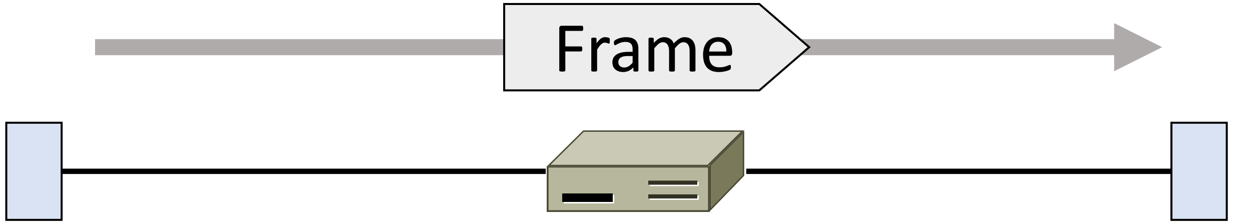
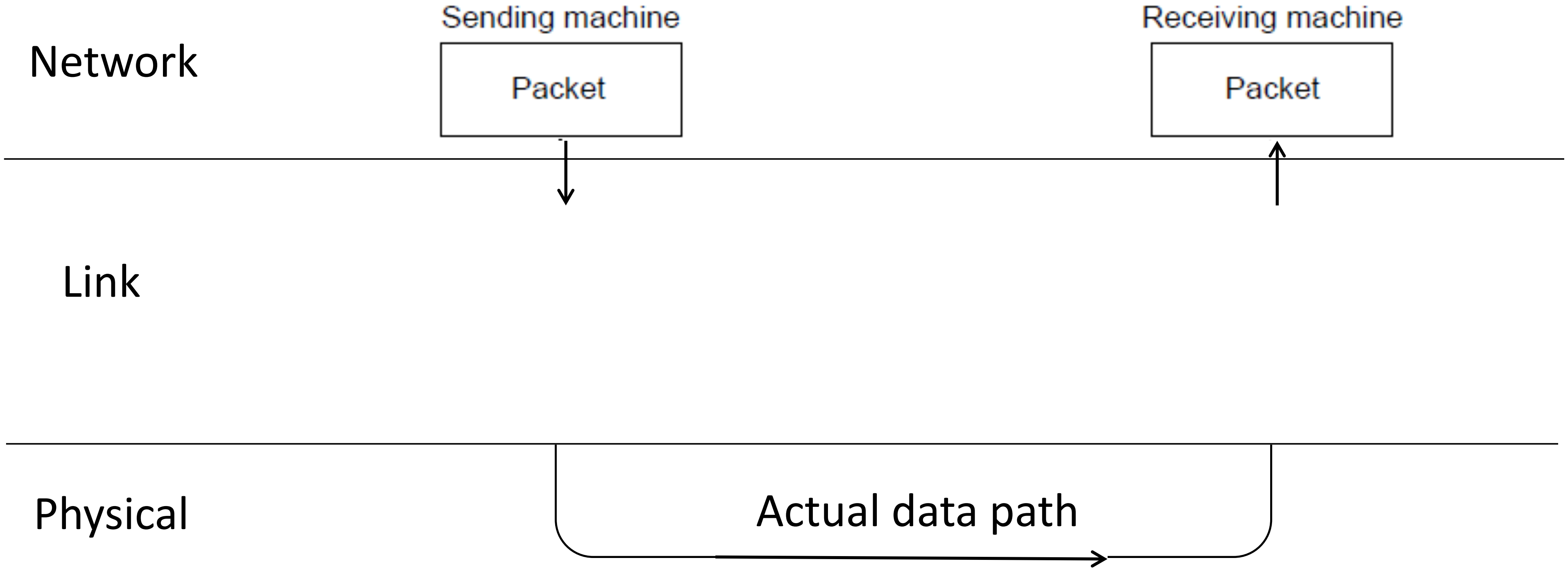
Link Layer

