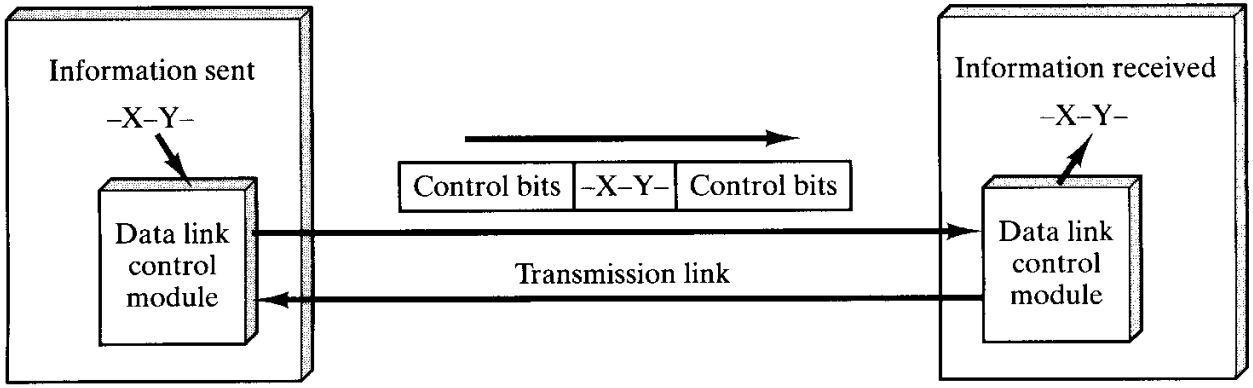
Data Link Layer



The job of the data link layer is to make the communication on the physical link reliable and efficient

Recall Data Link Layer Definition

- Data Link Layer - Provides for the reliable transfer of information across the physical link; sends blocks of data (frames) with necessary synchronization, error control, and flow control
- Examples HDLC, PPP

Data Link Layer

- The primary purpose of the Data Link Layer is to provide error-free transmission of information between two end stations "edge nodes" attached to the same physical cable or media. This then allows the next higher layer to assume virtually error-free transmission over the physical link. The Data Link Layer is responsible for packaging and placing data on the network media.

Data Link Layer

- It then manages how the flow process of the bit stream takes place to include the following:
  - Creates and recognizes frame boundaries
  - Checks received messages for integrity
  - Manages channel access and flow control
  - Ensures correct sequence and transmitted data
  - Detects and possibly corrects errors that occur in the Physical Layer without using the functions of the upper layers
  - Provides flow-control techniques to ensure that link buffer capacity is not exceeded

Data Link Layer Issues

- Link Configuration Control
- Link Discipline Control
- Link Management - bringing link up and down
- Addressing
- Framing
- Synchronization
- Error Control
- Flow Control

Link Configuration Control

- Link Configuration Control refers to the following:
  - Link Topology
  - Link Duplexity

Link Topology

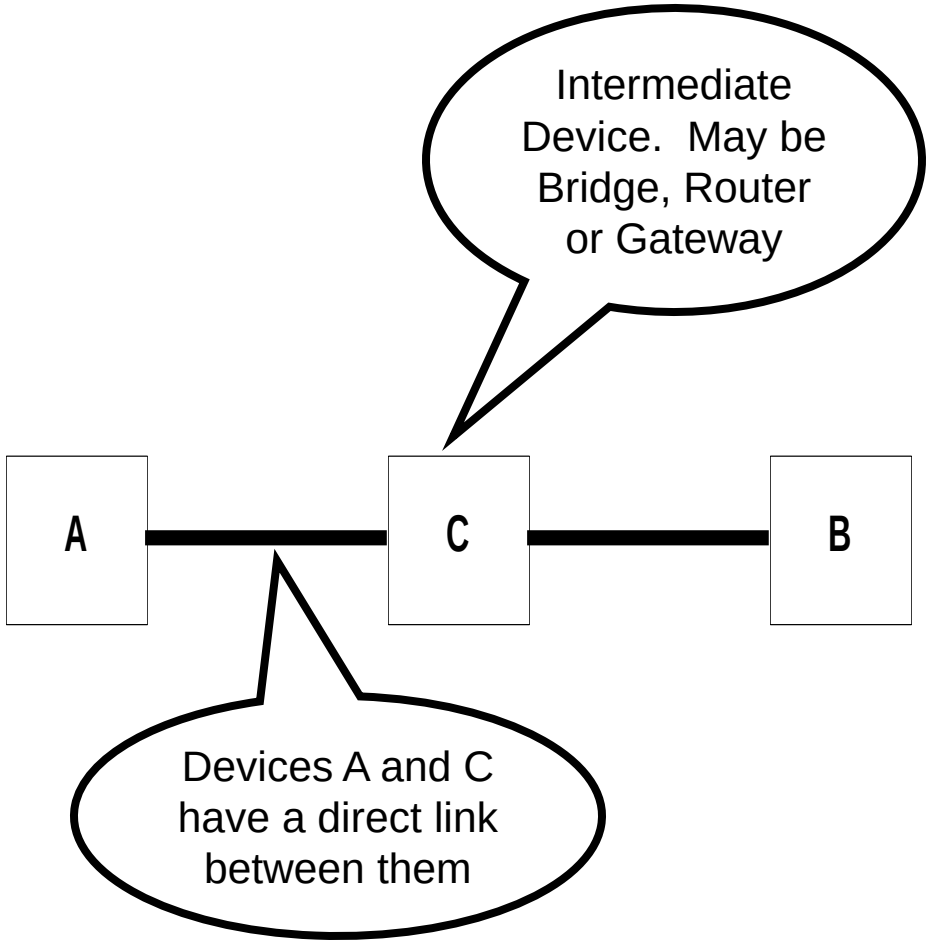
- The topology of a communication link refers to the physical arrangement of the connection between the devices. In its fundamental form the topology of a data link between two devices could be:
  - Direct Link
  - Indirect Link

