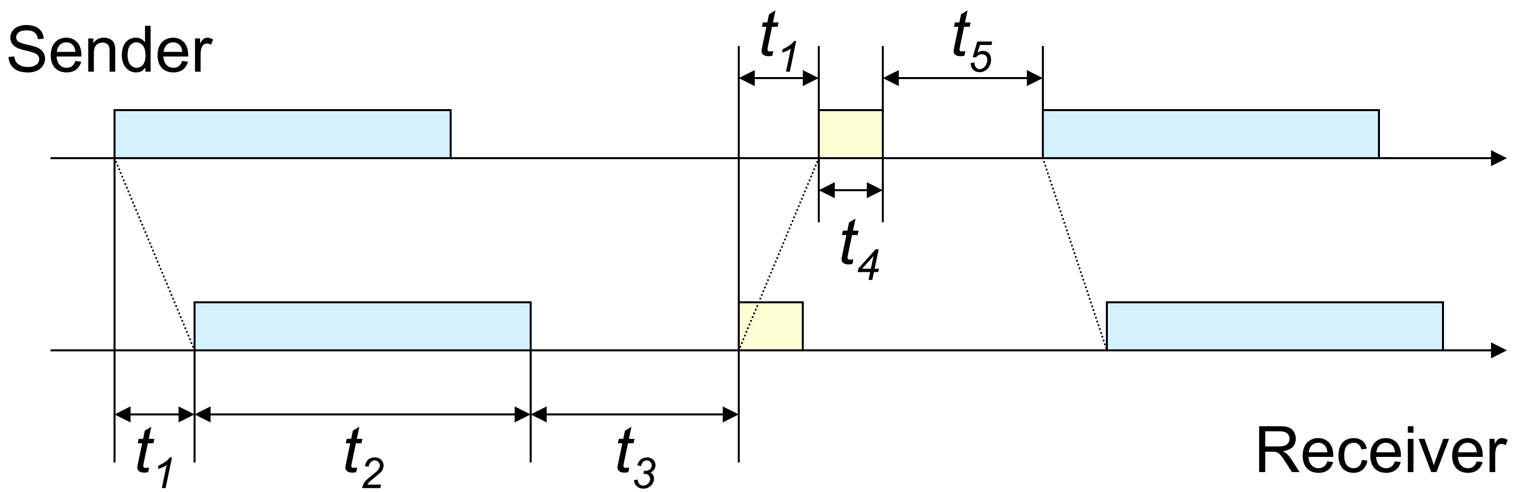
- Sender send
- Receiver waits to receive

- Problem: receiver's buffers may fill up



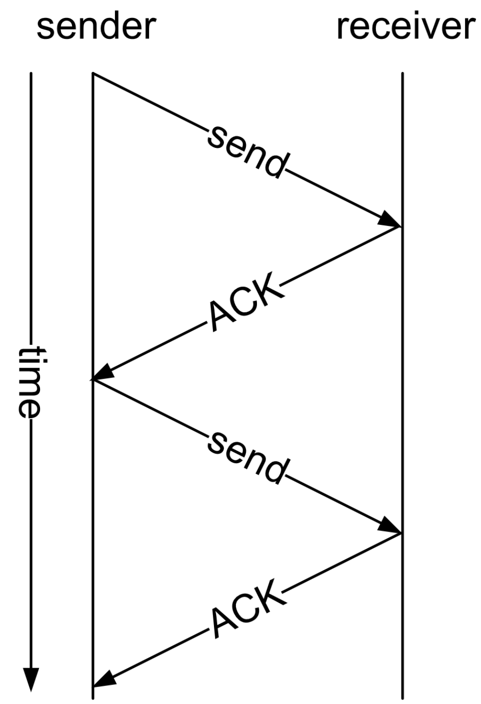
# Stop-and-wait ARQ (1)




$t_1$: Round Trip Time
$t_2$: Frame Transmission Time
$t_3$: Frame Processing Time
$t_4$: ACK Transmission Time
$t_5$: ACK Processing Time

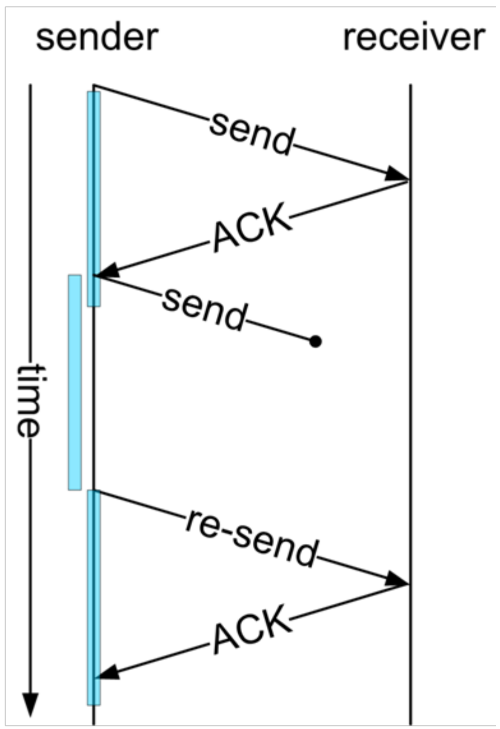
# Stop-and-wait ARQ (2)

- Procedure
  - Waiting to receive ACK on each frame transmission
  - Setting a sender timer greater than $2t_1+t_2+t_3+t_4$
  - Retransmission when sender timer times out.
- Characteristics
  - Simple
  - The buffer never contains more than one frame for the receiver and the sender
  - Channel usage rate is extremely bad