Link Layer

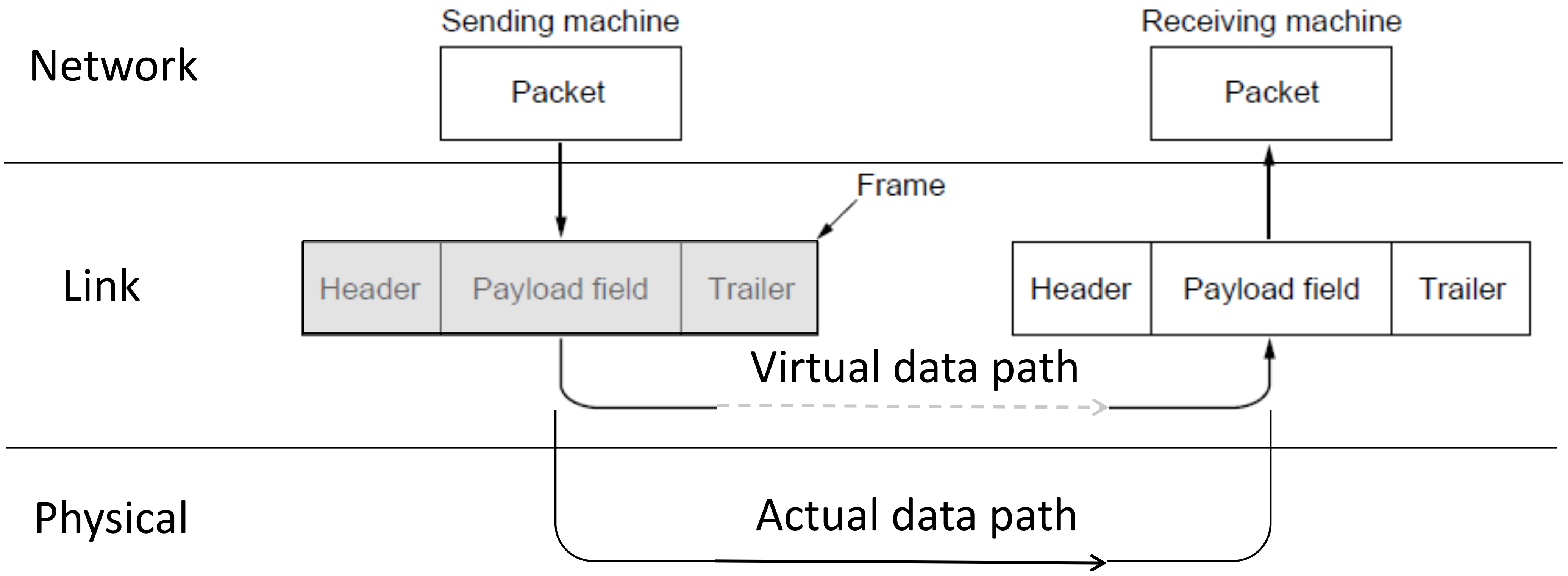
- Transfer frames over one or more connected links
  - Frames are messages of limited size
  - Builds on the physical layer which moves stream of bits