Direct Link

- Two devices are connected by a direct link if there are no intermediate devices (except repeaters or amplifiers) in between them.

Indirect Link

- If there are one or more intermediate devices between two devices then the link between them is referred to as an indirect link.
- Devices A and C have a direct link between them whereas devices A and B have an indirect link between them

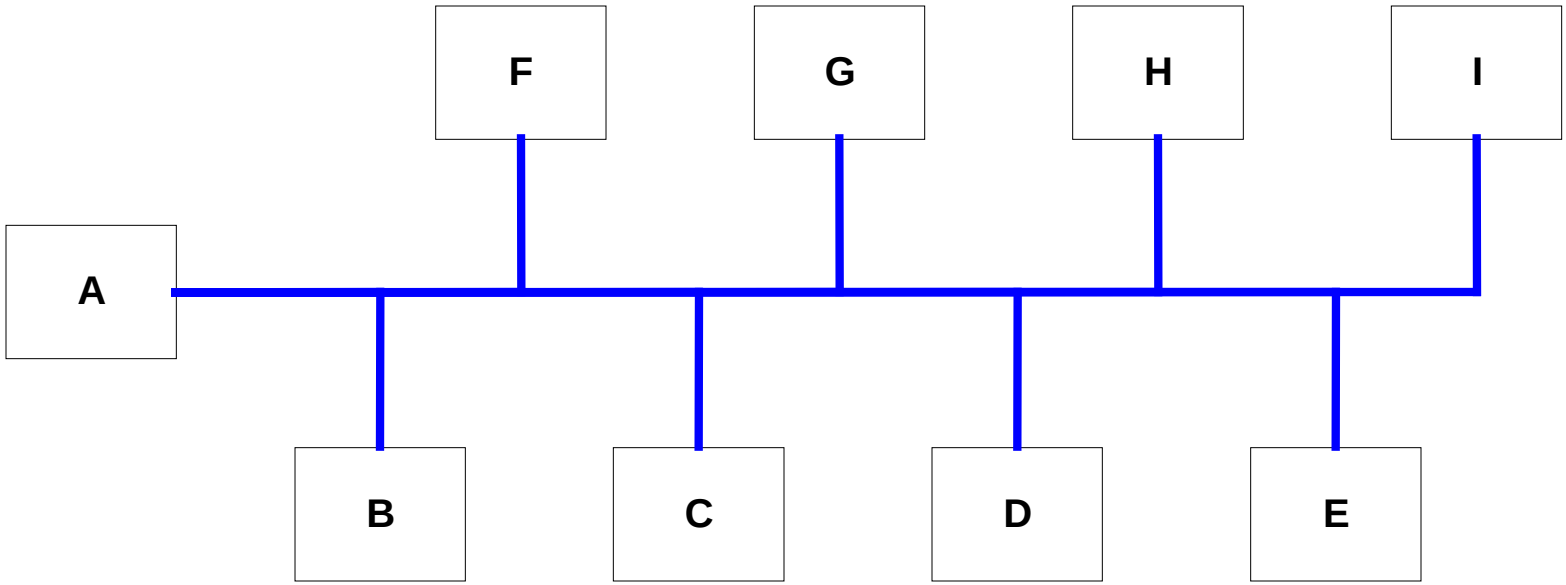


Direct Link - Subtypes

- There are two possibilities with a direct link:
  - Multipoint Link
  - Point to Point Link

