

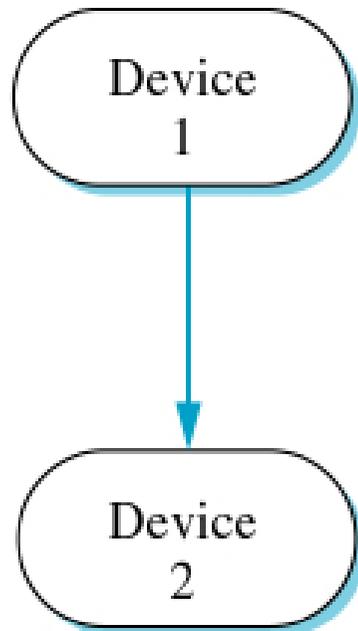
Lectures 14, 15, 16:
Connections, Protocols,
Link and Flow Control, LANs

Brian Carpenter

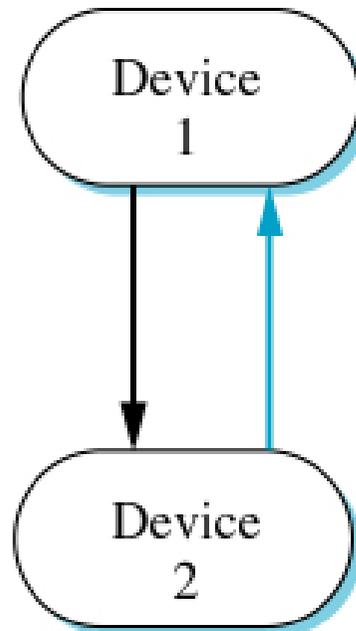
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Transmission Modes (Shay 4.3)

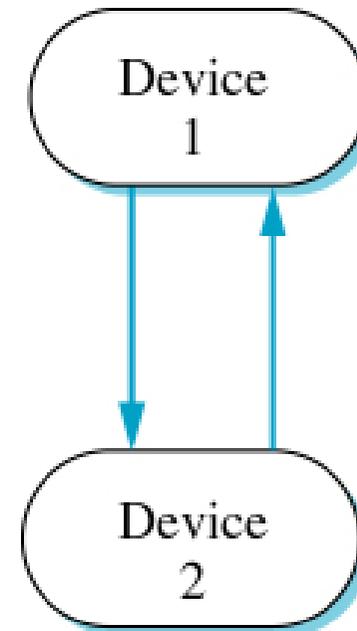
- Parallel (many wires) or Serial (one wire)
- Direction-related



Simplex
communication
goes one way only.



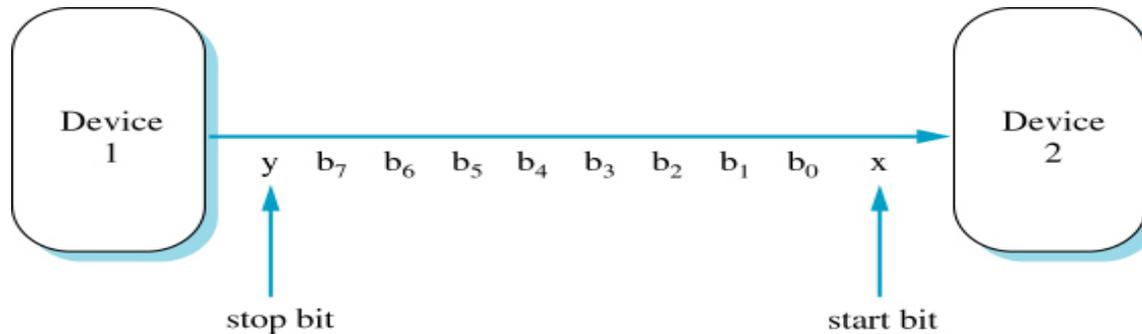
Half-duplex
communication can go
both ways, but devices
must alternate sending.



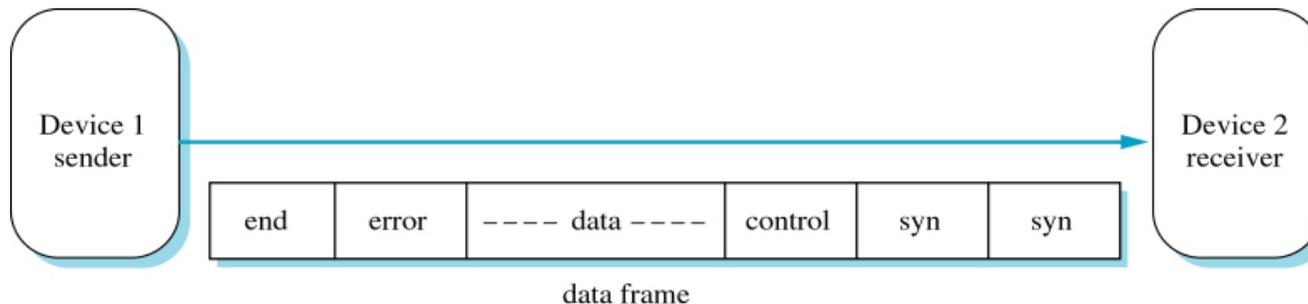
Full-duplex
communication can
go both ways
simultaneously.

Transmission Modes

- Time-related
 - **asynchronous**: may start/stop at any time



- **synchronous**: uses a continuous clock



syn = synchronization bits
control = control bits
data = data bits
error = error checking bits
end = end-of-frame bits

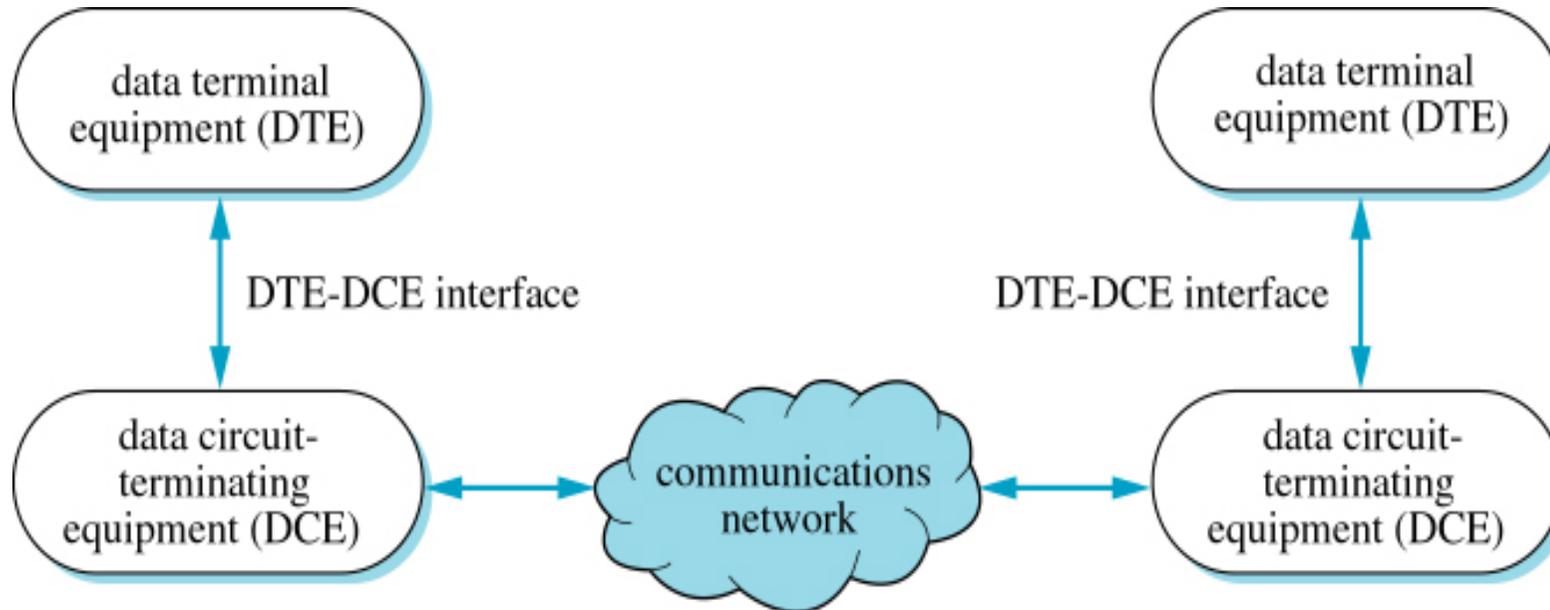
- **isochronous**: imposes gaps to match transmission rates

Interface Standards (Shay 4.4)

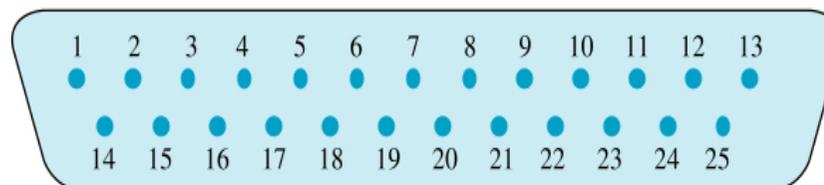
- There are lots of 'standard' interfaces for connecting devices together
- Shay has good descriptions of:
 - EIA-232 (RS-232) <= we only look at this one
 - USB
 - IEEE 1394 (Firewire)
 - X.21

RS-232 Serial Interface

- Connects DTE (computer) to DCE (modem)