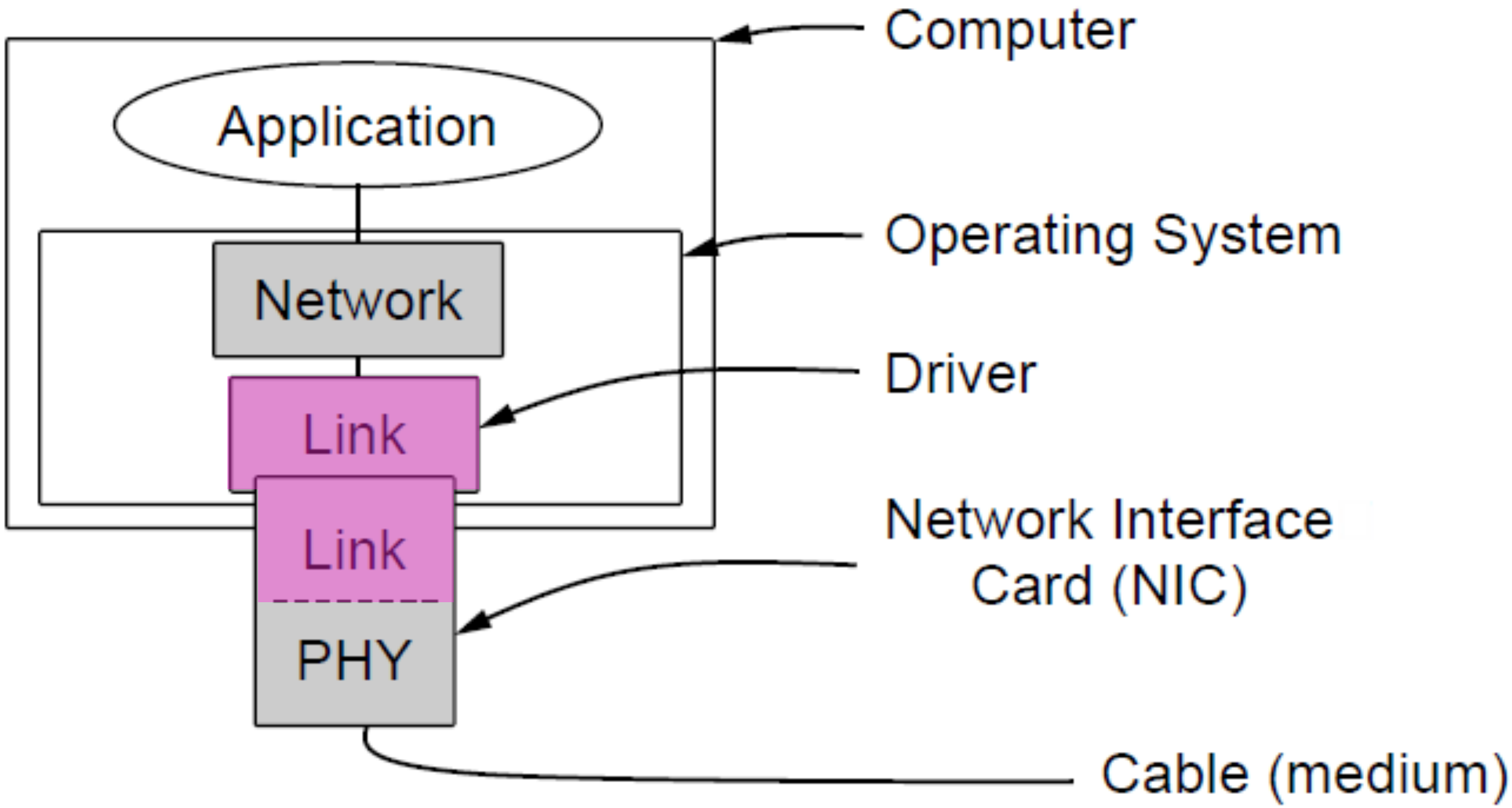
In terms of layers …



In terms of layers …



Typical Implementation of Layers (2)



Topics we'll cover

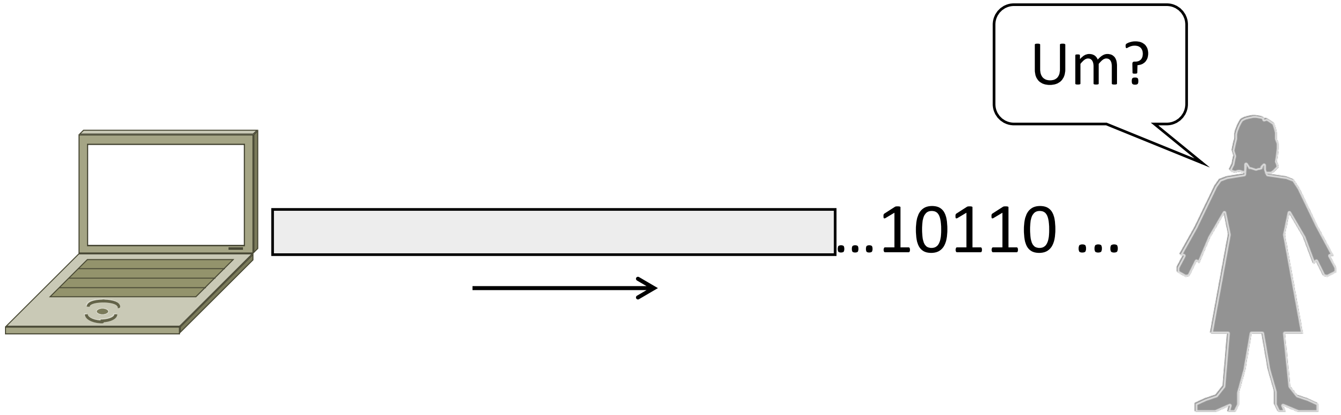
1. Framing
   - Delimiting start/end of frames
2. Error detection and correction
   - Handling errors
3. Retransmissions
   - Handling loss
4. Multiple Access
   - 802.11, classic Ethernet
5. Switching
   - Modern Ethernet