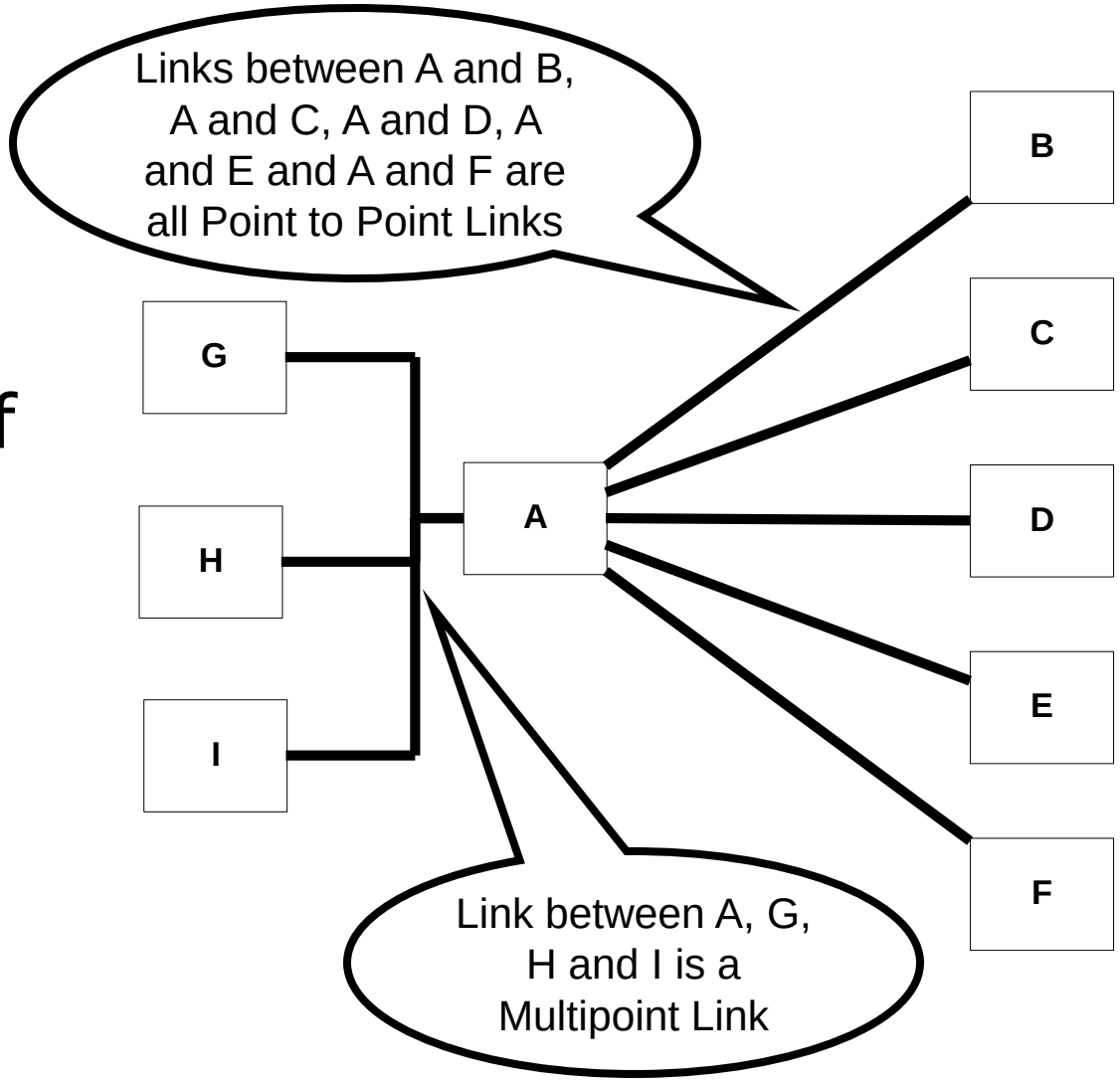
Multipoint Link

- A direct link is called a multipoint link is there are more than two devices sharing the link.



Point to Point Link

- A direct link between two devices is called a point to point link if and only if they are the only two devices sharing the link.



Link Duplexity

- Duplexity refers to the fact that either one station can transmit at a time (half duplex) or both can transmit simultaneously (full duplex).

Simplex

- Only one device can transmit to the other i.e. only transmit in one direction
- Not real communication, just one way communication, rarely used in data communications
- Examples: ordinary television, radio e.g., receiving signals from the radio station or CATV
- the sending station has only one transmitter the receiving station has only one receiver

Half Duplex

- Both devices can transmit to each other but not simultaneously, data may travel in both directions, but only in one direction at a time
- Devices take turns to speak
- Usually implies single path for both transmission and reception
- computers use control signals to negotiate when to send and when to receive
- the time it takes to switch between sending and receiving is called turnaround time

Full Duplex

- Both devices can transmit simultaneously
- Usually implies separate transmit and receive paths
- Complete two-way simultaneous transmission
- Faster than half-duplex communication because no turnaround time is needed