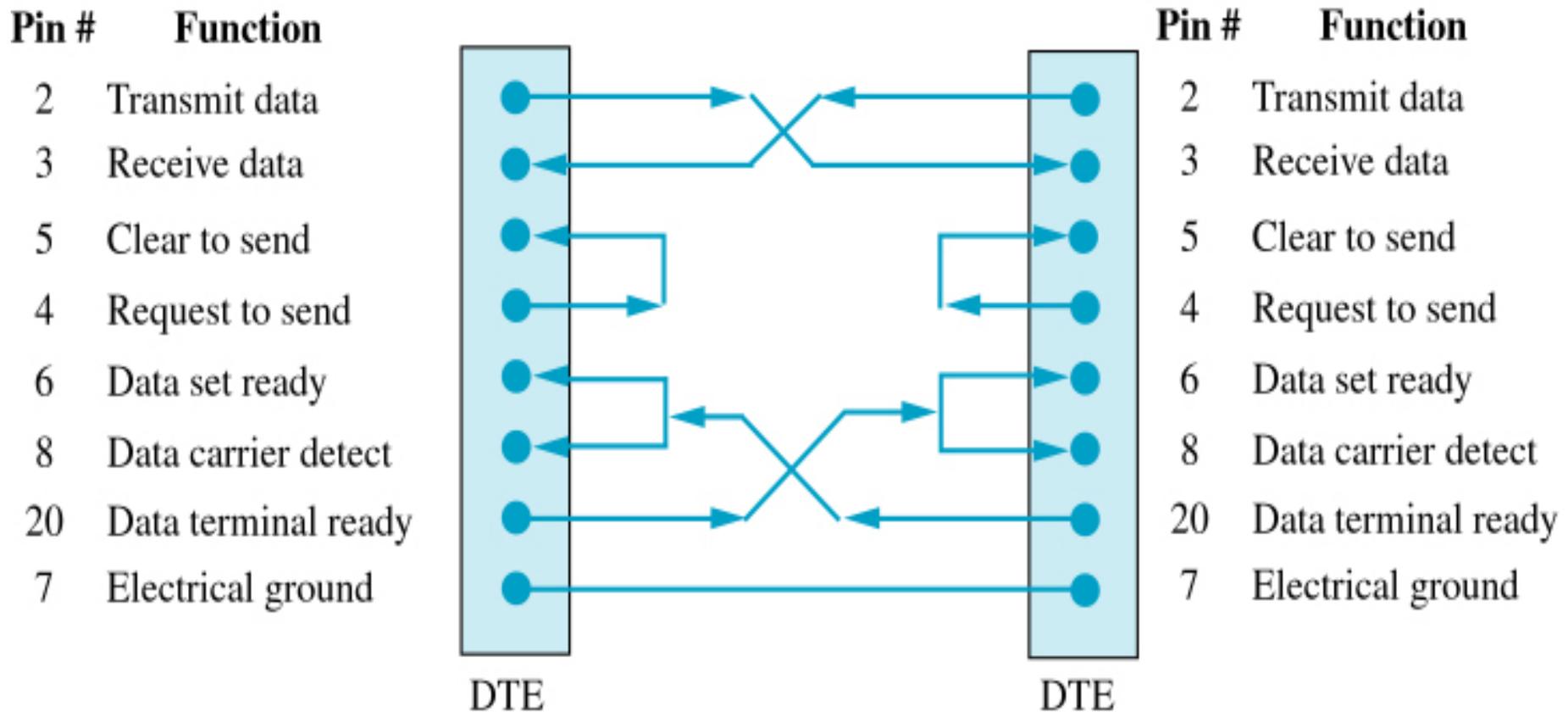


- 25-pin connector, we normally use only 9



RS-232 Serial Interface

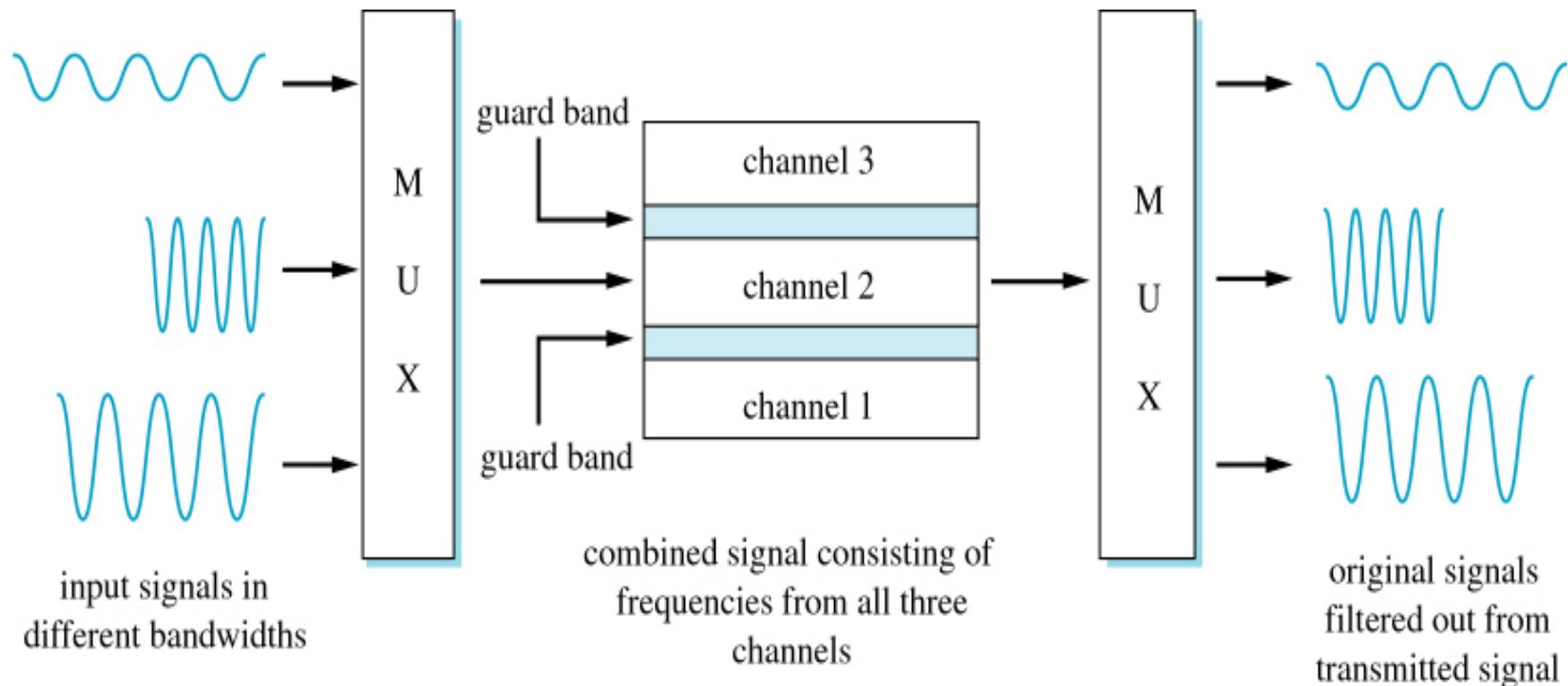
- *Null Modem* for connecting two DTEs



- *Not used here:* pin 22 = Ring Indicator, pin 1 = Protective Earth

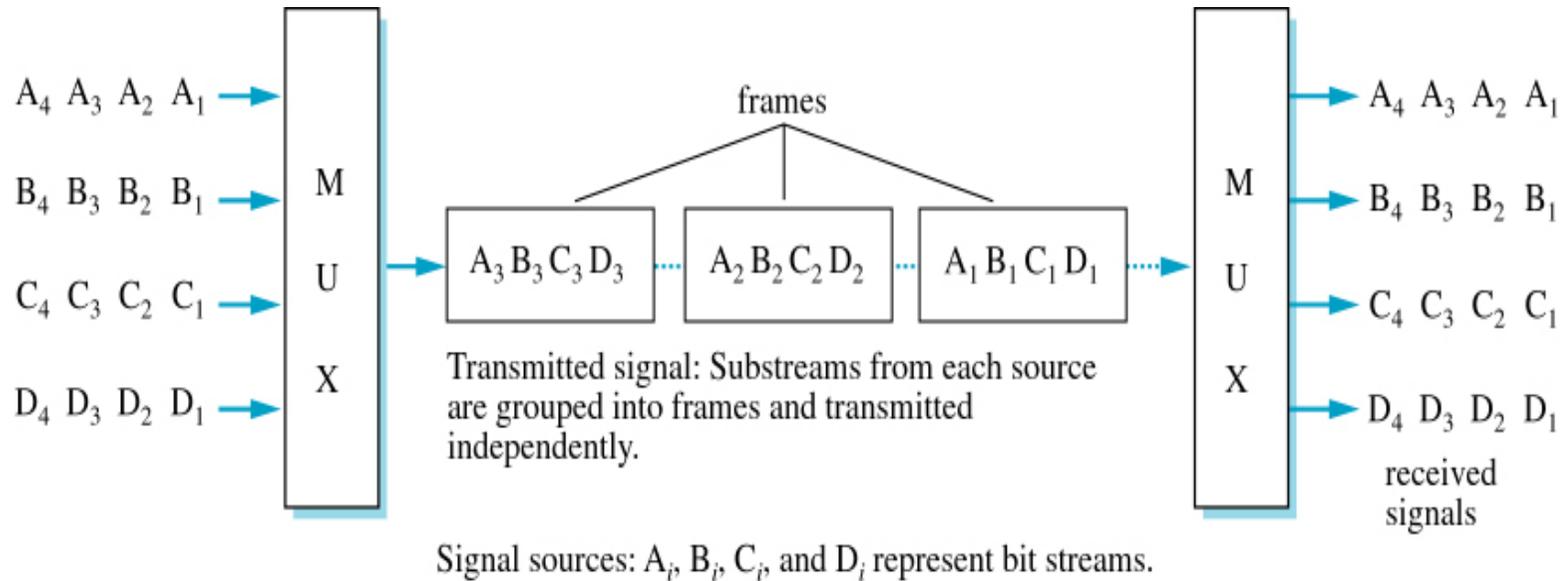
Multiplexing (Shay 4.5)

- Ways of carrying several different connections over a common link
- Frequency-Division (FDM):



Multiplexing (2)