Framing

Delimiting start/end of frames

Framing: Problem

- How do we interpret a stream of bits as a sequence of frames?



Ideas?

Framing Methods

1. Fixed-size frames (motivation)
2. Byte count (motivation)
3. Byte stuffing
4. Bit stuffing

- In practice, the physical layer often helps to identify frame boundaries
  - E.g., Ethernet, 802.11

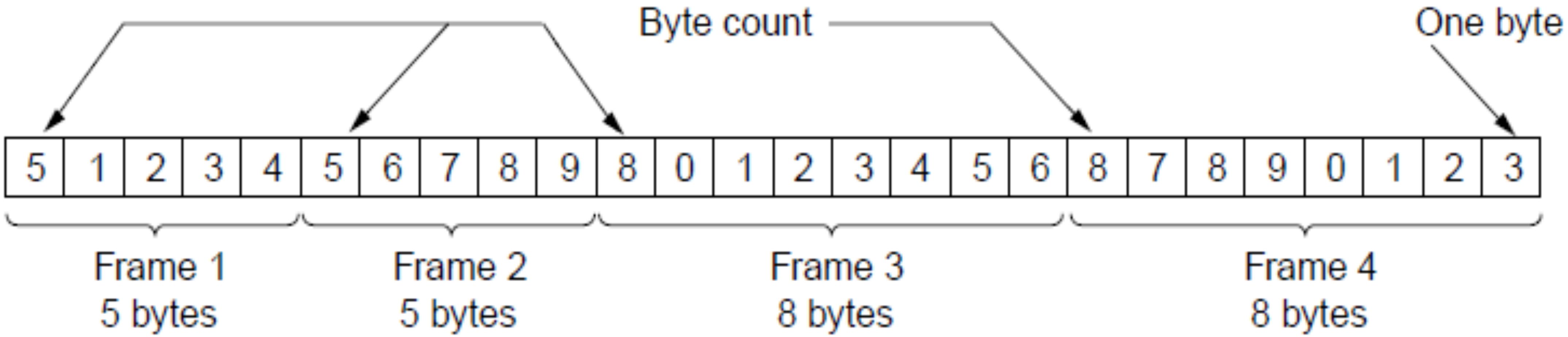
1. Fixed-size frames

- Make every frame a fixed number of bits
  - Pad smaller frames

- Problems?