Link Discipline Control

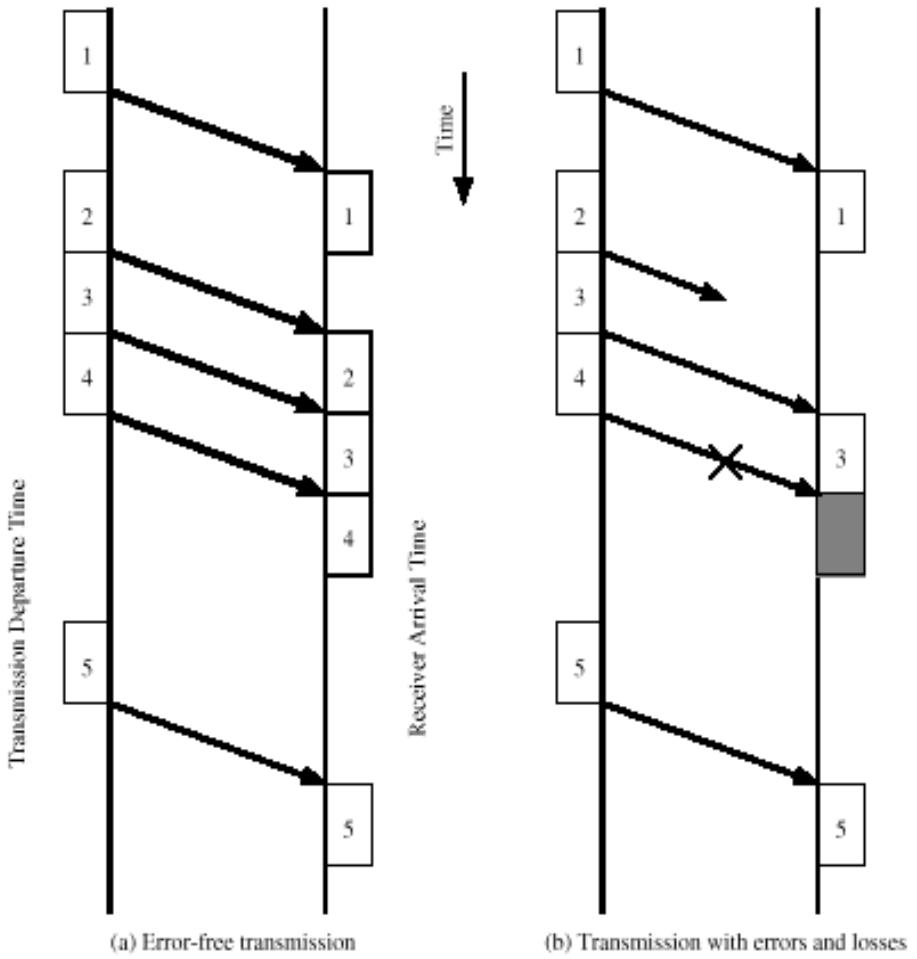
- Line Discipline Control refers to the following:
- Who will talk and when?
- How the above is decided?

Link Discipline Control

- Line discipline is dependent on three things:
- The topology of the link
- Duplexity of the link
- Relationship of the devices on the link i.e. Peer to Peer or Primary - Secondary
  - Primary - Secondary is the old terminal to host environment
  - Peer - Peer is the modern computer network environment

Link Discipline with Point to Point Links

- Simple
- One device may send an ENQ message to see if the other is ready
- On receiving an ACK the DATA frame may be sent
- Vertical Time Sequence Diagram



(a) Error-free transmission

(b) Transmission with errors and losses

Framing

- Framing refers to the fact that the beginning and the end of data are marked so to be recognized and help in synchronization.
- A frame is a quantum of data usually at layer two of the OSI reference model.
- The size of a frame is measured in bits. The size of a frame could range from a few bits (5 to 8) to few hundred or even thousand bits.

Synchronization

- Synchronization refers to the fact the receiver must know when the data begins and when it ends and also the receiver should be able to distinguish between each bit in the frame of data.
- Concerned with timing issues
- Small timing difference become more significant over time if no synchronization takes place between sender and receiver
- Synchronization occurs on the data link layer

Synchronous Synchronization

- Large blocks of bits (frames) are transmitted without start or stop bits after every 5 or 8 bits
- The beginning of a frame is marked by a preamble - flag
- End is marked by a postamble - flag
- Bit-stuffing is used to prevent occurrence of flag in the data - provides data transparency

Synchronous Synchronization

- Flag is usually a bit pattern 01111110
- For sizable blocks of data synchronous transmission is far more efficient
- e.g. HDLC with 1000 bit frame size and 48 control bits is only 4.8% overhead.
- Two types:
  - bit oriented
  - Character oriented

Flag Fields

- Delimit frame at both ends
- 01111110
- May close one frame and open another
- Receiver hunts for flag sequence to synchronize
- Bit stuffing used to avoid confusion with data containing 01111110
  - 0 inserted after every sequence of five 1s
  - If receiver detects five 1s it checks next bit
  - If 0, it is deleted
  - If 1 and seventh bit is 0, accept as flag
  - If sixth and seventh bits 1, sender is indicating abort

Bit Stuffing

- Example with possible errors

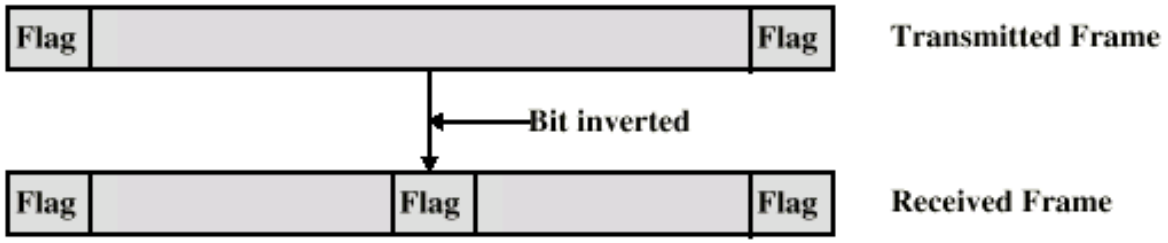
Original Pattern:

```
111111111111011111101111110
```