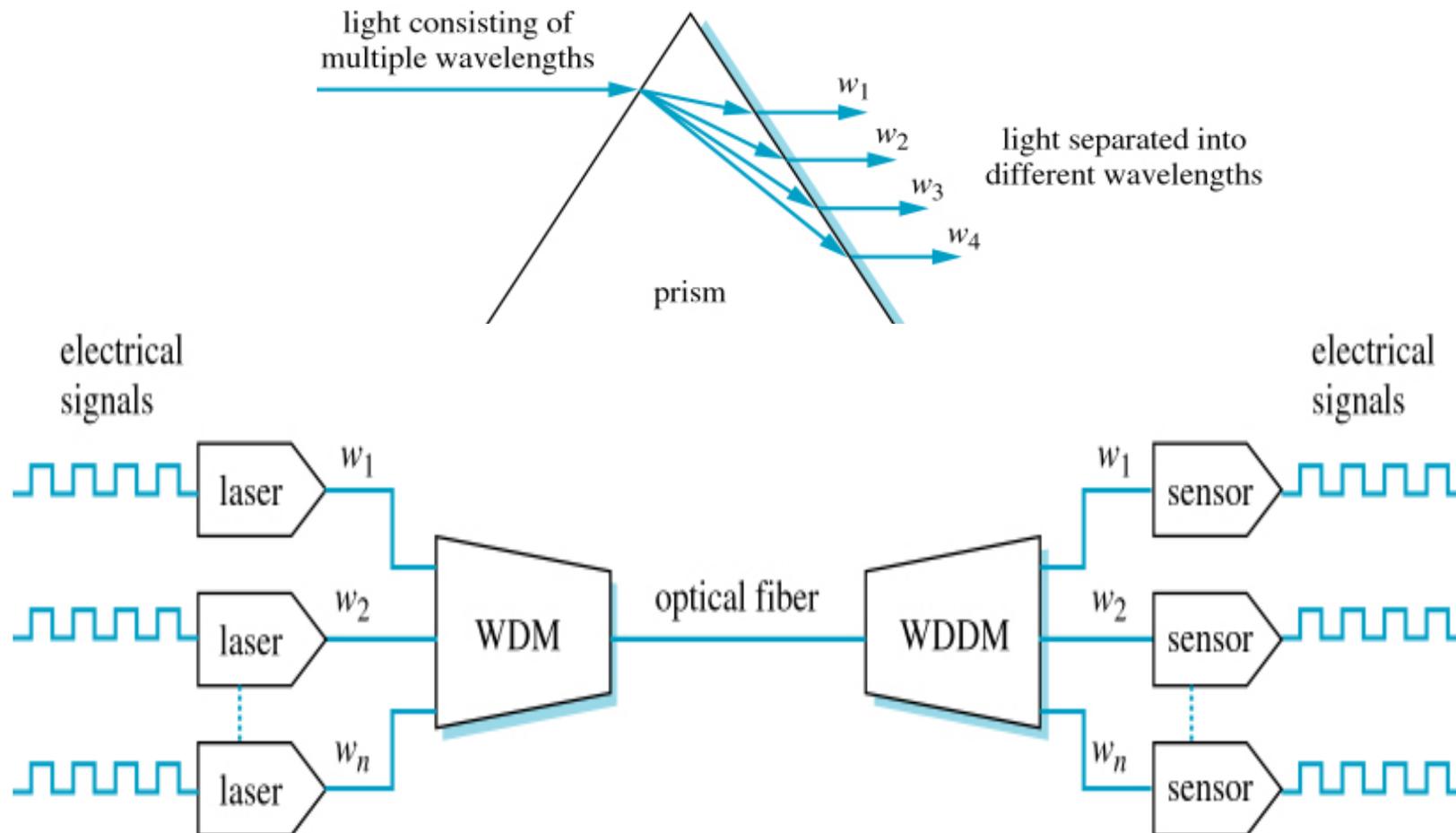
- Time-Division (TDM):



- Statistical Multiplexing
 - Much the same as TDM, but doesn't use fixed time allocations (slots)
 - Receiver must be able to identify incoming frames

Multiplexing (3)

- Wave-Division (WDM):



Flow Control (Shay 8.1)

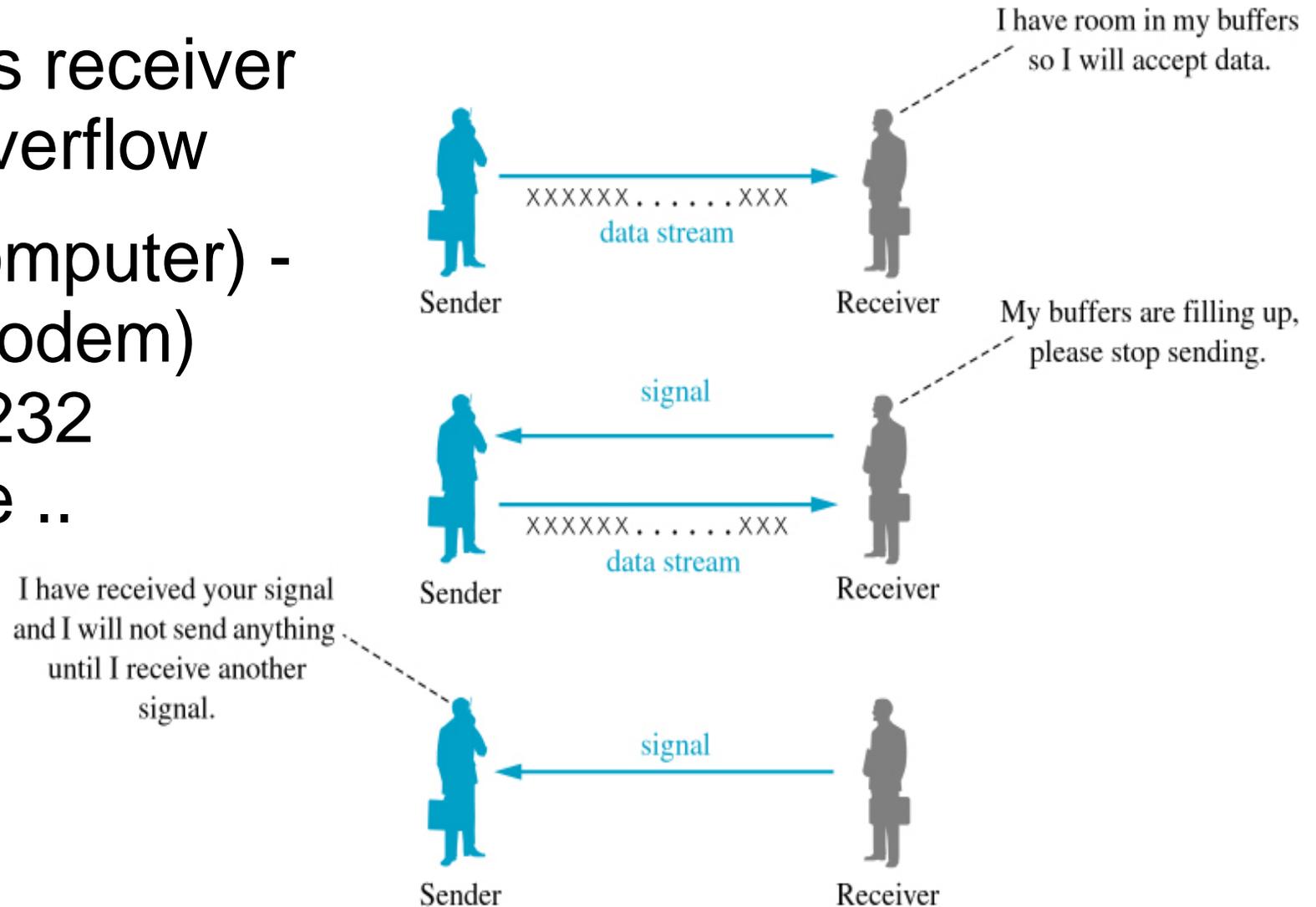
- Need for flow control
 - how can we send long messages, e.g. big files?
 - what happens when messages get lost, or are corrupted when they arrive?
 - what if the receiving *host* is busy, i.e. slow to accept incoming data?
 - how will a sender cope with lost (undelivered) messages?
 - will both hosts be able to send/receive at the same time?

What *is* Flow Control?

- Messages are broken into *frames*
- Flow Control defines
 - “the way frames are sent, tracked and controlled”
 - may be simple or complex
- Many examples of protocols around us, e.g. traffic rules (Road Code), 'phone conversations
- How can we be sure that a protocol is *correct*?
 - works properly
 - will never suddenly 'freeze'

Signaling (Shay 8.2)

- *Receiver tells sender when it's ready to receive*
- Prevents receiver buffer overflow
- DTE (computer) - DCE (modem) via RS-232 interface ..



X-ON/X-OFF

- Over the DTE-DCE path ..
 - send ASCII X-OFF (0x13, ^S) to stop transmission
 - send X-ON (0x11, ^Q) to start it again
- This is *in-band* signalling, i.e. send signal on same path as data
- How quickly does the transmitter stop sending?
- How can we send 0x11 or 0x13 to the receiver?

Frame-oriented Control (Shay 8.3)

- Idea is to break large sequences of chars into smaller *frames*
- Frames are sent from one *user* (higher protocol layer) to another
- *Unrestricted* protocol
 - simply assume it's always safe to send
 - not really a useable protocol!