  - Wasted transmissions for small frames

2. Byte Count

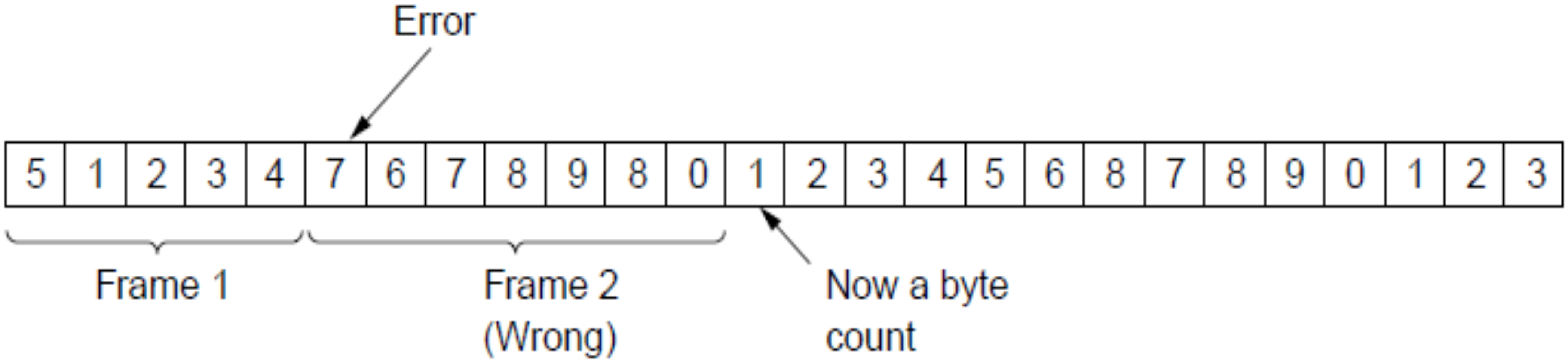
- Start each frame with a length field



- Problems?

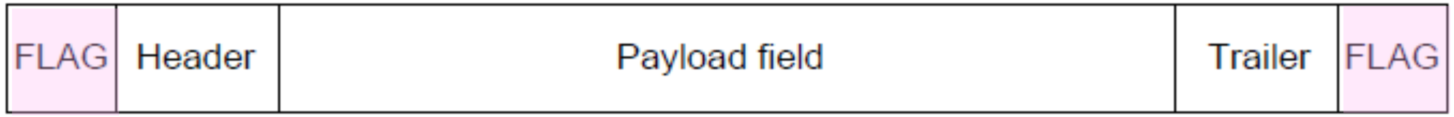
2. Byte Count: Problem

- Difficult to re-synchronize after framing error
  - Want a way to scan for a start of frame



3. Byte Stuffing

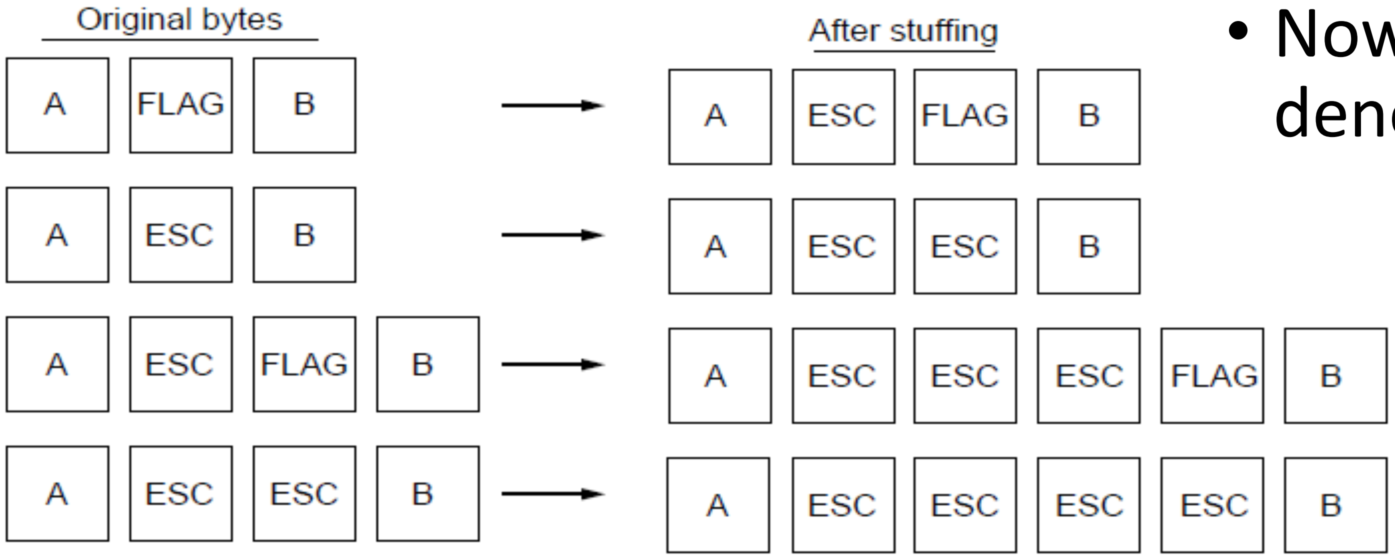
- A special flag byte value for start/end of frame
  - Replace ("stuff") the flag with an escape code



- Problems?