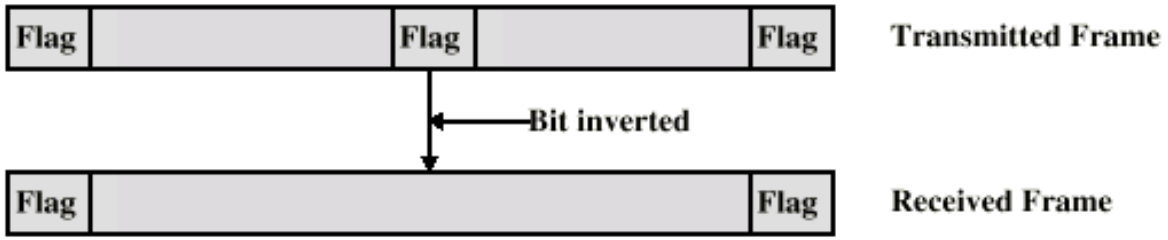
After bit-stuffing

```
111110111111011011111010111111010
```

(a) Example



(b) An inverted bit splits a frame in two



(c) An inverted bit merges two frames

Flow Control

- Flow Control refers to mechanisms that make sure that the sending station cannot overwhelm the receiving station with data.
  - Preventing buffer overflow
- Transmission time
  - Time taken to emit all bits into medium
- Propagation time
  - Time for a bit to traverse the link

Stop-and-Wait Flow Control

- The simplest form of flow control is Stop and Wait Flow Control.
- Stop and Wait Flow Control works like this:
- The sending station sends a frame of data and then waits for an acknowledgement from the other station before sending further data
- The other party can stop the flow of data by simply withholding an acknowledgement

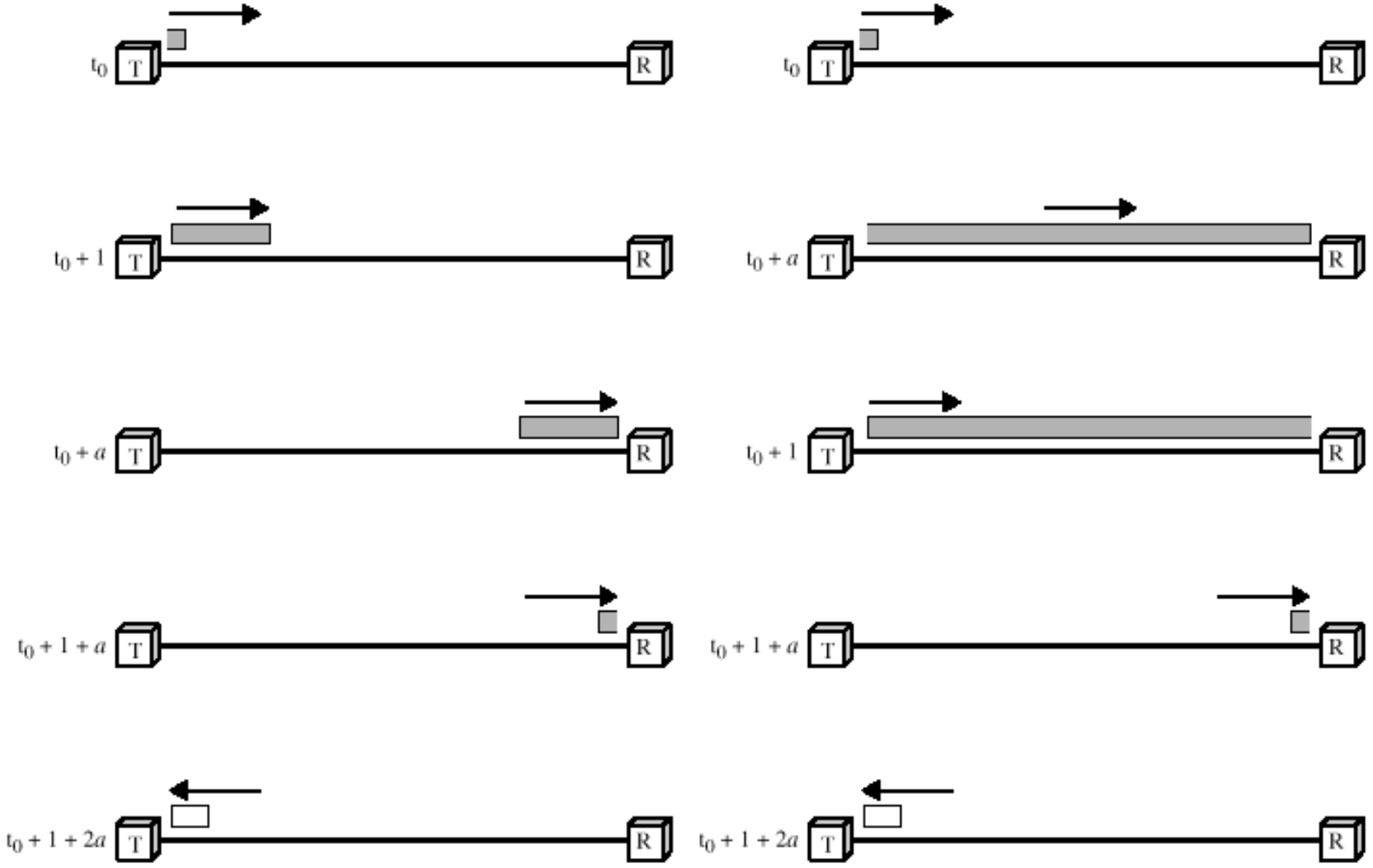
Stop-and-Wait Flow Control

- Source may not send new frame until receiver acknowledges the frame already sent
- Very inefficient, especially when a single message is broken into separate frames