Stop-and-Wait

- Sender:
 - send frame, wait for ACK or NAK
 - if NAK, send frame again. Repeat until get ACK
- Receiver:
 - receive frame, check for errors
 - if OK, send ACK. otherwise send NAK
- No way to handle lost (therefore not ACKed) frames

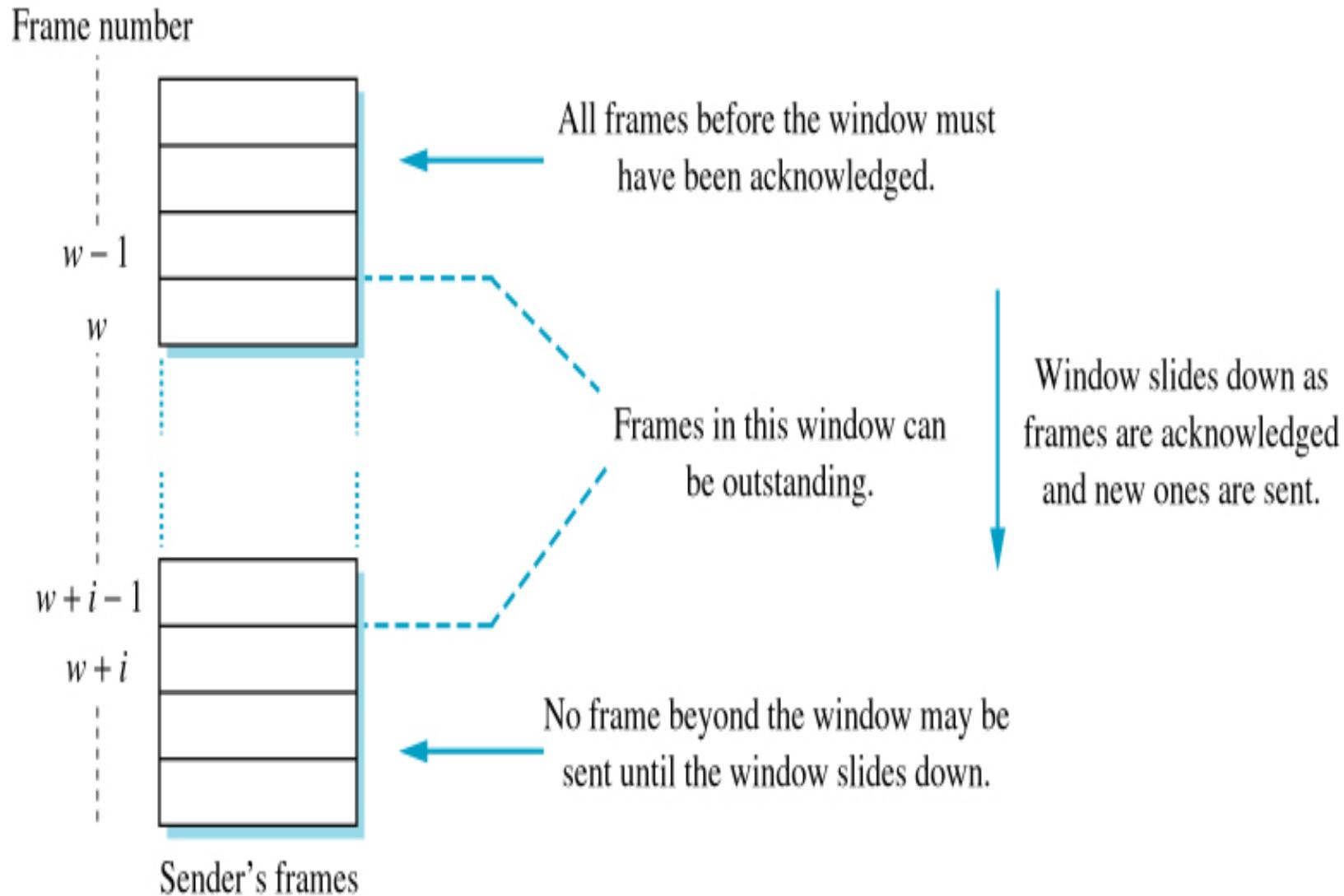
Protocol Efficiency: Effective data rate

- Shay derives formulae, we “just work it out”
- Remember, $velocity = distance / time$
 - in wire or fibre, v is $\sim 2/3$ speed of light, i.e. 2×10^8 m/s
 - Auckland-Hamilton is about 120 km, so a byte takes $(120 \times 10^3) / (2 \times 10^8) = 0.6$ ms to get there
 - If we send a 1500-Byte frame at 10 Mb/s, it will take $(1500 \times 8) / (10 \times 10^6) = 1.2$ ms to transmit
 - Assume that ACK is a 64-Byte frame, 0.0512 ms
 - Therefore, to send frame and receive ACK takes roughly $1.2 + 0.05 + 2 \times 0.6 = 2.45$ ms
 - Effective bit rate is $(1500 \times 8) / (2.45 \times 10^{-3}) = \underline{4.9 \text{ Mb/s}}$
 - *Half the time is wasted waiting for ACKs*

Side note: a catch in the notation

- Convention:
 - Mb/s for megabits per second
 - MB/s for megabytes per second
- Often leads to confusion, especially with marketing people, journalists, and politicians.
- If there is any chance of confusion, write "megabits" or "megabytes" in full.
- In data communications, we normally discuss megabits. But when considering application throughput, megabytes are more useful.

Sliding Window (Shay 8.4)



Sliding Window / *Go-back-n*

- Idea here is to have a maximum of i frames on the wire at any time. i is the *window size*
- Each frame has a sequence number, sender must hold each frame until it is ACKed
- Sender keeps track of w , sequence number of first (of i frames) in window. When frame w is ACKed, sender can forget it
- Window does not move until earliest frame has been ACKed

Go-back-n

- Shay develops a frame format for two-way communication

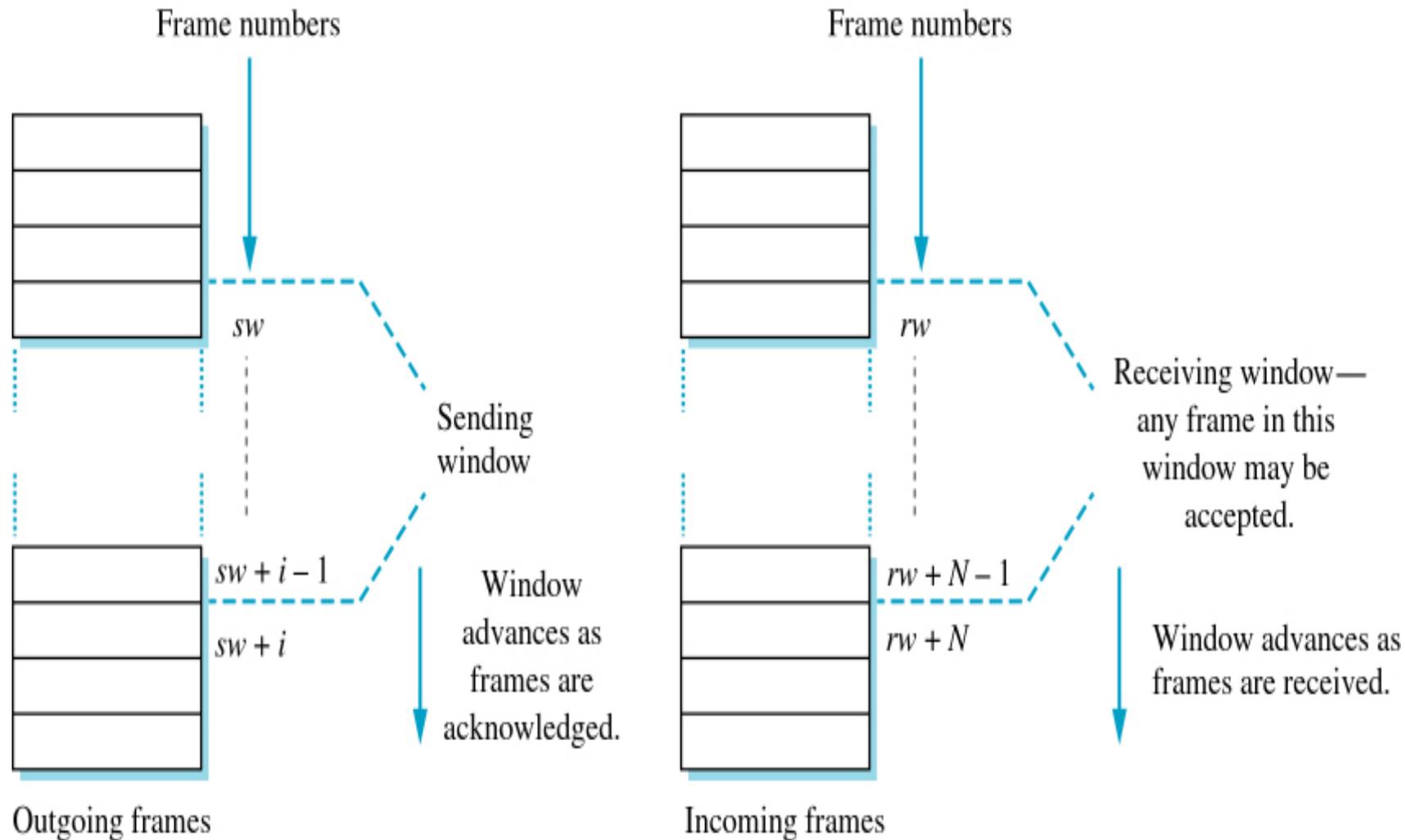


- Data frame in one direction can carry an ACK for the other direction, i.e. a *piggy-backed ACK*
- To handle lost frames, he has an *ACK timer* at the receiver ..
- and a *frame timer* at the transmitter

Sequence Numbers

- Sequence Numbers fit in a K -bit field; there can be at most 2^K frames in the window
- K should be big enough to handle the maximum window size we expect to use
- They are *unsigned* numbers, and can *wrap*, i.e. count through $2^K-2, 2^K-1, 0, 1, 2, \dots$
You can think of the sequence numbers as being arranged in a circle
- What happens if a host crashes and restarts?
- Some protocols used *lollipop sequence numbering* to handle restarts! (see Wikipedia)

Selective Repeat (Shay 8.5)



Selective Repeat (2)