3. Byte Stuffing: Problem

- Must escape the escape code too! Rules:
  - Replace each FLAG in data with ESC FLAG
  - Replace each ESC in data with ESC ESC



Original bytes → After stuffing

A FLAG B → A ESC FLAG B

A ESC B → A ESC ESC B

A ESC FLAG B → A ESC ESC ESC FLAG B

A ESC ESC B → A ESC ESC ESC ESC B

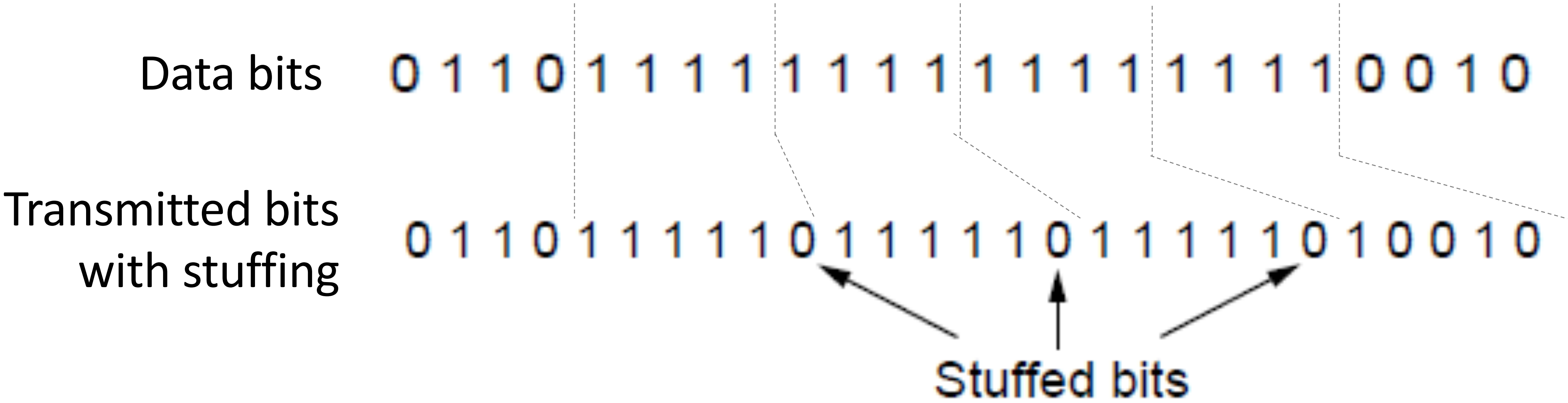
- Now any unescaped FLAG denotes frame start/end

Unstuffing

You see:	What it means
1. Solitary FLAG?	-> Start or end of packet
2. Solitary ESC?	-> Bad packet!
3. ESC FLAG?	-> remove ESC and pass FLAG through
4. ESC ESC FLAG?	-> removed ESC and then start of end of packet
5. ESC ESC ESC FLAG?	-> pass ESC FLAG through
6. ESC FLAG FLAG?	-> pass FLAG through then start of end of packet

4. Bit Stuffing

- Can stuff at the bit level too
  - Call a flag six consecutive 1s
  - On transmit, after five 1s in the data, insert a 0
  - On receive, a 0 after five 1s is deleted



Data bits 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0

Transmitted bits with stuffing 0 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 0 0 1 0