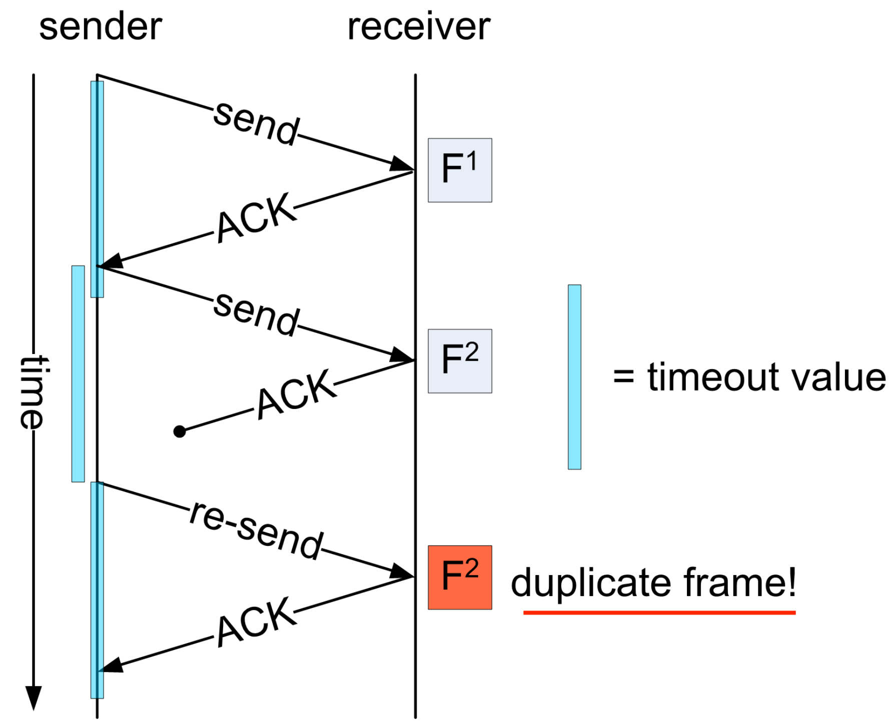


# Stop-and-wait ARQ (3)

- Timeout

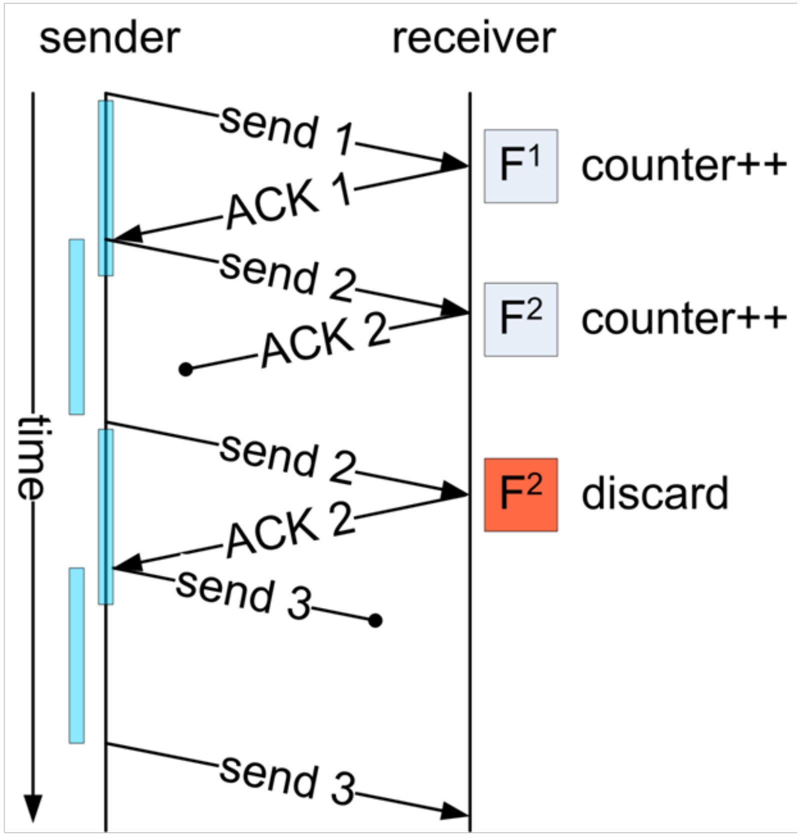



- Lost ACK



# Automatic Repeat Request (ARQ)

- Use sequence numbers to identify frames
- Sender sends SEQ *n*
  - Start timer
  - If ACK received, *n* = *n+1*, if timeout, resend *n*
- Receiver receives *n*
  - If expecting *n*, send ACK for *n*
  - If expecting *n+1* then ACK for *n* was lost
    - Resend ACK for *n*
    - Await delivery of *n+1*