Stop-and-Wait Flow Control

- Stop and Wait Flow control works great if data are sent as a few large frames.
- However large frames are undesirable for the following reasons:
  - Large frame means one station occupies the link for a longer time (undesirable on a multipoint link)
  - There is more chance of error in a large frame resulting in more lost data and more retransmission

For small frames let us see what happens with Stop and Wait flow control:



(a) $a > 1$

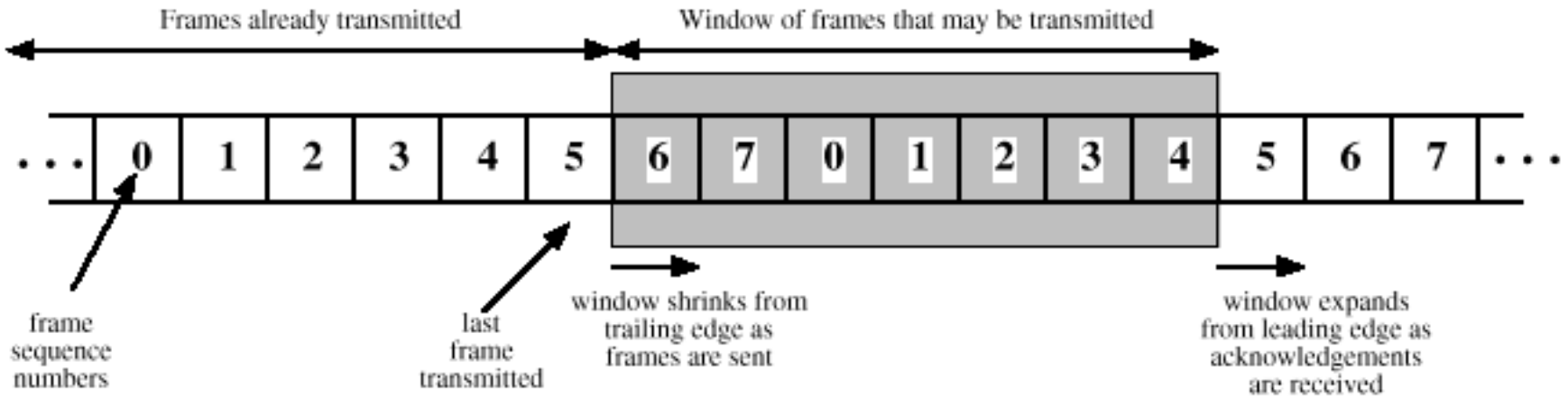
(b) $a < 1$

Utilization under SW Flow Control

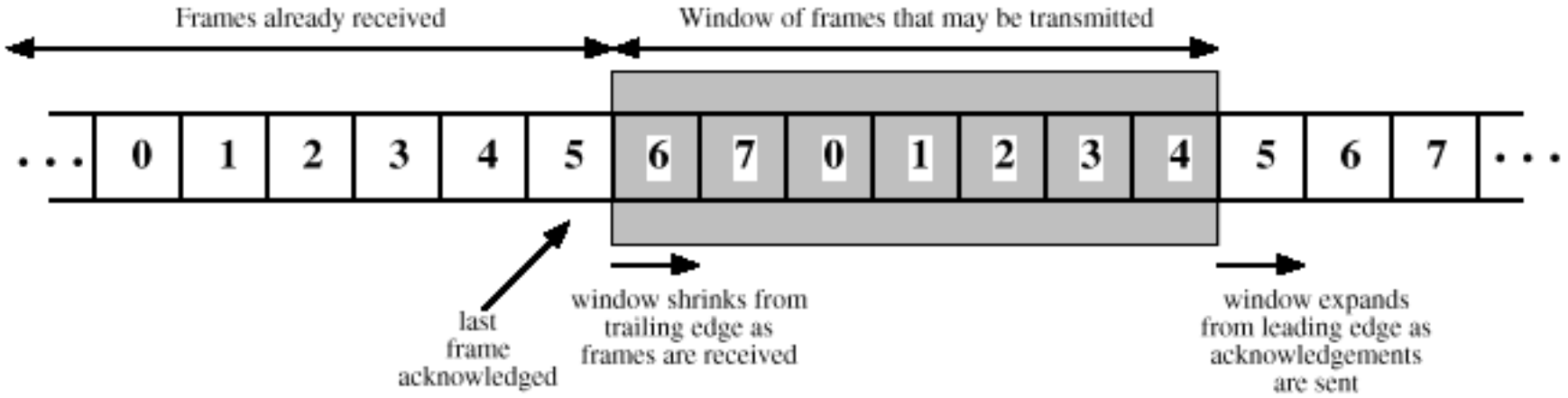
- Utilization = U = frame time / total time
- U = 1/1+2a
- a = Propagation Time / Transmission Time
- a = Medium length in bits / Frame length in bits