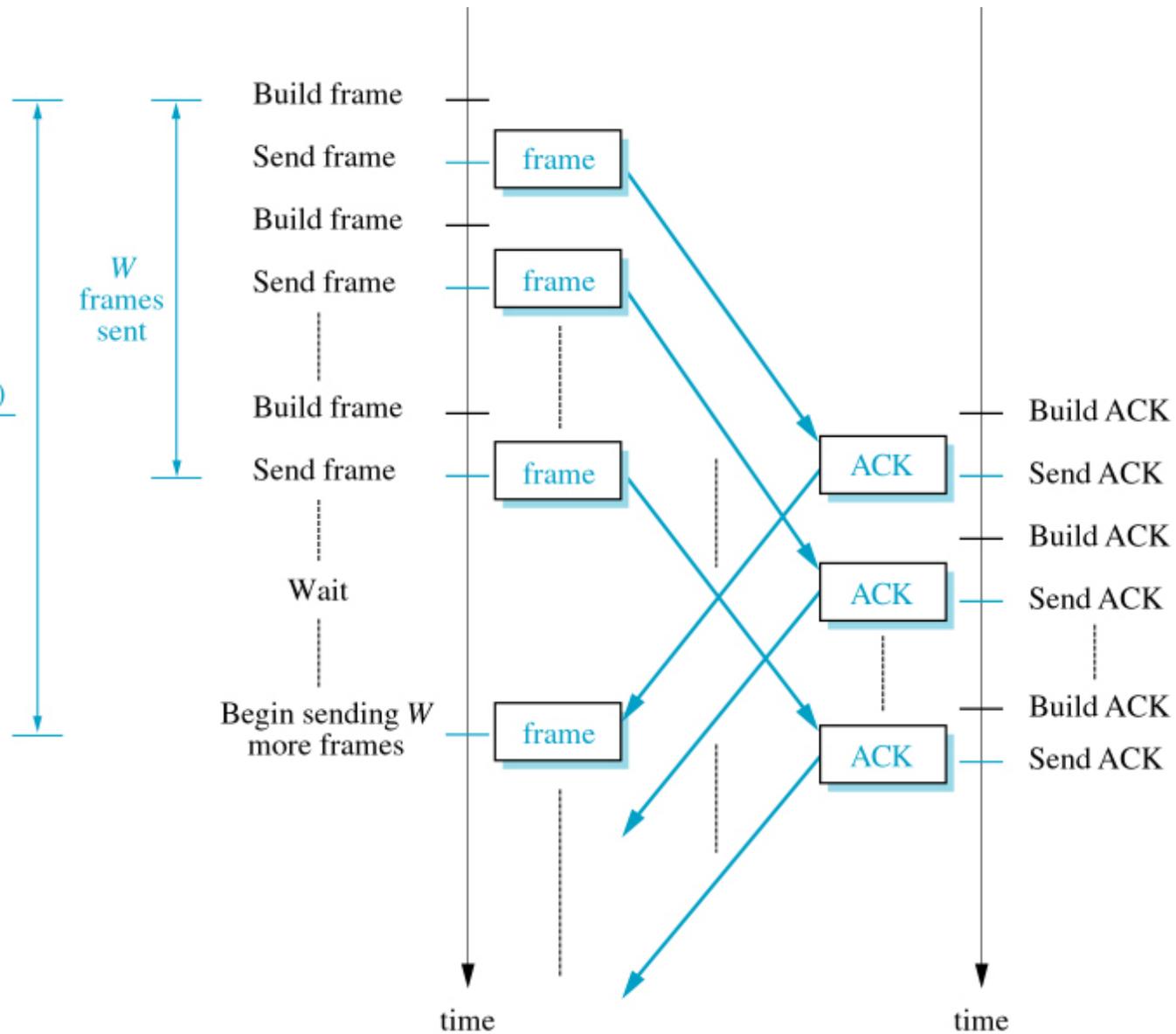
- Any frame can be ACKed, specifying its sequence number
- Frames arriving out of sequence are *buffered* until earlier frames have been ACKed
- When a NAK is received, only the NAKed frame is resent (Go-Back-n resent the whole window!)
- If a frame timer expires (no ACK or NAK), only the timed-out frame is resent
- Piggy-backed ACK acknowledges the *last frame delivered to the user*, so the sender knows that all frames up to that one have been safely received

Efficiency of Sliding Window Protocols (8.6)

- For a particular window size, message size, transmission speed and link distance, we can “just work it out,” as we did for stop-and-wait
- *We assume no lost or damaged packets !*
- Two cases
 - we get our first message ACKed before we've sent a whole window. That allows us to keep sending at full link speed
 - we have to wait for an ACK after sending a window, then we can send another window. Shay has a diagram illustrating this ..

Sending whole window and waiting

$$\text{time} = 2 \left(T + \frac{D}{S} \right) + \frac{(F + A)}{R}$$



Numerical examples

- Sending 100x 1500B frames in 20-frame windows, Auckland-Hamilton on a 10 Mb/s link
 - as for Stop-and-Wait: 1.2ms to send frame, 1.2ms round-trip time.
Any window > 2 frames can run at full speed, 10 Mb/s
- As above, but with 64B frames
 - send time is $(64 \times 8)/(10 \times 10^6) = 0.0512 \text{ ms}$
 - time to send 20 frames = $20 \times 0.0512 = 1.024 \text{ ms}$
 - first ACK returns after $1.2 + 2 \times 0.0512 = 1.3024 \text{ ms}$
 - effective bit rate is $(20 \times 64 \times 8)/1.3024 = 7.862 \text{ Mb/s}$
 - note the effect of using a *small frame size !*

Bandwidth-Delay Product (BDP)

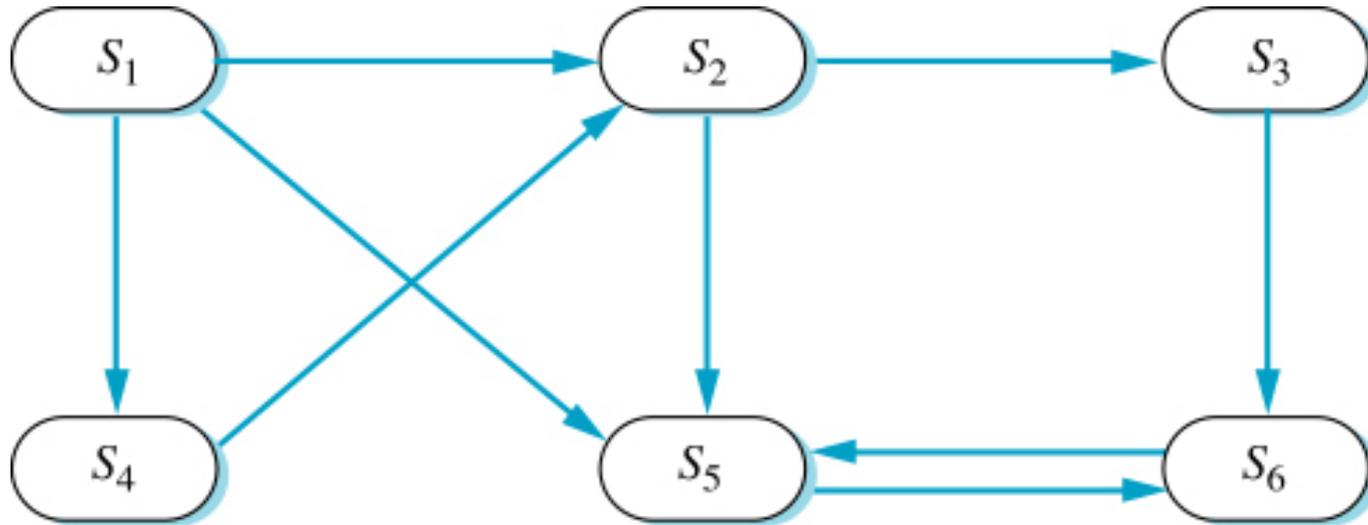
- BDP for a link = data rate x link delay*
- Auckland-Hamilton at 10 Mb/s:
BDP = 10 Mb/s x 0.6 ms = **6000 bits**
= **750 B**
- This is the maximum number of bits we can have 'on the wire'
- Need to have buffers **at least double this** so that transport protocol can keep the link busy
 - **fill the wire once, and then again before first ACK returns**
- Bigger frames sizes help to keep the link busy – less *protocol overhead*

*one-way delay, not round-trip time

Protocol Correctness (Shay 8.7)

- Shay discusses two ways to describe systems:
 - Finite State Machines
 - Petri nets
- Finite State Machine models a system as being in one of a finite set of *states*
- State Transition Diagrams (STDs) are graphs, each vertex represents a state, and each edge a transition between states
- Petri nets are more detailed, we won't discuss them further