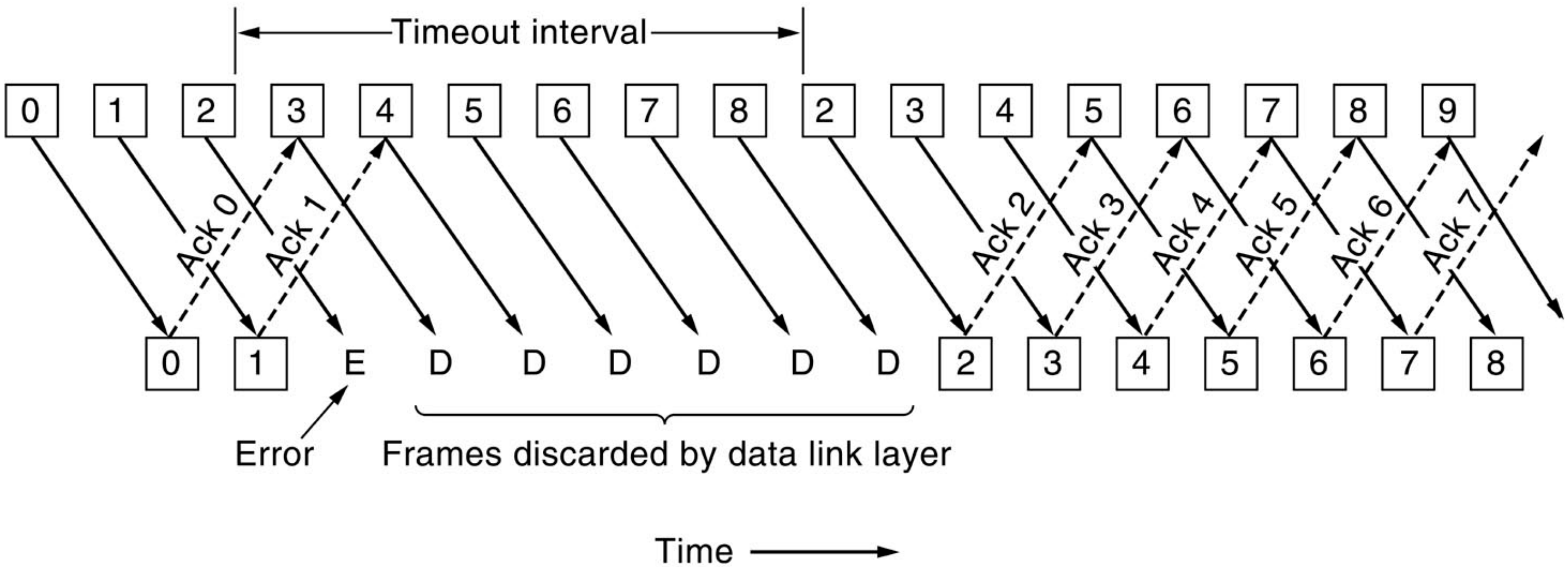


# Go-back-N ARQ (1)

- Improving Stop-and-Wait Protocol
  - ARQ performance is bad because the sender spends most of the time waiting for a timeout or an ACK
- How can we improve the channel utilisation of an ARQ protocol?
- Transmitting a frame in series
  - Assume operation $i$ is successful
  - Perform operations $i$+1,2,3… up to a max $n$
  - Be prepared to go back up to $n$ operations if one or more were incorrect
  - No ACK is returned until the frame is correctly received.

# Go-back-N ARQ (2)

- Frame and ACK errors solved with timeout
- e.g. window size of 7



# Go-back-N ARQ (3)

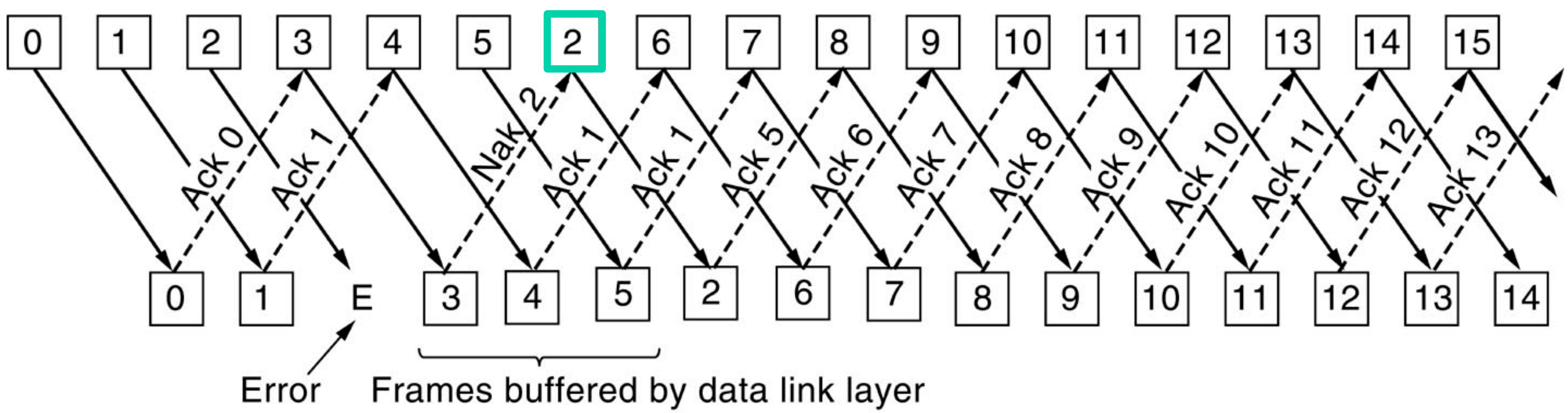
- Characteristics
  - Wastefulness: upon error detection, correct frames received after the error are also dropped.
    - Especially, setting a bigger value to the retransmission timer is a disadvantage.
  - On the sender side, a buffer is necessary for retransmission.
    - Frames that did not receive an ACK, buffering is necessary to enforce retransmission.
    - The “N” in Go-back-N corresponds to the number of frames sent without receiving an ACK (on-the-fly frames)
    - Buffer depends on the retransmission timer value.