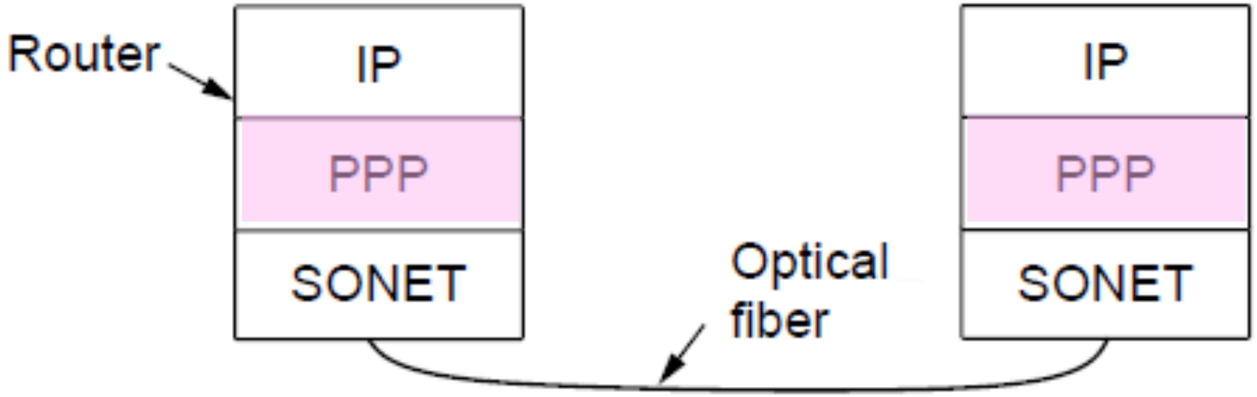
Stuffed bits

Link Example: PPP over SONET

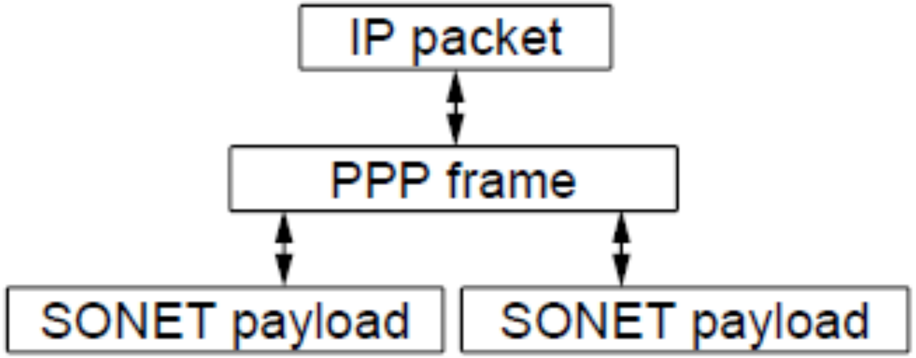
- PPP is Point-to-Point Protocol
- Widely used for link framing
  - E.g., it is used to frame IP packets that are sent over SONET optical links

Link Example: PPP over SONET (2)

- Think of SONET as a bit stream, and PPP as the framing that carries an IP packet over the link



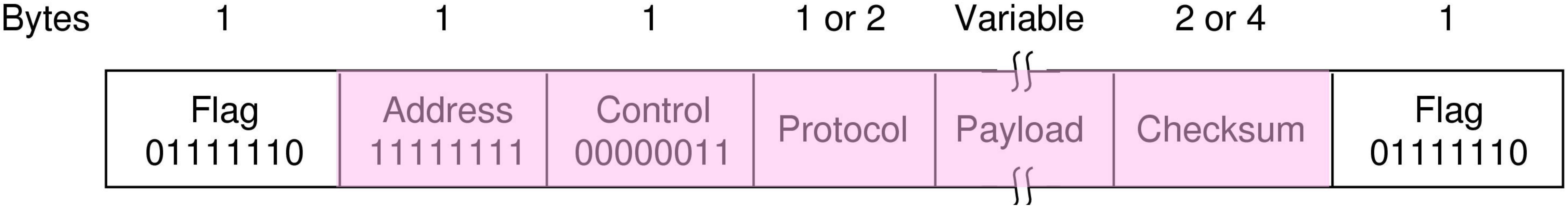
Protocol stacks



PPP frames may be split over SONET payloads

Link Example: PPP over SONET (3)

- Framing uses byte stuffing
  - FLAG is 0x7E and ESC is 0x7D



Bytes	1	1	1	1 or 2	Variable	2 or 4	1
	Flag 01111110	Address 11111111	Control 00000011	Protocol	Payload	Checksum	Flag 01111110

Link Example: PPP over SONET (4)

- Byte stuffing method:
  - To stuff (unstuff) a byte
    - add (remove) ESC (0x7D)
    - and XOR byte with 0x20
  - Removes FLAG from the contents of the frame