State Transition Diagrams

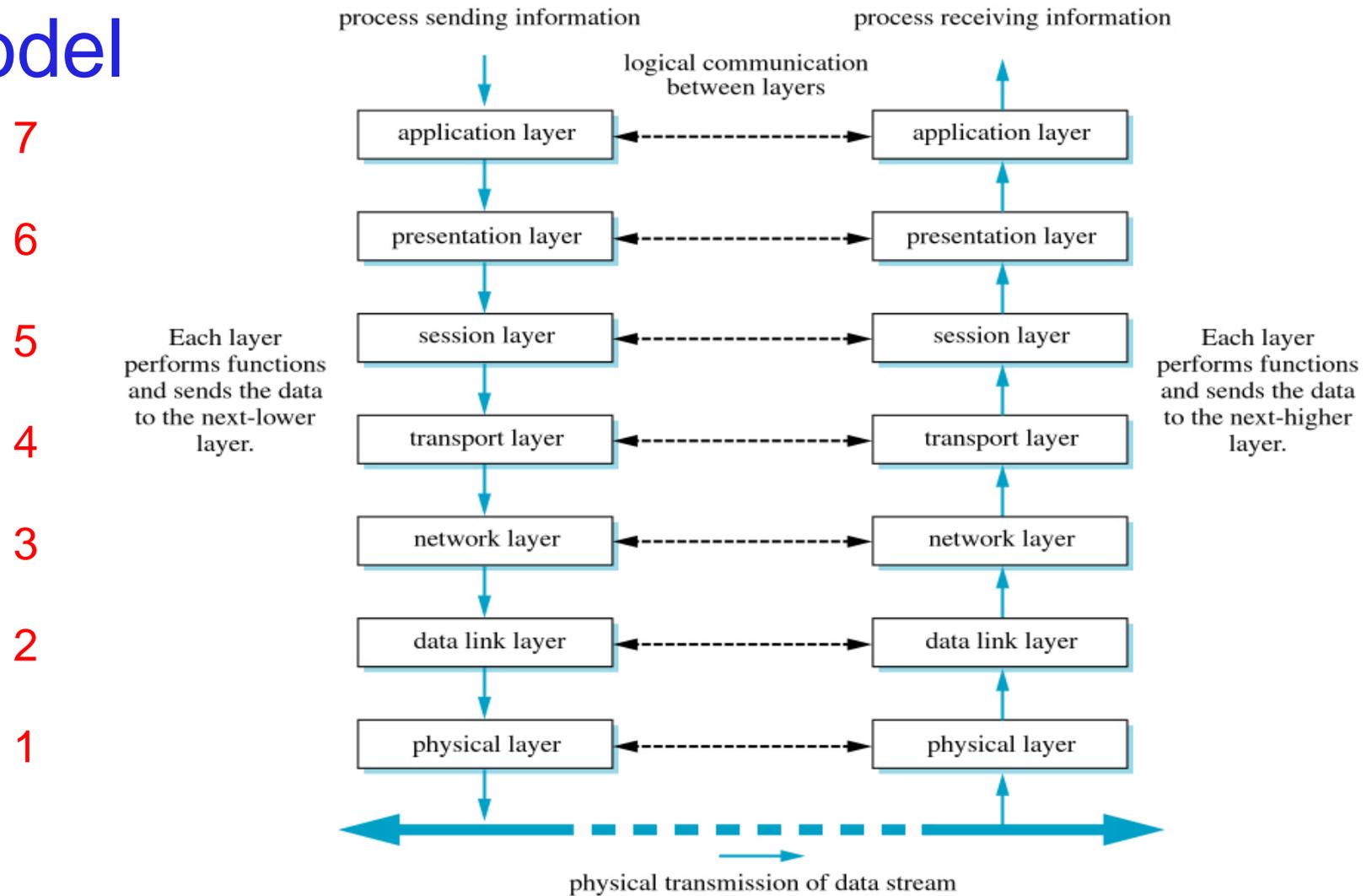


- Look for problems on graph
 - No edges pointing to S_1
 - $S_5 - S_6$ is an infinite loop
- This kind of analysis helps find flaws
 - *it doesn't prove correctness!*

Protocol Layers, the OSI Model (reminder)

- Layers are an abstraction, they provide a simple view of what happens in a communication system
- Layer n
 - provides services to layer $n+1$
 - uses services from layer $n-1$
- Generally we implement systems this way, but sometimes we may find it useful to peek between layers, or 'break layer purity'

OSI Model



- OSI has 7 layers, TCP/IP collapses 5-7 into 5
- So far, we've mainly discussed layer 1

Introduction to LANs (Shay 9.1)

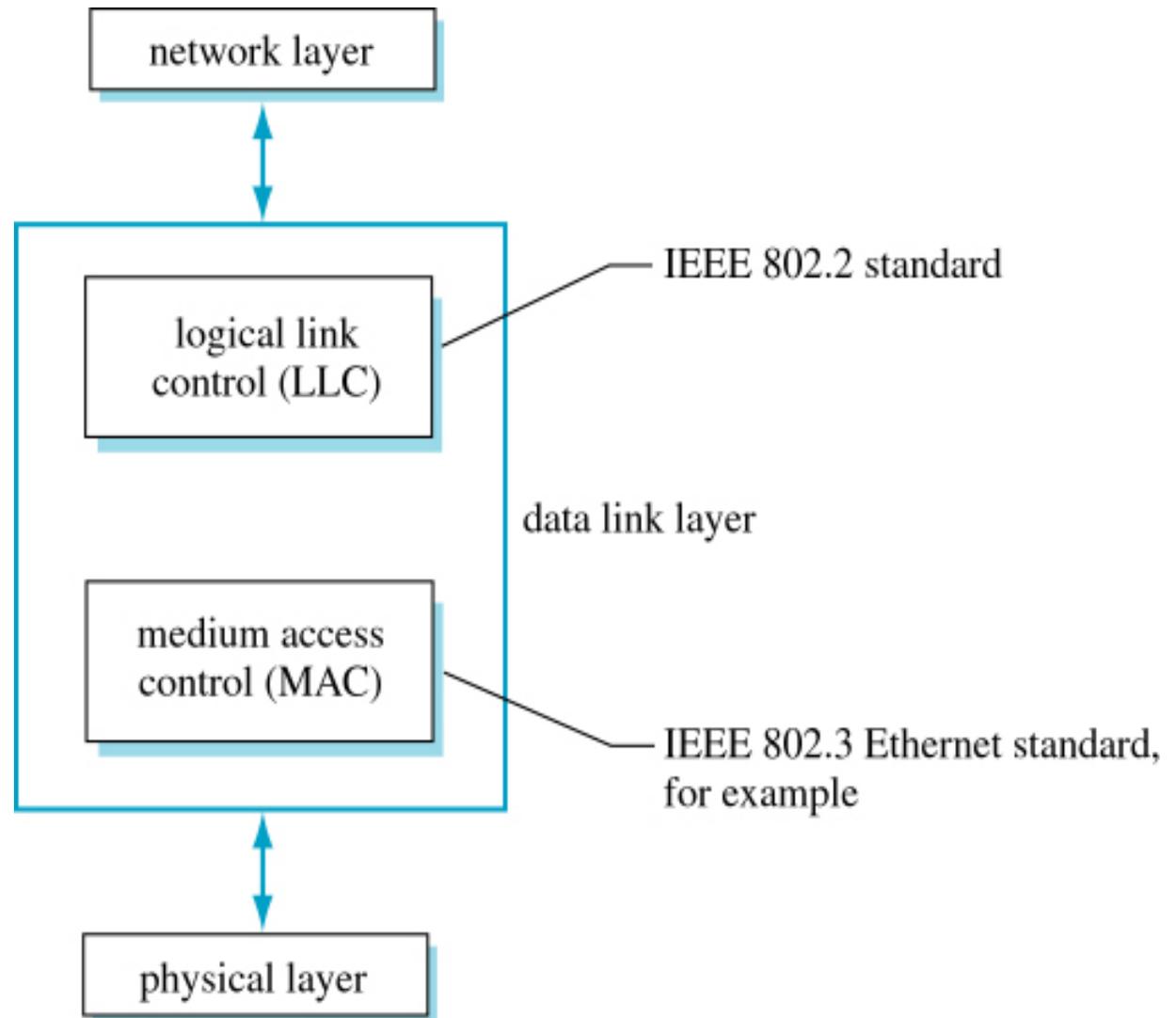
- LANs connect many hosts (devices) together
- Link medium may be copper (coax or UTP), fibre or wireless
- Topology may be
 - *bus*: hosts share the medium by taking turns
 - *ring*: access is controlled by passing a token
- Ethernet – today's most common LAN physical layer – uses a bus topology
- Point-to-point link is a LAN with only two hosts

LAN Layers

- Layer **1** is the **Physical** layer. On this layer, you've already looked at signaling and modulation methods
- Layer **2**, the **Link** layer, is where hosts talk to each other. Protocols here send frames (packets) to other hosts, and receive frames in response
- Layer **3**, the **Network** layer, is used to pass packets between LANs. For example, we often use IP to pass frames between Ethernet-connected hosts

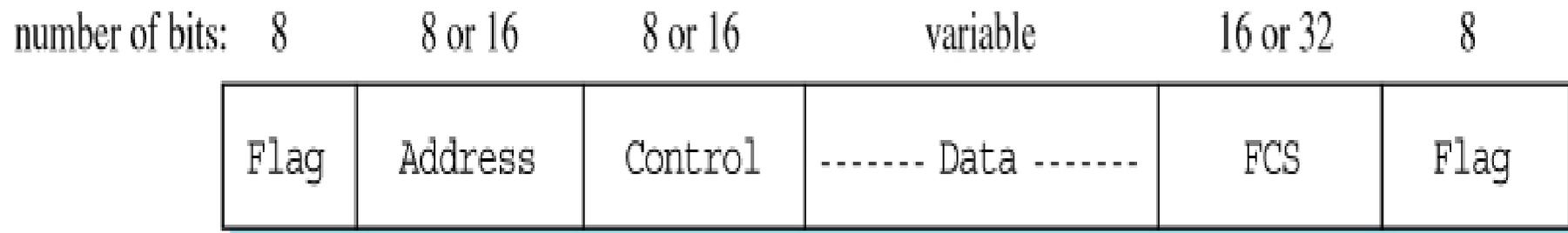
Data Link Control (Shay 9.2)

- Link layer is divided in two – LLC and MAC
- Shay presents HDLC, a fore-runner of IEEE 802.2
- These are bit-oriented protocols