# Selective-Repeat ARQ (1)

- Improving Go-back-N protocol
  - Go-back-N's retransmission overhead is very large
- Characteristics
  - Transmission efficiency is better than Go-back-N
    - Not dropping correct frames uselessly
  - Processing is complex
    - Needs a buffer on the receiver side
    - Frame sequence control is necessary

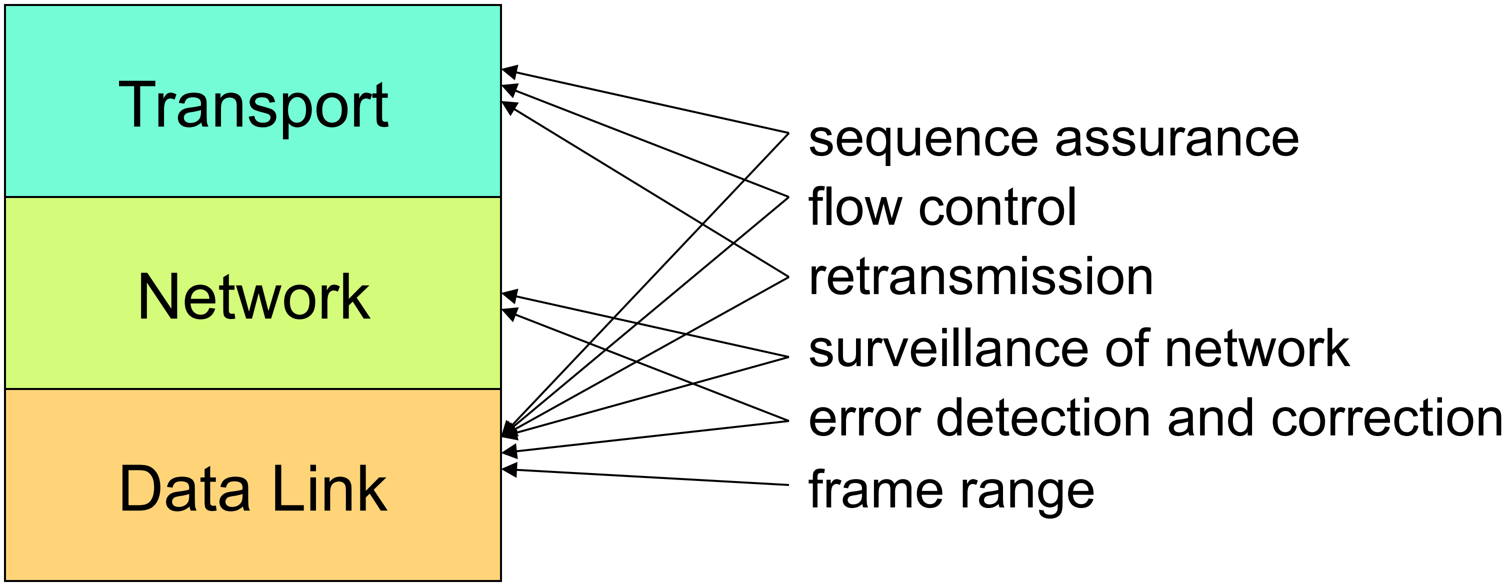
# Selective-Repeat ARQ (2)

- Send Negative ACK (NAK) if a frame is skipped over
- ACK for frame *n* implicitly acknowledges all frames ≤ *n*



# Role Allocation

- Role allocation depends on a system design
- Various solutions exist



# HDLC & PPP

# High-Level Data Link Control (HDLC)

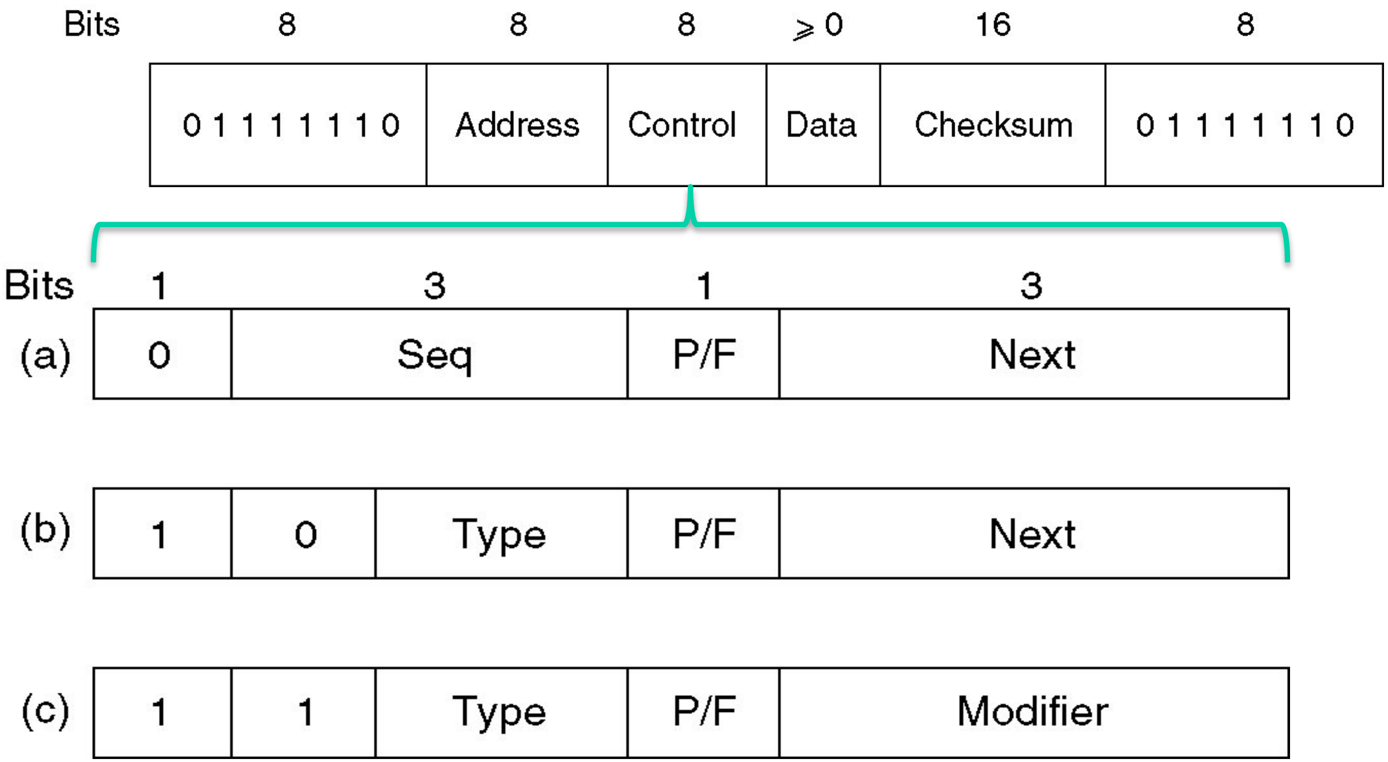
- A bit-oriented synchronous data link layer protocol developed by the ISO
- It provides both connection-oriented and connectionless service
- It is still widely used nowadays even if it is an old protocol
  - Employed in public data communication networks such as ISDN
  - Existing online network, e.g., online banking system