Sliding-Window Flow Control

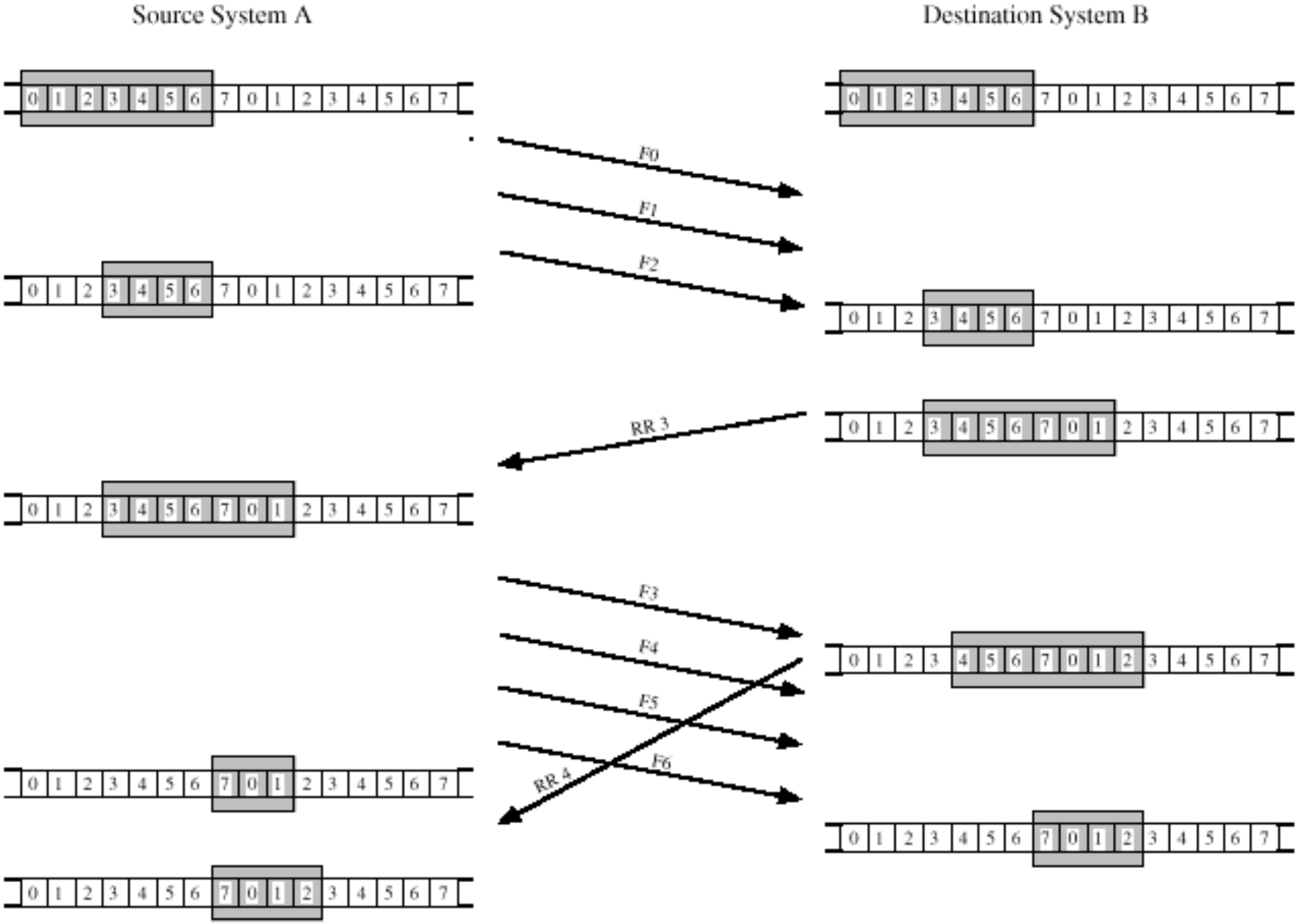
- Allows multiple frames to be in transit
- Receiver sends acknowledgement with sequence number of anticipated frame
- Sender maintains list of sequence numbers it can send, receiver maintains list of sequence numbers it can receive
- ACK (acknowledgement) supplemented with RNR (receiver not ready)



(a) Transmitter's Perspective



(b) Receiver's Perspective


Source System A
Destination System B
F0
F1
F2
RR 3
F3
F4
F5
F6
RR 4

Error Control

- All transmission media have potential for introduction of errors
- Error Control refers to the facts that errors must be:
  - Detected reliably
  - Something should be done to retransmit the frame that has been received in error