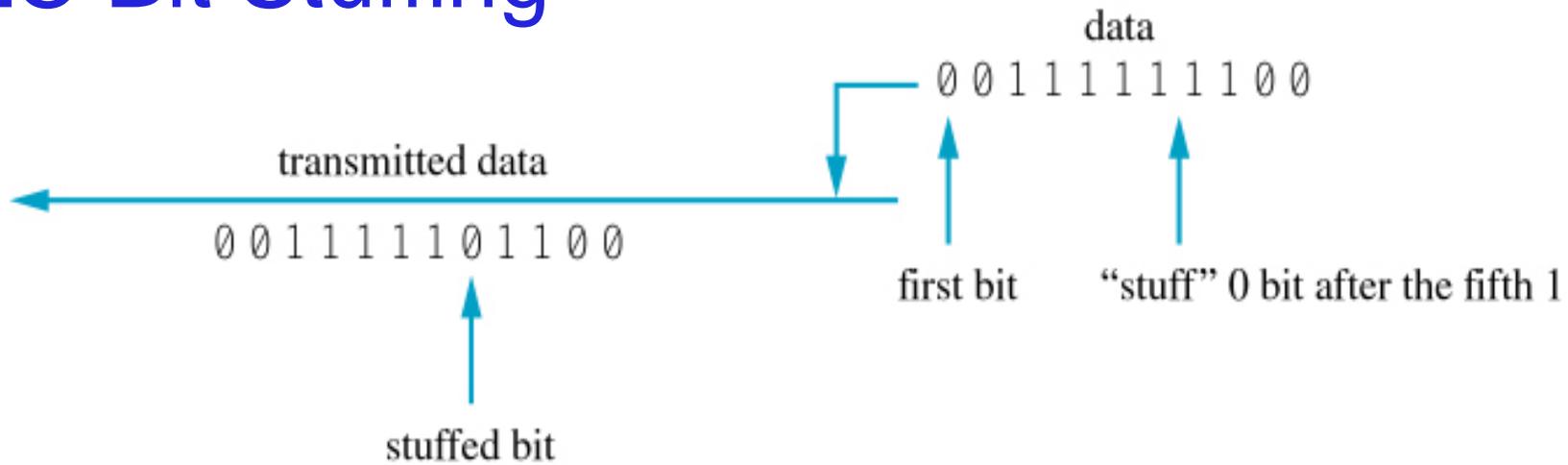
HDLC Frame Format

- *Flag* pattern, 01111110 (six 1s) marks start and end of frame. Receiver watches medium for flags

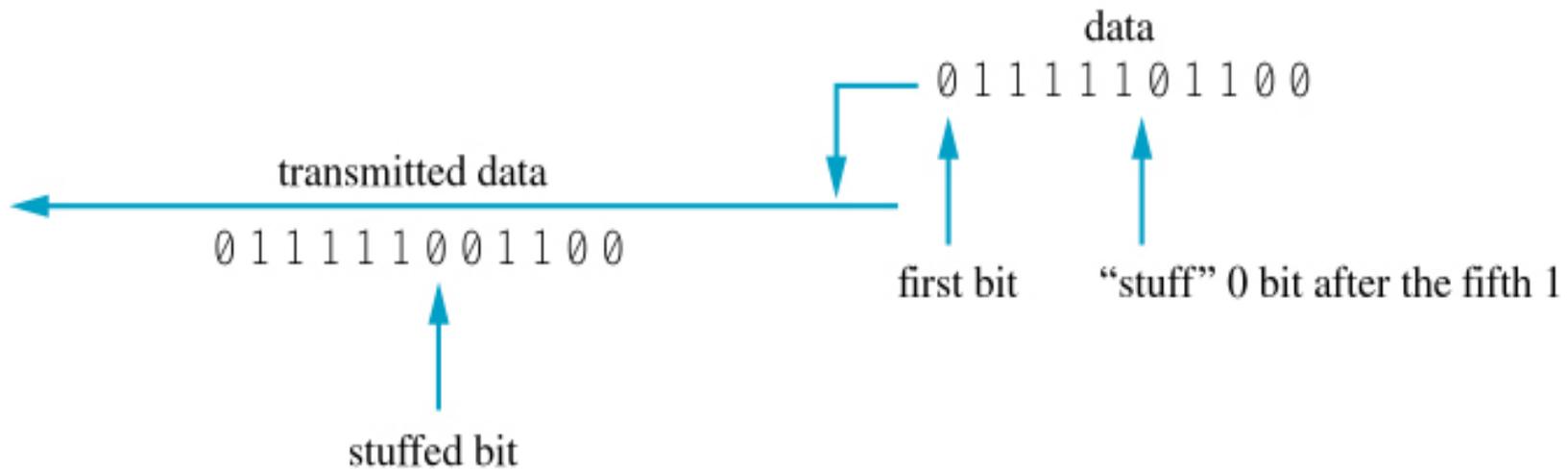


- How do we send the flag pattern within the data part of the frame?

HDLC Bit Stuffing

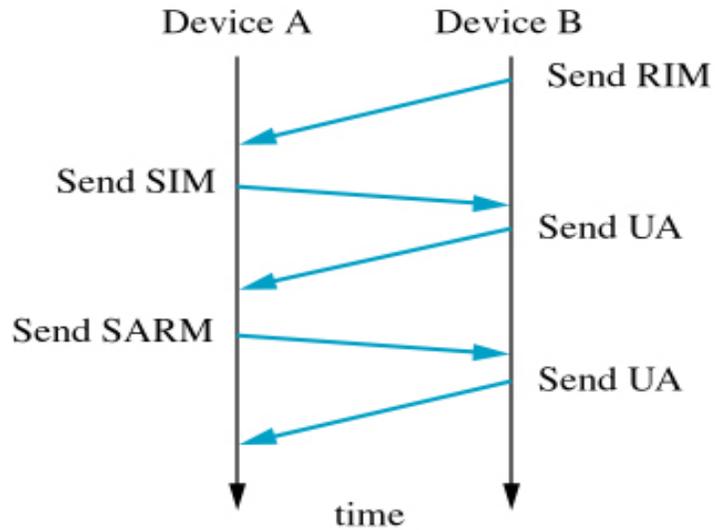


(a) More than five consecutive 1s

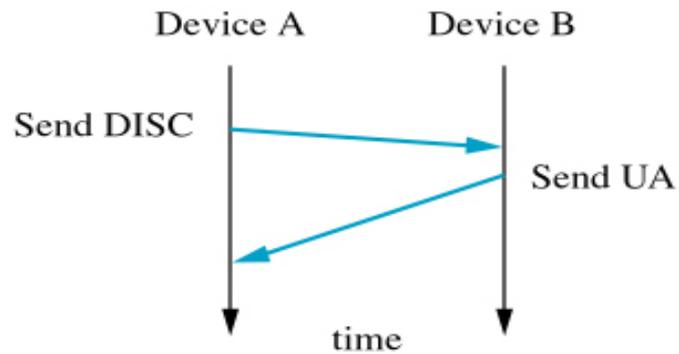


(b) Five consecutive 1s

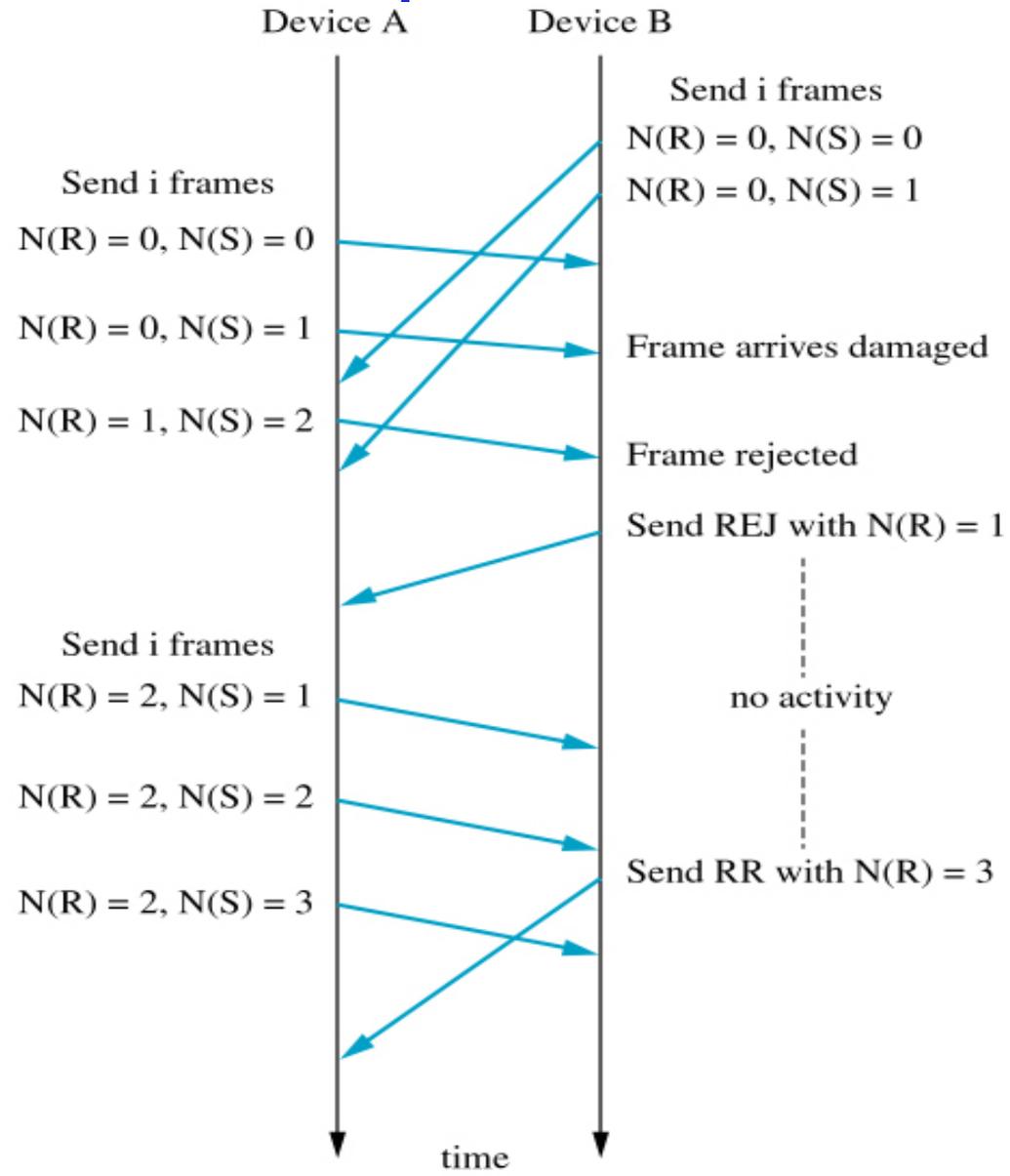
HDLC communication example



(a) Establishing link



(c) Terminating link



(b) Exchanging frames

802.2 LLC Header Formats (if used)

DSAP address 8 bits	SSAP address 8 bits	Control field 8 or 16 bits	Information field N*8 bits
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General form
of LLC header