# HDLC Frame (1)

| Bits | 8 | 8 | 8 | ≥ 0 | 16 | 8 |
|---|---|---|---|---|---|---|
| | 0 1 1 1 1 1 1 0 | Address | Control | Data | Checksum | 0 1 1 1 1 1 1 0 |

- Address: identifies a communication station (terminal)
- Control: information for communication control
- Data: information to be transmitted
- Checksum: CRC-CCITT

# HDLC Frame (2) – Control Field




Control field of:
(a) an information frame
(b) a supervisory frame
(c) an unnumbered frame

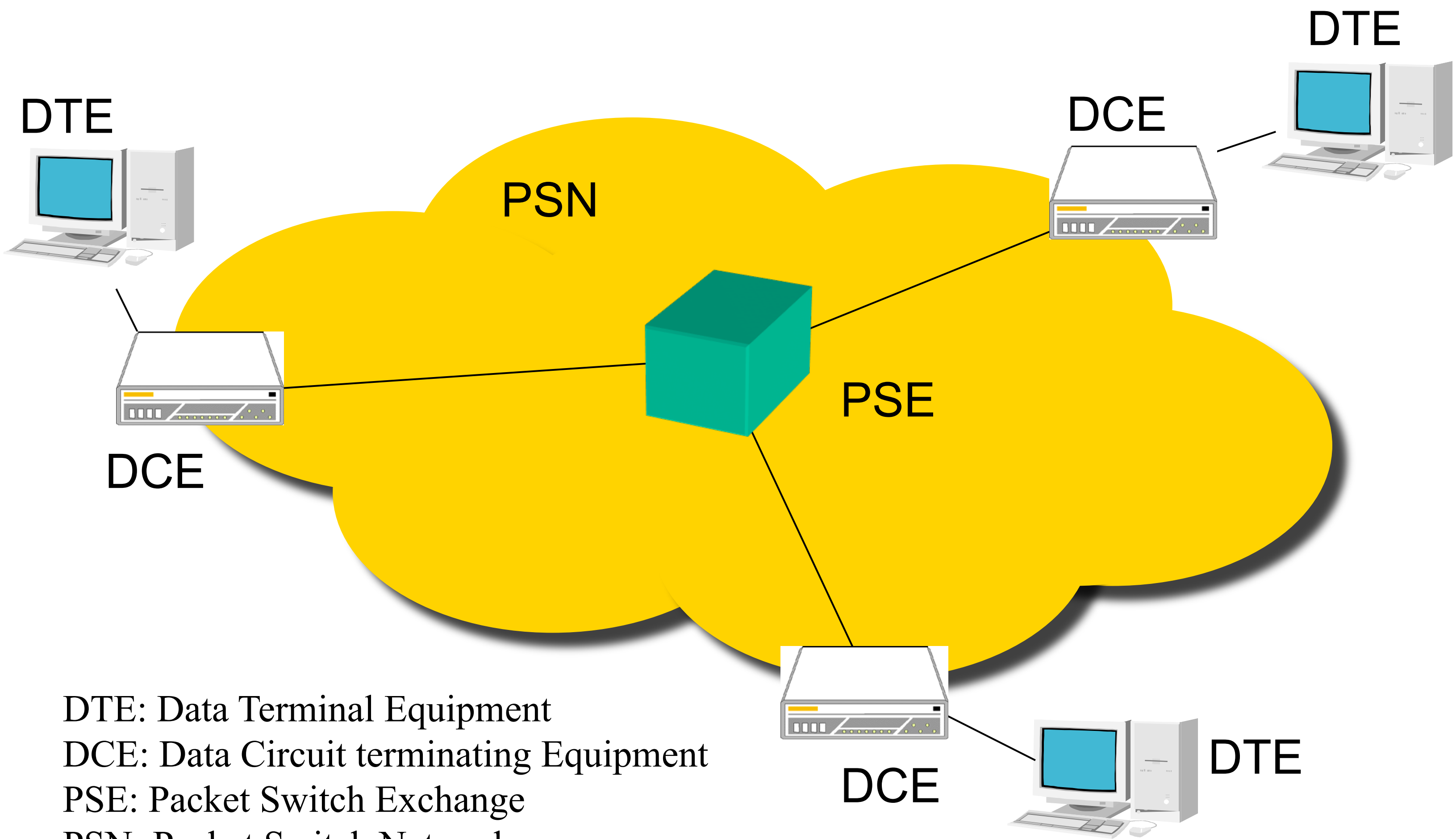
# HDLC Frame (3) – Control Field

- Define three main types of frames:
  - Information frame (*I-frame)*
    - carry the data to be transmitted for the user
    - flow- and error-control data are piggybacked on an information frame
  - Supervisory frame (*S-frame*)
    - provide the ARQ mechanism when piggybacking is not used
  - Unnumbered frame (*U-frame*)
    - provide supplemental link control functions, e.g. link termination