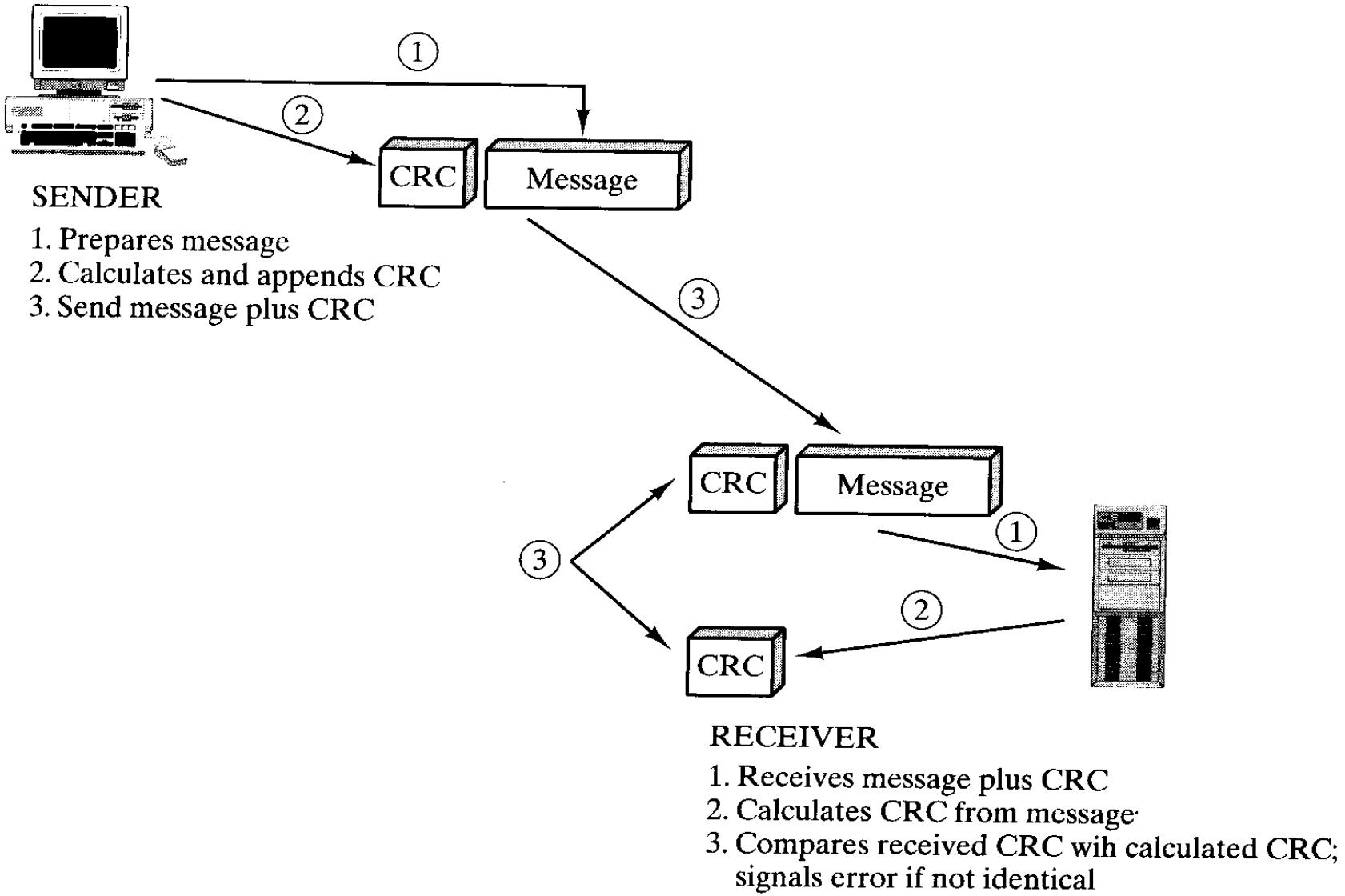
Error Detection

- Error detection refers to the techniques used to send extra information that can help in indicating to the receiver if the data might have been changed during the course of travelling through the medium.
- Parity error detection and CRC error detection are two techniques that will be discussed for error detection.

Cyclic Redundancy Check

- For a Message block of *k* bits (called M) transmitter generates *n* bit sequence (Called Frame Check Sequence or F)
- Transmit *k+n* bits which is exactly divisible by some number called P which is *n+1* bits long
- Receive divides frame by that number
  - If no remainder, assume no error

FIGURE 5.14 Error Detection Using CRC.



CRC Example

1. Given

Message M = 1010001101 (10 bits)
Pattern P = 110101 (6 bits)
FCS R = to be calculated (5 bits)

2. The message is multiplied by 2^5, yielding 101000110100000.
3. This product is divided by P:

```
                1101010110 <-Q
P -> 110101 | 101000110100000 <- 2^n M
              110101
               111011
               110101
                 111010
                 110101
                   111110
                   110101
                     101100
                     110101
                      110010
                      110101
                          1110 <- R
```

CRC Example - Continued

4. The remainder ($R = 01110$) is added to 2^nM to give $T = 10100011010110$, which is transmitted.
5. If there are no errors, the receiver receives T intact. The received frame is divided by P:

```
                1101010110
        ------------------
110101 | 10100011010110
         110101
         -------
          111011
          110101
          ------
           111010
           110101
           ------
            111110
            110101
            ------
             101111
             110101
             ------
              110101
              110101
              ------
                   00
```

Since there is no remainder, it is assumed that there have been no errors. ■