- DSAP, SSAP are Service Access Point addresses
 - 04 = IBM SNA, 06 = IP,
AA = SNAP (Subnetwork Attachment Point)

AA AA 03 LLC	00 00 00 3 octet OUI	08 00 2-octet type field
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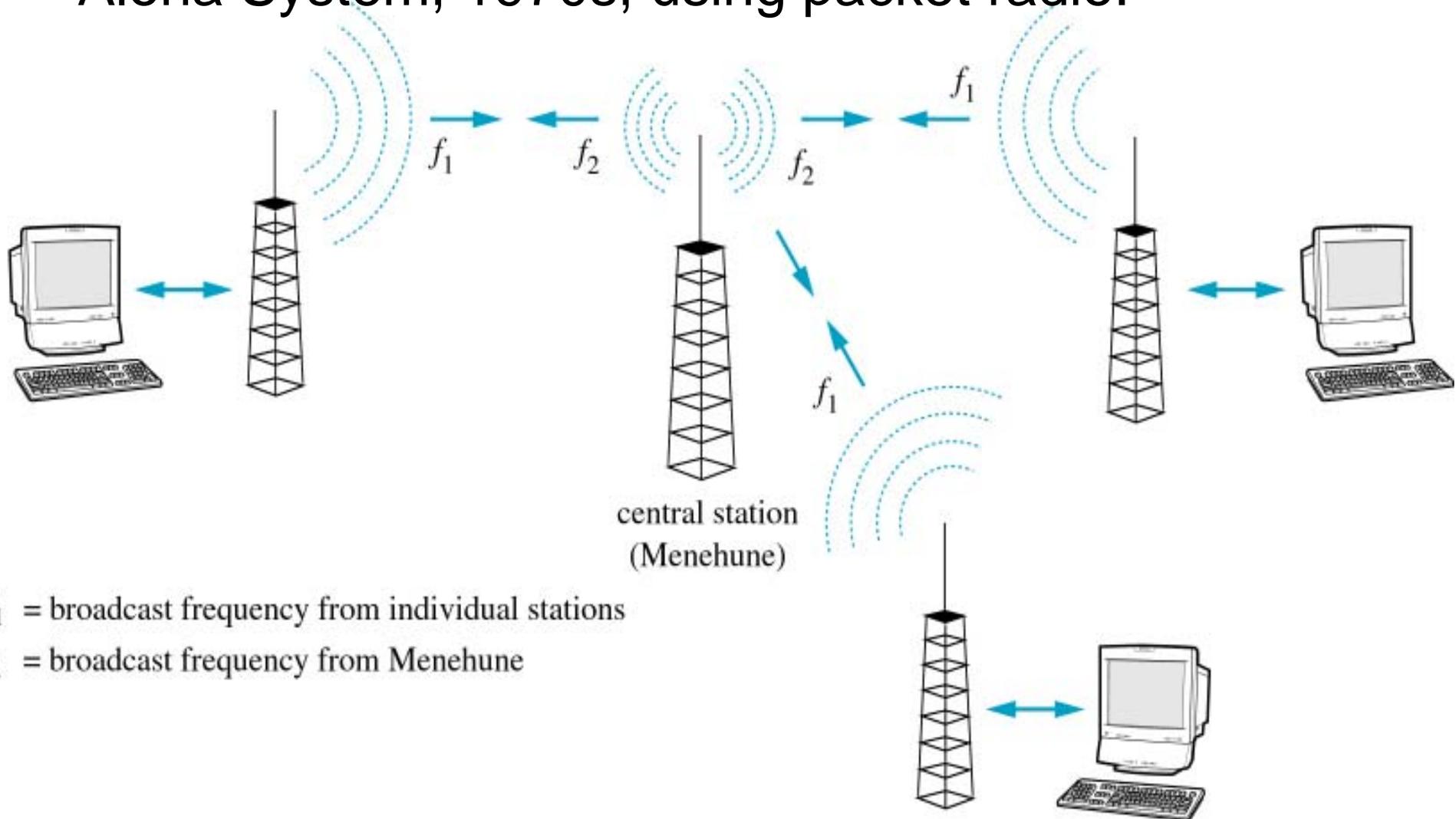
SNAP header
(8 bytes)

2-octet type field

- OUI = Organisation Unique Identifier
- Type field values are Ethernet type (Ethertype) values
 - 0800_{16} = IP, 0806 = ARP, 6003 = DECnet phase IV, ...

Contention Protocols (Shay 4.7)

- Basic idea: Hosts must *share* the medium
- Aloha System, 1970s, using packet radio:



Aloha Protocol

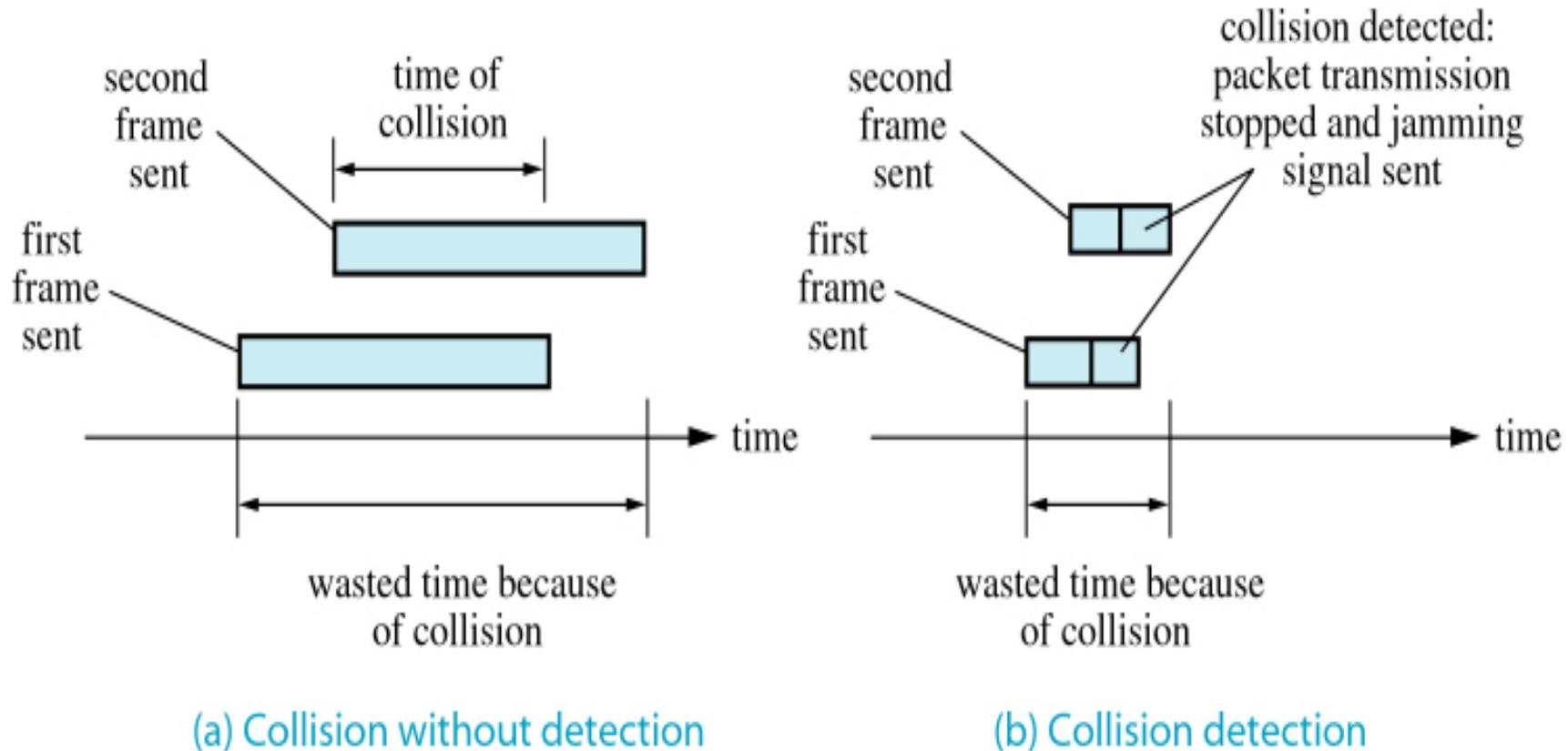
- Any host can broadcast a message to Menehune at any time
- If the message is received correctly, Menehune ACKs it (on a different frequency)
- If two host transmissions overlap (and interfere) the message is lost
- If a message is not ACKed the host assumes it was lost, waits a random time, then resends
- Worked and was simple, but not a very efficient use of the medium

Carrier Sense Multiple Access (CSMA)

- Like Aloha, *listen to medium* for any activity
- If no activity, transmit; otherwise wait
- Can still get collisions, various ways to reduce them:
 - use 'slot time,' hosts can only transmit at start of a slot
 - random choice, probability p , to decide whether to transmit or wait for next slot
 - Fig. 4.44 compare various schemes

Collision Detection

- Start transmitting any time, but watch medium for a collision
- When collision detected, stop transmitting, send jam signal
- This is CSMA/CD



How to exit a stop sign using CSMA/CD



Oops!



Oops *!#&*



OK! 3rd
time
lucky