# X.25

- WAN: Wide Area Network
  - Technology built at a time when LAN (Local Area Network) and WAN were connected through different technologies
  - communication networks by telephone engineers
    - Nowadays, almost extinct
    - e.g., ISDN
- Approved as an international standard
  - CCITT standard → ITU-T standard
- Layer 1 – Layer 3 of the OSI reference model
  - Network layer: PLP
  - Data link layer: HDLC (ITU-T), LAPB (CCITT)
  - Physical layer: X.21 bis

# X.25 Network Model



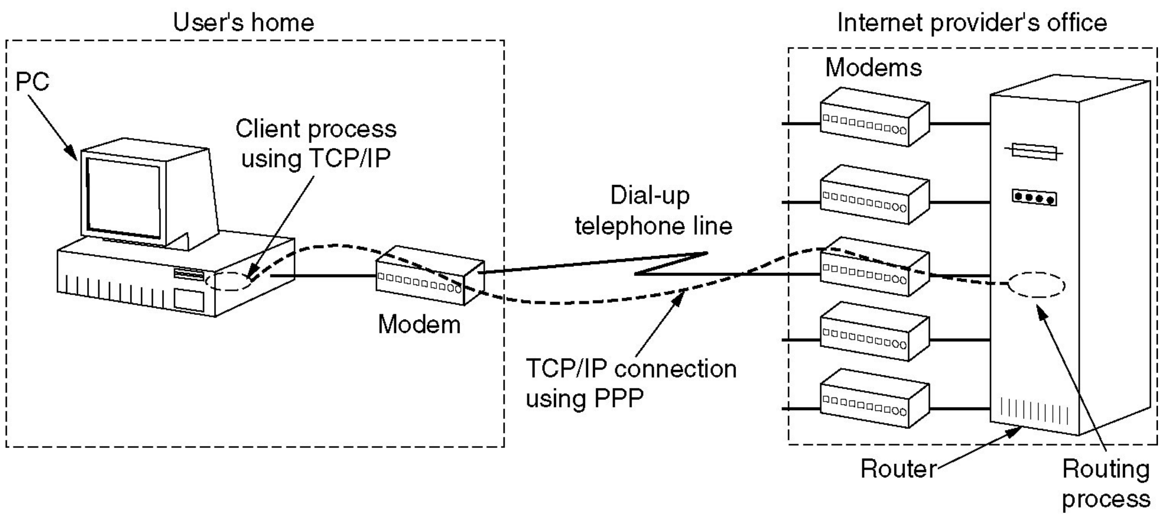

DTE: Data Terminal Equipment
DCE: Data Circuit terminating Equipment
PSE: Packet Switch Exchange
PSN: Packet Switch Network

# Point-to-Point Protocol (PPP)

- PPP design requirement (RFC 1557)
  - Packet framing: encapsulation of network-layer datagram in data link frame
    - Carry network layer data of any network layer protocol (not just IP) at same time
    - Ability to demultiplex upwards
  - Bit transparency: must carry any bit pattern in the data field
  - Error detection (no correction)
  - Connection liveness: detect, signal link failure to network layer
  - Network layer address negotiation: endpoint can learn/configure each other's network address
- Error recovery, flow control, data re-ordering all relegated to higher layers
- PPP over SONET/SDH
  - 2-point connection in large-scale or long-distance

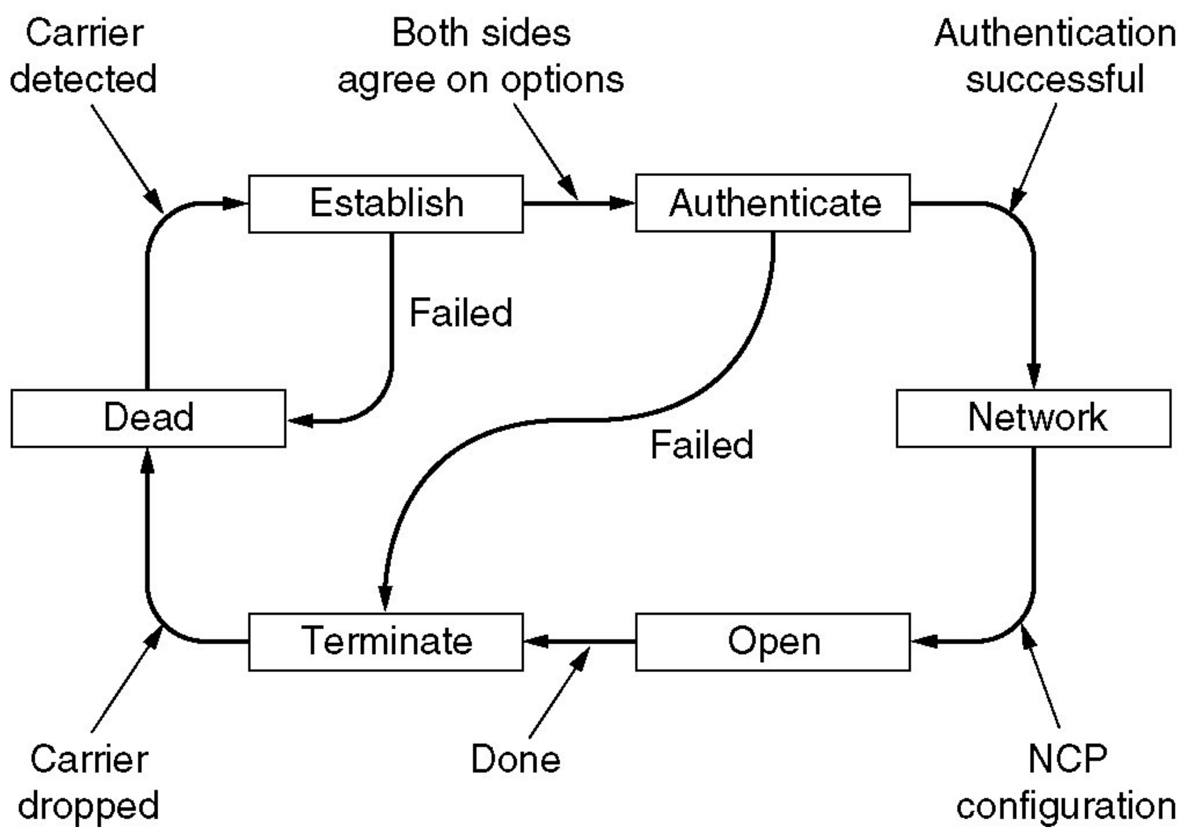
# PPP Data Control Protocol

- Before exchanging network layer data, data link peers must
  - configure PPP link (max. frame length, authentication)
  - learn/configure network layer information
  - For IP: carry IP Control Protocol (IPCP) messages to configure/ learn IP address



# PPP Phase Diagram

- A simplified phase diagram for bring a line up and down.

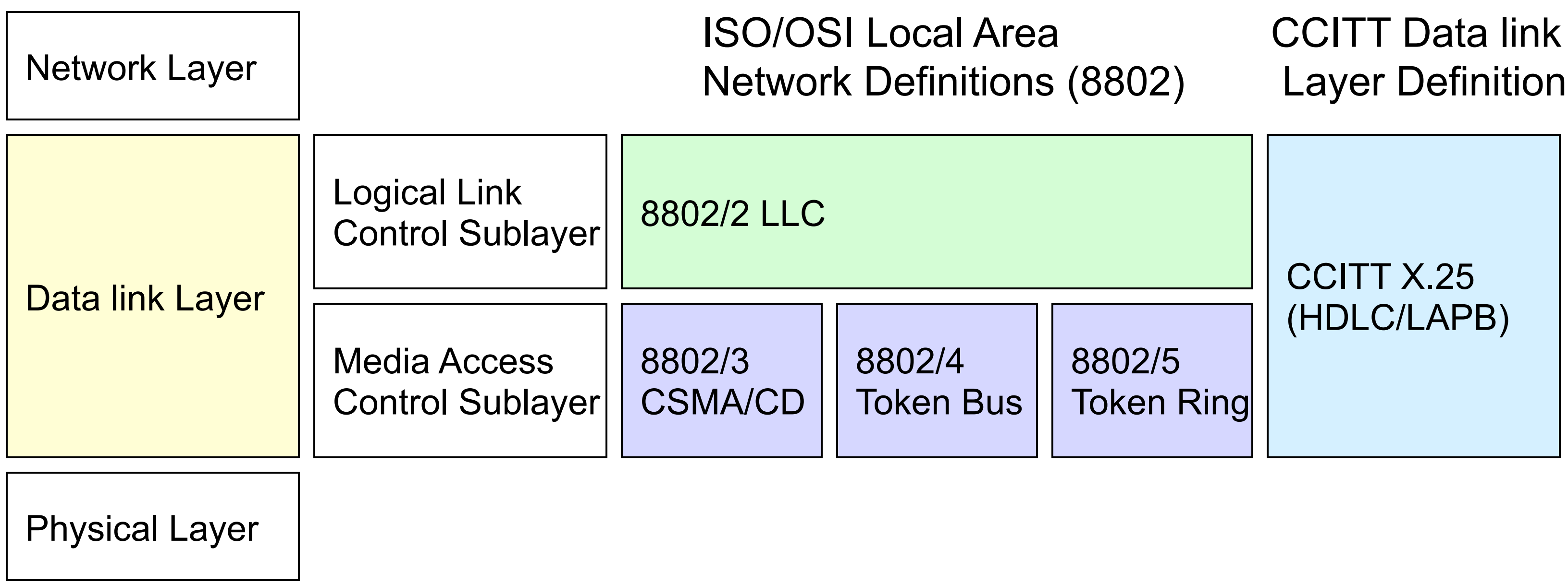


# Sublayers of the Data Link

# From monolithic structure to sub-layered structure

- Data link basic concepts were formed from the technologies using point-to-point connection type data link back in the 1960s.
- LAN standardization from the late 1970s moved to sub-layered structure.
  - Architecture of ISO/OSI 8802 and IEEE802 groups.
  - Constructing a common IEEE802.2 (ISO8802/2) Logical Link Control (LLC)
  - IEEE802.x specialized for each medium

# Sublayers of the Data Link Layer



# Logical Link Control (LLC) (1)

- Unacknowledged Connectionless Service (LLC type1)
  - Transmitting frame without synchronization between sender and receiver.
  - No special processing, upon error detection.
    - Enforcing error control in upper layers.
  - Control method for high speed and errorless links.
  - LAN, real-time traffic (voice/speech)

- Acknowledged Connection-oriented Service (LLC type2)
  - Setting up a connection, before data transmission
    - Enabling synchronized processing between sender and receiver
  - Ensuring reliability (error and sequence)
  - Processing is usually complex
  - For low speed and error-prone links

# Logical Link Control (LLC) (2)

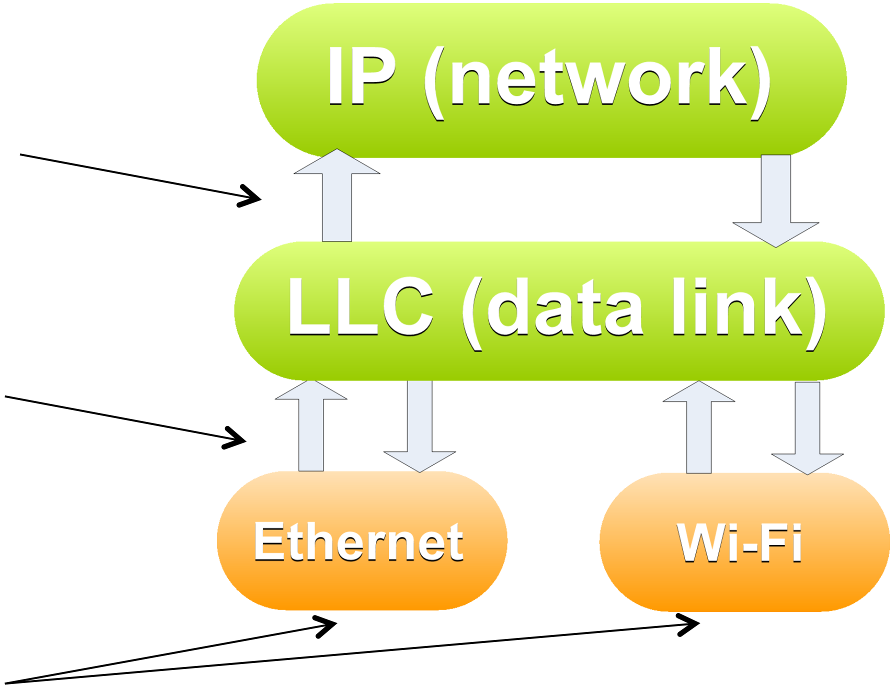
- Acknowledged connectionless Service (LLC type3)
  - Receiver sends ACK for each frame.
  - Enforcing error control at data link layer level
  - Improving reliability
- Unacknowledged Connection-oriented Service
  - Not ensuring reliability (error and sequence)
  - Control method for high speed and errorless links.

# Media Access Control (MAC) (1)

Data link layer provides packet send/ receive service to network layer

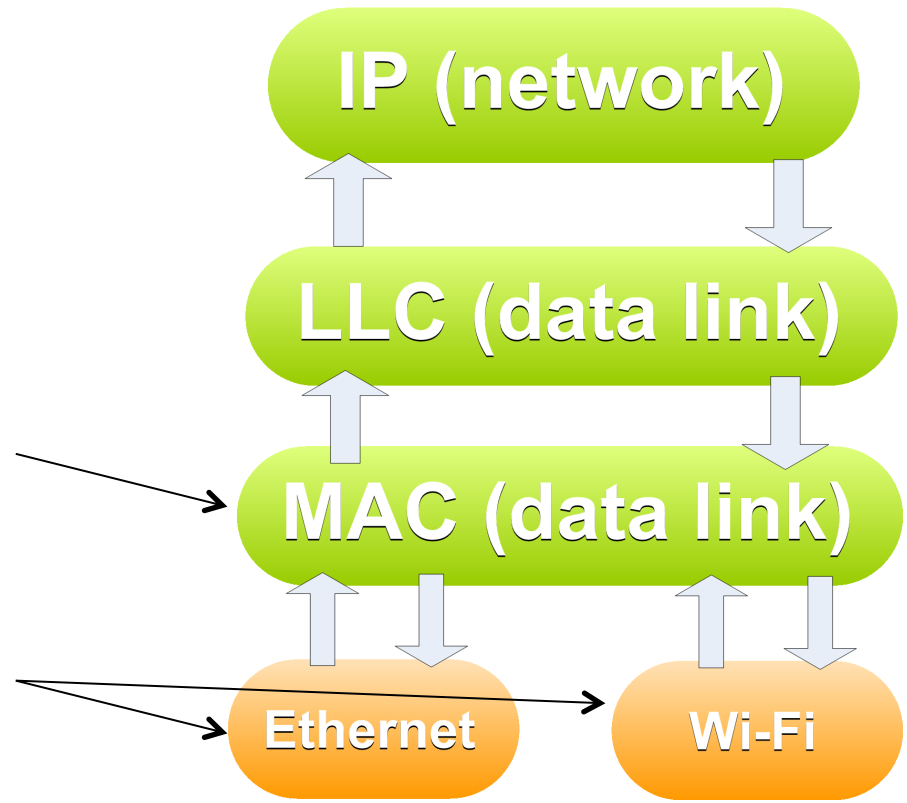
Physical Layer provides binary send/receive to data link layer

Different media have different constraints about multiple nodes accessing the medium




We want to reserve the medium for a longer space of time!

# Media Access Control (MAC) (2)




MAC layer provides medium access service to the data link layer

A separate protocol is needed to implement the service for each different transmission medium

Next class, we will learn about the channel allocation (multiplexing)